Scientific Journal Impact Factor (SJIF) : 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Unified Power flow controller for reactive power compensation based on reference frame theory

Shasikala.G[1]
[1]Assistant Professor, *Department of Electrical and Electronics Engineering,*
Er.Perumal Manimekalai College of Engineering, Hosur, India,

Abstract— This paper proposes a new algorithm to generate reference voltage for a unified power flow controller (UPFC) operating in voltage control mode. The proposed scheme exhibits several advantages compared to traditional voltage-controlled UPFC. The proposed scheme ensures that unity power factor (UPF) is achieved at the load terminal during nominal operation, which is not possible in the traditional method. Also, the compensator injects lower currents and, therefore, reduces losses in the feeder, voltage source converter and voltage source inverter. Further, a saving in the rating of UPFC is achieved which increases its capacity to mitigate voltage sag. Nearly UPF is maintained, while regulating voltage at the load terminal, during load change. The state-space model of UPFC for fast load voltage regulation during voltage disturbances. With these features, this scheme allows UPFC to tackle power-quality issues by providing power factor correction, harmonic elimination, load balancing, and voltage regulation based on the load requirement. Simulation results are presented to demonstrate the efficacy of the proposed algorithm.
Keywords- FACTS, UPFC, power quality (PQ), voltage-control mode, voltage-source inverter.

I. INTRODUCTION

Unified Power Flow Controller (UPFC) is the universal and most flexible FACTS (Flexible ac Transmission System). It is used to control the power flow in the transmission systems by controlling the impedance, voltage magnitude and phase angle. This device can allow the path of power as we desire. UPFC consist of two Voltage Supply Inverters, one series converter and one shunt converter. This device is actually a combination of two FACTs device which are STATCOM (Static Synchronous Compensator) and SSSC (Static Series Synchronous Compensator). SSSC is used to add controlled voltage magnitude and phase angle in series with the line, while shunt converter STATCOM is used to provide reactive power to the ac system, besides that, it will provide the dc power required for both inverter. The reactive power can be compensated either by improving the receiving voltage or by reducing the line reactance. UPFC should be installed to control the voltage, as well as to control the active and reactive power flow through the transmission line. However, the right transmission line to be injected by UPFC and the effect of injection will only know by doing the analysis using MATLAB. Thus, this paper presents the active and reactive power control through a transmission line by placing the UPFC using computer simulation. MATLAB program are used to model and to verify the performance of UPFC in order to increase the ability of the system. Unified Power Flow Controller (UPFC) is the most widely used Flexible ac Transmission system (FACTS) device to control the power flow and to optimize the system stability in the transmission line.

It should be installed to control the voltage, as well as to control the active and reactive power flow through the transmission line. The cost of losing synchronous through a transient instability is extremely high in modern power systems. Consequently, utility engineers often perform a large number of stability studies in order to avoid this problem. A unified power flow controller (UPFC) is the most promising device in the FACTS concept. It has the ability to adjust the three control parameters such as the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently. A UPFC performs this through the control of the in-phase voltage, quadrature voltage, and shunt compensation. UPFC can control the three control parameters either individually or in appropriate combinations at its series-connected output while maintaining reactive power support at its shunt-connected input. The mechanism of the three control methods of a UPFC in enhancing power system damping. It was shown that a significant reduction in the transient swing can be obtained by using a simple proportional feedback of machine rotor angle deviation. It is generally accepted that the addition of a supplementary controller to the UPFC can significantly enhance power system damping. The main function of the UPFC is to control the flow of real and reactive power by injecting of a voltage in series with the transmission line. Both the magnitude and the phase angle of the volt age can be varied independently. Real and reactive power flow control can allow for the power flow in prescribed routes, loading of transmission lines closer to their thermal limits and can be utilized for improving transient and small signal stability of the power system.

