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Modeling and Simulation of Multi-machine System Using UPFC for Enhancing Transient Stability

Amritpreet Singh^a, Lini Mathew^b

Electrical Engineering Department,
National Institute of Technical Teacher Training & Research, Chandigarh, India

^{a,b}E-mail address: amritpreetsingh007@gmail.com, lenimathew@yahoo.com

ABSTRACT

In this paper, transient stability of IEEE 9- bus system combined with Unified Power Flow Controller (UPFC), has been accomplished. UPFC based on Voltage Source Controller (VSC) has a higher switching frequency, an obvious voltage harmonic and a lower voltage level. Under a symmetrical three-phase short circuit with a different fault locations were used and the load angle variation also studied to test the control performance. The multi machine system combined with UPFC controller, perform outstanding to reduce damping oscillation in power system observed in results of simulation.

Keywords: FACTS, UPFC, Transient Stability, Reactive Power compensation

1. INTRODUCTION

Nowadays, the increase in loading of existing power transmission system results in the problems of voltage instability. Maintaining constant voltage level at all buses is a major challenge due to heavy loading on transmission network it make the stabilizing problem more challenging. With the application of FACTS devices, the stability of power system can be enhanced considerably [1] Generally, FACTS devices can be connected in series, shunt, or combination of both. FACTS devices are skillful to control the real, reactive power, voltage-magnitude and line impedance simultaneously and thus improves the overall act of the system.

FACTS devices not only increase the power transmission capability, but also enhance the stability, transfer capability, as well as reduce the transmission losses [2].

These abilities make the UPFC most power full device in current scenario control and transmission system. To find the optimum location for UPFC and the angle and amount voltage to be injected is a prime issue. In the present revamp energy market, new modelling methods for UPFC and controller design are being established to elevate the power system performances [3],[4]. UPFC is comprised of shunt and series converter which are connected via a common dc link. The series transformer is used to connect the series converter to the transmission line and inject series voltage V_b . Operating function of shunt convertor is to supply active power, which is required by series converter, dc bus voltage regulator to overcome losses in the line and also compensates reactive power independently. It Control and meet the different objectives in variety of ways.

This has made UPFC generalize to control for various uses [5]. The many researchers have developed few approach to identify the optimal location in transmission line [6]. A optimization algorithms have used to obtain the size and optimal location [7]. In section II discourse about UPFC controller and its topology, Section III present modeling and simulation of multi machine system using with and without UPFC and Results and discussions are discoursed in Section IV.

2. UNIFIED POWER FLOW CONTROLLER

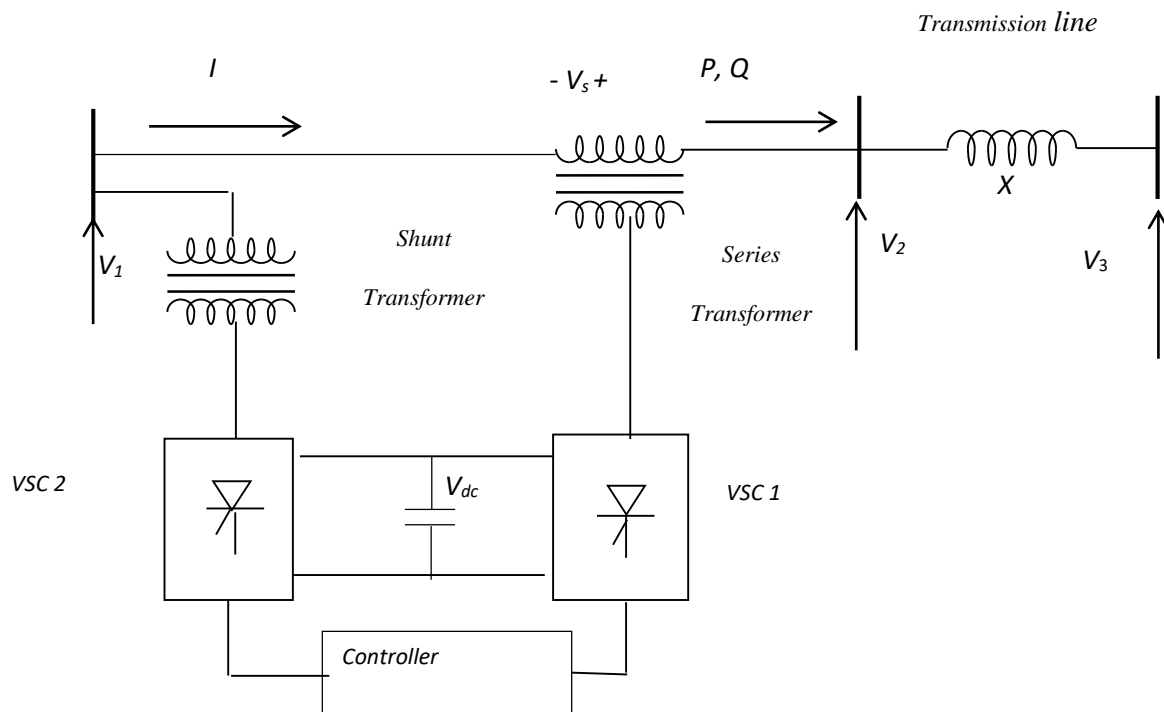


Figure 1. Single-Line Diagram of a UPFC

The UPFC concept was proposed by Gyugyi in 1991. It is a powerful FACTS device that uses two voltage source converters together (VSC). Since voltage sourced converters are used along with passive devices to control power flow, UPFC provides fast-acting reactive power compensation on high-voltage electricity transmission networks. UPFC works in both directions to maintain real and reactive power in transmission systems.

