Transient Stability Performance Analysis of Multimachine Power System using Facts Device

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Abstract
Modern power system transmission networks are becoming with increasing complexity due to growing demand. Losing stability is one of the major problems of such modern power system following a disturbance. Transient stability control plays a vital role in ensuring the stabile operation of power system during the fault. FACTS technologies is an effective tool for better controllability and increase transfer capability. The main objective is the comparative performance analysis of STATCOM, SVC and UPFC for improve the transient stability of multi machine system so a simple SIMULINK is considered for this purpose.

Keywords - *FACTS ,power system stability ,svc , statcom , upfc, IEEE 9bus system & IEEE 14bus system.*

I. INTRODUCTION

A power system generally consists of three stages: generation, transmission, and distribution. Power systems are designed to provide continuous power supply that maintains voltage stability. However, due to undesired events, such as lightning, accidents short circuits may occur between phases to phase or phase to ground is known as fault. Due to this one or more generators may be severely disturbed causing an imbalance between generation and demand if the fault is not cleared in a pre-specified time; it may cause severe damage to the equipment. Protective equipment is installed to detect fault and clear/isolate [1]. FACTS technology is becoming more and more popular due to improvement in Power Electronics technology and reduction in costs. The term FACTS coverts number of devices which may be working in isolation or in coordination with a few other devices. Several FACTS controllers for shunt, series or both shunt and series compensation are now operating in power systems around the world. By controlling impedance or phase angle or series injection of appropriate voltage a FACTS Controller can control the power flow as required. The FACTS facilitates power flow control, increased power transfer capability, and enhances the security and stability of power systems without expanding transmission and generation utilities. Excellent applications of FACTS controllers, such as the static var compensator (SVC), the unified power flow controller (UPFC), and the Static Synchronous Compensator (STATCOM), have yielded successful results. It has been shown in recent case studies that FACTS can provide a more flexible stability margin to power systems and also improve power transfer limit in either shunt or series compensation [2]. 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 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 analysis of SVC, STATCOM and UPFC for improvement of transient stability of multi machine systems [1].

The paper is mainly organized into four sections the first section is introduction, the second one is a related work, the third one is research work in both two and three sections explain about the modeling. The fourth section is mat lab simulation and results of both 9-bus and 14-bus systems the fifth section is conclusion and followed by acknowledgment and references.

II. RELATED WORK

A. Multi Machine System Modeling

The popular western system coordinated council (WSCC) 3-machine 9-bus practical power system with loads assumed to be represented by constant impedance model has been considered as a test case. Fig.1 shows the WSCC 3–machine 9–bus system. The base MVA of the system is 100, and system frequency is 50HZ. Here, generator G1 is connected to slack bus 1, whereas generator G2 and G3 are connected to bus bars 2 and 3, respectively. Loads A, B, C are connected in bus bar 5, 6 and 8 respectively. The transient stability analysis has been carried out by monitoring the performance of the generators (G1 G2 and G3) and different busses. The transient stability analysis of this power system network has been considered when three phase fault occur in the network. It is considered that a 3-phase symmetrical short circuit fault of 0.2 seconds occur at bus B4.The system losses its stability. Hence the FACTS devices are used to control stability problems. These are placed at bus B7 [1].

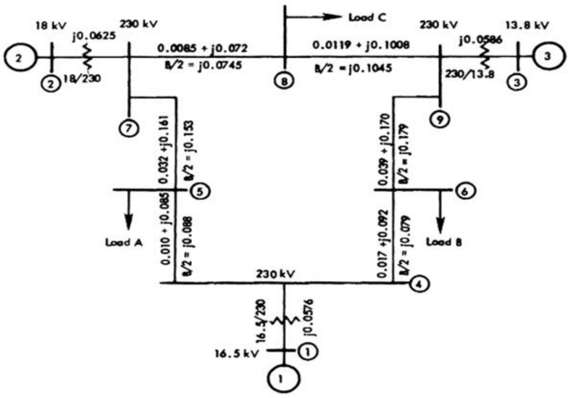

Fig 1: WSCC 3-machine 9-bus system

III. RESEARCH WORK

The IEEE 5-machine 14-bus practical power System with loads assumed to be represented by constant impedance model has been considered as another test case.Fig-2 shows the block diagram of IEEE 5-machine 14-bus system. The base MVA of the system is 100, and system frequency is 50HZ. Here generator G1 is connected to bus 1 and generators G2, G3, G4 and G5 are connected to bus bars 2, 3, 4, and 5 respectively. Loads A, B, C, and D are connected to bus bars 6, 10, 11 and 13 respectively. It is considered that a 3-phase symmetrical short circuit fault of 0.2 seconds occur at bus B5.The system losses its stability. Hence the FACTS devices are used to control stability problems. These are placed at bus B13.