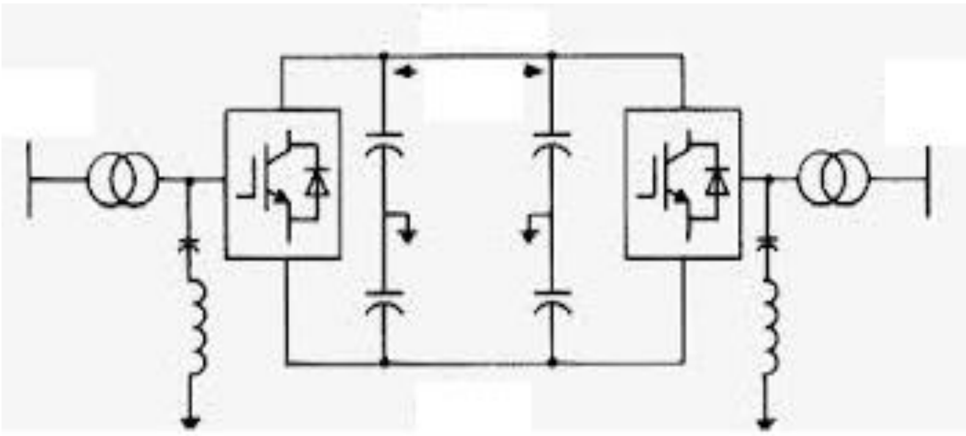

Figure 1. General diagram of UPFC

The schematic of the UPFC is shown in Figure 1. The UPFC consists of two branches. The series branch consists of a voltage source converter which injects a voltage in series through a transformer. Since the series branch of the UPFC can inject a voltage with variable magnitude and phase angle it can exchange real power with the transmission line. The energy storing capacity of this dc capacitor is generally small. Therefore, active power drawn by the shunt converter should be equal to the active power generated by the series converter. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system. However the UPFC as a compensator cannot supply or absorb real power in steady state (except for the power drawn to compensate f or the losses) unless it has a power source at its DC terminals. Thus the shunt branch is required to compensate (from the system) for any real power drawn/ supplied by the series branch and the losses. If the power balance is not maintained, the capacitor cannot remain at a constant voltage. In addition to maintaining the real power balance, the shunt branch can independently exchange reactive power with the system. The main advantage of the power electronics based FACTS controllers over mechanical controllers is their speed. Therefore the capabilities of the UPFC need to be exploited not only for steady state load flow control but also to improve stability.

II. OPERATING PRINCIPLE OF UPFC

The UPFC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and the SSSC. The main reasons behind the wide spreads of UPFC are: its ability to pass the real power flow bi-directionally, maintaining well regulated DC voltage, workability in the wide range of operating conditions etc .The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer. The DC terminals of the two VSCs are coupled and this creates a path for active power exchange between the converters. Thus the active supplied to the line by the series converter can be supplied by the shunt converter as shown in figure 2. Therefore, a different range of control options is available compared to STATCOM or SSSC.

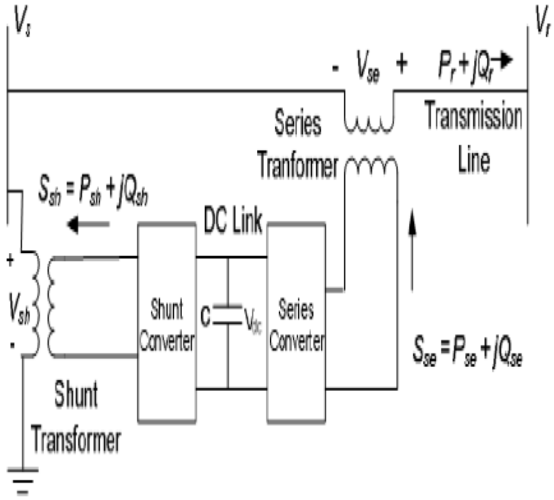

Figure 2. UPFC schematic diagram

The UPFC can be used to control the flow of active and reactive power through the transmission line and to control the amount of reactive power supplied to the transmission line at the point of installation. The series inverter is controlled to inject a symmetrical three phase voltage system of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is 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 constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point. dc V The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line. The UPFC can also provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. The UPFC has many possible operating modes: Var control mode, automatic voltage control mode, direct voltage injection mode, phase angle shifter emulation mode, line impedance emulation mode and automatic power flow control mode.

III. PROPOSED SYSTEM WITH REFERENCE CURRENT EXTRACTION (dq method)

Because of the complication of the linear feedback-feed forward controller to accomplish simultaneously acceptable stead state and transient state conditions, the dynamic models of the active filter system consist of multiple control inputs and the state variables. Nonlinear control model based on the traditional d-q and p-q-r theory is utilized to overcome the dynamic control problem of linear control strategy. It is impossible to attain the harmonic in p-q-r theory based harmonic control strategy. To improve performance of the active power filters, synchronous rotating reference frame, adaptive notch filters, flux based controller, PI controller, sliding Mode Control, power balance theory, and nonlinear controller have been used in many techniques but most of the control techniques are subjected to a number of transformations and are difficult to implement. PI controller's controlling performance mostly depends on the gains and the performances of time response and also the steadiness of the system is decided by the gain tuning process. Sliding mode control technique is only applicable for bounded case sliding region, but the surface trajectory is not possible for unbounded case. Here, a hybrid control strategy is proposed to improve the performance of the shunt APF filter thereby improving the PQ of nonlinear load. The proposed control strategy is the combination of RBNN and an optimization technique called cuckoo search. The proposed technique is implemented in the MATLAB/Simulink platform and the harmonic elimination performance is evaluated.

