Scientific Journal of Impact Factor(SJIF): 3.134
e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2, Issue 5, May -2015

Power Flow Control using Unified Power Flow Controller for WSCC9 bus System

Hiren Damor[1], Jayesh Makwana[2], Yuvarajsinh Bharthaniya, Krunal Dattesh[3]

[1]P.G Student, [2] P.G Student, [3]P.G Student, [4]Assistant Professor
Electrical Engineering Department
Parul Institute of Engineering and Technology

Abstract —*Unified Power Flow Controller (UPFC) is most versatile FACTS device in power system because it will independently control all the parameter that will affect the power flow in transmission line i.e. voltage magnitude, phase angle and impedance. It is also a unique capability to control both the real and reactive power flows on a transmission line as well as to regulate voltage at the bus where it is connected. UPFC creates a tremendous quality impact on power system stability. These features become even more significant knowing that the UPFC can allow loading of the transmission lines close to their thermal limits, forcing the power to flow through the desire paths. This give the power system operators much needed flexibility in order to satisfy the demands that the deregulated power system will impose. Hear we take a one case study for the WSCC9 bus system for the power flow control. We can simulate WSCC9 bus system with and without UPFC and compare their results.*

Keywords- *Flexible AC Transmission System (FACTS); Voltage Source converter (VSC); Static Synchronous compensator (STATCOM); Static Synchronous Series compensator (SSSC); Unified Power flow controller (UPFC).*

I. INTRODUCTION

FACTS Technology is concerned with the management of Active and Reactive Power to improve the performance of electrical transmission network. The concept of FACTS technology embraces a wide variety of tasks related to both utility and consumer problem, especially related to power quality issues. Where a lot of quality issues can be improved or enhanced with an adequate control of power flow.

In general, the concepts of power control are concerned with two jobs: load support and voltage compensation. Through the demand operation, the tasks are to raise the amount of the network power factor, to increase the active power from the source, to compensate voltage regulation and to decrease harmonics components resulted from the large and fluctuating nonlinear loads especially in industry application.

Series and shunt VAR compensators are able to alter the performance characteristics of electrical networks. Series compensator changes the parameter of the transmission grid or distribution levels, where shunt compensator modify impedance at the connected terminals. In both of them, the reactive power through the system can significantly improve the performance of the power system.

II. UNIFIED POWER FLOW CONTROLLER (UPFC)

2.1 Construction of UPFC

The UPFC concept was proposed by Gyugyi in 1991 within the concept of using converter based FACTS technology. It consists of two voltage source converter connected back-to-back through a common DC link provided by a dc storage capacitor as illustrated in figure 1.

As indicated before, this arrangement functions as an ideal ac to ac power converter in which the real power can freely flow in either direction between the ac terminals of the two converters, and each converter can independently generate or absorb reactive power at its own ac output terminal.

The series converter is connected to the transmission line through a booster transformer in a manner similar to the SSSC. The shunt converter is connected to the system bus through an excitation transformer in the same way as an STSTCOM. Therefore, the UPFC can be considered as a multi-function controller which is capable of providing the performance of one or two FACTS devices. Because of its structure, the UPFC provides new dimensions of controllability, which have not been achieved with other FACTS controllers.

