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Improvement of Transient Stability of Power System by Placement of UPFC with POD Controller

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Abstract — *UPFC is a combination of a Static Synchronous Compensator (STATCOM) and a Static Synchronous Series Compensator (SSSC) coupled via a common DC voltage link. UPFC is a FACTS controller which can independently control both real and reactive power through line. Transient stability of power system can be improved by placing UPFC. In this paper transient stability enhancement of 11 bus system is done with help of UPFC. Time domain simulation is carried out in PSAT (Power System Analysis Tool-box) in MATLAB by creating fault at a bus and results show that UPFC increases the transient performance under large disturbance conditions by damping out the power oscillations with less settling time.*

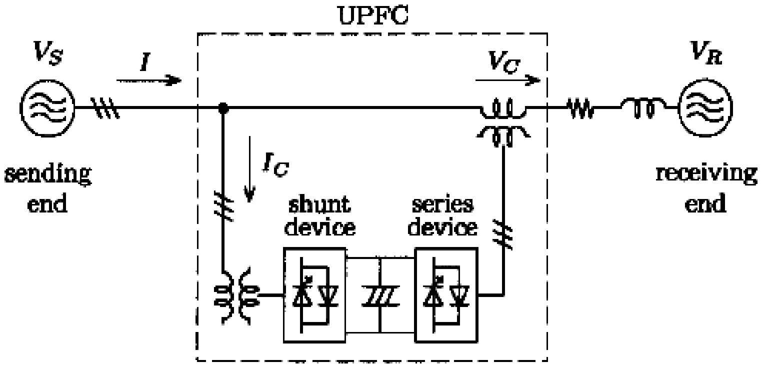
Keywords- *Transient stability, FACTS devices, UPFC, POD Controller, PSAT.*

I. INTRODUCTION

In recent years, environmental, right-of-way, and cost concerns have delayed the construction of both power stations and new transmission lines, while the demand for electronic energy has continued to grow in many countries. This situation has spurred interest in providing already-existing power systems with greater operating flexibility and better utilization. The revolution of Power Electronics Technology has given opportunities for developing the FACTS devices for stable operation of power system [1]. In the last two decades number of Power Electronic based devices are implemented and known as FACTS (Flexible AC transmission System).These devices are effectively used for voltage control, power flow control, harmonic elimination, damping oscillation and improving transient stability and minimization of losses [2]. Many FACTS devices are widely used like SVC (Static Var Compensator), STATCOM (Static synchronous Compensators), UPFC, TCSC. All these FACTS devices have their own advantages to control active and reactive power for static and dynamic voltage stability [3], [6]. Also whenever a disturbance occurs in the system like load imbalance or any fault, the system loses stability and the generators go out of synchronism [8]. Among the converter based FACTS devices Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC) are the popular FACTS devices. They play an important role, not only in increasing the amount of energy transported over the lines, but also in oscillatory and transient-stability enhancement, system reliability, and controllability over the power flow [7]. Considering the practical application of the UPFC in power systems, it is of importance and interest to investigate the benefits as well as model of these devices for power system Transient Analysis [4], [9]. Unified Power Flow Controller (UPFC) is a power electronic based device that has capability of controlling the power flow through the line by controlling appropriate its series and shunt parameter. It has been reported that UPFC can improve transient stability of a system [5], [11]. In this paper simple and effective method has been implemented for finding the best location of FACTS device based on transient stability using Continuation Power Flow (CPF), modal analysis and time domain simulation. Simulations are carried out in PSAT software which is very user friendly. Critical bus is determined by Eigen value analysis. The eigenvectors are calculated for each bus and the bus having maximum value of eigenvector is the weakest bus of the system.

