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APPLICATIONS OF UPFC FACTS DEVICE FOR IMPROVING POWER SYSTEM STABILITY

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ABSTRACT

This paper presents thethe application of UPFC with two permanent magnet synchronous generator (PMSG) where the UPFC is connected between the line buses in parallel. Thus for the overall requirement of real and reactive power of the system and also make impact on to damped some vibrational oscillations. The application of UPFC for power system stability and also the fault recovery time is observe. Stability is the main important challenge for scientist and power engineers as due to the development of the modern power system which led to an increasing complexity in the study of power system stability.The FACTS devices are mainly considered with the best use of any one technology automation for particular requirement. As the UPFC is also connected to line for fault recovery time which is taken for some time second without UPFC and with UPFC in on and off conditions that shows the better recovery time to system stability. The stator voltages also increases comparatively as there is no FACTS devices and it also increases the oscillations in the system and system stops after some time as there is no stability in the system due to effect of variable loads. When UPFC is used stator voltages decreases comparatively and the system remains oscillation free.

KEYWORDS: UPFC, Fact devices, Distributed generation, Fault etc

1. INTRODUCTION

Due to segregation of industrial, commercial, residential and educational areas the variation of electrical load on the time axis of the day is more. For example, high load conditions prevail during the day time in case of industrial, educational institutes, office complex, etc. while the domestic loads are low. On the other hand during the evening and late evening hours, the domestic loads are at peak while industrial and institutional loads are at minimum level [1]. It is found that this load deviation causes overvoltage with low demand and low voltage at heavy demand [2]. Poor bus voltage profile and high losses put an extra burden on distribution system which forces lines to operate at its capacity limits and cause voltage instability [3]. To make the power system more stable and efficient, a number of devices with different objectives have been used by various researchers in the past, few are discussed in this paper. Prakash et al. [4] applied loss sensitive factor with differential evolutionary technique to locate best site and VAR of capacitor. Optimal capacitor placement improves the bus voltage as well as reduced active power loss in radial network. Mini et al. [5] proposed a probabilistic fuzzy approach for feeder reconfiguration to counter voltage collapse and instability in radial system. Le et al. [6] used the sensitivity based technique to develop a coordination of voltage control action by different voltage controller in distribution system.

2. LITERATURE REVIEW

For managing the flow of power, FACTS are emerging solution, which are the power electronic devices and able to control one or more than one electrical parameters of distribution network. Jaiswal et al. [7] found FACTS can increase efficiency, voltage stability and reliability of the existing system. Numbers of FACTS are available which can control various parameters like- Static Var Compensator (SVC) can control bus voltage and power flow. Thyristor Controlled Reactor (TCR) can boost voltage and power factor while, Thyristor Controlled Series Compensator (TCSC) facilitates proper load sharing among lines. Static Synchronous Series Compensator (SSSC) can provide control against overloading of lines. Static Synchronous Compensator (STATCOM) is controlling voltage by generating/absorbing reactive power. UPFC is a most resourceful FACTS device because it controls all three parameters, voltage, impedance, and power angle of the power

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system. Feng and Shrestha [8] applied a genetic algorithm to find optimal number and place of TCSC to improve transmission lines loadability and trim down system losses. Saravanan et al. [9] used PSO to determine best site of FACTS controller, their type and integration cost. Application of hybrid-fuzzy genetic algorithm for STATCOM controller was studied by Stella et al. [10]. They installed VSI based STATCOM for regulating parameters of transmission system. Mehrdad et al. [11] used TCSC, SVC, and UPFC. They developed a PSO based technique to find best possible setting of FACTS controller for 30-bus and 118-bus. Hossein and Mehdi [12] proposed a reactive power planning with bacterial foraging based PSO technique. In IEEE 57-bus network FACTS are integrated to reduce cost of installation. Laifa et al. [13] developed a multi-objective function to reduce generation cost, improve bus voltage and congestion management. They applied PSO to find out finest position and parameters of UPFC. Ahmad and Jasronita [14] studied the application of FACTS to counter the problems of power distribution system such as line congestion, bus voltage variation and reduction of stability margin. They also found that to get maximum advantages from FACTS, type of FACTS, FACTS location, and its setting are important. Sebaa et al. [15] investigated the control action of UPFC for stability improvement of transmission system in different operating conditions. Ali and Reza [16] developed an Imperialist Competitive Algorithm (ICA) based UPFC for damping low-frequency oscillations and enhanced dynamic stability. Hassan et al. [17] formulated a Genetic Algorithm based multi-objective optimization function with an aim to maximizing electromechanical modes damping ratio using UPFC. Afshin et al. [18] proposed a multi-objective function for optimal placement of UPFC with constrains of total cost of fuel, system loss plus loadability of lines. In reference [19] authors found bus number of SVC to get better loadability and high voltage stability is important. Authors of reference [20] studied the application of SVC and D- STATCOM to mitigate the voltage sags and swells. Vijay and Srikanth [21] used genetic based search technique for placement of UPFC for improvement of dynamic stability of system. Nascimentoa and Gouvea [22] employed an evolutionary algorithm for allocation of automatic FACTS controller for improvement voltage stability. Subramani et al. [23] studied the application of PSO to select best line and parameters of UPFC. Their objectives are to minimize power loss and increase voltage stability. Faid et al. [24] proposed a Fuzzy Logic Controller (FLC) based UPFC for dynamic control of power flow and power system parameters. Vijay and Srikanth [25] compared Firefly Algorithm (FA) and Cuckoo Search (CS) to optimize capacity of UPFC and searched its optimal location to curtail loss and increase voltage stability. UPFC can be used to improve power flow power quality, dynamic stability, optimal power flow, efficiency, transient stability, power oscillation damping, optimization of power system operation, congestion management, deal with contingency etc. UPFC is competent to control flow of power along with bus voltage at the same time. UPFC is combinations of two converters which are tied by a DC link. Shunt controller is mainly responsible for reactive power compensation while series converter can inject ac power of required magnitude and angle.

