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TRANSIENT STABILITY PERFORMANCE ANALYSIS OF AN IEEE 9 BUS POWER SYSTEM USING FACTS DEVICE

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Abstract:

Modern power system transmission networks are becoming with increasing complexity due to growing demand and restrictions on building new lines. Losing stability is one of the major problem of such a modern power system following a disturbance. Transient stability control plays a vital role in ensuring the stable operation of power system during the fault and large disturbances. FACTS technologies are found 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 systemby 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. The better Flexible AC Transmission Systems (FACTS) device can be identified by this project for transient stability of IEEE 9 bus power system.

Key Words: FACTS, STATCOM, SVC and UPFC, Transient Stability & IEEE 9 Bus Power System

1. Introduction:

Power systems generally consist of three stages: generation, transmission, and distribution. In the first stage, generation, the electric power is generated mostly by using synchronous generators. Then the voltage level is raised by transformers before the power is transmitted in order to reduce 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 designed to provide continuous power supply that maintains voltage stability. However, due to undesired events, such as lightning, accidents or any other unpredictable events, short circuits between the phase wires of the transmission lines or between a phase wire 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 imbalance between generation and demand. If the fault persists and is not cleared in a pre-specified time frame, it may cause severe damages to the equipment's which in turn may lead to a power loss and power outage. Therefore, protective equipment's are installed to detect faults and clear/isolate faulted parts of the power system as quickly as possible before the fault energy is propagated to the rest of the system. Simulink is an interactive 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 studying 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.

2. Power System Stability:

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain 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 timeframe 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.

3. Transient Stability:

When a power system is under steady state, the load plus transmission loss equals to the genaration 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 former case the system is said to be stable and in the later case it is said to be unstable.

4. 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 :

- ✓ Series Controller
- ✓ Shunt Controller
- ✓ Combined series-series Controller
- ✓ 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

4.1 Static VAR Compensator (SVC): SVC is an electrical device for providing 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.

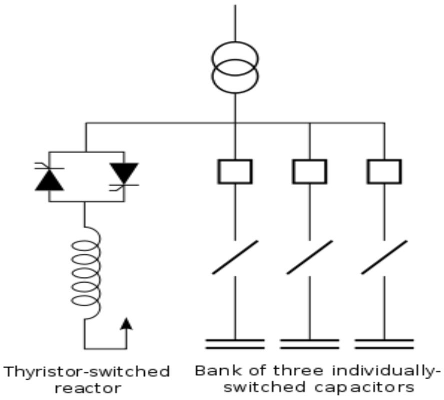

Figure 1: SVC Model

SVCs 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.

4.2 Static Synchronous Compensator (STATCOM): A Static synchronous compensator 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 because of its small energy storage device i.e. small dc capacitor, if this dc capacitor is replaced with dc storage battery or other dc voltage source, the controller can exchange real and reactive power with the transmission system, extending its region of operation from two to four quadrants.

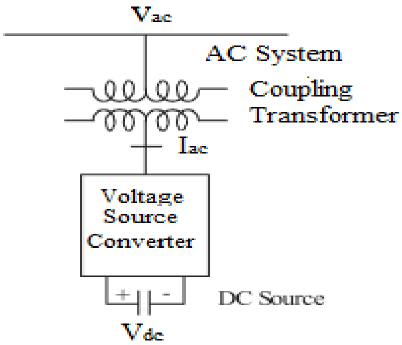

Figure 2: STATCOM Model

4.3 Unified Power Flow Controller (UPFC): The 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. Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers. In addition, the shunt converter functions like a STATCOM and independently regulate the terminal voltage of the interconnected bus by generating/ absorbing a requisite amount of reactive power .