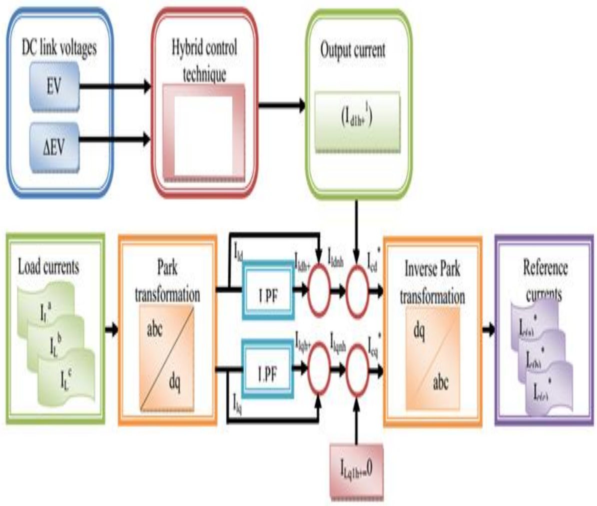

Figure 3. Reference current generation using Id, Iq method

In this section, figure 3 represents the electrical scheme of a UPFC for a three-phase power system, which can compensate current harmonics. To detect the harmonic and reactive current of the UPFC and also to inject the balance current of the active filter into a system, the UPFC is coupled with the nonlinear load in parallel. The three phase source voltages and currents are denoted as V_s^a , V_s^b , V_s^c and I_s^a , I_s^b , I_s^c respectively. The three phase load currents and inductances are I_L^a, I_L^b, I_L^c and L_1, L_2, L_3 respectively. Then the proposed hybrid controller is used to calculate the reference currents ($I_{ca}^*, I_{cb}^*, I_{cc}^*$) used by the inverter to produce the compensation currents (I_{ca}, I_{cb}, I_{cc}). Forcing the source current to be purely sinusoidal in a way by generating the equal and opposite current in polarity to the harmonic current strained by the load and injecting it to the point of common coupling is the basic principle of the active filter. The UPFC does not want energy storage units i.e. it does not consume any active power wrapped up from the resource which is the strange characteristic of the shunt converter. So it needs an effective compensation policy in order to achieve this function. Here, the instantaneous active and reactive current method is used with the proposed controller. With the help of the reference current generator the reference current signals are generated which are fed in to the hysteresis controller as the input. Following this, the gate signals for the UPFC are produced. The detailed analysis is described in the following section.

The instantaneous phase current and load current are represented as follows,

$$I_s(t) = i_L(t) - i_c(t) \qquad (1)$$

$$i_L(t) = \sum_{n=1}^{\infty} I_n \sin(n\omega t + \Phi_n) \qquad (2)$$

Then the compensation current of the shunt active filter is denoted as,

$$I_c(t) = i_L(t) - i_s(t) \qquad (3)$$

Here, the active power filter estimates the fundamental component of the load current and compensates harmonic current and reactive power.

IV. PROPOSED SYSTEM SIMULATION RESULTS

The proposed system Simulink shows the results for UPFC. It shows the Simulink blocks, source voltage, source current, load voltage, load current, series converter dc link voltage, shunt converter output voltage and the proposed system results are compared with the PI. Fuzzy logic controllers.