The UPFC combines with the two FACTS devices: Static Synchronous Series Compensator (SSSC) and Static Synchronous Compensator (STATCOM). In the presence of two converters, UPFC supplies active and reactive power. [8] In steady-state operation, UPFC neither injects reactive power nor absorbs active power.

The voltage sourced converters VSC1 and VSC2 are connected to the transmission line by coupling transformers shown in Figure 1.

The DC terminals of the converters are coupled to form a common DC link. Active power is exchanged with the help of the DC circuit in UPFC. The reactive power supply in the transmission line and the flow of active power in the transmission line are controlled by controlling the magnitude and supplied angles of voltage by the converters. It is an ability to control line impedance, voltage and phase angle simultaneously or selectively; this capability is due to both shunt and series compensation. UPFC can be used to independently and simultaneously control the flow of active power through the line.

3. MODELLING AND SIMULATION OF MMIB USING UPFC

In this section, Controlling and Simulation of UPFC has been discussed using MATLAB environment. For Multi Machine (3 machines 9 bus) system simulation work has been carried out. By considering the occurrence of three phase fault and varying different system parameters has been analyzed for various responses in this case. With the damping constant, Fault clearing time and the location of fault and its effect on the system stability leads to learning about variation of load angle has been carried out during investigation.

3. 1. WSCC-Multi-Machine Infinite Bus (MMIB) System

The WSCC (Western System Coordinated Council) System having 3-machines 9-bus with standard value of parameters has been considered as a test case. Figure 2. shows the WSCC 3-machines 9-bus system.

3. 2. UPFC controller

UPFC is contained of shunt and series converter which are connected via a common DC link. The adjustable phase angle voltage and magnitude can be generated by a series converter.

The primary requirement of the real power provided by shunt converter but VAR compensator, it can also act as an independent operator. The exchange of active power in UPFC controller is done by DC link with the loss in the controller component and the flow through link, disturbs the DC voltage level.

Hence DC voltage regulator required for proper operation of the controller, which can be attained by separate control loop. Finally, a control procedure is required to start up the UPFC.