II. BASIC CONFIGURATION OF UPFC

The Unified Power Flow Controller (UPFC) concept was proposed by Gyugi in 1991. UPFC is an electrical device for providing fast-acting reactive power compensation on high-voltage electricity transmission networks [12]. The UPFC is a combination of a Static Synchronous Compensator (STATCOM) and a Static Synchronous Series Compensator (SSSC) coupled via a common DC voltage link. The UPFC is made out of two voltage-source converters (VSC) with semiconductor devices having turn-off capability, sharing a common dc capacitor and connected to a power system through coupling transformers. Fig. 1 shows a system configuration of a general UPFC, which is installed between the sending end V_S and the receiving end V_R. The UPFC consists of a combination of a series device and a shunt device, the dc terminals of which are connected to a common dc-link capacitor [13]. The series device acts as a controllable voltage source V_C, whereas the shunt device acts as a controllable current source I_C.

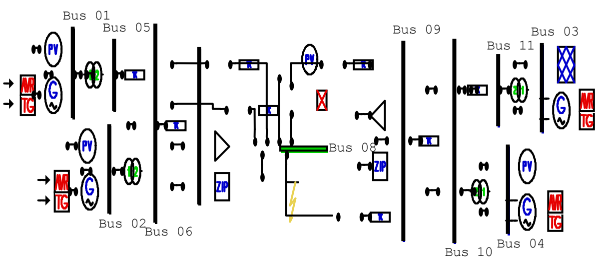


"Figure 1. System configuration of a general UPFC"

III. PSAT SIMULATION MODEL

System I

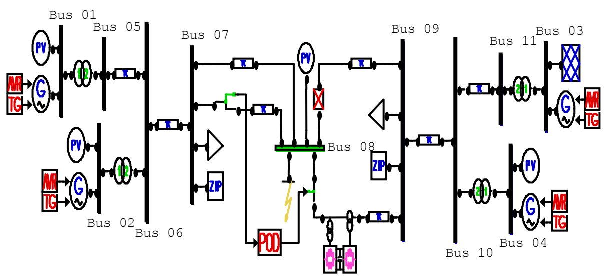
In this Model there are 11 Buses, Bus No. 3 is kept as Slack bus which maintain its voltage at 1 p.u. and Bus 1,2 & 4 are Generator (PV) Buses. Fault is simulated at Bus 8 at 1sec. and Fault clearing time at 1.05 sec. The all four Generators have been modeled with Power Rating of 900MVA and 20KV at 60HZ frequency. All buses connected to each other by π- Section of transmission line. The automatic voltage regulator used is type 3 in PSAT tool of MATLAB with the range of +100KV to -100KV and having the gain of 200p.u. for maintaining the voltage level as near to 1p.u. Turbine Governor is used of type 2 and having the ref. speed of 1 p.u. and the droop is kept 0.02p.u. with max. torque and min. torque limit at1.2 and 0.3p.u. Generators are connected to the system via transformers maintaining the system voltage at 230KV and 100MVA. Load is also connected to the Bus7 and Bus8. In this Model, Voltage profile at all 11 buses and Rotor angle are studied without any FACTS devices.



"Figure 2. 11 Bus System without UPFC"

System II

The all the parameters of Generators, Slack bus, Transformers and Load are kept same as were in above given Model. UPFC is employed in between Bus8 where fault is simulated and Bus9 with POD controller for maintaining the voltage at faulty bus. The Voltage profile of all the buses and Rotor angle are studied at different Fault clearing time with UPFC and their results are compared with the results of 11Bus test system without any FACTS device.

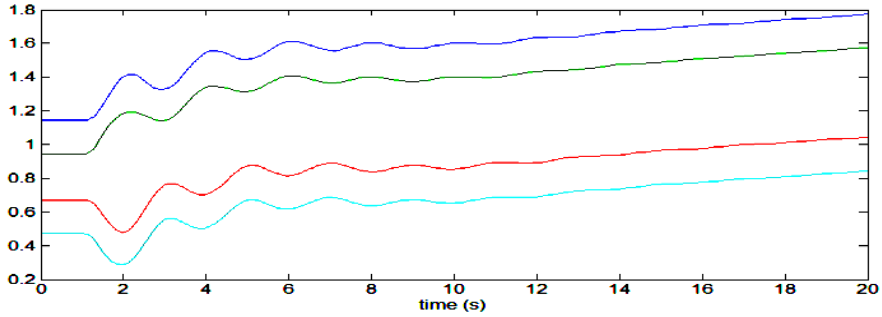


"Figure 3. 11 Bus System with UPFC"