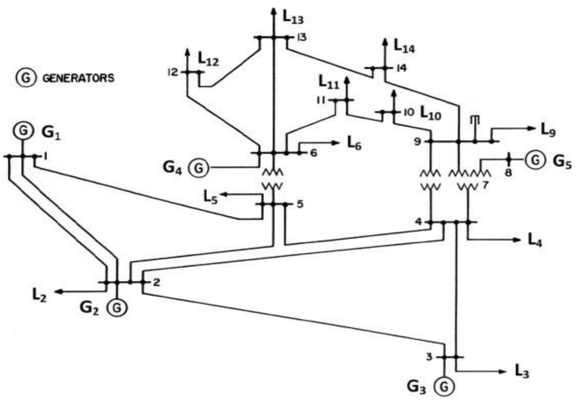

Fig 2: IEEE 5-machine 14-bus system

IV. SIMULATION AND RESULTS

A. Matlab/Simulink model of multi-machine (3-machine, 9-bus) WSCC system without facts

IEEE 9-bus bar power system as shown in Fig-3

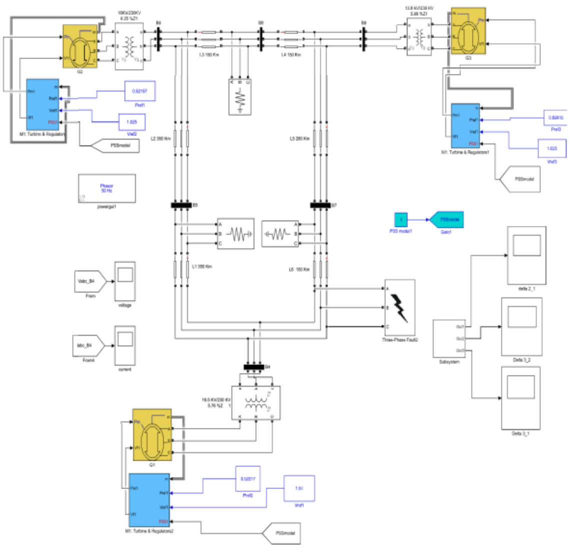

Fig 3: MATLAB/SIMULINK model of WSCC 3-Machines 9-Bus System without facts

The relative angular positions for delt2_1, delt3_2 and delt3_1 of IEEE 9 bus system with out facts device showen in Fig-4, Fig-5 and fig-6 respectively and The total simulation time taken is 40 sec.