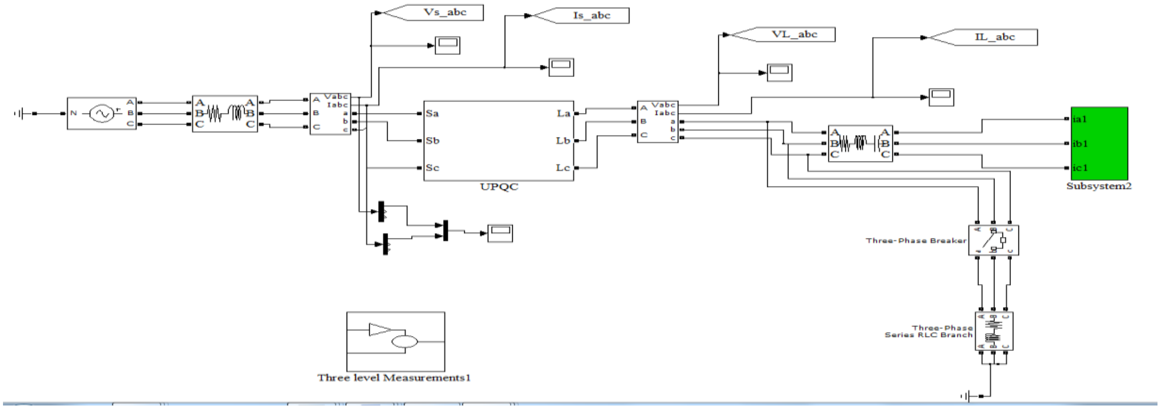

Figure 4. Matlab Simulink diagram for UPFC

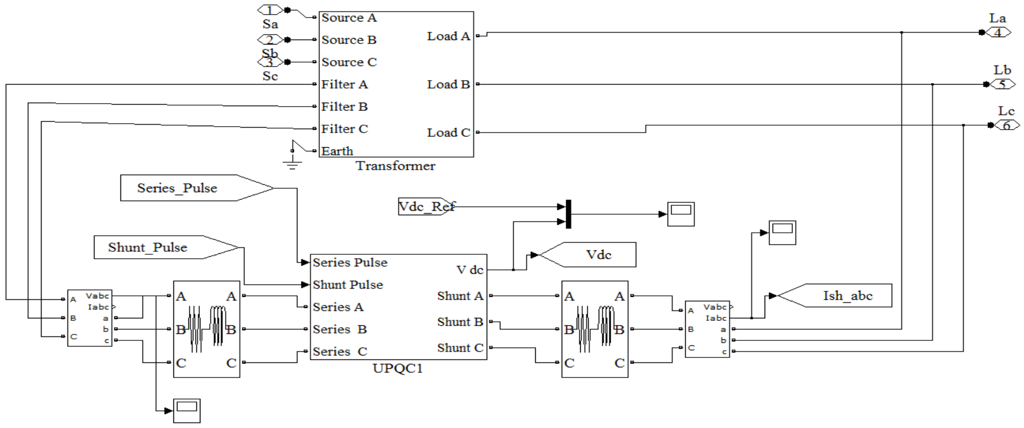

Figure 5. Matlab Simulink diagram for UPFC shunt and series converter

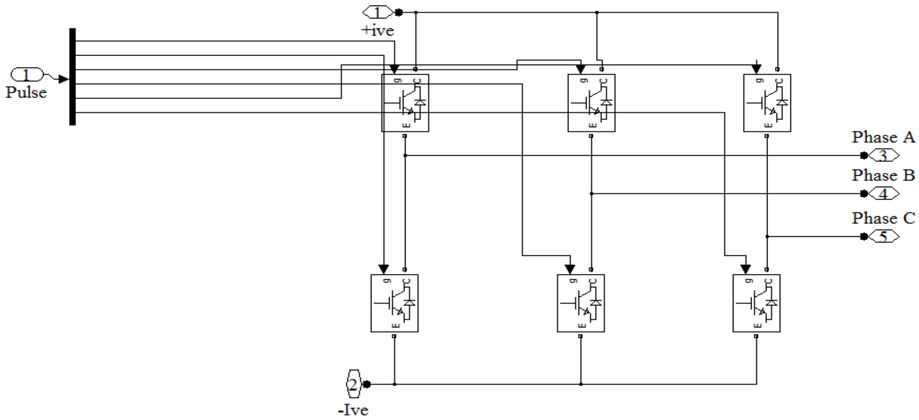

Figure 6. Matlab Simulink diagram for UPFC series converter