IV. SIMULATION RESULTS AND DISCUSSION

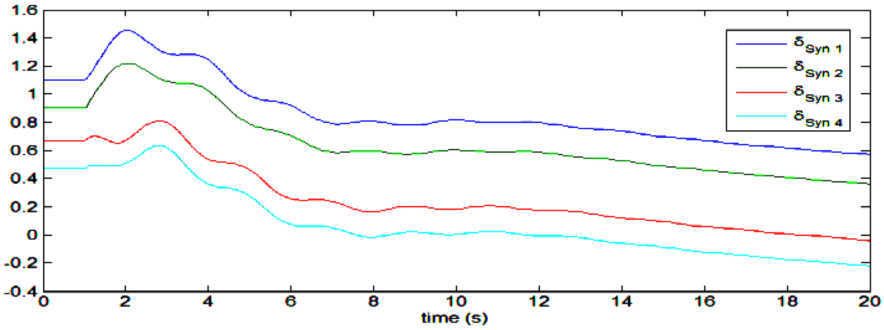
FIG. 4 – 14 SHOWS THE SIMULATION RESULTS OF ROTOR ANGLE, VOLTAGE AT DIFFERENT BUSES AND ANGULAR FREQUENCIES IN PSAT.

Rotor Angle :

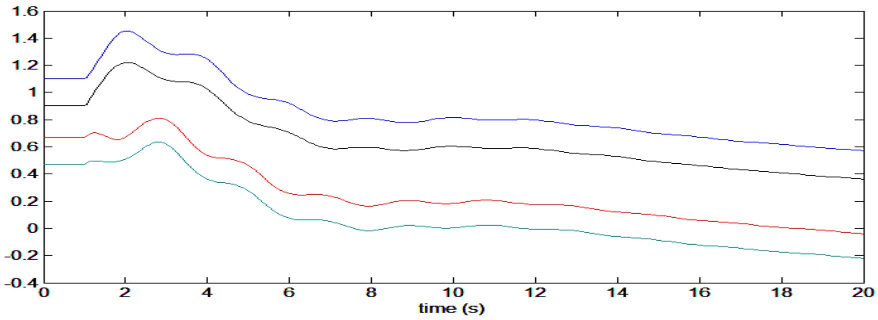


"Figure 4. Rotor Angle 1, 2, 3 & 4 without UPFC"

As shown in Fig. 4, Fig. 5 and Fig. 6 without using the UPFC the Rotor Angle are increasing and go out of synchronism but with the UPFC they remain in synchronism at time 1.05 sec. and 1.2 sec.



"Figure 5. Rotor angle 1, 2, 3 & 4 with UPFC at fault clearing time a 1.05sec"

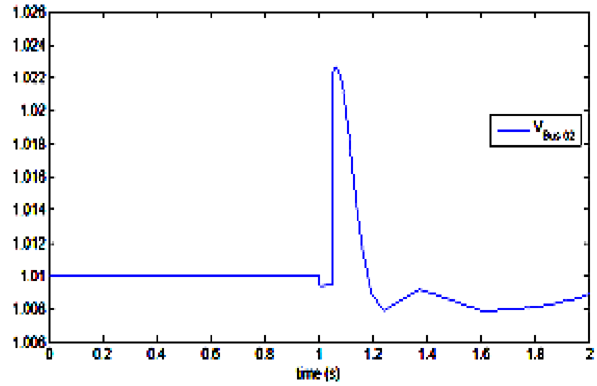


"Figure 6. Rotor angle 1, 2, 3 & 4 with UPFC at fault clearing time a 1.2sec"