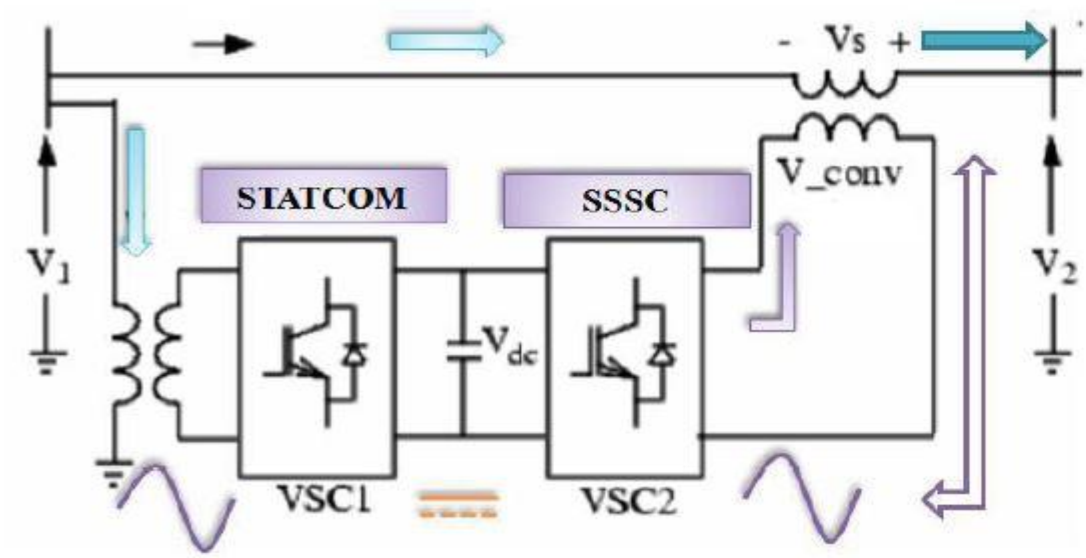

Figure-1 Equivalent Circuit of UPFC

2.2 Principle of Operation

The Series converter (SSSC) provides the main function of the UPFC by injecting a voltage V_{ser} in series with the transmission line. That is, the phase angle of V_{ser} can be controlled independently of the line current between 0 to 2π, and the magnitude is ranging from zero to a predefined maximum value. This maximum value defined by the VA rating of the UPFC series converter.

The transmission line current flows through this voltage sources resulting in reactive and real power exchange between it and the ac system. The real power measured at the converter output is supplied or absorbed by the dc link side. The reactive power is generated or absorbed internally between phases connected by the converter switches. As the magnitude and phase angle of series converter injected voltage is fully controlled, it can be used to achieve different conventional compensation e.g. voltage regulation, series compensation or phase angle regulation.

Converter 1 which is connected in shunt with the AC system is used essentially to provide the active power demand of the series converter at the common dc link. As converter 1 is a voltage source, it can generate or absorb reactive power at its connection point. Such a reactive power is independent of both the reactive power generated by the series converter and the active power through the dc link. Therefore, the shunt converter can fulfil the function of the SVC in providing reactive power compensation at the system bus bar and at the same time performing an indirect dc voltage regulation within the UPFC.

III. UPFC CONTROL SYSTEM

In order to understand the UPFC control system the phasor diagram is given in fig.1 and 2.

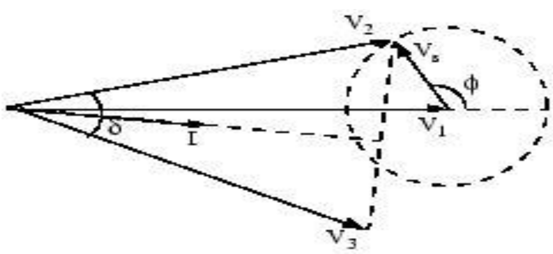

Figure -2 Phasor Diagram of Voltage and Current

$$P = \frac{V_2 \times V_3 \sin \delta}{X}$$

$$Q = \frac{V_2(V_2 - V_3 \cos\delta)}{X}$$

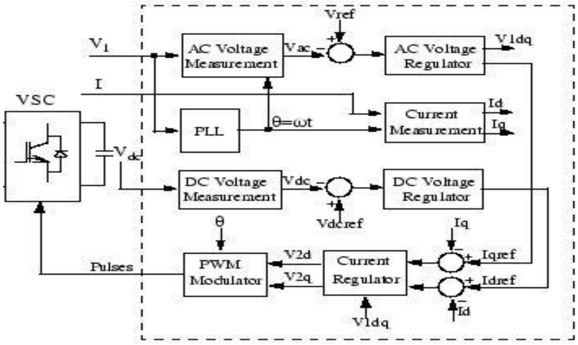

Figure 3 – Shunt Converter Control System

The shunt converter operates as a STATCOM control the ac voltage at its terminals and the voltage of the dc bus. It uses a dual voltage regulation loop: an inner current loop and an outer current loop regulating ac and dc voltages.

A phase-locked loop(PLL) which synchronizes on the positive sequence component of the three-phase primary voltage V_1. The outer of the PLL is used to compute the direct axis and quadrature axis components of the ac three phase voltage and currents like V_d , V_q ,or I_d , I_q on the diagram.