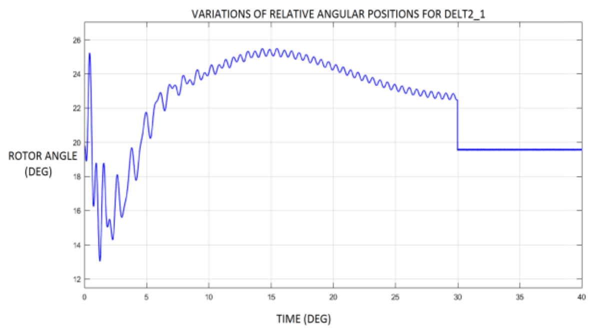

Fig 4: Variation of Relative angular position for delt2_1

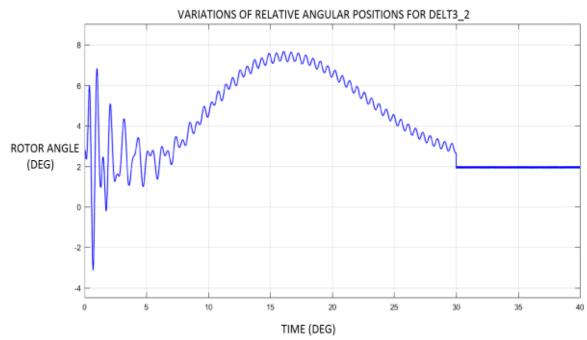

Fig 5: Variation of Relative angular position for delt3_2

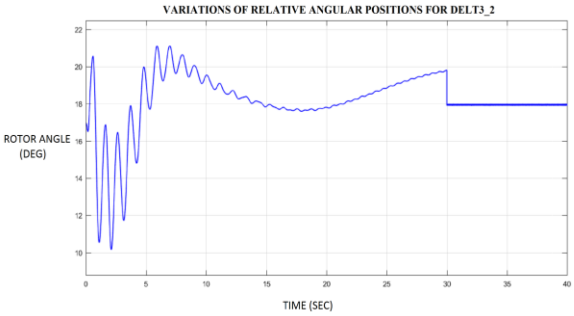

Fig 6: Variation of Relative angular position for delt3_1

B. Matlab/Simulink model of multi-machine (3-machine, 9-bus) WSCC system incorporated with SVC

IEEE 9-bus bar power system incorporated with svc is shown in Fig-7

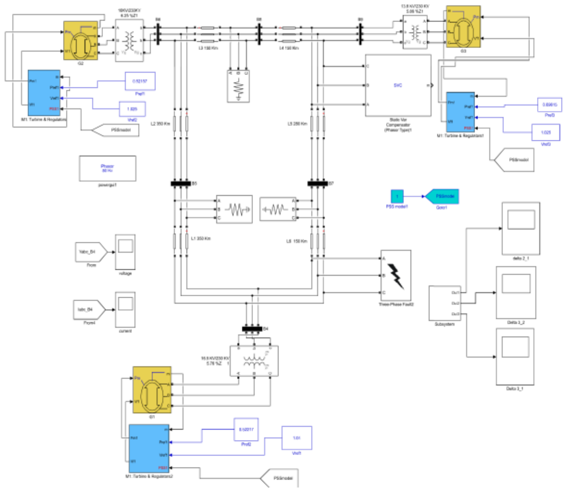

Fig 7: MATLAB/SIMULINK model of WSCC 3-Machine 9-Bus system incorporated with SVC

The relative angular positions for delt2_1, delt3_2 and delt3_1 of IEE 9 bus system incorporated with SVC shown in Fig-8, Fig-9 and Fig-10 respectively. The total simulation time taken is 10 seconds. It has been analyzed at various instance of time as the fault takes place in the system, the system becomes unstable. To bring back the system SVC has been placed.

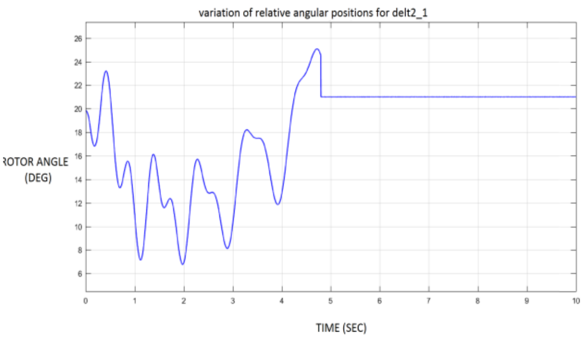

Fig 8: Variation of Relative angular position for delt2_1

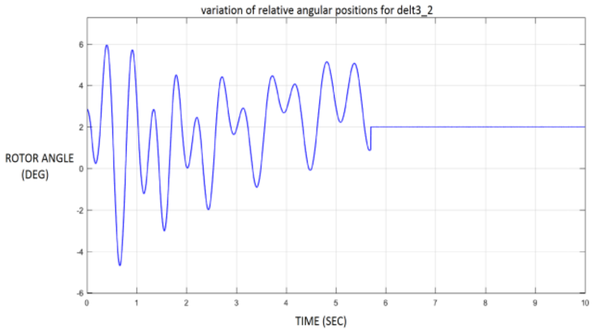

Fig 9: Variation of Relative angular position for delt3_2

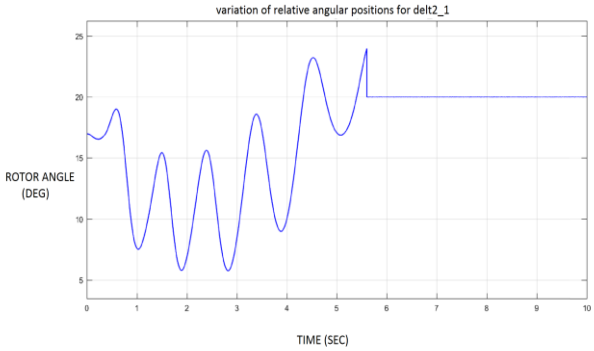

Fig10: Variation of Relative angular position for delt3_1

C. Matlab/Simulink model of multi-machine (3-machine, 9-bus) WSCC system incorporated with STATCOM

IEEE 9-bus bar power system incorporated with svc is shown in Fig-11. The relative angular positions for delt2_1, delt3_2 and delt3_1 of IEEE 9 bus system incorporated with STATCOM shown in Fig-12, Fig-13 and Fig-14 respectively. Simulation time is 10sec.