3. PRESENT WORK

A. Modeling of UPFC

The UPFC can supervise flow of active and reactive power along with voltage magnitude. UPFC is a combination of series and shunt controller, which are coupled by a DC link via a capacitor. Shunt converter provides reactive power compensation by generating and/or absorbing reactive power. Series converter controls the magnitude and phase angle of injected voltage. Figure 1 shows a model of UPFC with two converters. Figure 2 represents electrical model of UPFC [26]. Figure 3 represents the power injection model of UPFC, in which impedance of convertors transformers are included in admittance matrix of load flow along with added injected power by UPFC at buses m and k. Power injection equations are given by equation (1) & (2).

$$P_{M(inj)} + jQ_{M(inj)} = -V_m \left(\frac{Vse}{Zse} \right)^* - V_m I_{sh}^*$$

$$P_{k(inj)} + jQ_{k(inj)} = -V_k \left(\frac{Vse}{Zse} \right)^*$$

$$I_{sh} = I_p + jI_q$$

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Where

$P_{M(inj)} + jQ_{M(inj)}$ = complex power injected into node m

$P_{k(inj)} + jQ_{k(inj)}$ = complex power injected into node k

V_m = bus voltage of node m

V_k = bus voltage of node k

V_{se} = voltage injected through series transformer in line

Z_{se} = series impedance of UPFC

I_{sh}^* = conjugate of shunt converter current

I_p= real component of shunt converter current

I_q =imaginary component of shunt converter current

UPFC injects complex power with control variables are Vse, δse (phase angle of this voltage) and Iq .

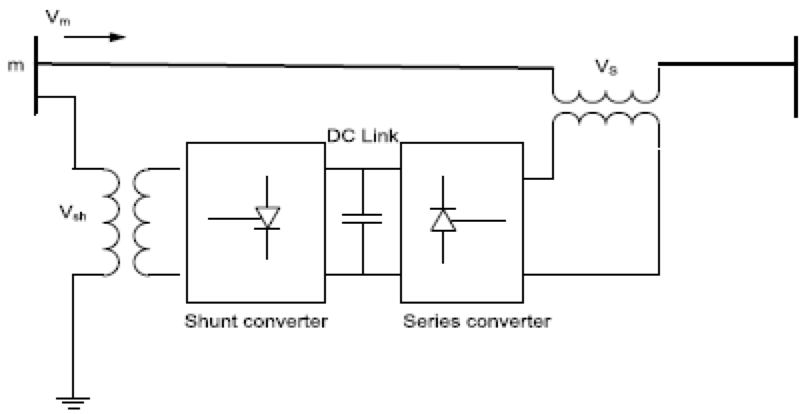

Figure 1: Two Converter Model of UPFC

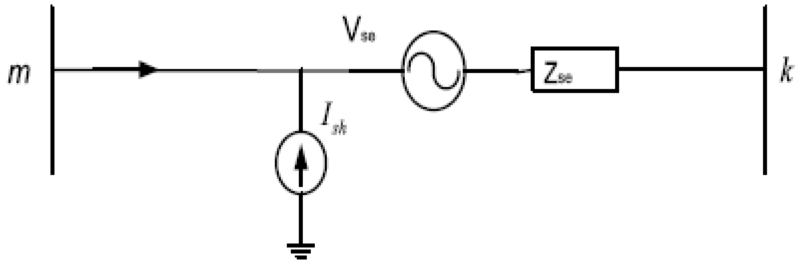

Figure 2: Electrical Model of UPFC

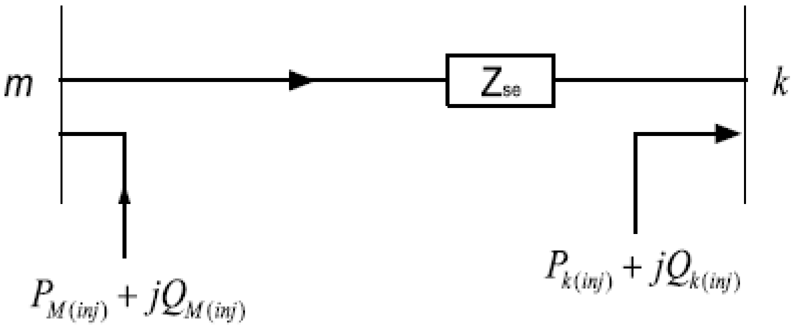

Figure 3: Injection Model of UPFC

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B. Principle of operation

The UPFC is all-around functional and comprehensive multivariable controller tool through which the compensation of series make effectiveness in the system.