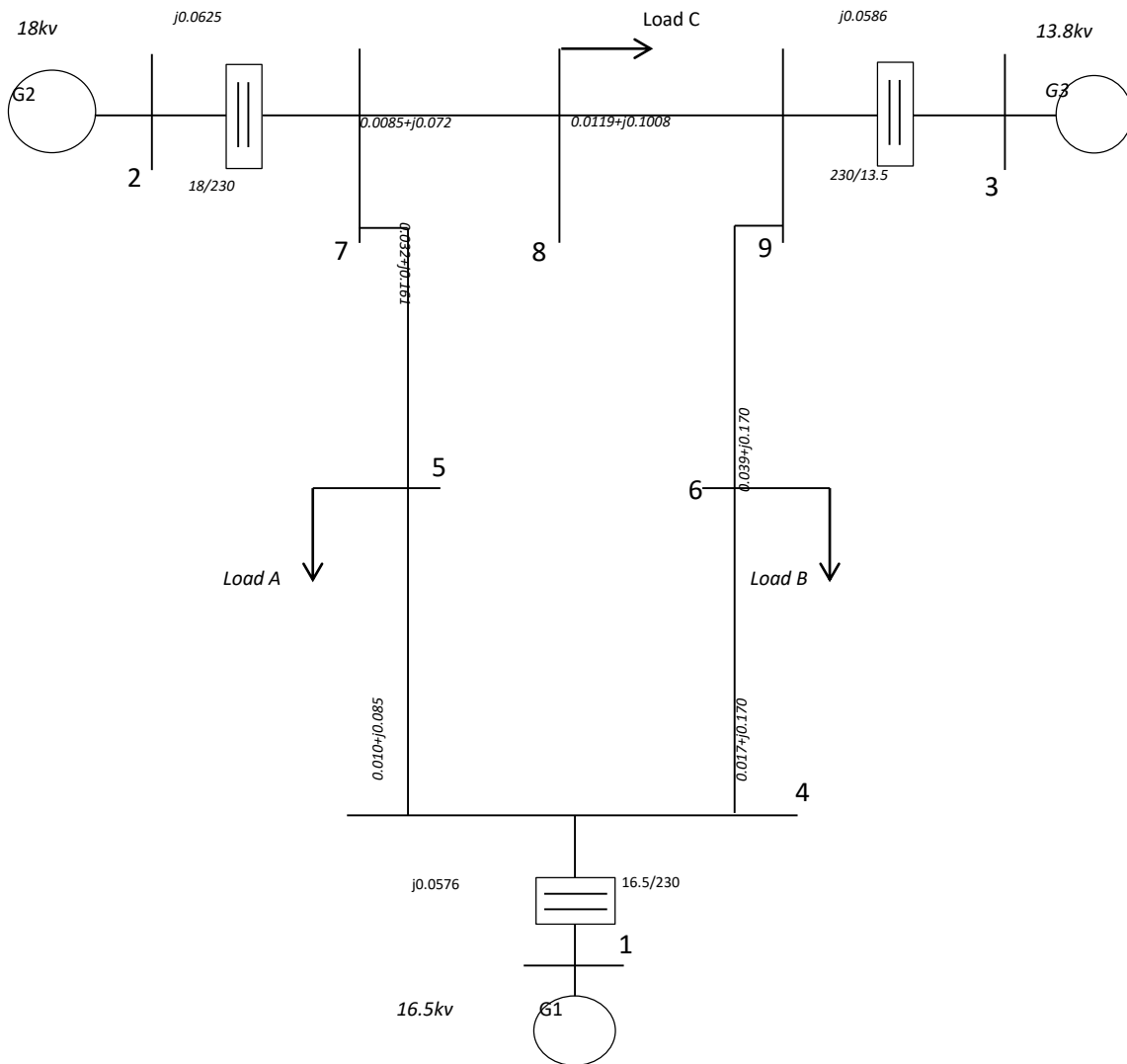


Figure 2. WSCC 3-Machines, 9-Bus System

3. 3. MATLAB/Simulink based model of WSCC without UPFC

The MATLAB/Simulink based model of WSCC 3-Machine 9-Bus system without UPFC shown in Figure 3. In this model three phase fault and compensating device is not connected. It provides transient response of system in the condition of without fault.

3. 4. MATLAB/Simulink based model of WSCC with UPFC

In MATLAB/Simulink based model of WSCC 3-Machine 9-Bus system with UPFC and three phase fault at three different location are shown in Figure 4.