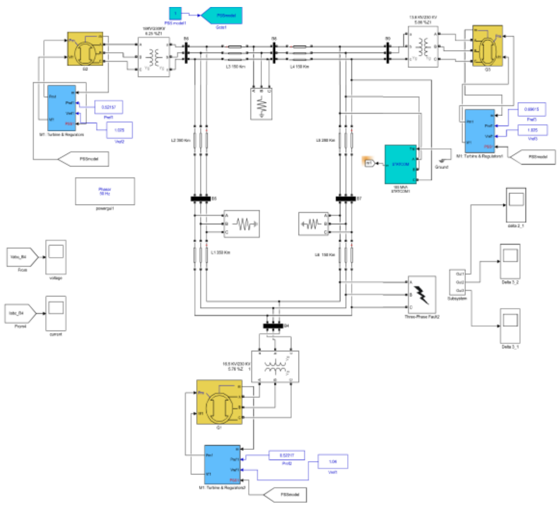

Fig11: MATLAB/SIMULINK model of WSCC 3-Machine 9-Bus system incorporated with STATCOM

It has been analyzed at various instance of time as the fault takes place in the system, the system becomes unstable. To bring back the system to stability the STATCOM has been place.

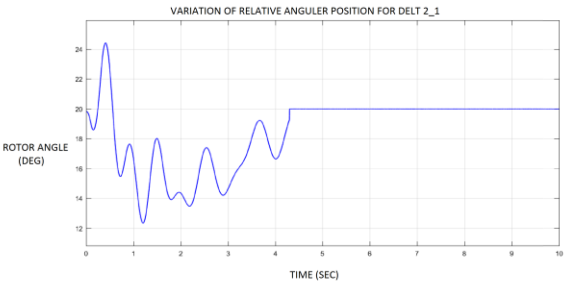

Fig12: Variation of Relative angular position for delt2_1

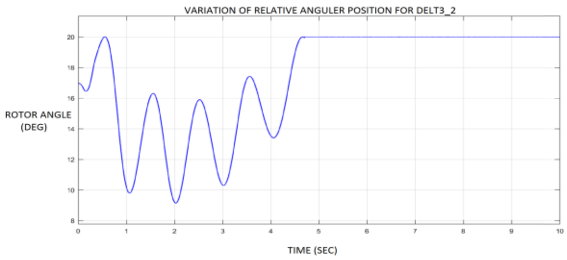

Fig13: Variation of Relative angular position for delt3_1

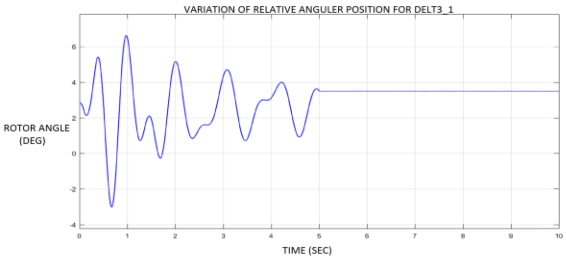

Fig14: Variation of Relative angular position for delt3_1

D. *Matlab/Simulink model of multi-machine (3-machine, 9-bus) WSCC system incorporated with UPFC*

IEEE 9-bus bar power system incorporated with svc is shown in Fig-15.

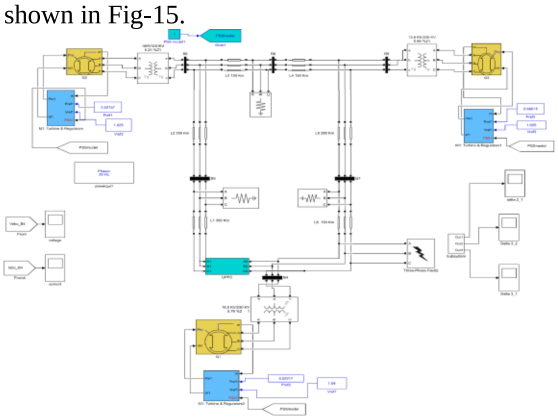

Fig 15: MATLAB/SIMULINK model of WSCC 3-Machine 9-Bus system incorporated with UPFC

*The relative angular positions for delt2_1, delt3_2 and delt3_1 of IEE 9 bus system incorporated with UPFC are shown in Fig-16, Fig-17 and Fig-18 respectively.*The total simulation time taken is 10 seconds. It has been analyzed at various instance of time as the fault takes place in the system, the system becomes unstable. To bring back the system to stability the UPFC has been place.

