Location of UPFC in A Multimachine System for Damping Power Oscillation

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ABSTRACT

Day by day electrical power consumption has been increasing very rapidly. It must be necessary to supply to all the consumers with quality and reliability. So the exact prediction of load is not possible but only estimated that the generation must be equal to load all the times. Due to variation in load low frequency oscillation, electromechanically oscillations are unavoidable characteristics of power system. FACTS devices can be use to damp these low frequency oscillations. In this paper, result obtained for the dynamic control of the power transmission, damping oscillations with UPFC based on theory & computer simulation through PSAT software. The objective of this paper is to find location of UPFC in a Multimachine power system tested on IEEE-14 bus system, relation between system parameters and effect of oscillation.

Keywords - UPFC, FACTS, Power oscillation damping, PSAT.

1. INTRODUCTION

In electrical energy system, faults and switching event cause power oscillations of generator that can increase the loss of synchronism. The loss of synchronism becomes more difficult by growth of generators units, rated power increasing loads on interconnection lines. In the environment, high performance control of the power network is required. "Flexible ac transmission system'' (FACTS) is the technology that minimizing the gap between the stability and thermal limits and provides the needed corrections of the transmission functionality in order to fully utilize the existing transmission facilities.

A unified power flow controller (UPFC) is an electronic device, which can control power, line impedance and phase angle. Actually, UPFC is a multifunction FACTS controller with the primary function of power flow control and possible secondary duties of voltage support, transient stability improvement and oscillation damping [1][2]. In this paper, a study is performed for damping oscillation in Multimachine power system using UPFC. The purpose of this paper is to study effect of various UPFC locations and to improve the damping of low frequency oscillation of IEEE-14bus system and evaluate the results by simulating in PSAT (Federico, 2005) [5].

1.1. UPFC Unified Power Flow Control

The UPFC (Unified Power Flow Control) is the most versatile of the FACTS controller. It not only performs the function of STATCOM, TCSC and the phase angle regular but also provides additional flexibility by combine same functions of above controllers. The main function of UPFC [6] is to control the flow of real and reactive power by injection of a voltage in series with transmission line. Both the magnitude and the phase angle of the voltages can be varying independently. Real and Reactive power flow control can allow power flow in prescribed routes, loading of transmission line closer to their thermal limits and can be utilized for improving transient and small signal stability [8].

1.2 Basic operating principle

The UPFC has two voltage source inverters sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI connect in shunt to the transmission system via a shunt transformer, while the other one connected in series through a series transformer [1]. The series inverter controlled to inject a symmetrical three-phase voltage system (Vse) of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. Therefore, this inverter will exchange active and reactive power with the line. The series inverter electronically provides the reactive power, and the active power transmitted to the dc terminals. The shunt inverter operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vde constant. Therefore, the net real power absorbed from the line by the UPFC is equal only to the shunt inverter can be used to exchange reactive power with the line to provide a voltage regulation at the connection point.

The two VSI's can work complementary to each other by separating the dc side. Therefore, in that case, the shunt inverter is operating as a STATCOM that connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate power to regulate the current flow, and hence the power flows on the transmission line.

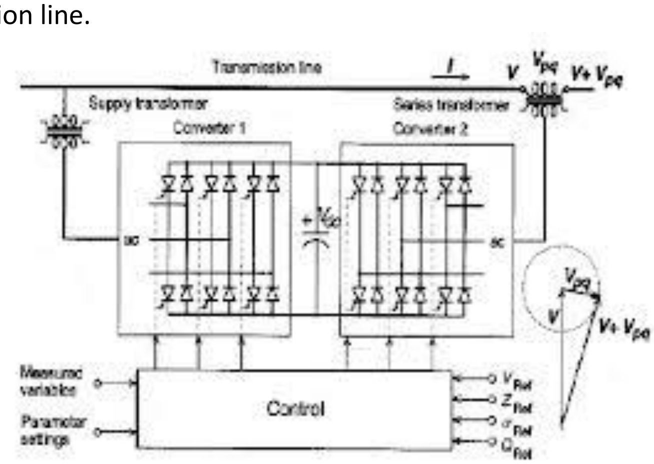

Figure 1: A basic UPFC functional scheme

2. STUDY SYSTEM

The IEEE 14 bus system modeled in PSAT software is shown in fig2.It consists of 5 generators, 14 transmission lines, 11 static loads and 4 transformers. Base MVA taken as 100 and base system voltage is 69KV.