- The UPFC controller can independently very quick and insist rapid impact on real and reactive power flow.
- In figure two VSCs are coupled with a common dc terminal channel are depicted below in fig4.1
- Both VSC can perform individual work one of them is linked in shunt and other is in series and each of them are link with line by a channel of coupling transformer.
- The same capacitor bank feed the dc voltage for each converter.
- The substitute of real and reactive power by series converters and that converter internally producing or gobble the reactive power.
- The transmission line derives the power from converter 2 which is passing from converter one. Constant bus voltage is stable by shunt converter.
- The capacitor made feasibility by producing or gobble the real power.

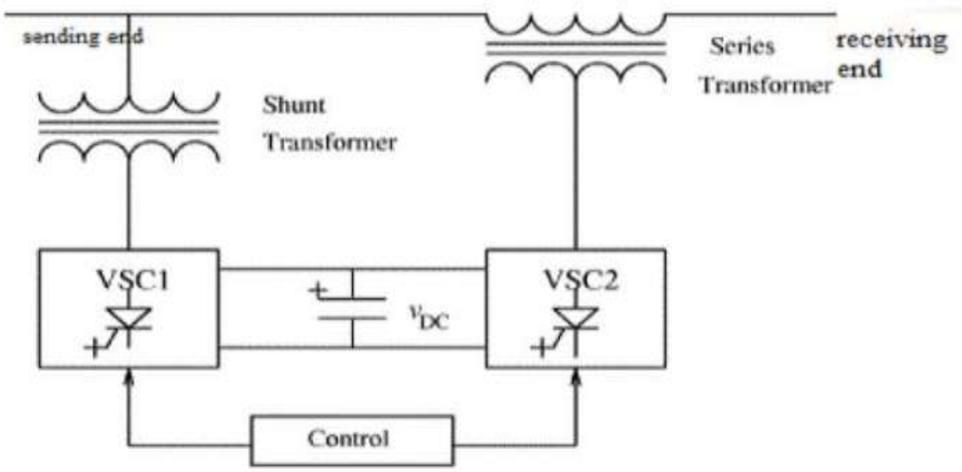

Figure 4: schematic UPFC with two VSCs converter

The main focus is to revolve the variation in real power at load area system and also equivalent output at other part with UPFC, we consider two 3-phase permanent magnet synchronous machines design in the dq rotor indicating structure. The neutral point are at output side of wye connection with stator winding.

In this synchronous machine one is set to produce 2100MVA real power and synchronous machine two is set to produce 1400MVA active power. After that a voltage upgrade transformer has been impart to scale down the output voltage of 13.8KV to 500KV.two power generation substation are at grid side and a load center side.

Six machines each of them is 350 MVA and also on other side 4 machines they also are 350 MVA. one of the capacity at first generation substation M1 and other one at generation substation of M2. Also on load center side is nearly to 2200MW and is design by a dynamic or vital load model so that the real and reactive power is gobble by the load performing system voltage.

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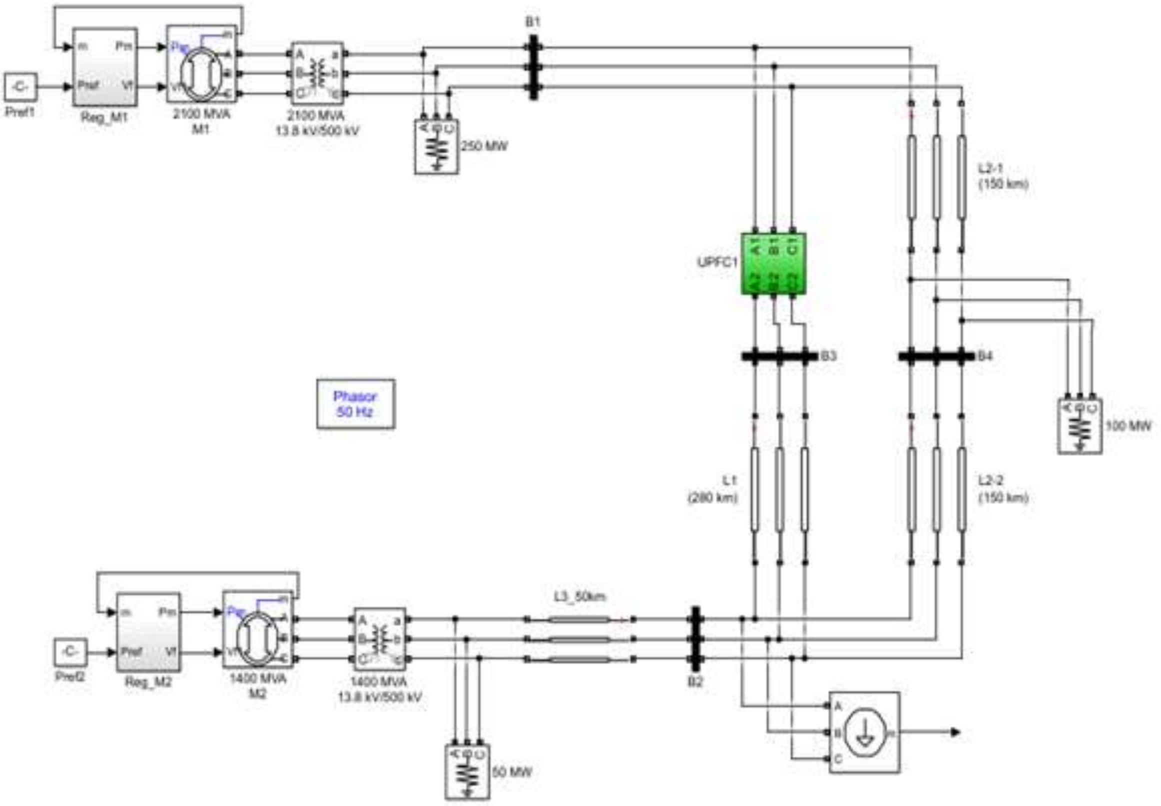