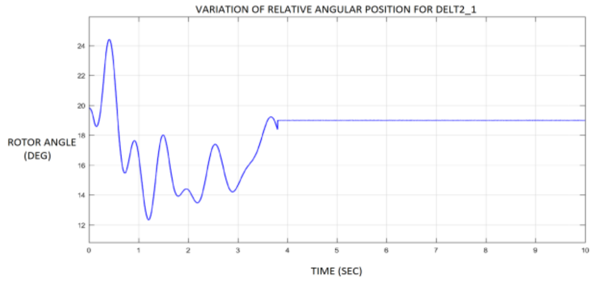

Fig16: Variation of Relative angular position for delt2_1

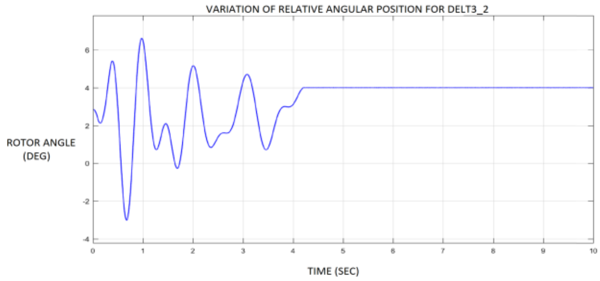

Fig17: Variation of Relative angular position for delt3_2

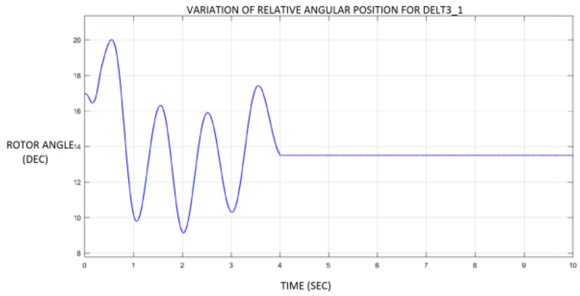

Fig18: Variation of Relative angular position for delt3_1

E. *Comparision of time taken for stability*

Table 1 shows the time taken for stability comparison of SVC, STATCOM, and UPFC of an IEEE 3-machine 9-bus system (WSCC)

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_2 (In sec.)
SVC	Between bus 7 and bus 9	4.8	5.7	5.6
STATCOM	Between bus 7 and bus 9	4.3	5	4.6
UPFC	Between bus 7 and bus 9	3.8	4	4.1

F. Matlab/Simulink model of multi-machine (5-machine, 14-bus) IEEE system without facts

IEEE 14-bus bar power system as shown in Fig-19

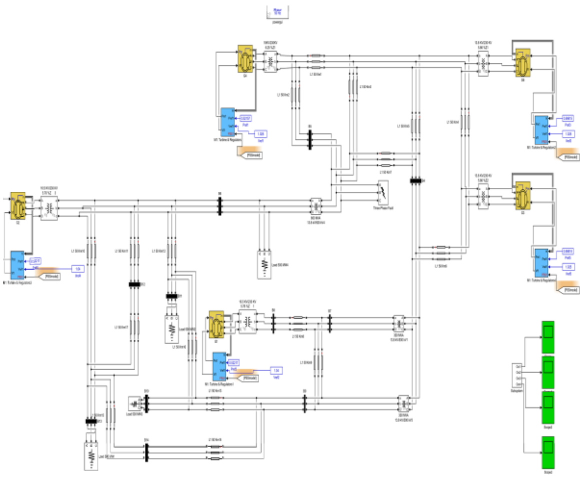

Fig 19: MATLAB/SIMULINK model of WSCC 5-Machines 14-Bus System without facts

The relative angular positions for delt2_1, delt3_2 , delt3_1 and delt4_1 of IEEE 14 bus system with out facts device showen in Fig-20, Fig-21, Fig-22, and fig-23 respectively and the simulation time is 40 seconds.