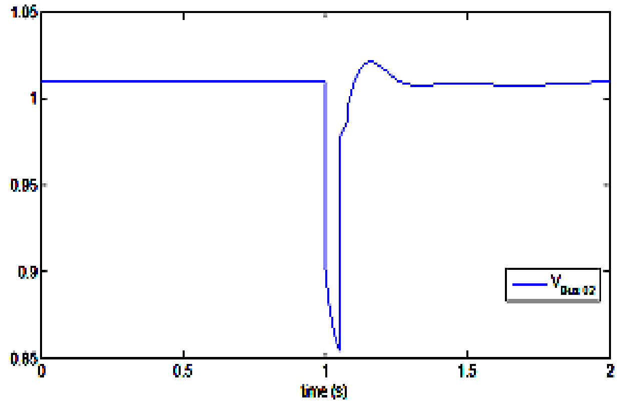
Voltage Profile

Fig.7 shows voltage profile of Bus1 at different fault clearing time with and without UPFC. With FACTS Device (UPFC) the voltage is settling down at 1.2 sec without any oscillatory behavior, whereas without UPFC it takes more than 2 sec due to the oscillations after the major disturbance settles at 1.2 sec. Bus 1 is a PV bus.

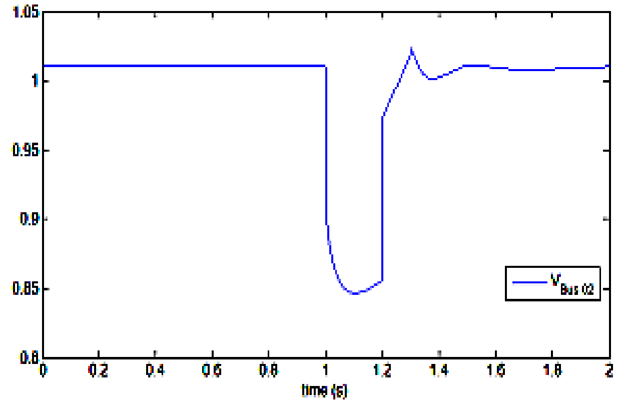
Fig.8 shows Voltage profile of Bus 2 (PV Bus) at different fault clearing time with and without UPFC. It's showing voltage rise after fault clearance time without UPFC and take more time to settle down but with UPFC it follows the normal profile and settles down quickly.