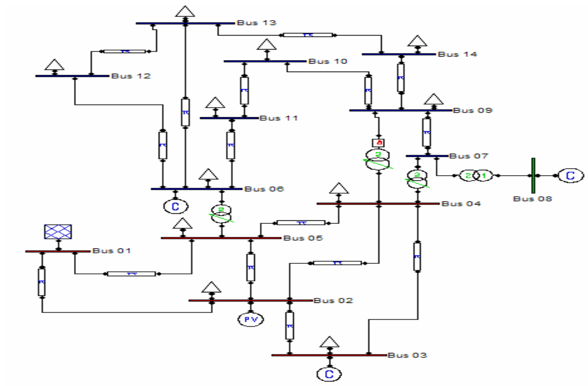

Figure 2: IEEE 14-bus system

3. MODELING OF UPFC (UNIFIED POWER FLOW CONTROLLER)

UPFC can represent by two-voltage source representing fundamental components of output voltage waveforms of the two converters and impedances being leakage reactance of the two coupling transformers.

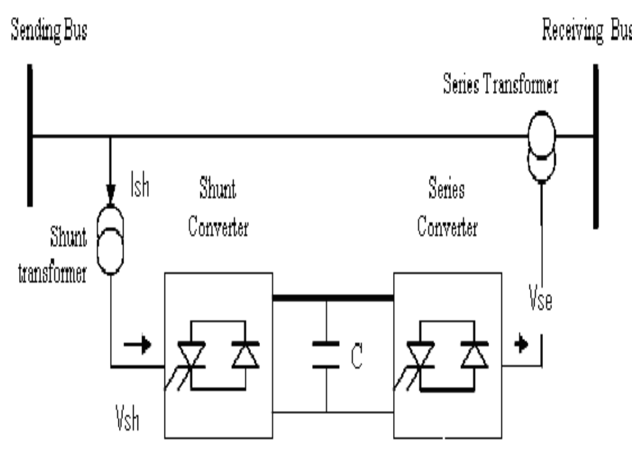

Figure 3: Diagram of UPFC

The active and reactive power equations written as

At bus k

$$P_k = V_k^2 G_{kk} + V_k V_m [G_{km} \cos(\theta_k - \theta_m) + B_{km} \sin(\theta_k - \theta_m)] + V_k V_{CR} [G_{km} \cos(\theta_k - \delta_{cr}) + B_{km} \sin(\theta_k - \delta_{cr}) + V_k V_{vr} [G_{vr} \cos(\theta_k - \delta_{vr}) + B_{vr} \sin(\theta_k - \delta_{vr})] \quad (1)$$

$$Q_k = -V_k^2 B_{kk} - V_k V_m [G_{km} \sin(\theta_k - \theta_m) - B_{km} \cos(\theta_k - \theta_m)] + V_k V_{cr} [G_{km} \sin(\theta_k - \delta_{cr}) - B_{km} \cos(\theta_k - \delta_{cr}) + V_k V_{vr} [G_{vr} \sin(\theta_k - \delta_{vr}) + B_{vr} \cos(\theta_k - \delta_{vr})] \quad (2)$$

At bus m

$$P_m = V_m^2 G_{mm} + V_k V_m [G_{mk} \cos(\theta_m-\theta_k) + B_{mk} \sin(\theta_m-\theta_k)] + V_m V_{cr} [G_{mm} \cos(\theta_m-\delta_{vr}) + B_{mm} \sin(\theta_m-\delta_{cr})] \quad (3)$$

$$Q_m = -V_m^2 B_{mm} + V_k V_m [G_{mk} \sin(\theta_m-\theta_k) - B_{mk} \cos(\theta_m-\theta_k)] + V_m V_{cr} [G_{mm} \sin(\theta_m-\delta_{vr}) - B_{mm} \cos(\theta_m-\delta_{cr})] \quad (4)$$