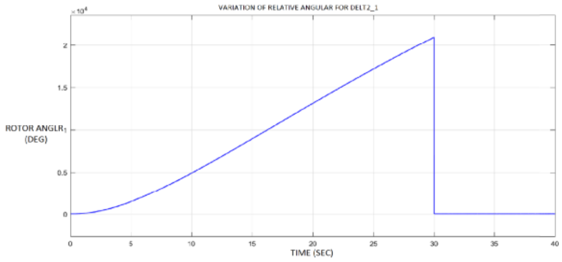

Fig20: Variation of Relative angular position for delt2_1

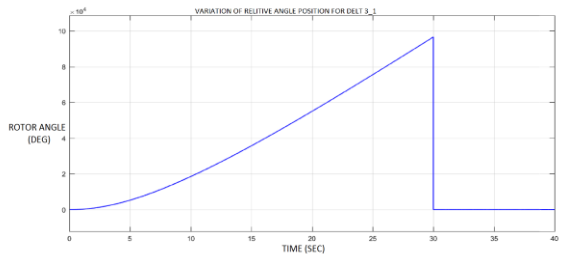

Fig21: Variation of Relative angular position for delt3_1

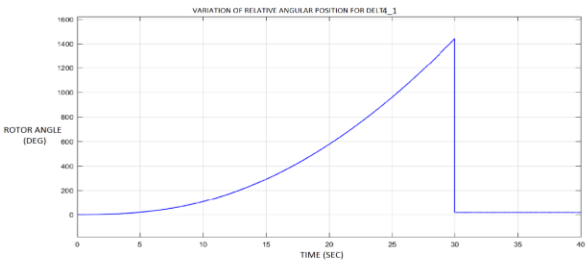

Fig22: Variation of Relative angular position for delt4_1

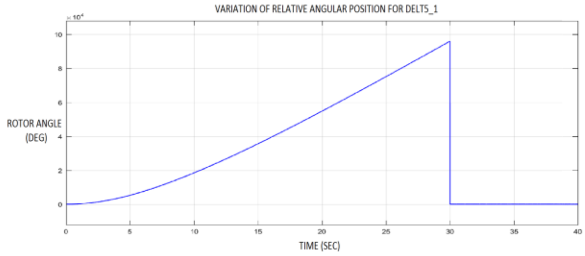

Fig23: Variation of Relative angular position for delt5_1

G. Matlab/Simulink model of multi-machine (5-machine, 14-bus) IEEE system incorporated with SVC

IEEE 14-bus bar power system incorporated with svc is shown in Fig-24

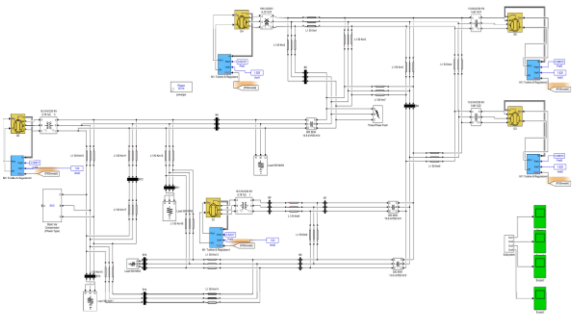

Fig 24: MATLAB/SIMULINK model of WSCC 5-Machine 14-Bus system incorporated with SVC

The relative angular positions for delt2_1, delt3_1, delt4_1 and delt5_1 of IEE 14 bus system incorporated with SVC shown in Fig-25, Fig-26, Fig-27, and Fig-28 respectively. The total simulation time taken is 10 seconds. It has been analyzed at various instance of time as the fault takes place in the system, the system becomes unstable. To bring back the system SVC has been placed.