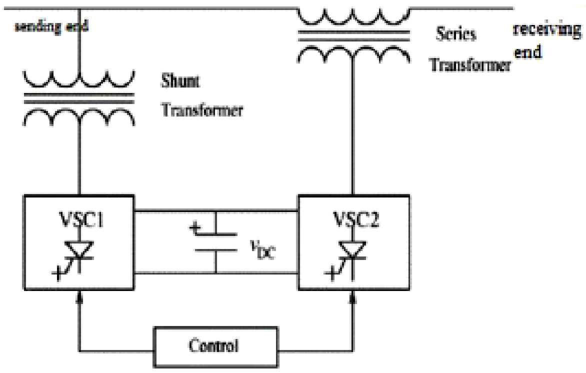

Figure 3: UPFC Model

5. Power System Stabilizers:

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 suboptimal 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

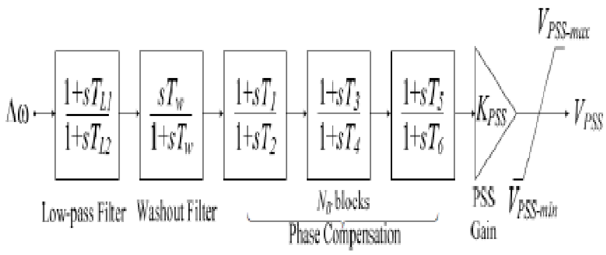

Figure 4: Power System Stabilizer Model

6. Simulation Model and Results:

The Matlab software is used to analysis of transient stability of the multi-machine, IEEE 9-bus bar power system network using ieee std 421.5 power system stabilizer. The base MVA and system frequency are considered to be 100 MVA and 50 Hz, respectively. The Here, generator G1 is connected to slack bus 1, whereas generators 2 (G2) and 3 (G3) are connected to bus bars 2 and 3, respectively. Loads A, B and C are connected in bus bars 5, 7 and 8 respectively. The transient stability analysis has been carried out by monitoring the performance of the generators (G1, G2 and G2) and different buses. The transient stability analysis of this power system network have been considered when three phase fault occurs in the network.

6.1 IEEE 9-Bus Bar Power System With Three Phase Fault: IEEE 9-bus bar power system as shown in fig.-5 is considered in this study.

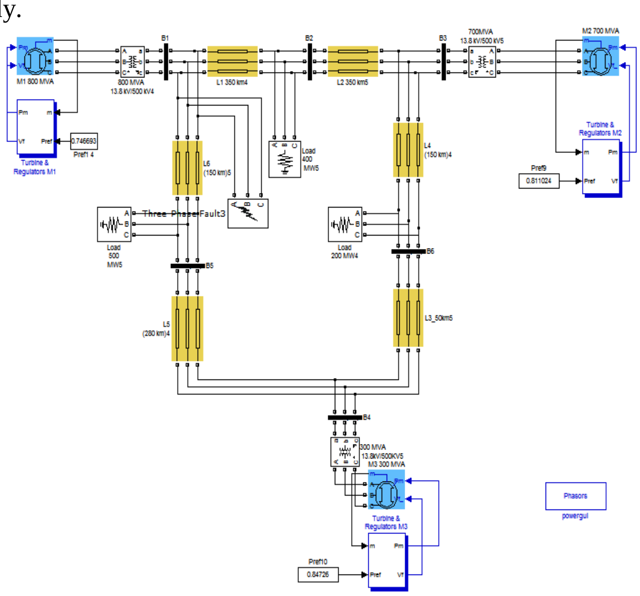

Figure 5: IEEE 9-Bus Power System during Three Phase Fault

It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B4. The fault is cleared of 0.5 seconds. The system losses its stability. Hence the FACTS devices are used to control stability problems. The PSS also included to this MATLAB simulation.

6.2 IEEE 9-Bus Bar Power System With FACTS Device (STATCOM) and Power System Stabilizer: IEEE 9-bus bar power system as shown in fig-6 is considered in this study.