Series converter

$$P_{cr} = V_{cr}^2 G_{mm} + V_{cr} V_k [G_{km} \cos(\delta_{cr}-\theta_k) + B_{mk} \sin(\delta_{cr}-\theta_k)] + V_m V_{cr} [G_{mm} \cos(\delta_{cr}-\theta_m) + B_{mm} \sin(\delta_{cr}-\theta_m)] \quad (5)$$

$$Q_{cr} = -V_{cr}^2 B_{mm} + V_{cr} V_k [G_{km} \sin(\delta_{cr}-\theta_k) - B_{mk} \cos(\delta_{cr}-\theta_k)] + V_m V_{cr} [G_{mm} \sin(\delta_{cr}-\theta_m) - B_{mm} \cos(\delta_{cr}-\theta_m)] \quad (6)$$

Shunt converter

$$P_{vr} = -V_{vr}^2 G_{vr} + V_{vr} V_k [G_{vr} \cos(\delta_{vr}-\theta_k) + (B_{vr} \sin(\delta_{vr}-\theta_k))] \quad (7)$$

$$Q_{vc} = V_{vr}^2 B_{vr} + V_{vr} V_k [G_{vr} \sin(\delta_{vr}-\theta_k) - B_{vr} \cos(\delta_{vr}-\theta_k)] \quad (8)$$

4. SIMULATIONS RESULT AND DISCUSSION

Simulations of this system carried out with and without UPFC.At fault duration, it is observe that the system without UPFC oscillates after the fault is cleared, whereas the desired power flow conditions reach quickly after the fault is cleared for the system with UPFC. The power swings of the machines in IEEE-14bus network are prominent in the speeds and rotor angles of that M/c, particularly at contingencies for stability.

A three phase to ground fault is create at bus 4 and time domain simulation has done using PSAT software. Fig.4, 6, 8,10,12,14 shows the plots of relative rotor angles, angular speeds and lowest voltages. It is cleared that without UPFC, oscillations damp out after a considerable period.

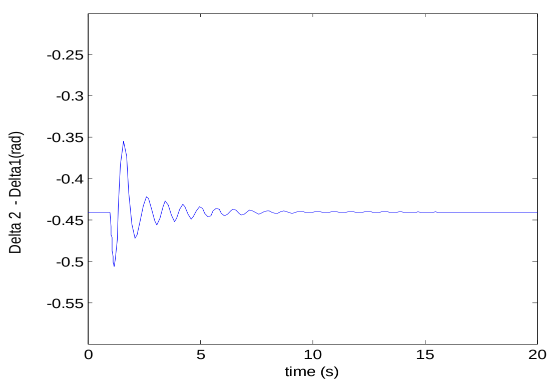

Figure4: Simulation results of Multimachine system without UPFC and Fault applied with respect to Load angle

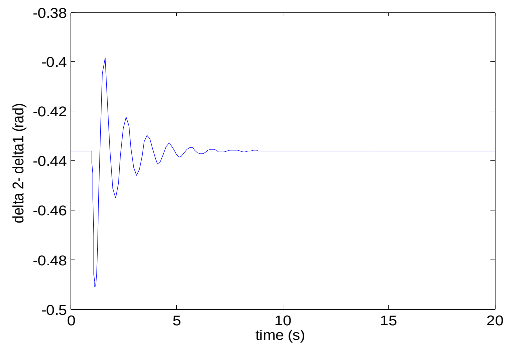

Figure 5: Simulation results of Multimachine system with UPFC and Fault applied with respect Load angle.

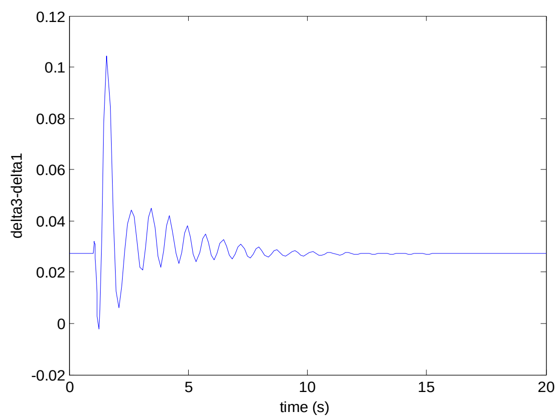

Figure 6: Simulation results of Multimachine system without UPFC and Fault applied with respect to Load angle