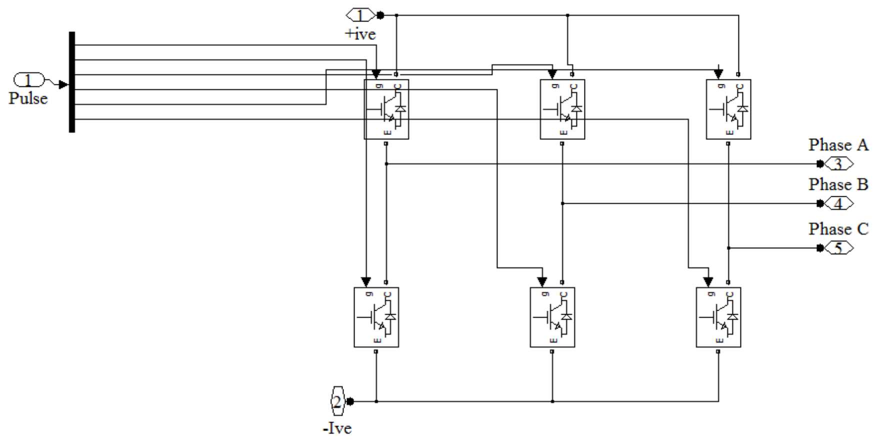

Figure 7. Matlab Simulink diagram for UPFC shunt converter

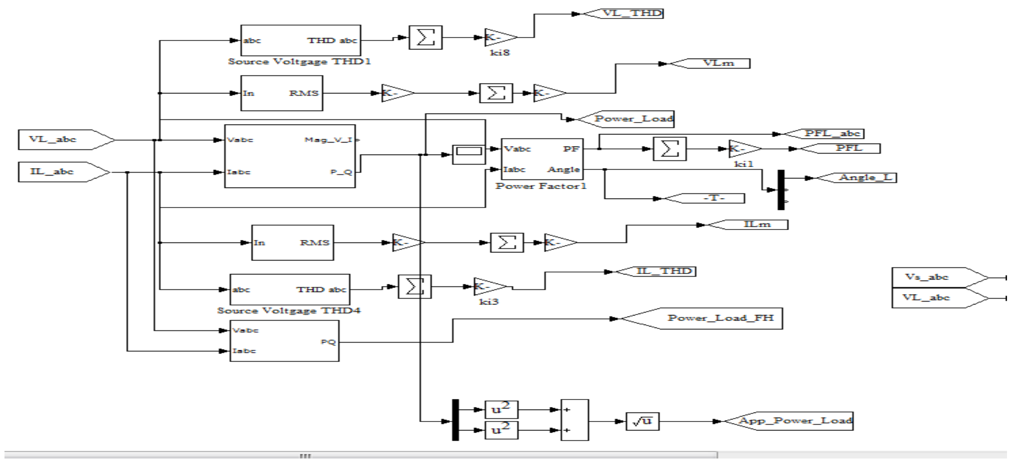

Figure 8. Matlab Simulink diagram for UPFC reference current generation

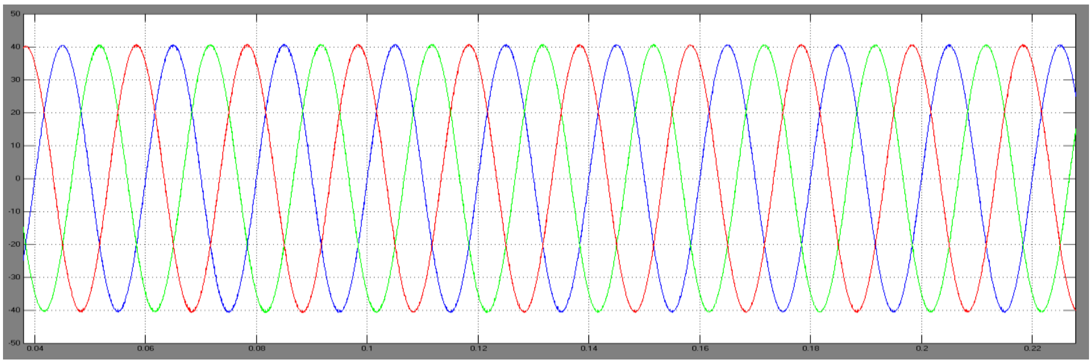

Figure 9. Matlab Simulink diagram for UPFC source voltage