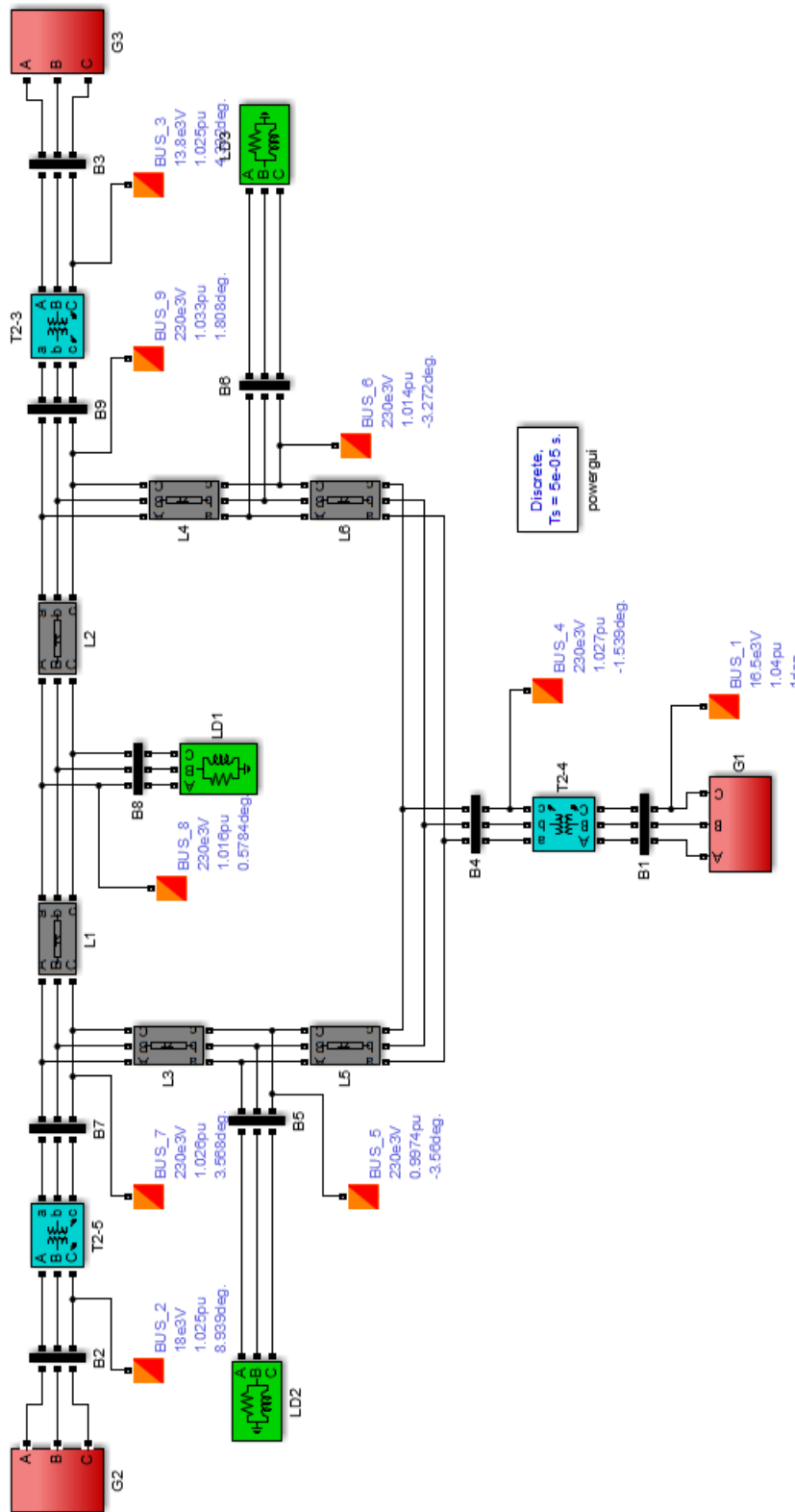


Figure 3. MATLAB/Simulink Based Model of WSCC without UPFC

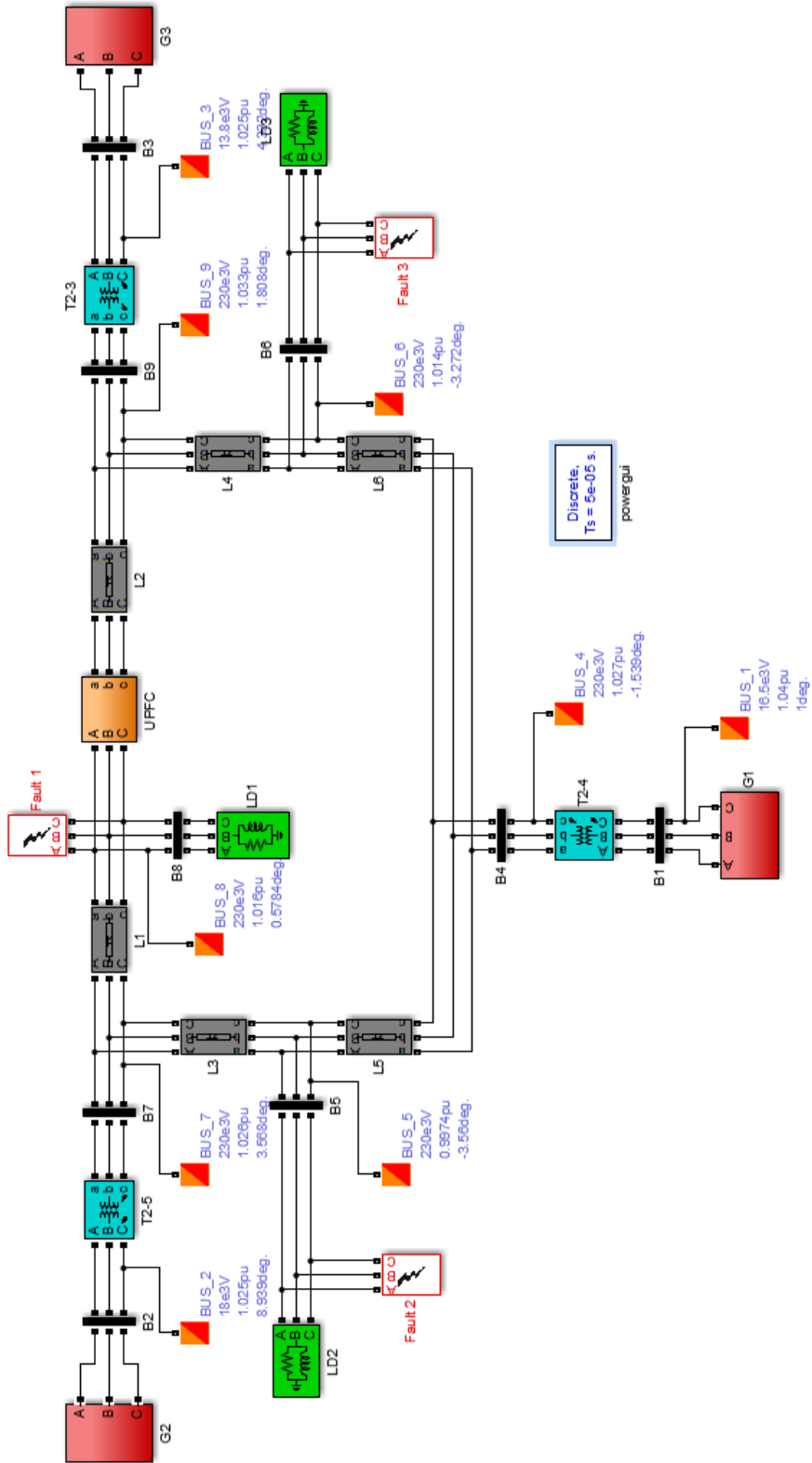


Figure 4. MATLAB/Simulink Based Model of WSCC with UPFC

3. 5. Converter controller

In converter controller different type of blocks are used like Phase Locked Loop (PLL), measurement, current regulator and reference computation block. To match the frequency of an input signal voltage driven oscillator that repeatedly adjusted by the PLL block. The value of P, Q, Vd, Vq, Id, and Iq are measure by measurement system with the help of bus terminal frequency and voltage. Measurement of Id and Iq reference values done by reference computation block with the help of reference values of P, Q and Vd, Vq. The Vd, Vq value and the current value are generated by current regulator block. between both converters and generate sigma signal voltage is compared with DC voltage transferred in Sigma Computation block. To control the operation of converters Firing pulse generator produces firing pulse on basis of reference values. MATLAB/Simulink mode of UPFC is shown in Figure 5.