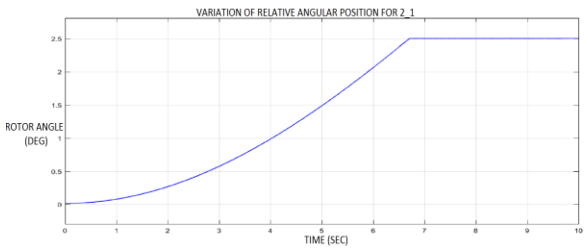

Fig25: Variation of Relative angular position for delt2_1

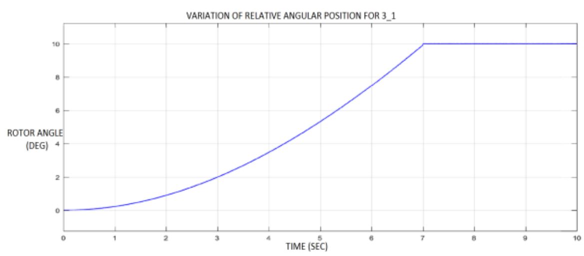

Fig26: Variation of Relative angular position for delt3_1

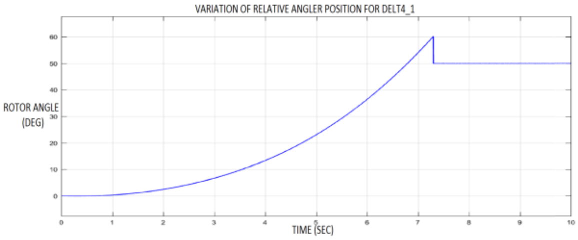

Fig27: Variation of Relative angular position for delt4_1

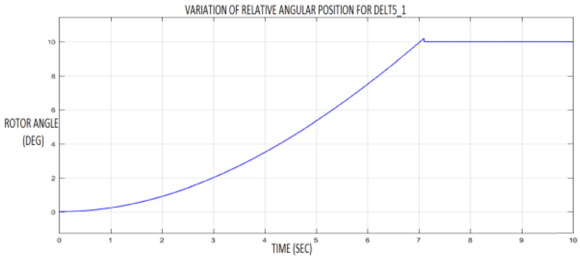

Fig28: Variation of Relative angular position for delt5_1

H. *Matlab/Simulink model of multi-machine (5-machine, 14-bus) IEEE system incorporated with STATCOM*

IEEE 14-bus bar power system incorporated with STATCOM is shown in Fig-29

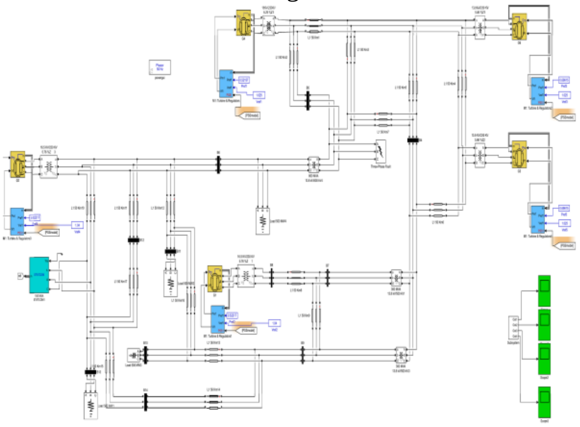

Fig 29: MATLAB/SIMULINK model of WSCC 5-Machine 14-Bus system incorporated with STATCOM

The relative angular positions for delt2_1, delt3_1, delt4_1 and delt5_1 of IEE 14 bus system incorporated with SVC shown in Fig-30, Fig-31, Fig-32, and Fig-33 respectively. The total simulation time taken is 10 seconds. It has been analyzed at various instance of time as the fault takes place in the system, the system becomes unstable. To bring back the system STATCOM has been placed.