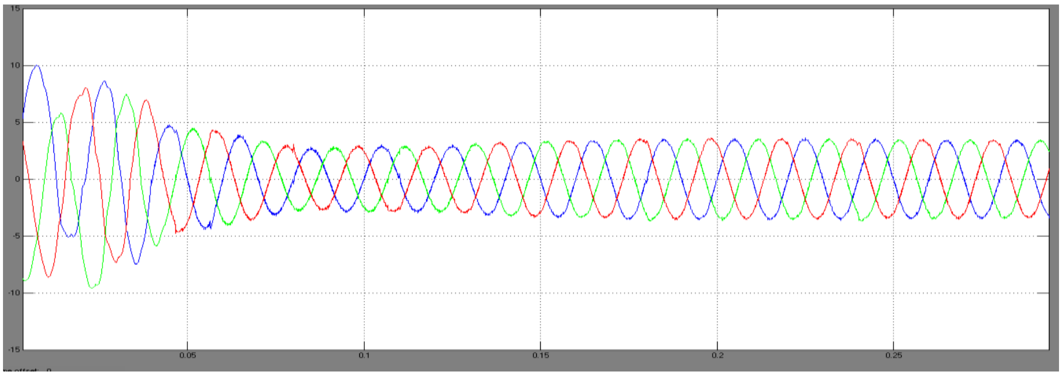

Figure 10. Matlab Simulink diagram for UPFC source current

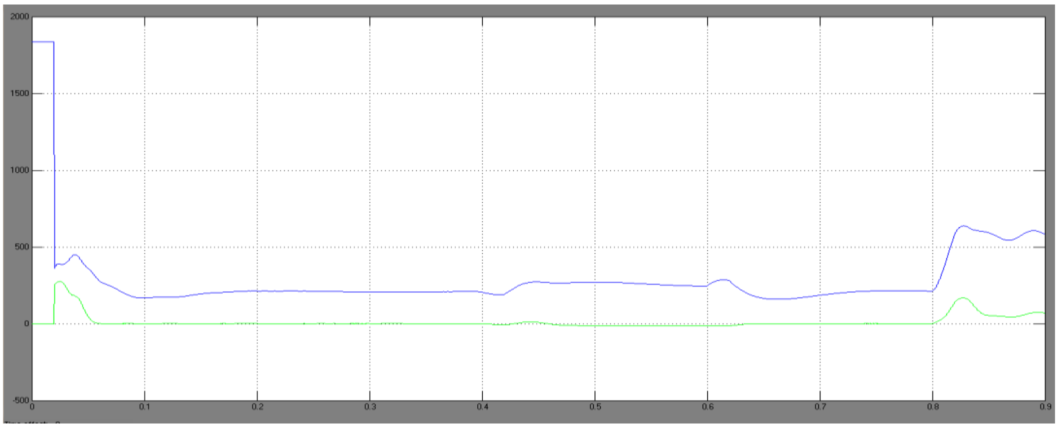

Figure 11. Matlab Simulink diagram for real and reactive power

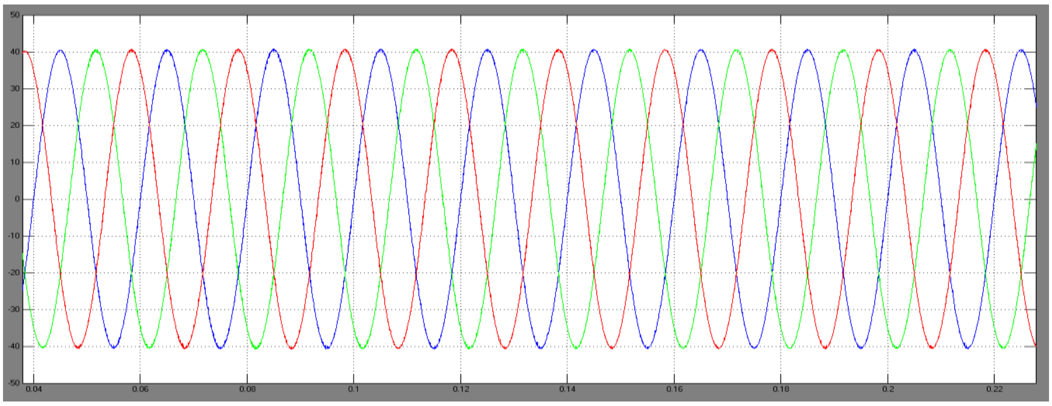

Figure 12. Matlab Simulink diagram for UPFC load voltage

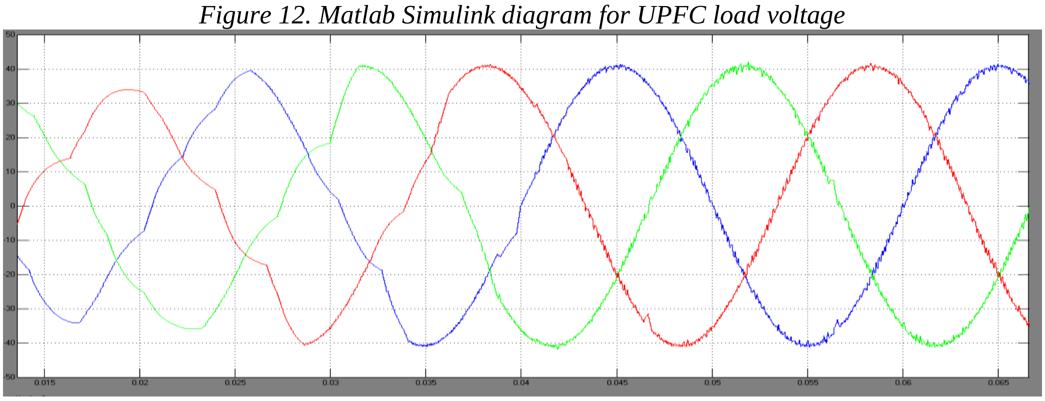