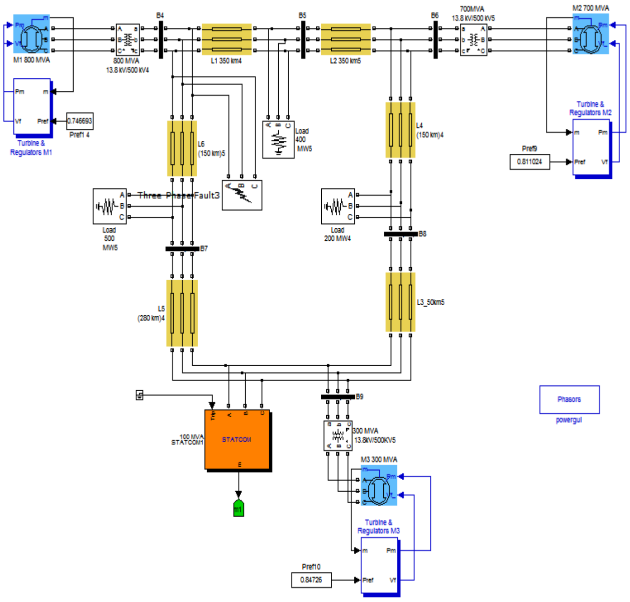

Figure 6: IEEE 9-bus power system installed with STATCOM and PSS

The system has a STATCOM installed at B7. It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B4. Put the Generic type PSS in service by setting the command in PSS block equal to 1. Open the STATCOM block menu and change the STATCOM mode of operation to voltage regulation. fig 7: shows the relative angular positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with STATCOM controller placed between Bus 7 and Bus 9 and fault taking place between Bus 4 and Bus 7.The total simulation time taken is 10 sec.

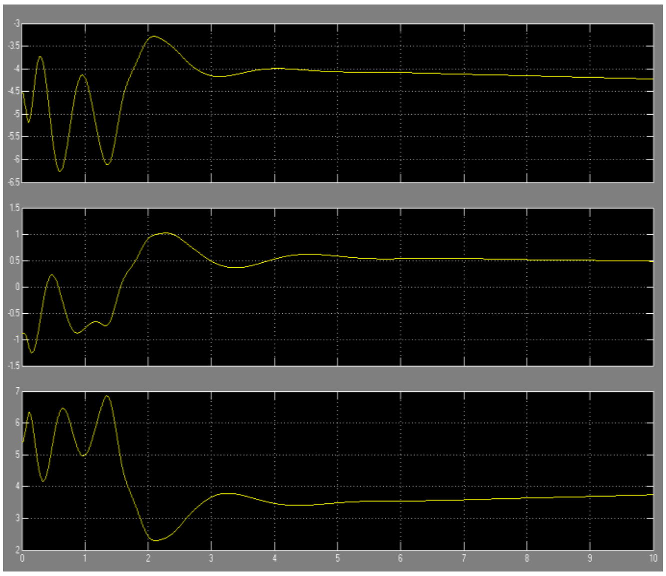

Figure 7: Relative two rotor angle positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with STATCOM and PSS

Table 2: Stability time for STATCOM placed between bus 7 and bus 9

Fault Position	STATCOM position	Stability time for delt 2_1(in sec.)	Stability time for delt 3_2(in sec.)	Stability time for delt 3_1(in sec.)
Between bus 4 and bus 7	Between bus 7 and bus 9	4.2	4.9	4.8

6.3 IEEE 9-bus bar power system with FACTS device (SVC) and Power System Stabilizer: IEEE 9-bus bar power system as shown in fig-8 is considered in this study.