4. RESULT AND DISCUSSIONS

A fault was considered at three different locations and their effect was studied with and without UPFC. The three phase fault is occurring just after 5 second and fault clearing time is 1 second. The variation of relative angular position load angle 1-2, load angle 2-3 and load angle 3-1 with respect to time is observed.

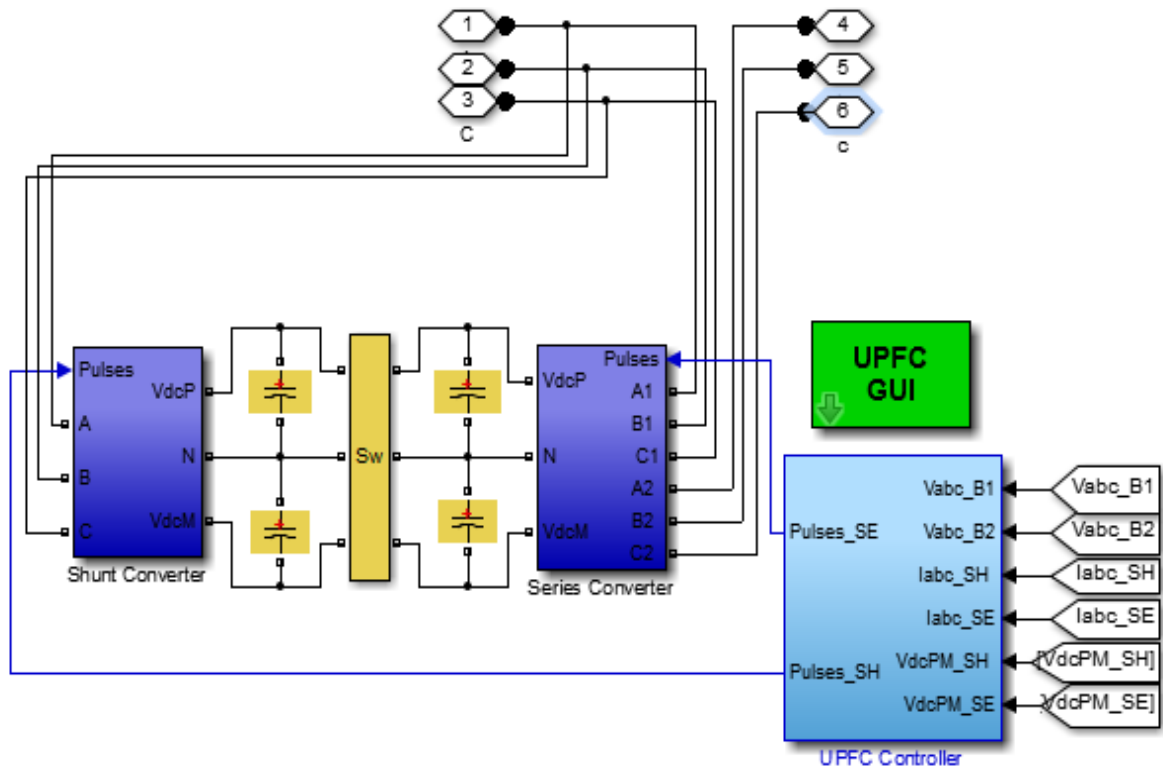


Figure 5. MATLAB/Simulink Based Model of UPFC

4. 1. Veriatio of relative load angles at location 1

The results of variation in maximum value of overshoot (degree), steady state stable value of relative angular position (degree) and value of time taken to attain stability (second) at location 1 are shown in Figure 6-8 for with and without UPFC.