Measurement system measuring the d and q components on AC positive sequence voltage and current to be controlled as well as the Dc votage $V_{dc.}$

An outer regulation loop consisting of an AC voltage regulator and a DC voltage regulator. The outer of the ac voltage regulator is the reference current I_{qref} for the current regulator (I_q = current in a quadrature with the voltage which controls reactive power flow). The outer of dc voltage regulator is the references current I_{dref} for the current regulator (I_d = currnt in phase with the voltage which controls active power flow).

An inner current regulation loop consisting of the current regulator. The current regulator controls the magnitude and the phase of the voltage generated by the PWM converter(V_{2d} , V_{2q}) from the I_{dref} and i_{qref} reference current produced respectively by the dc voltage regulator and the ac voltage regulator . the current regulator assisted by a feed forward type regulator which predicts the V_2 voltage output (V_{2d} V_{2q}) from the V_1 measurement (V_{1d} V_{1q}) and the transformer leakage reactance.

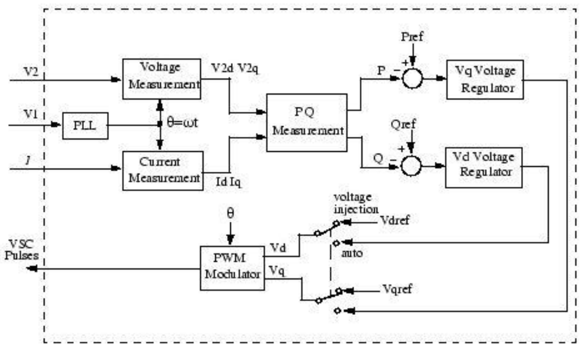

Figure.4 – Series Converter Control System

The series converter can operate either in power flow control mode or in manual voltage injection mode. In power flow control mode. The measured active power and reactive power are compared with reference values to produced P and Q errors. The P error and Q errors are used by two PI regulators to compute respectively V_q and V_d component of voltage to be synthesized by the VSC. (V_q in quadrature with V_1 controls active power and Vd in phase with V_1 controls reactive power). In manual voltage injection mode, regulators are not used. The reference values of injected voltage V_{dref} and V_{qref} are used to synthesize the converter voltage.

IV. SIMULATION OF 3-MACHINE 9-BUSSTANDARD (WSCC) SYSTEM

The basic controlling block diagram of this system is shown in fig. & he system parameters are specified in [2]

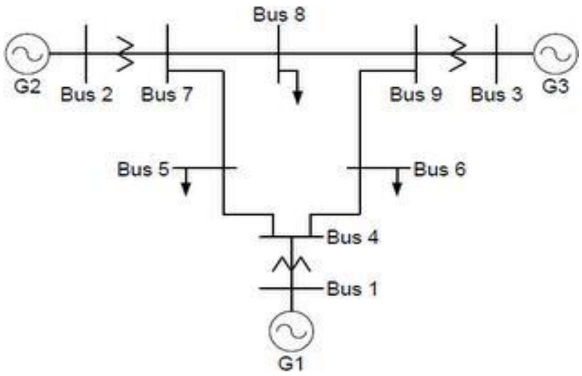

Figure5. Basic controlling of 3-Machine 9-Bus Standard (WSCC) System

The MATLAB simulation circuit of 3-Machine 9-Bus system is shown in fig .6. and the simulation results are shown and compare with each other.