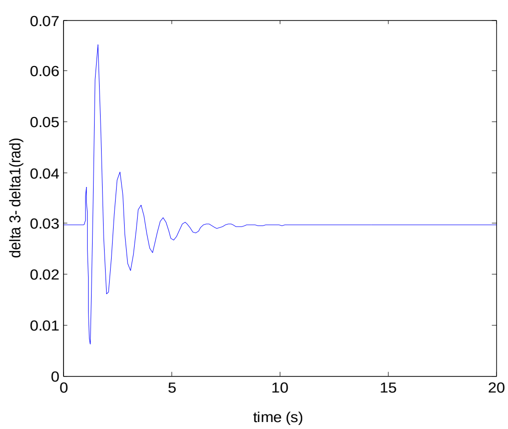

Figure 7: Simulation results of Multimachine system with UPFC and Fault applied with respect to Load angle.

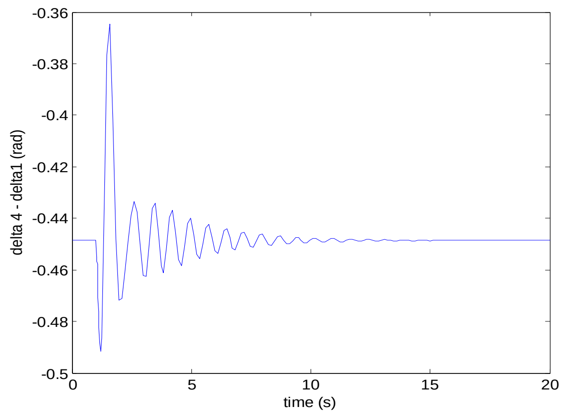

Figure 8:.Simulation results of Multimachine system without UPFC and Fault applied with respect to Load angle.

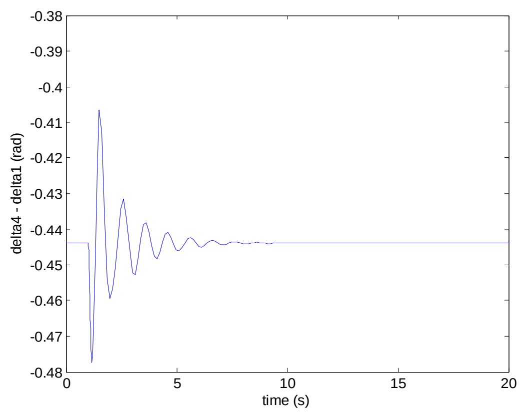

Figure 9:.Simulation results of Multimachine system with UPFC and Fault applied with respect to Load angle.

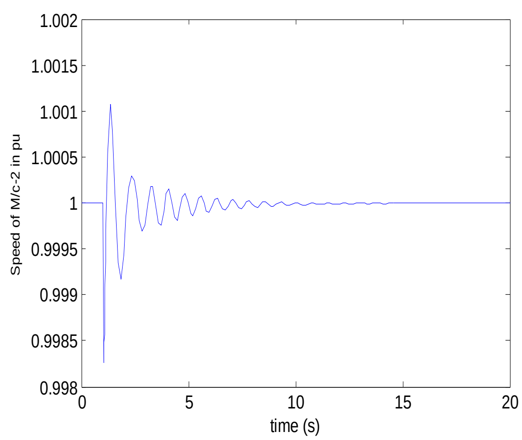

Figure 10:.Simulation results of Multimachine system without UPFC and Fault applied with respect to Rotor speed.

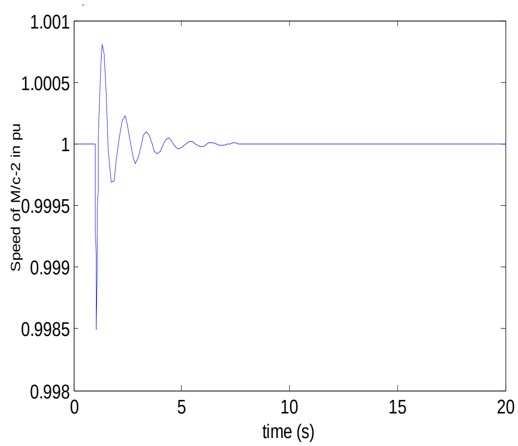

Figure 11:.Simulation results of Multimachine system with UPFC and Fault applied with respect to Rotor speed.