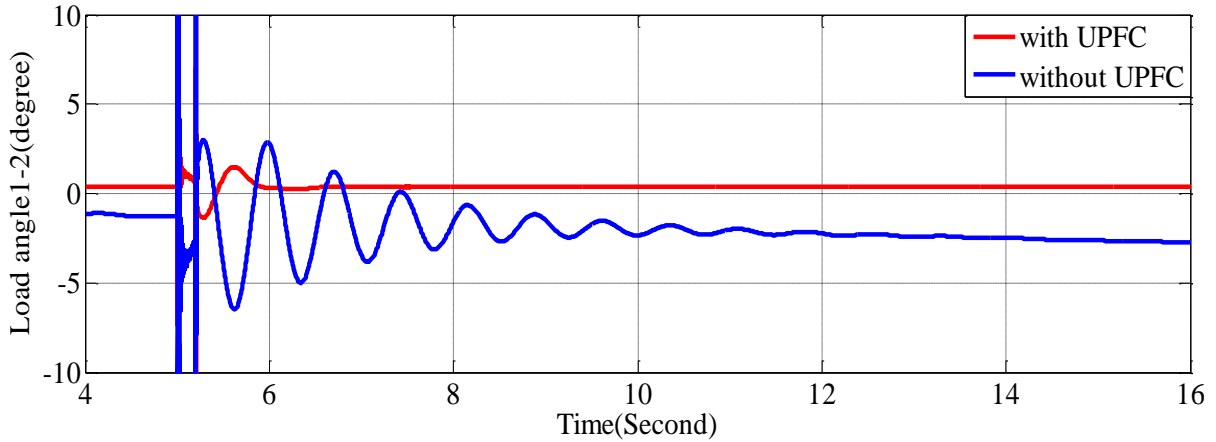


Figure 6. Relative Load Angle 1-2 w.r.t Time

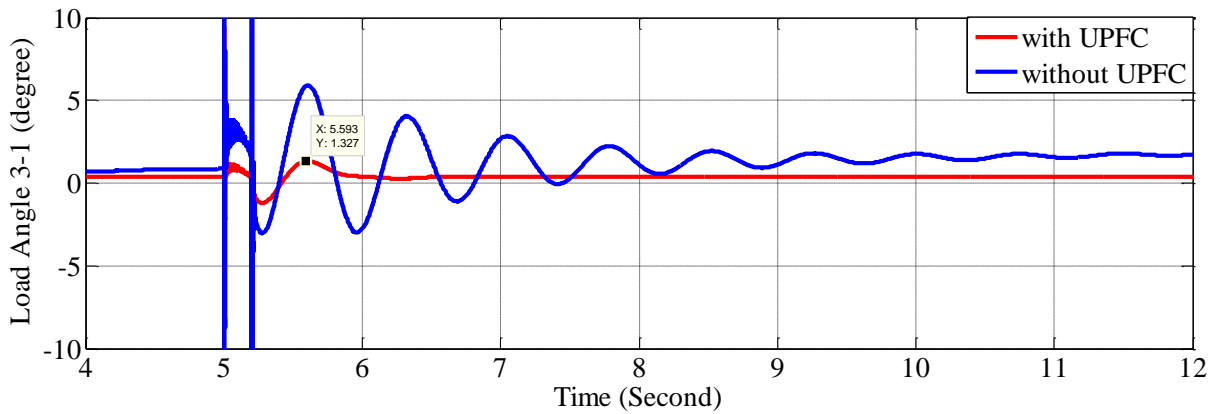


Figure 7. Relative Load Angle 2-3 w.r.t Time

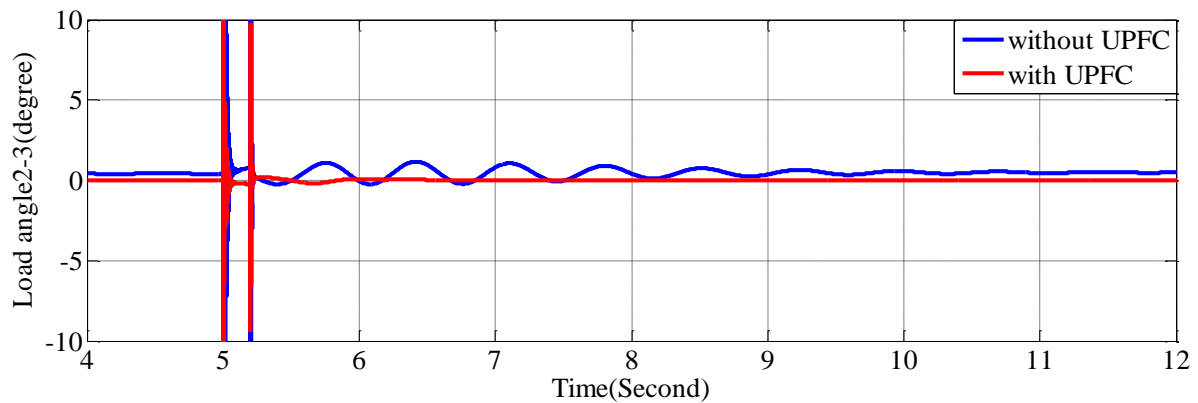


Figure 8. Relative Load Angle 3-1 w.r.t Time

4. 2. Veriatio of relative load angles at location 2

The results of variation in maximum value of overshoot (degree), steady state stable value of relative angular position (degree) and value of time taken to attain stability (second) at location 1 are shown in Figure 9-11 for with and without UPFC.