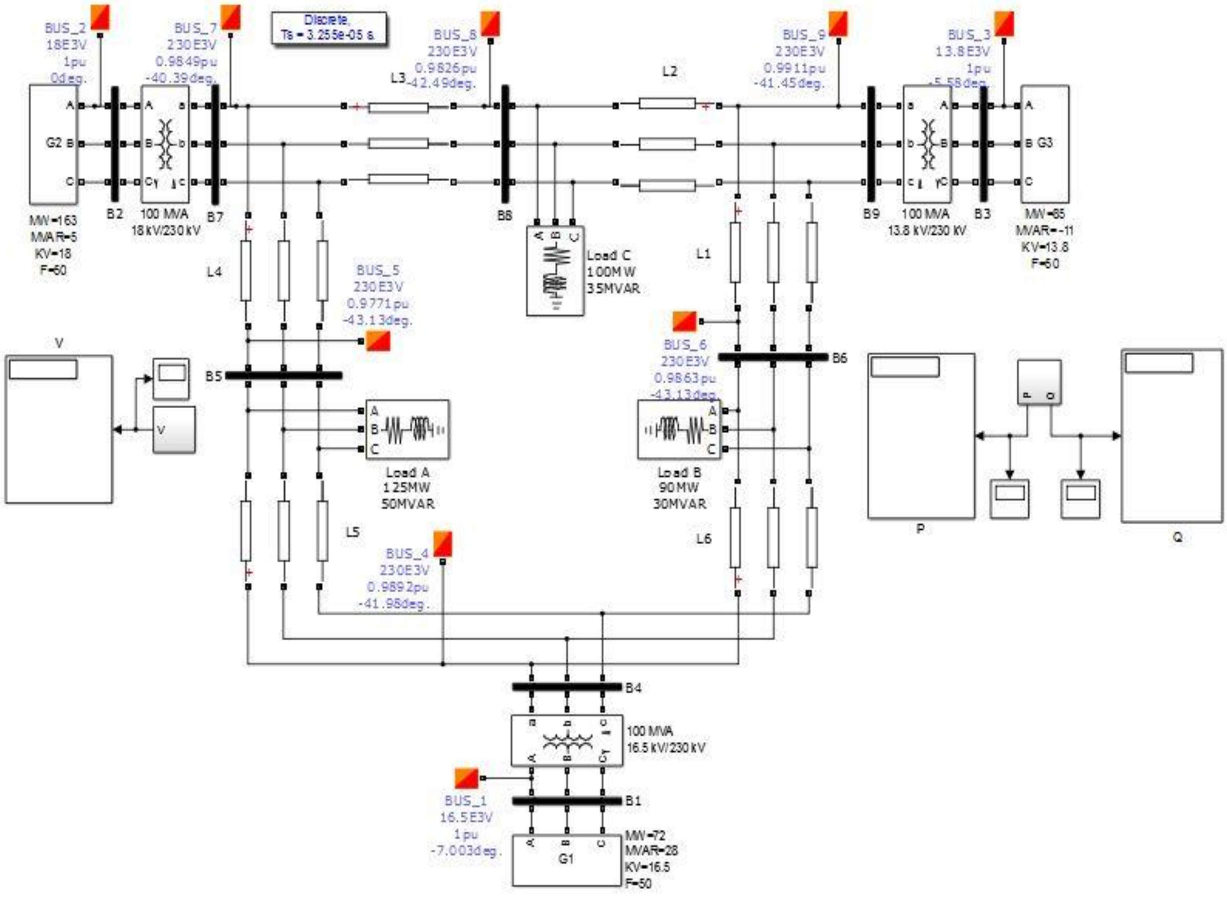

Figure 6 – Simulation of WSCC9 bus system

V. SIMULATION OF UNIFIED POWER FLOW CONTROLLER

The matlab simulation of UPFC is shown in fig.