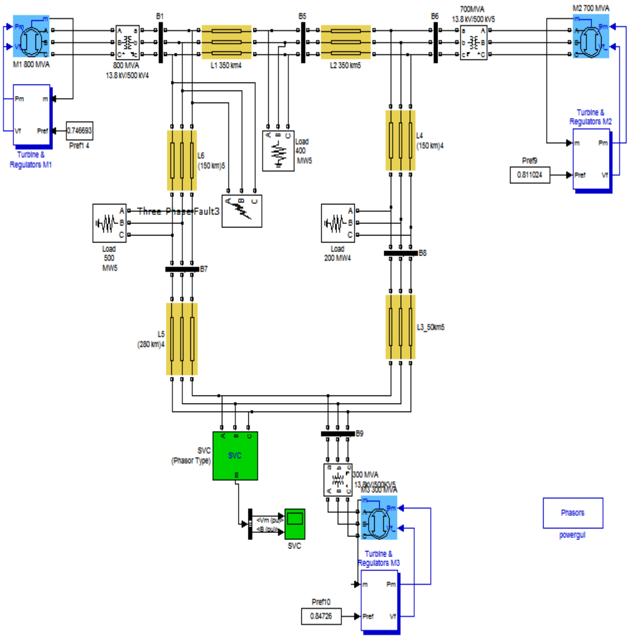

Figure 8: IEEE 9-bus power system installed with SVC and PSS

The system has a SVC installed at B7. It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B4. Put the Generic type PSS in service by setting the command in PSS block equal to 1. Open the SVC block menu and change the SVC mode of operation to voltage regulation. fig 9: shows the relative angular positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with SVC controller placed between Bus 7 and Bus 9 and fault taking place between Bus 4 and Bus 7.The total simulation time taken is 10 sec.

Table 3: Stability time for SVC placed between bus 7 and bus 9

Fault Position	SVC position	Stability time for delt 2_1(in sec.)	Stability time for delt 3_2(in sec.)	Stability time for delt 3_1(in sec.)

Between bus 4 and bus 7	Between bus 7 and bus 9	4.8	5.4	5.2

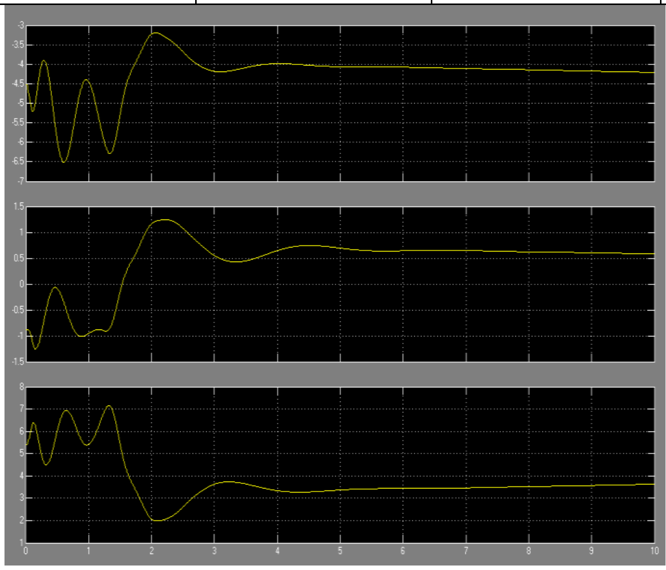

Figure 9: Relative two rotor angle positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with SVC and PSS

6.4 IEEE 9-Bus Bar Power System With FACTS device (UPFC) and Power System Stabilizer: IEEE 9-bus bar power system as shown in fig-10 is considered in this study.