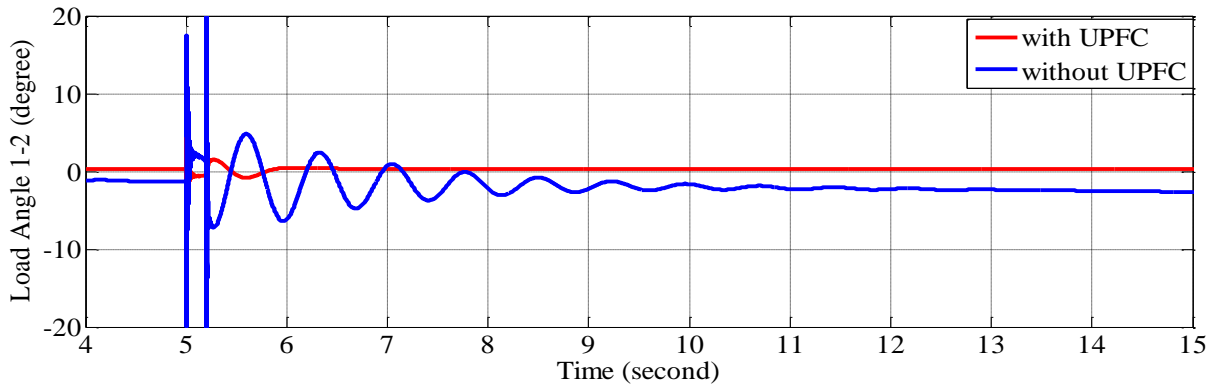


Figure 9. Relative Load Angle 1-2 w.r.t Time

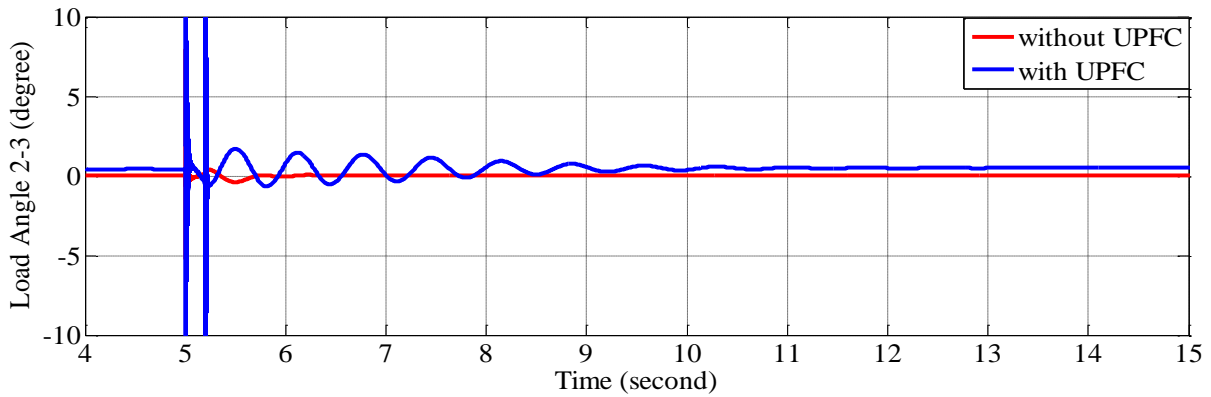


Figure 10. Relative Load Angle 2-3 w.r.t Time

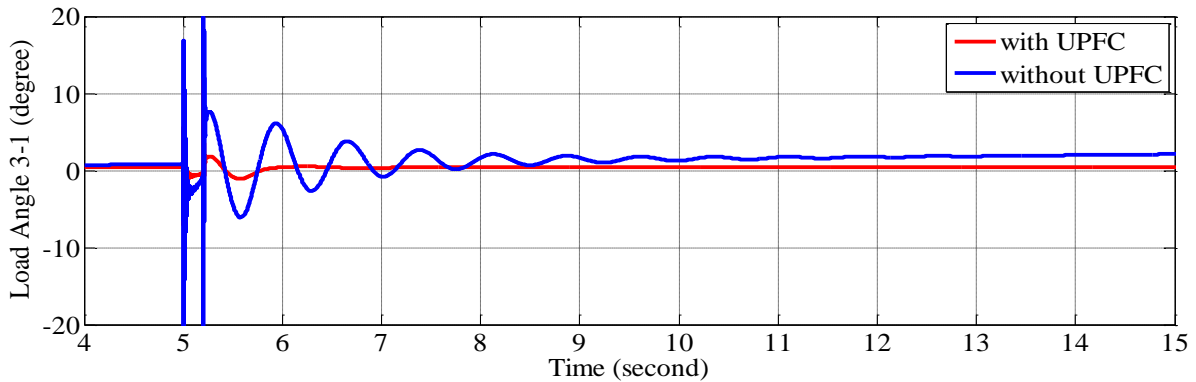


Figure 11. Relative Load Angle 3-1 w.r.t Time

4. 3. Veriatio of relative load angles at location 3

The results of variation in maximum value of overshoot (degree), steady state stable value of relative angular position (degree) and value of time taken to attain stability (second) at location 1 are shown in Figure 12-14 for with and without UPFC.