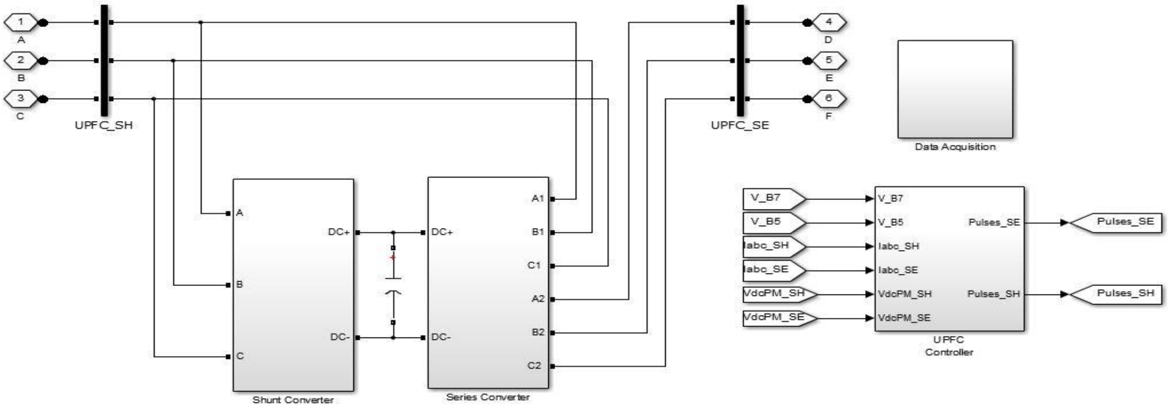

Figure 7. MATLAB simulation of UPFC

Here both shunt and series converter are simulated by 24- pulse converter, comparing 4 set of 6-pulse converter with 4 set of Zig-zag transformer achieving phase difference of 15° degree in each set.

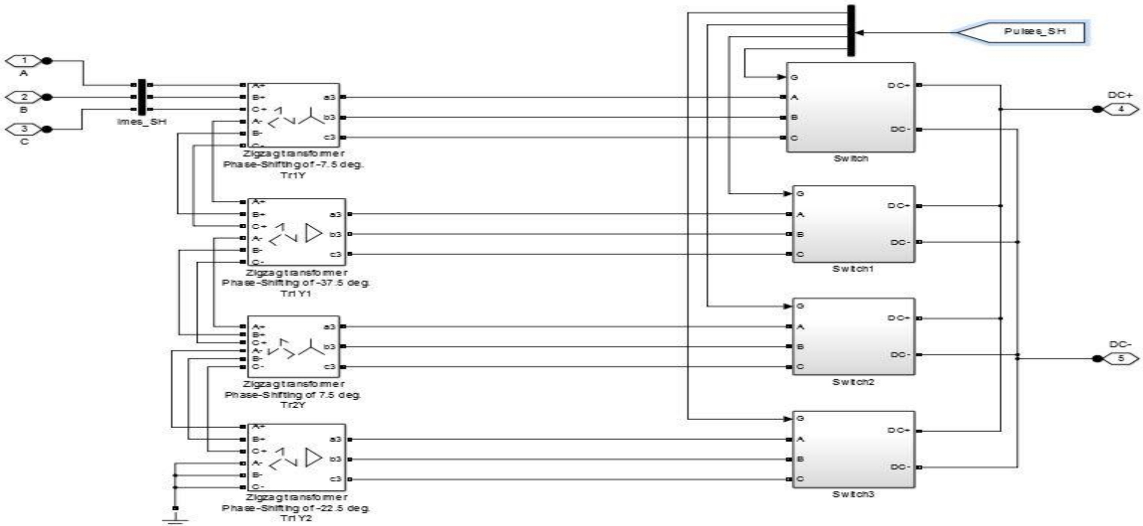

Figure 8 – Shunt Connected Zig-Zag transformer

This will generate ±7.5° phase shifted wave forms, combining with compensating voltage and current can be generated. Fig. 8 shows simulation of shunt VSC.fig. 9 shows simulation of series VSC.