Figure 13. Matlab Simulink diagram for UPFC load current

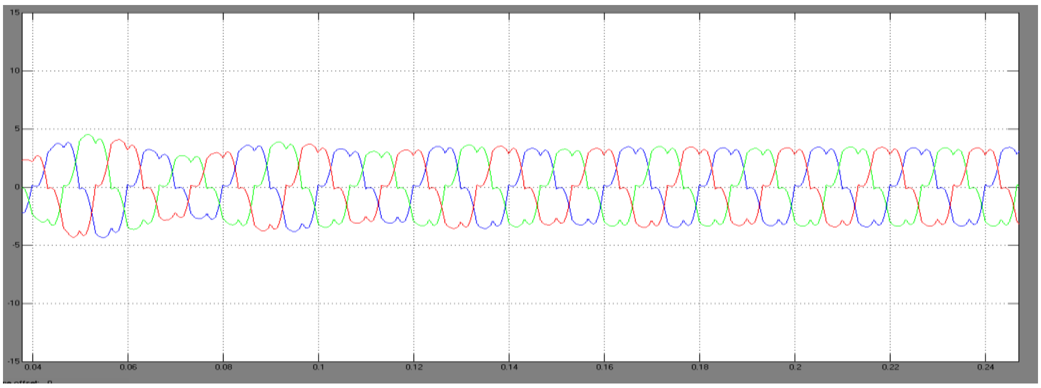

Figure 14. Matlab Simulink diagram for UPFC voltage across shunt converter

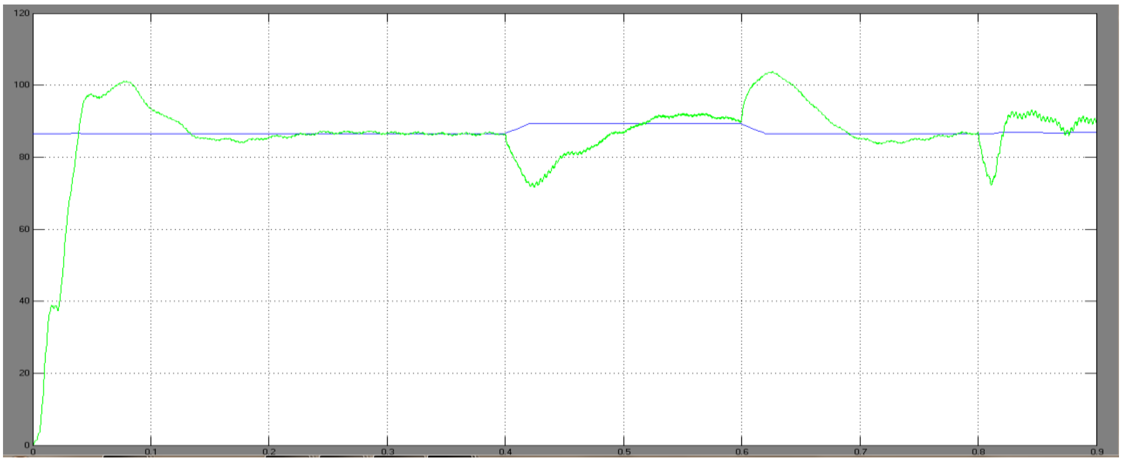

Figure 15. Matlab Simulink diagram for UPFC DC link voltage across series converter