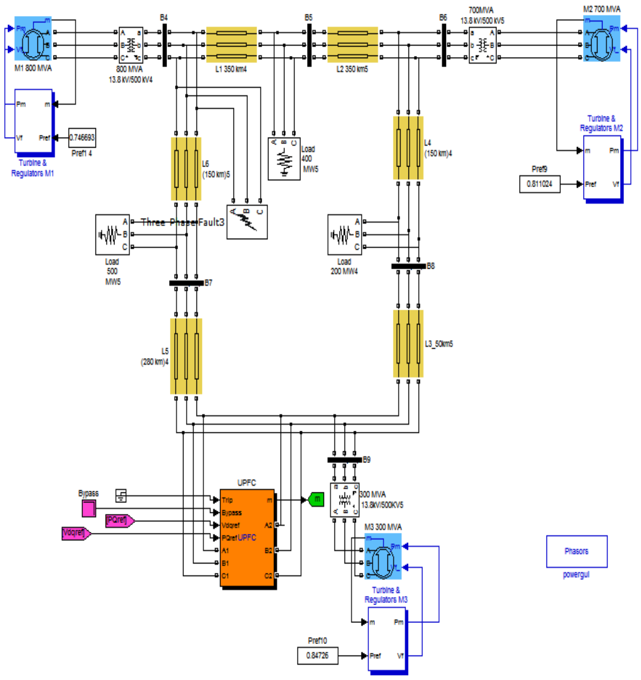

Figure 10: IEEE 9-bus power system installed with UPFC and PSS

The system has a UPFC installed at B7. It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B4. Put the Generic type PSS in service by setting the command in PSS block equal to 1. Open the UPFC block menu and change the UPFC mode of operation to power flow control. Fig 11: shows the relative angular positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with SVC controller placed between Bus 7 and Bus 9 and fault taking place between Bus 4 and Bus 7.The total simulation time taken is 10 sec.

Table 4: Stability time for UPFC placed between bus 7 and bus 9

Fault Position	UPFC position	Stability time for delt 2_1(in sec.)	Stability time for delt 3_2(in sec.)	Stability time for delt 3_1(in sec.)
Between bus 4 and bus 7	Between bus 7 and bus 9	3.8	4.15	4

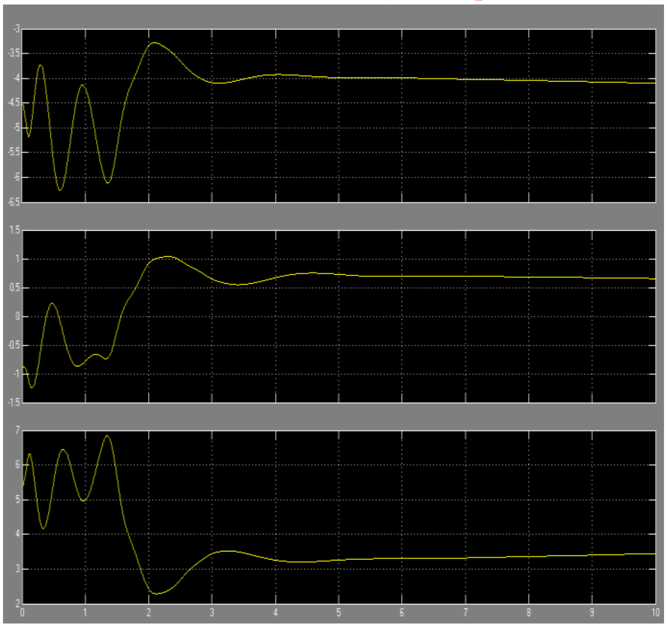

Figure 11: Relative two rotor angle positions for delt2_1, delt3_2and delt3_1 IEEE 9 bus system with UPFC and PSS

6.4 Comparison Between FACTS Devices: From the simulation results shown in Fig 7-Fig 9 and Fig 11, 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 SVC as the post settling time obtained from the use of UPFC is less as compared to that obtained from STATCOM and SVC.

Table 5: Comparison between FACTS Devices for Power System

FACTS Device	FACTS position	Stability time for delt 2_1(in sec.)	Stability time for delt 3_2(in sec.)	Stability time for delt 3_1(in sec.)
STATCOM	Between bus 7 and bus 9	4.2	4.9	4.8
SVC	Between bus 7 and bus 9	4.8	5.4	5.2
UPFC	Between bus 7 and bus 9	3.8	4.15	4

7. Conclusion:

The power system stability has been compared and discussed for improvement of a 3-machine 9 bus system by STATCOM, SVC & UPFC. The dynamic behaviour of the power system is compared with the presence of STATCOM, SVC & UPFC in the system in the event of a major disturbance. Then the performance of UPFC for power system stability improvement is compared with the STATCOM and SVC. It is clear from the simulation results that there is a considerable improvement in the system performance with the use of UPFC for which settling time in post fault is found to be around 3.8 sec.

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