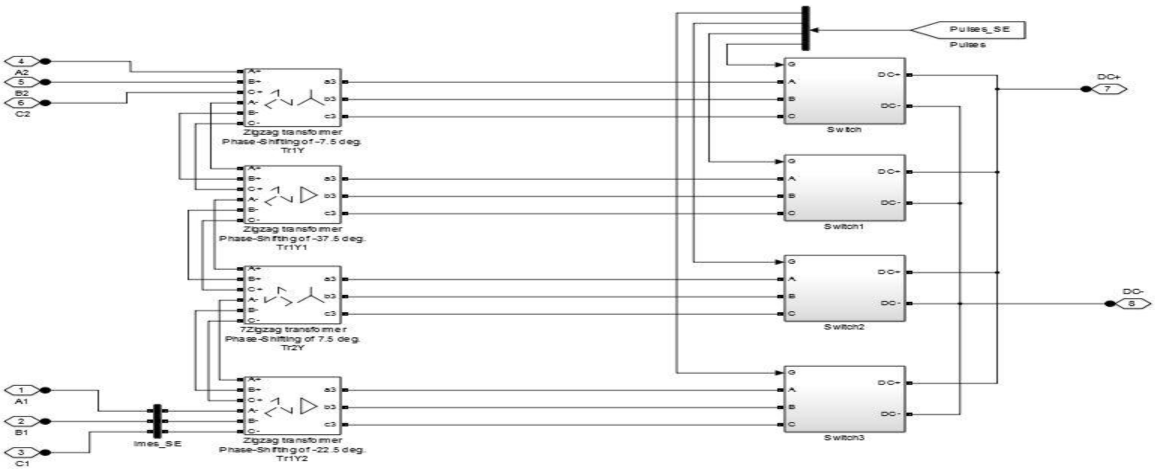

Figure 9 –Seriest Connected Zig-Zag transformer

VI. OPTIMAL PLACEMENT OF UNIFIED POWER FLOW CONTROLLER

Facts devices which are power electronics based devices can change parameter like impedance, voltage and phase angle. They also helps to reduced flows in heavily loaded line, resulting in an increasing low system losses, improve stability of the network, reduced cost of production and fulfilled contractual requirement by controlling the power flow in the network. For this it should be properly installed in the system with appropriate parameter setting.

Voltage stability is becoming an increasing source of concern in secure operating of present day power system. The problem of voltage instability is mainly considered as the instability of the network to meet the load demand impose in the terms of inadequate reactive power support or a active power transmission capability or both. It is mainly concern with the analysis and the enhancement of steady state voltage stability based on L-index. This L-index determines how any system is closed to its instability limit. The equation for stability index can be written as.

$$L_{(pu)} = 4\left\{\left(\frac{PX - RQ}{V_{s}2}\right) + \left(\frac{RP - XQ}{V_{s}2}\right)\right\}$$

Where L = Stability index

For Stable System L<1

Line	P(pu)	Q(pu)	V(pu)	L-Index
1	0.52	0.0701	0.991	0.021796
2	0.3249	0.1402	0.991	0.01713
3	0.6421	0.0238	0.985	0.024826
4	0.8361	0.122	0.985	0.035772
5	0.3595	0.2034	0.989	0.021193
6	0.3564	0.0384	0.989	0.014777

Table 1 – L- index Calculation

By calculating voltage stability index (L-index) from the table in between line 7-5 is more critical or a over loading line. So i put UPFC at the bus 5 to increase voltage level.