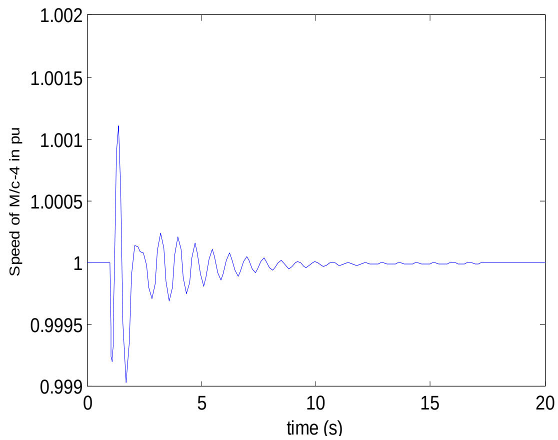

Figure 12:.Simulation results of Multimachine system without UPFC and Fault applied with respect to Rotor speed.

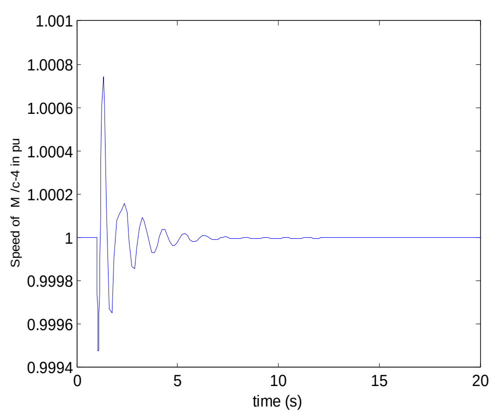

Figure 13:.Simulation results of Multimachine system with UPFC and Fault applied with respect to Rotor speed.

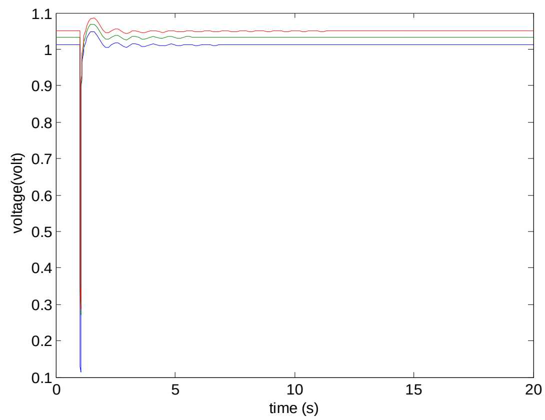

Figure 14: Variation of three lowest voltages without UPFC

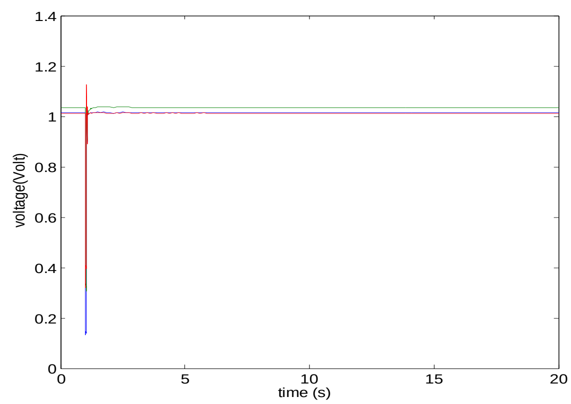

Figure 15: Variation of three lowest voltages with UPFC

Fig 5, 7, 9,11,13,15 shows various graphs of relative angular positions, angular speeds of individual generators and voltages. It is clear from the result that with the insertion of UPFC at the proper location oscillations die out rapidly hence transient behavior is improved. Therefore, when fault is located at bus 4, the best location of UPFC is between lines 1-5.

5. CONCLUSION

This study is attempted to find the location of UPFC devices for damping power oscillation. Simulations performed on IEEE-14 bus system. It is observed that when 3-phase fault occurred at bus no4 near the generator increase the oscillation and makes the system unstable. When a UPFC is keyed at a particular location then it is not only damps the system oscillations of the multimachine system but also reduces the oscillation present in the real and reactive power and phase voltage i.e. it maintains the constant power flow after the occurrence of the fault . Thus, the simulations studies revealed that oscillations present after occurrence of fault greatly reduces after location of UPFC

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