Figure 5: model of UPFC with two synchronous generation units

4. RESULTS AND DISCUSSION

The two transmission line L1 and L2 are connected with generation substation M1.whereas the line 1 is 280-km long and line 2 is break into two parts of 150 km in respective to perform a 3 phase fault at a center point of the line.

The line L3 is also interlinked with production substation M2. The simulation model designed in Simulink matlab has been depicted in figure 5.

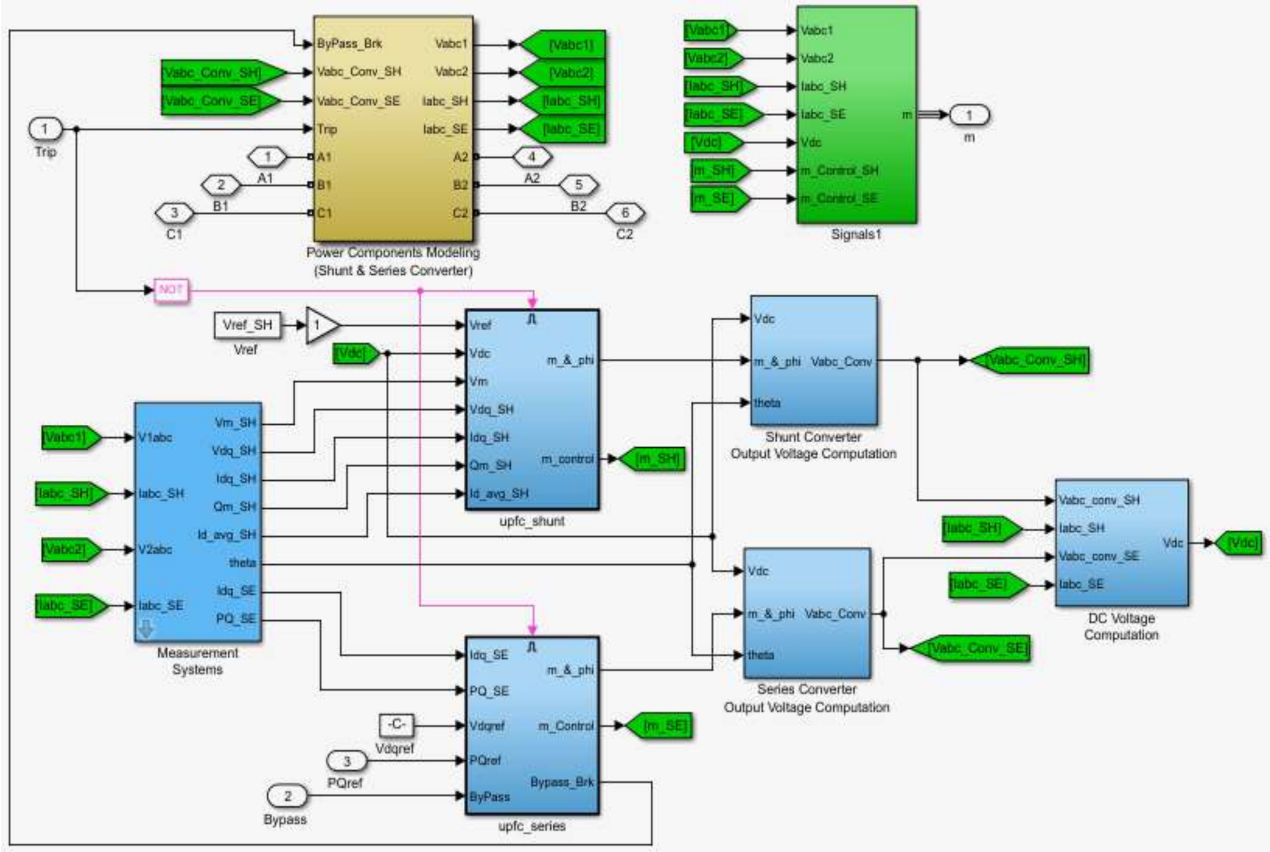

Figure 6: building blocks of UPFC containing shunt and series converter block and control signal