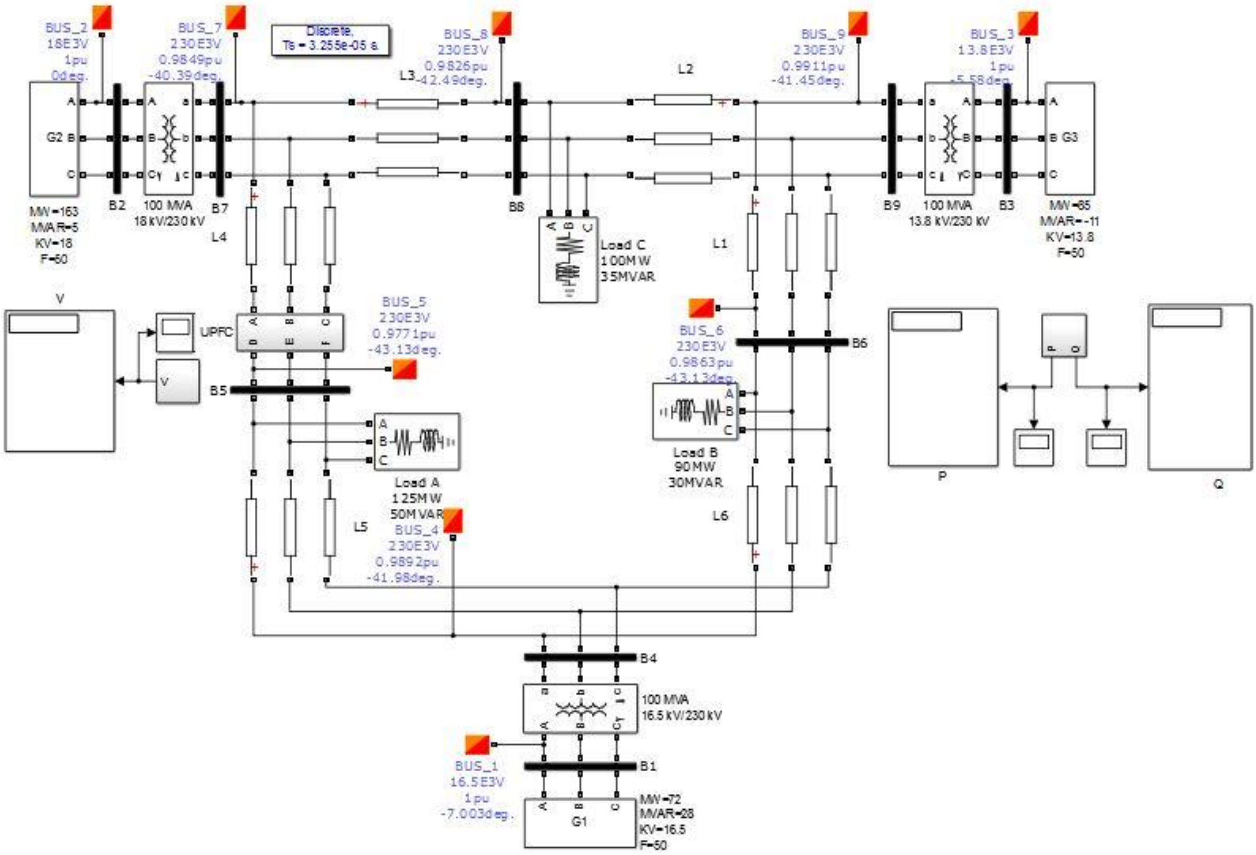

Figure 10 –UPFC connected in WSCC9 bus system

VII. RESULTS AND ANALYSIS

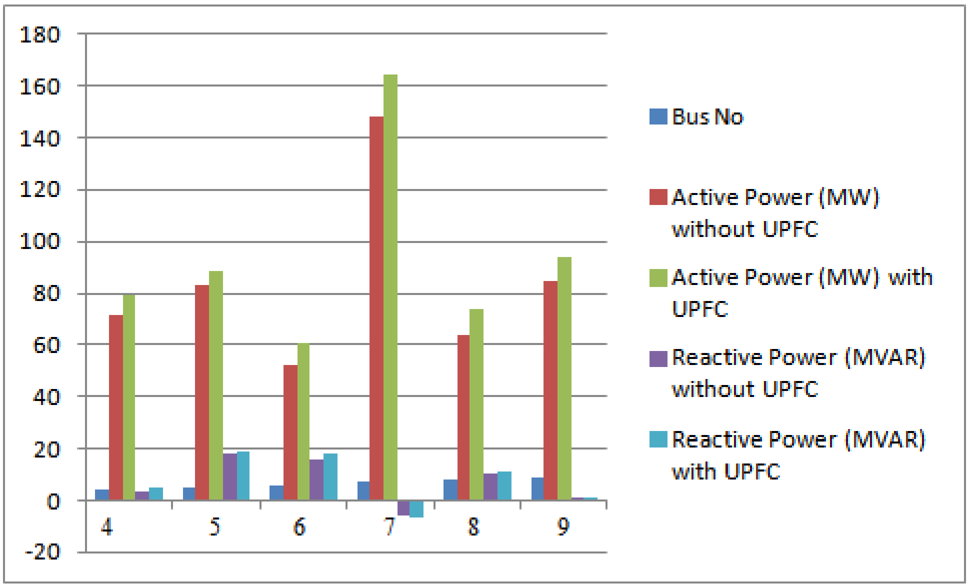

Figure 11 –Comparison of Power Profile With & Without UPFC

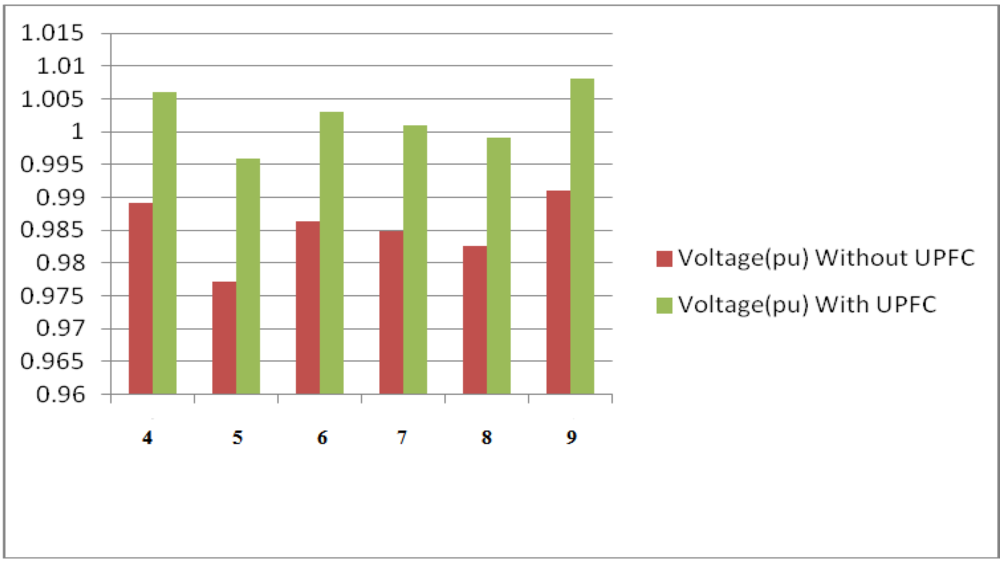

Figure 12 –Comparison of Voltage Profile With & Without UPFC

As shown from the voltage and power profile we can say that without UPFC voltage at bus no 5 is 0.9771 and while we implement UPFC at bus no 7 to 5the voltage magnitude is 0.9959. so we can say that the voltage profile increased. Also from the power profile, we can say that power at bus no5 is increased.

VIII. CONCLUSIONS

In this Paper, Power flow Control using UPFC is discussed. Here the simulation of WSCC9 bus test system is considered for the power flow control. In that simulation of WSCC9 bus system without UPFC is done. Using a linear stability index we can find the optimal placement for the UPFC. We can observe that at line no 4 between the buses 7-5 there is maximum loading in the line. So UPFC installed in between the bus 7-5. By installing Unified Power Flow Controller (UPFC) we can control both the Active and Reactive power. Also we can observe that voltage magnitude of the difference bus also increased. That means by installing UPFC in the system we can also increased the voltage profile.

REFERENCES