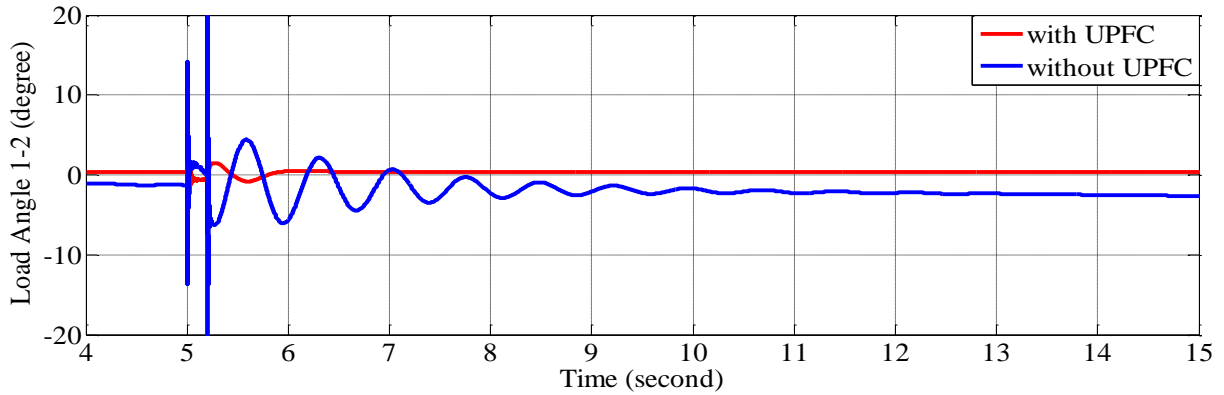


Figure 12. Relative Load Angle 1-2 w.r.t Time

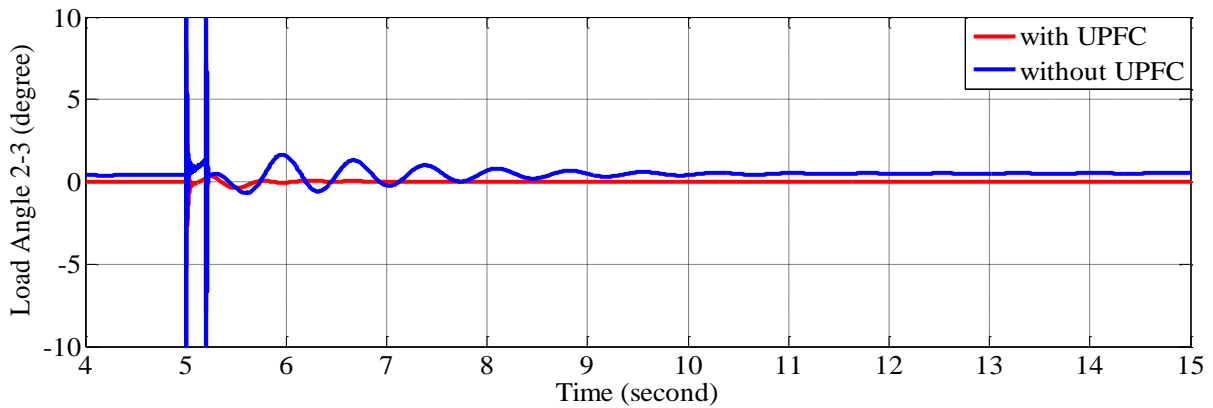


Figure 13. Relative Load Angle 2-3 w.r.t Time

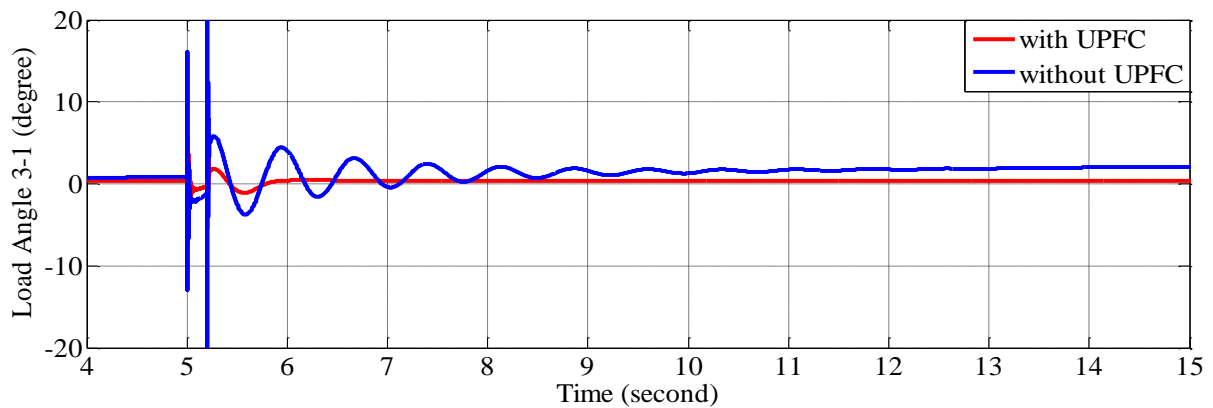


Figure 14. Relative Load Angle 3-1 w.r.t Time

It can be observed from above figures that irrespective of location of fault, UPFC reduces the time taken to attain stability value approximate 1/4rd of uncompensated network. UPFC tends to the steady state stable value of relative angular position near to zero. Maximum value of overshoot value is reduced by around 1/3rd of uncompensated network by UPFC, irrespective of fault location. The response of the generator nearest to the fault location having more transient.

5. CONCLUSIONS

The present work shows that irrespective of the location of fault, 3- Machine 9- Bus WSCC system has been successfully modelled and investigated by implementing voltage source converter type FACTS – UPFC in MATLAB/Simulink environment and the controller performance in enhancing power system transient stability was investigated. Simulation result is quite encouraging and shows the effectiveness of UPFC. It has been found to be versatile FACTS controller as it has unique capability of controlling simultaneously/ selectively all the parameters affecting power flow in transmission line i.e voltage, impedance and phase angle. It is also seen UPFC can independently control both real and reactive power flow in transmission line. Performance evaluation in terms of transient stability improvement has been studied and the load angle variations with time have been plotted in both the cases by varying the location of fault UPFC improves the transient response of system. The extent of change in the value of parameters such as steady state stable value, time taken to attain stability and maximum value of overshoot, depends on distance between fault location and both, generator and Controller.

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