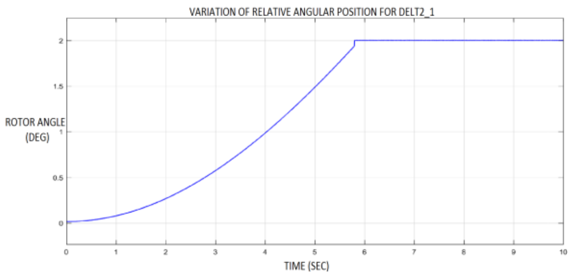

Fig30: Variation of Relative angular position for delt2_1

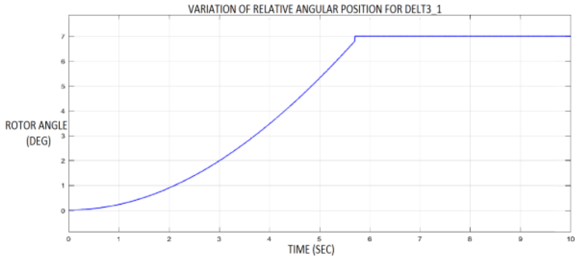

Fig31: Variation of Relative angular position for delt3_1

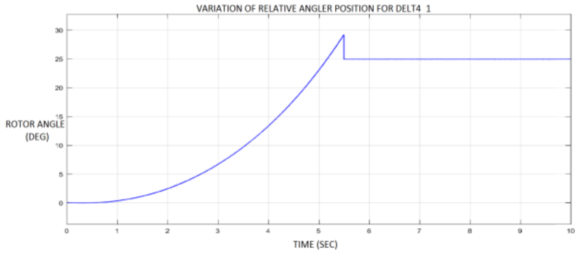

Fig32: Variation of Relative angular position for delt4_1

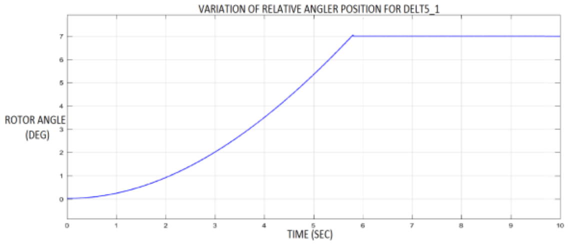

Fig33: Variation of Relative angular position for delt5_1

I. *Matlab/Simulink model of multi-machine (5-machine, 14-bus) IEEE system incorporated with UPFC*

IEEE 14-bus bar power system incorporated with UPFC is shown in Fig-34

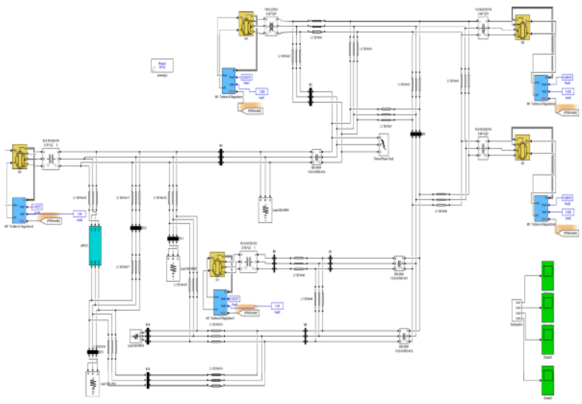

Fig 34: MATLAB/SIMULINK model of WSCC 5-Machine 14-Bus system incorporated with UPFC

The relative angular positions for delt2_1, delt3_1, delt4_1 and delt5_1 of IEE 14 bus system incorporated with SVC shown in Fig-35, Fig-36, Fig-37, and Fig-38 respectively. The total simulation time taken is 10 seconds. It has been analyzed at various instance of time as the fault takes place in the system, the system becomes unstable. To bring back the system UPFC has been placed.

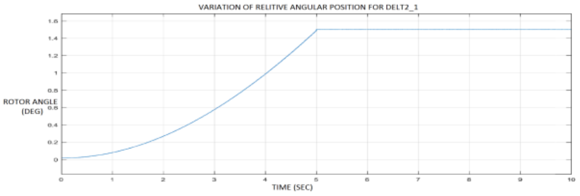

Fig35: Variation of Relative angular position for delt2_1

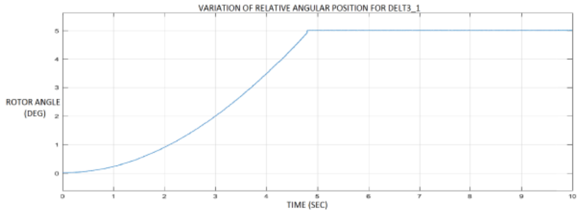

Fig36: Variation of Relative angular position for delt3_1

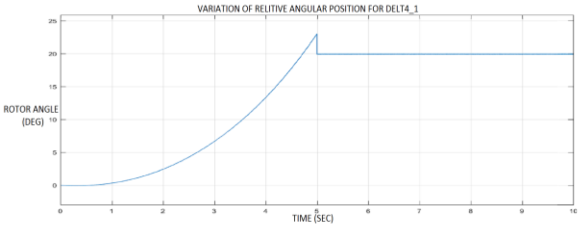

Fig37: Variation of Relative angular position for delt4_1

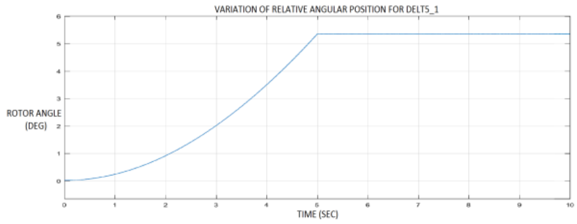

Fig38: Variation of Relative angular position for delt5_1

J. Comparision of time taken for stability

Table 2 shows the time taken for stability comparison of SVC, STATCOM, AND UPFC of a IEEE 5-machine 14-bus system.

Facts devices	Facts position	Stability time for delt2_1 (In sec.)	Stability time for delt3_1 (In sec.)	Stability time for delt4_1 (In sec.)	Stability Time for delt5_1 (In sec.)
SVC	Between bus 2 and bus 13	6.6	7	7.2	7.1
STATCOM	Between bus 2 and bus 13	5.8	5.7	5.5	5.9
UPFC	Between bus 2 and bus 13	5	4.8	5	5.1

V. CONCLUSION

In this paper the power system stability has been compared and discussed for improvement of a 3-machine 9 bus and 5-machine 14-bus systems by STATCOM, SVC & UPFC. The dynamic behavior 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 good while compared to SVC and STATCOM and hence the time taken for settle the system to stable state is less compared with the STATCOM and SVC. **It is 3.8 seconds for 9-bus system and 5 seconds for 14 bus system**

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