[1] Djilani Kobibi Y.I, Hadjeri Samir, Zidi Sid Ahmed, Djehaf Mohamed , Intelligent Control and Electrical Power System Laboratory ,Djillali Liabes University , Sidi Bel-Abbes , Algeria, " Modelling a Unified Power Flow Controller for the Study of Power System Steady state and Dynamic Characteristics " IEEE 5th International Conference on, vol.,no.,pp.1,6, 28-30 April 2013

[2] Swaroop Nallagalva, Mukesh Kumar Kirar, Dr. Ganga Agnihotari, "Transient Stability Analysis of the IEEE9-bus Electric Power System" International journal of scientific engineering and technology, volume No.1, Issue No 3, ISSN:2277-1581.

[3] Rishabha Shah, Sarafraz Gandhi, "Optimal Placement & Control Modeling of Unified power Flow Controller using voltage stability index and Alpha-Beta Transformation Throry for multi-machine power system" volume 2,issue 2, ISSN: 2321-9939. IJERD 2014

[4]L. Gyugyi, C. D. Schauder, S. L. Williams (Westinghous science & Technology Center), T. R. Rietman, D. R. Torgerson (western area power administration), A. Edris (Electrical power Research Institute)," The Unified Power Flow Controller: A New Approach to Power Transmission Control" IEEE Transaction on Power Delivery, Vol. 10, No 2,April 1995

[5]Pengcheng Zhu; Liming Liu; Xiaoyuan Liu; Yong Kang; Jian Chen, "A Novel Control Scheme For a Unified Power Flow Controller" Transmission and Distribution Conference and Exhibition, 2005/2006 IEEE PES, vol., no., pp.684,692, 21-24 May 2006

[6] J. Bian; D.G. Ramey; R. J. Nelson; A. Edris " A study of equipment sizes and constraints for a unified power flow controller " power delivery, IEEE transaction on , vol.12, no. 3,pp.1385,1391, Jul 1997