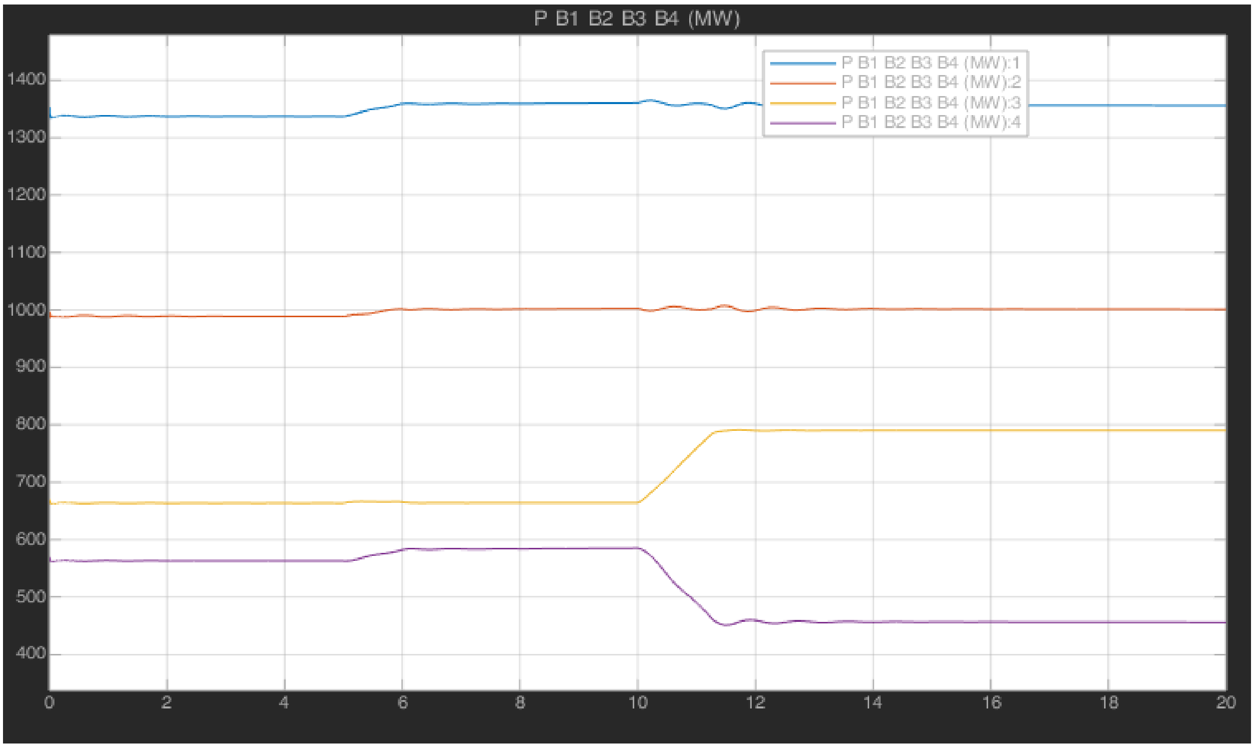

Figure 7: Active power using UPFC at buses b1, b2, b3, b4

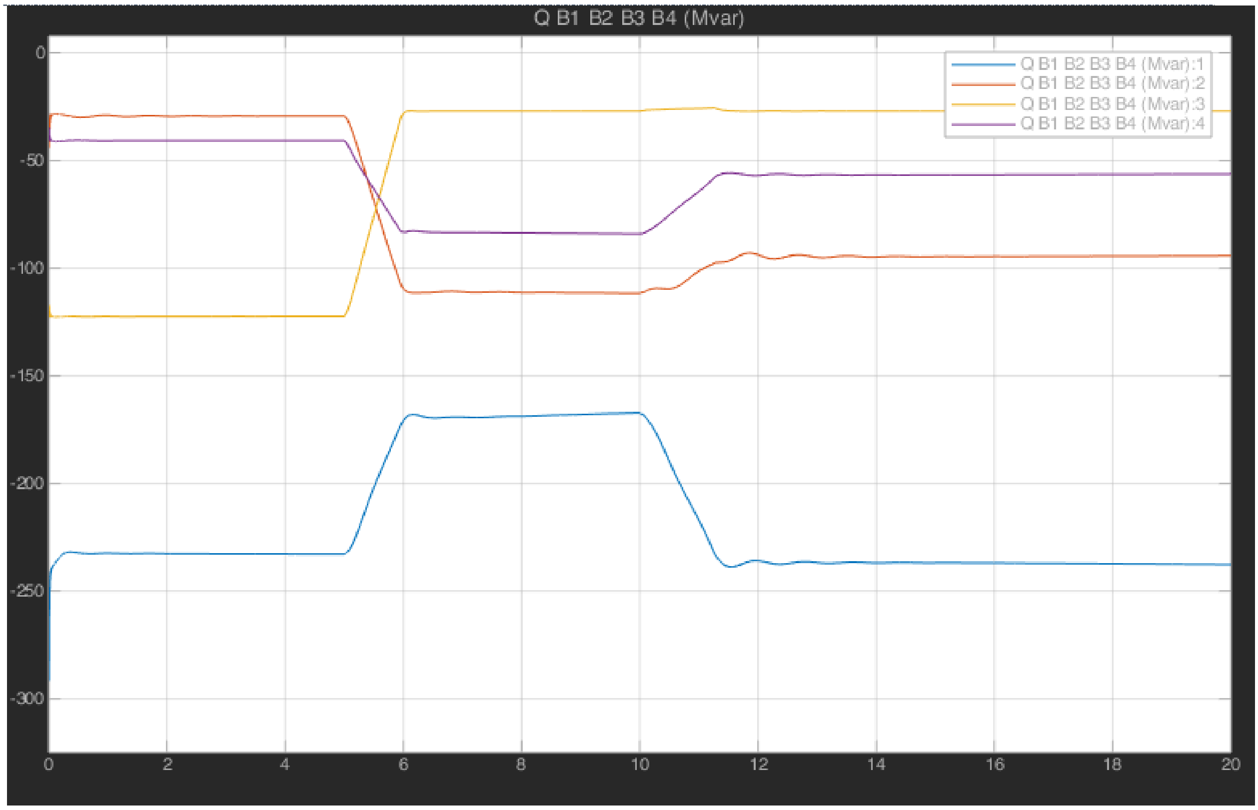

Figure 8: Reactive power using UPFC at buses b1, b2, b3, b4

Table 1: active and reactive power at different bus location using UPFC

Parameters	Active Power (MW)				Reactive Power (-MVAR)			
	B1	B2	B3	B4	B1	B2	B3	B4
Bypass UPFC	1337	988	664	563	232	29.3	122.4	40.7
UPFC ON with pref=6.64 and Qref 0.27 (time 5 to 10)	1360	1002	664	584	168	111.1	27.01	83.7
UPFC ON with pref=7.9 and Qref 0.27 (time 10 to 20)	1360	1002	790	456	237	94.45	27.01	56.4

When UPFC is bypassed the power towards the load are as follows:
988 MW pass on L1 (measured at bus B2), 563 MW through on L2 (measured at B4) and 664 MW pass on L3 (measured at B3). Total power flow towards the dynamic load is 2199 MW.