V2 without UPFC

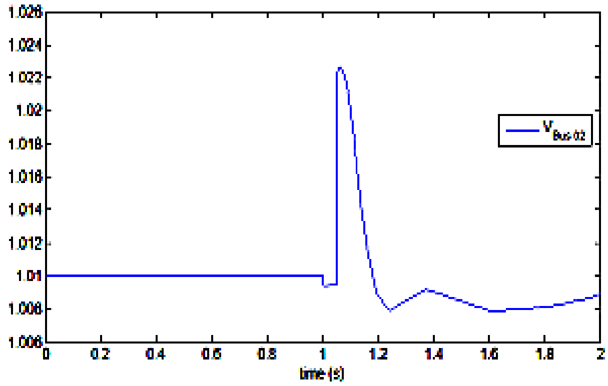


V2 with UPFC at Fault clearing time 1.05

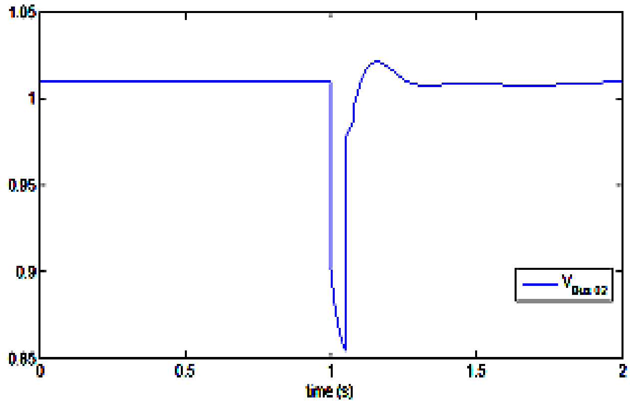


V2 with UPFC at Fault clearing time 1.2

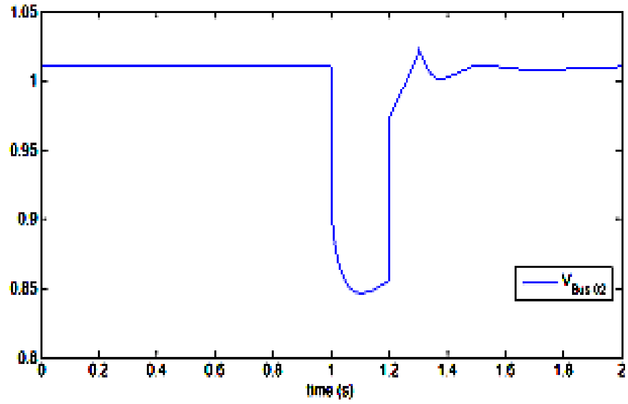
Figure 7. Voltage profile at bus 1”



V2 without UPFC



V2 with UPFC at Fault clearing time 1.05

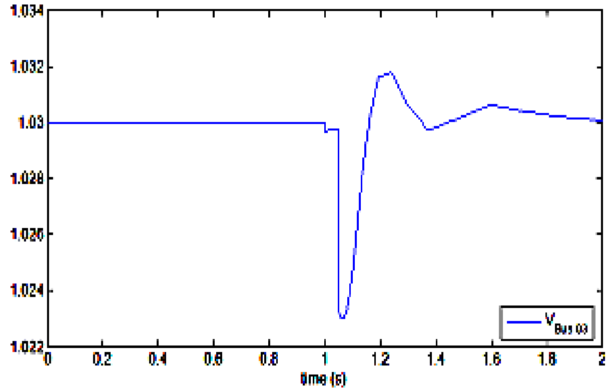


V2 with UPFC at Fault clearing time 1.2

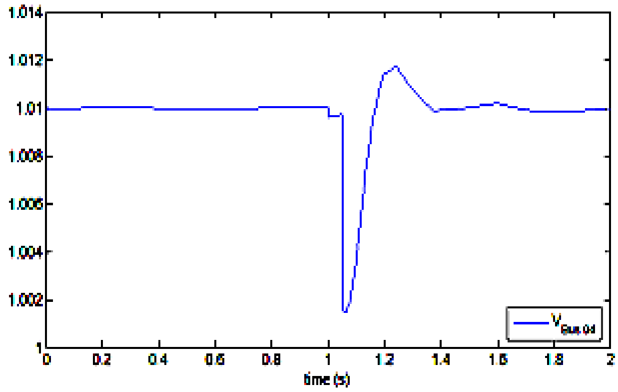
“Figure 8. Voltage Profile at Bus 2”

Fig.9 shows Voltage profile of Bus 3 at different fault clearing time with and without UPFC. Bus 3 is a Slack bus so Voltage profile will be same with and without FACTS device.

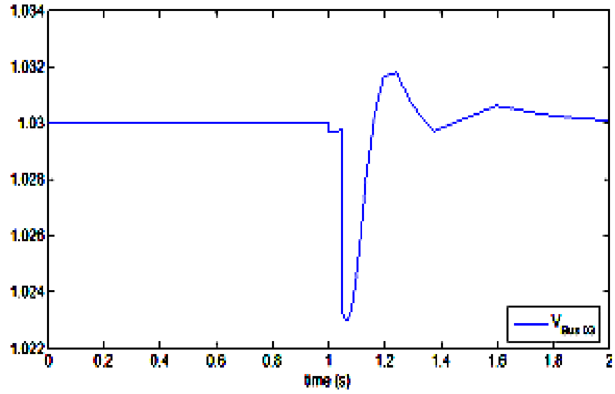
Fig.10 shows Voltage profile of Bus 4 (PV Bus) at different fault clearing time with and without UPFC. The settling time is reduced with UPFC.