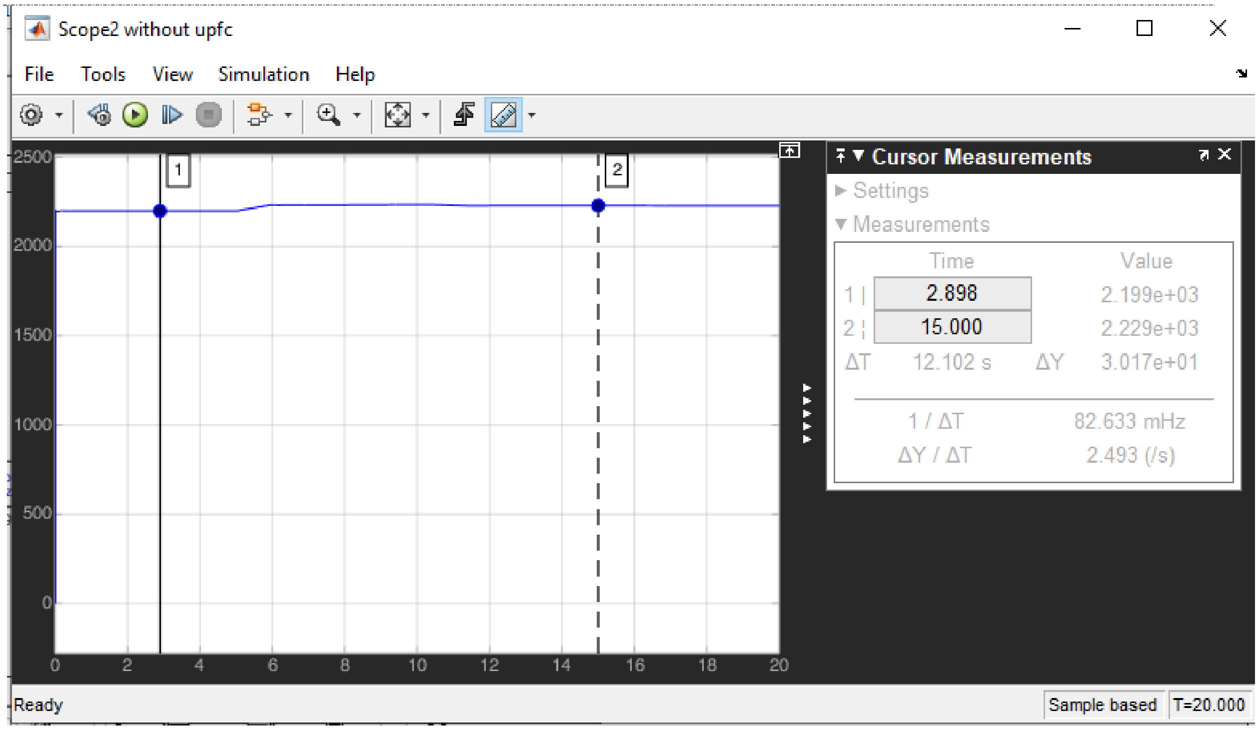

Figure 9: active power flow at the dynamic load

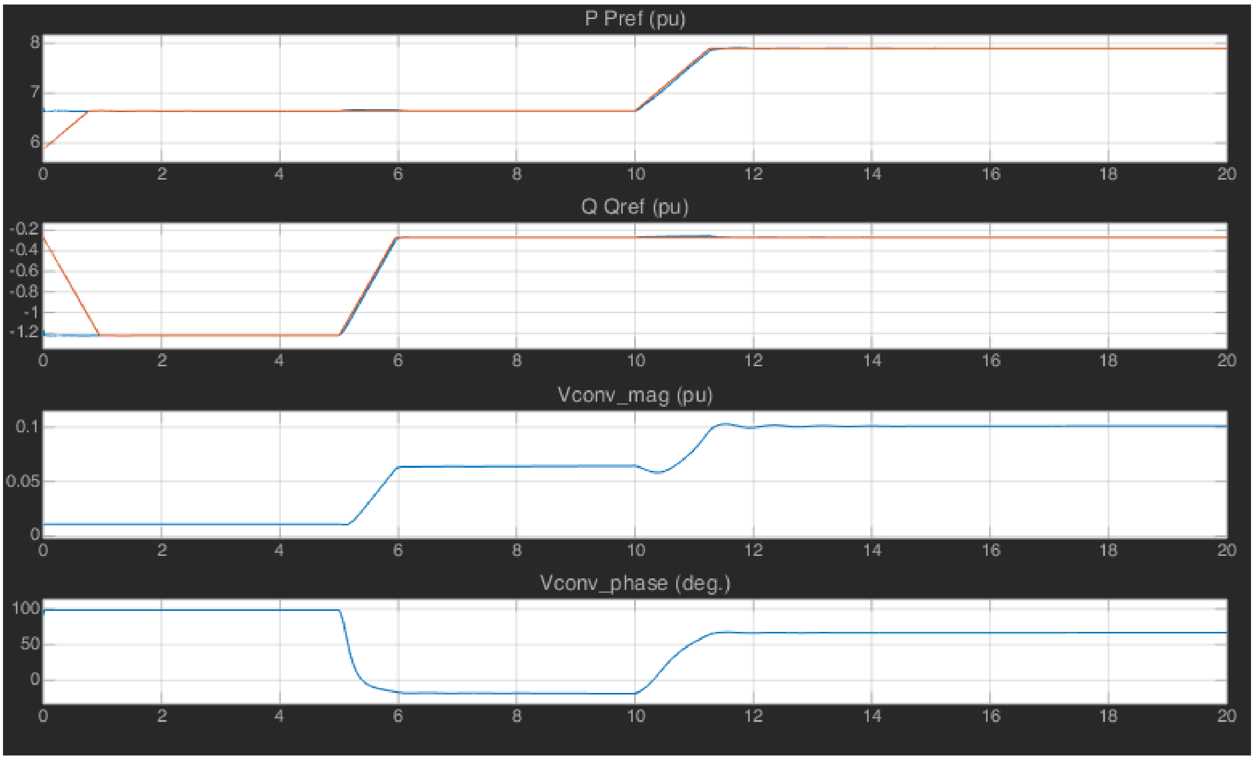

Figure 10: (a) Pref (pu) (b) Qref (pu) (c) voltage injection in series (pu) (d) Angle of voltage injection (degree).

When UPFC is on after t=5 sec to t=10 sec.
1002 MW pass on L1 (measured at bus B2), 584 MW through on L2 (measured at B4) and 664 MW through on L3 (measured at B3). Total power flow towards the dynamic load is 2229 MW.

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When UPFC is on and Pref increase at the rate of 1.26 pu/s after t=10 sec.
1002 MW pass on L1 (measured at bus B2), 456 MW through on L2 (measured at B4) and 790 MW pass on L3 (measured at B3). Total power flow towards the dynamic load is 2229 MW.

Hence total power flow remains the same towards dynamic load when UPFC is on but it controls the active power at B3 (Line 1) according to Pref and Qref values.

The UPFC reference real and reactive powers are fix in the blocks. "Pref (pu)" and "Qref (pu)". During starting the Bypass roller is block and the outcome of power at bus B3 is 664 MW and -122.4 Mvar (-1.2 pu). The Pref scope is programmed with at starting real power of 6.64 pu proportionate to the power flow. Then, at t=10s, Pref is adding by 1.26 pu (126 MW), from 6.64 pu to 7.90 pu, while Qref is kept consistent value at -0.27 pu. After running the simulation and looking on the UPFC block, P and Q achievement at bus B3 follow the desired values. At t=5. And also At t=10 s, the power increment at a rate of 1.26 pu/s, and takes a time of one second for the power to adding and getting the new increment in power 790 MW. This 126 MW increment of real power at bus B3 is achieved by introducing a series voltage of 0.056 Pu with an angle of 67 degrees. These outcome is nearly 126 MW and reducing in the real power passing through bus 4 value of active power flow decreases.

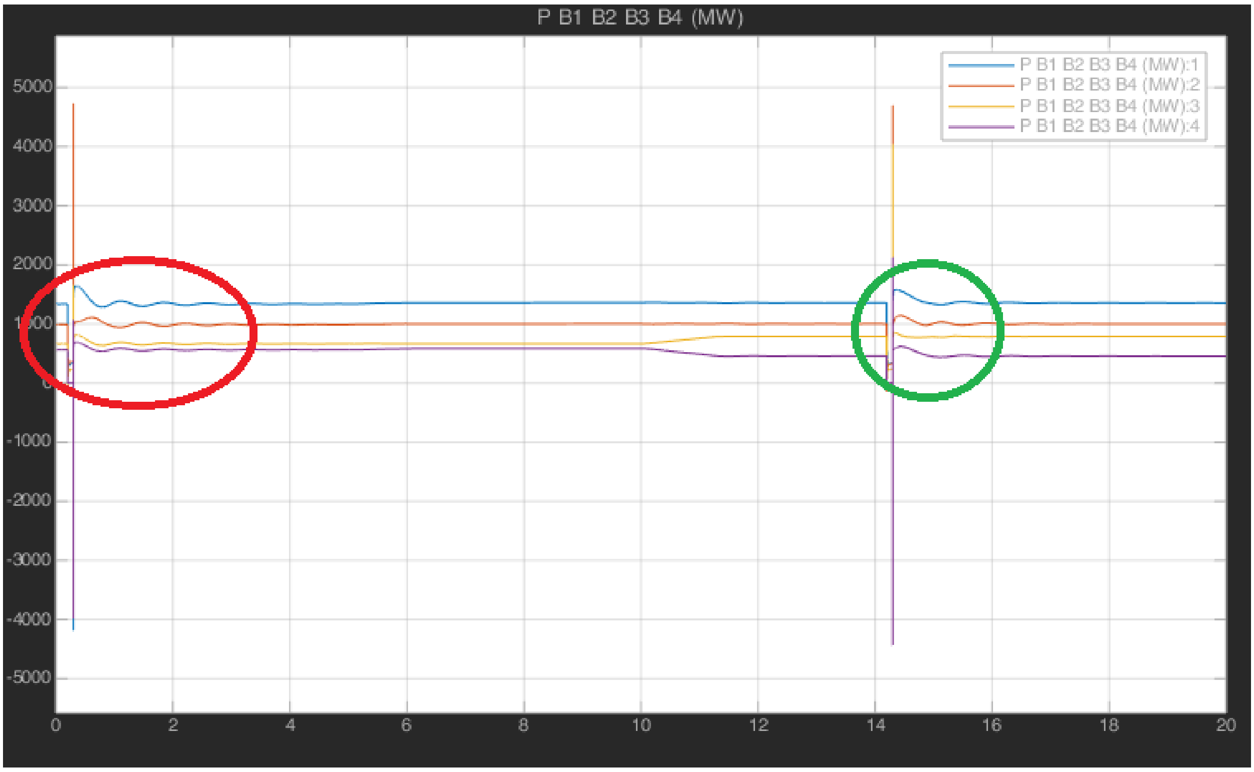

Figure 11: System recovery when fault introduce with UPFC in ON

Active Power with fault at time .2 to .3 when UPFC is bypassed and Fault at time 14.2-14.3 when UPFC is working. The UPFC model diagram with fault are depicted in fig 5.13. Figure shows more oscillations in the power waveform and last for approx. 2.5 seconds after fault is pulled off whereas when UPFC is working Power waveform recovers to stability in approx. 1.5 seconds of time.

5. CONCLUSION

MATLAB simulation and performance of UPFC controller used have evaluated. As we know that transmitted power in each line is a function of sending and receiving of amplitude of voltage, phase shift end buses and the line of series impedance. UPFC can affect the related and unrelated factors of enlarging the system stability of the line. Therefore it could be concluded that UPFC would improves some of the system parameters, and on the

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results obtained, UPFC improved the real and reactive power of the line bus and also take part to damped some oscillations. This improvement was interms of to maintain the voltage steady with the increasing of load and to support the bus when there is any collapses. UPFC is able for to real power transfer between compensated lines and independently summing the compensate of reactive power. We also seen the fault recovery time response is better with UPFC. It also enlarges the effectiveness of system at any collapses.

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