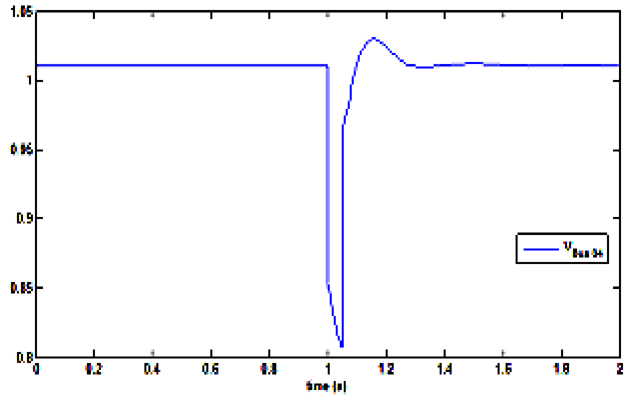
V3 without UPFC



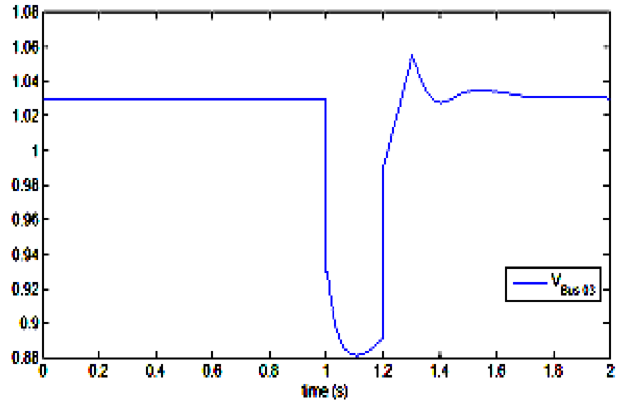
V4 without UPFC



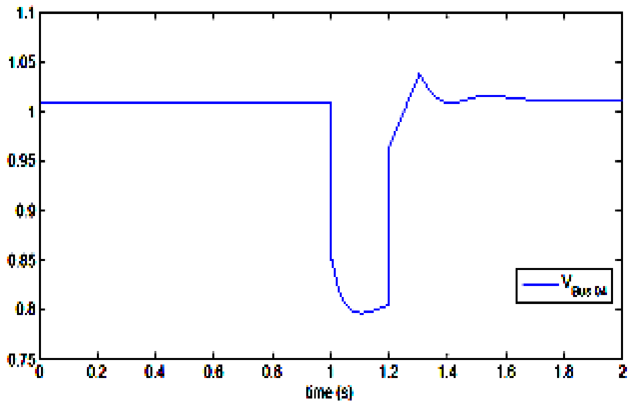
V3 with UPFC at Fault clearing time 1.05



V4 with UPFC at Fault clearing time 1.05



V3 with UPFC at Fault clearing time 1.2

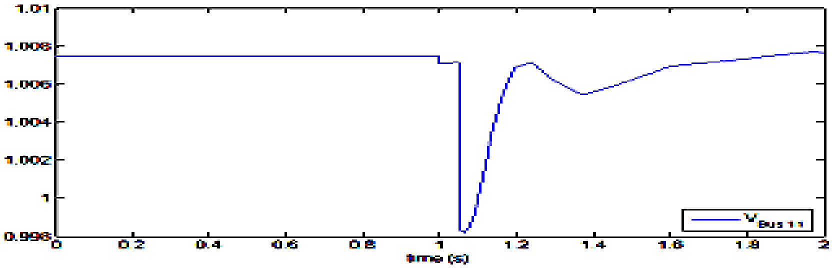


V4 with UPFC at Fault clearing time 1.2

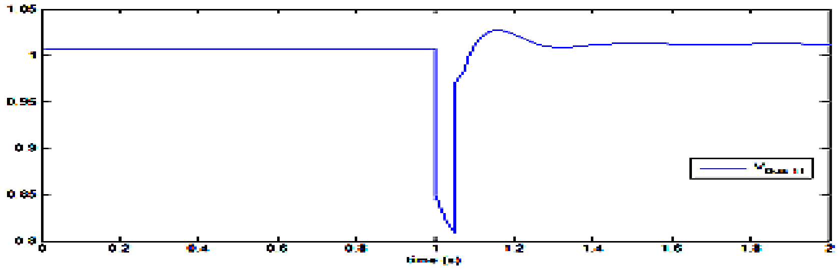
"Figure 9. Voltage profile at bus 3"

"Figure 10. Voltage profile at bus 4"

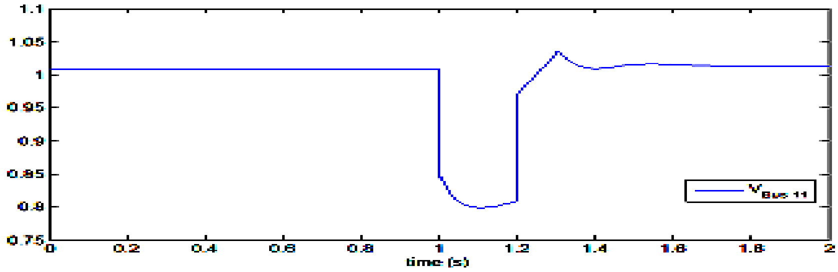
Fig.11 shows Voltage profile of Bus 11 at different fault clearing time with and without UPFC. At Bus11 settling time is reduced and Voltage reaches to its pre fault value quickly without oscillations.



V 11 without UPFC



V 11 with UPFC at Fault Clearing time at 1.05

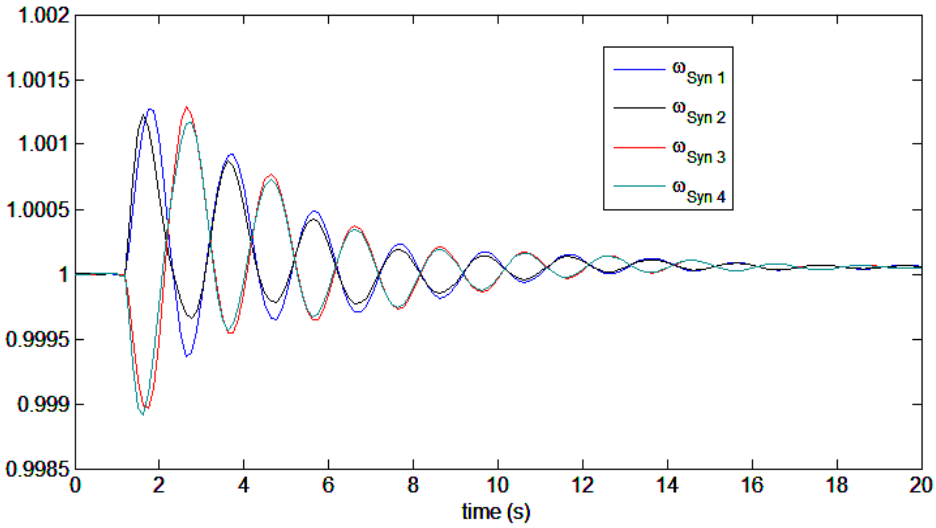


V 11 with UPFC at Fault Clearing time at 1.2

"Figure 11.Voltage profile at bus 11"

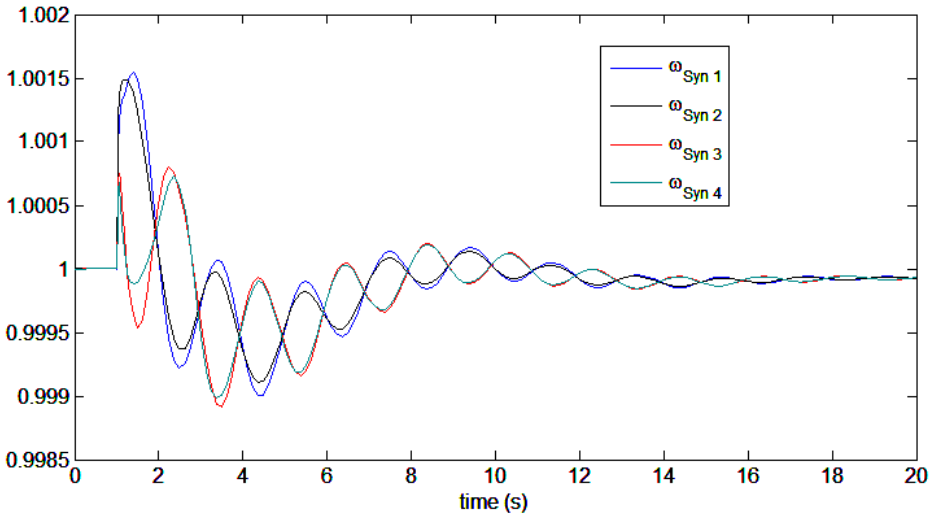
Angular Frequency

Fig. 12 shows Angular Frequency at all generator Buses without UPFC. The peak value of Angular Frequency is 1.0012.



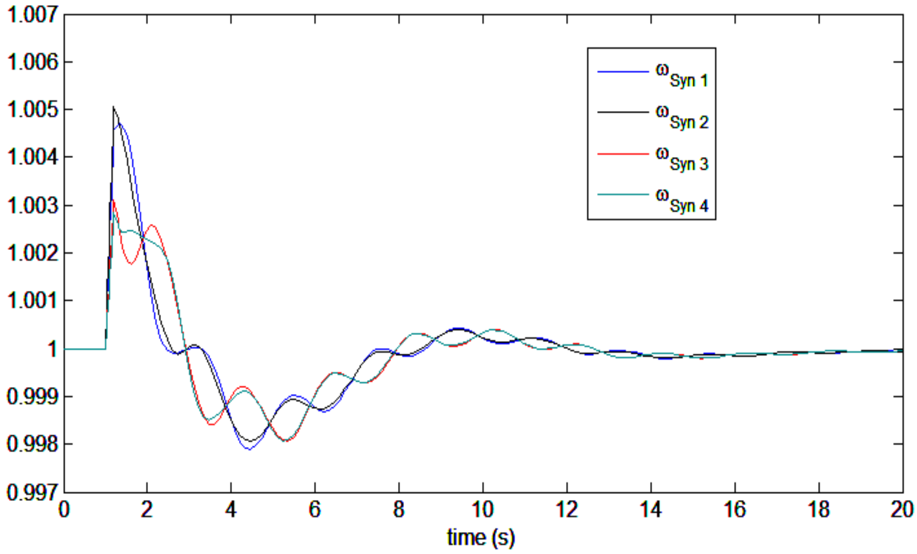
"Figure 12 Angular Frequency at all generator Buses without UPFC"

Fig.13 shows Angular Frequency with UPFC at fault clearing time 1.05 sec.



"Figure 13. Angular Frequency at all generator Buses with UPFC at fault clearing time 1.05 sec"

Fig.14 shows Angular Frequency with UPFC at Fault clearing time 1.2 sec. As shown in Fig.14 with the increase in the fault clearing time the peak value of Angular Frequency increases to 1.005.



"Figure 14. Angular Frequency at all generator Buses with UPFC at fault clearing time 1.2 sec"

V. CONCLUSION

In this paper transient stability enhancement of 11 Bus Two-area Power System is done with help of UPFC. Simulation is carried out in PSAT (Power System Analysis Tool-box) in MATLAB. The analysis of Generator Rotor angle, Voltage Profile and Angular Freq is done with and without UPFC at fault clearing time 1.05 sec and 1.2 sec. Without UPFC the Rotor angle of all the buses increases and will lead the system out of synchronism whereas with UPFC the Rotor angle of all the buses decreases and settling down. System will remain in synchronism. Settling time of all buses is more than 2 sec without UPFC. With the application of UPFC the settling time is reduced to 1.18 sec. for all buses. The Angular Freq without UPFC settles to 1 p.u. value after 20 sec. With UPFC Angular freq starts settling down after 15 sec. at fault clearing time 1.05 sec. and 1.2 sec.

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