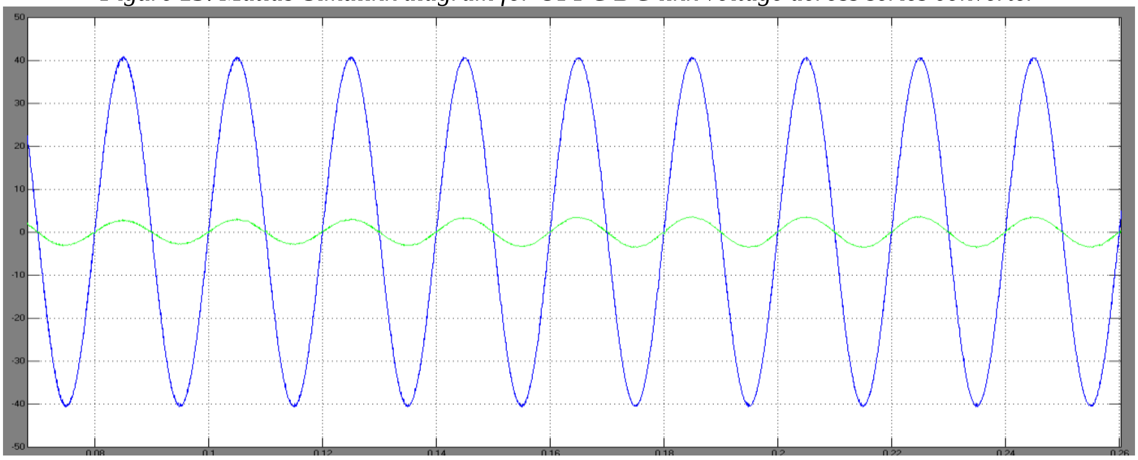

Figure 16. Matlab Simulink diagram for UPFC Input source voltage and current

V. CONCLUSIONS

In this paper, a control algorithm has been proposed for the generation of reference load voltage for a voltage-controlled UPFC. The performance of the proposed scheme is compared with the traditional voltage-controlled UPFC. The proposed method provides the following advantages: 1) at nominal load, the compensator injects reactive and harmonic components of load currents, resulting in UPF; 2) nearly UPF is maintained for a load change; 3) fast voltage regulation has been achieved during voltage disturbances; and 4) losses in the VSI and feeder are reduced considerably, and have higher sag supporting capability with the same VSI rating compared to the traditional scheme. The simulation and results show that the proposed scheme provides UPFC, a capability to improve several PQ problems (related to voltage and current).

REFERENCES

[1] Vibhor Gupta, "Study and Effects of UPFC and its Control System for Power Flow Control and Voltage Injection in a Power System", International Journal of Engineering Science and Technology, vol.2 (7), 2010, pp-2558-2566.
[2] Distributed generation and FACTS Technology - Wikipedia, the free encyclopaedia.
[3] J. Hao, L. B. Shi, and Ch. Chen, "Optimizing Location of Unified Power Flow Controllers by Means of Improved Evolutionary Programming", IEE Proc. Genet. Transm. Distrib. 151(6)(2004), pp. 705–712.
[4] N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York: IEEE Press, 2000.
[5] L. Gyugyi, T. Rietman, and A. Edris, "The UPFC Power Flow Controller: A New Approach to Power Transmission Control", IEEE Trans. on Power Delivery, 10(2) (1995), pp. 1085–1092.
[6] I.Papic, "Mathematical analysis of FACTS devices based on a voltage source converter, part II: steady state operational characteristics", Electric Power systems Research, vol. 56, pp. 149-157, 2000.

[7] I.Papic, "Mathematical analysis of FACTS devices based on a voltage source converter, part 1: mathematical models", Electric Power System.
[8] S.D. Round, Q. Yu, L.E. Norum, T.M. Undeland, "Performance of a Unified power flow controller using a D-Q control system", IEEE AC and DC power transmission Conference, Pub.IEE No 423, pp. 357-362, 1996.
[9] Q. Yu, S. D. Round, L. E. Norum, T. M. Undeland, "Dynamic control of UPFC", IEEE Trans.Power Delivery.vol.9 (2), pp.508 – 514, 1996.
[10] D. Soto and T. C. Green, "A comparison of high-power converter topologies for the implementation of FACTS controllers," IEEE Trans. Industrial Electronics, vol. 49, no. 5, pp. 1072–1080, October 2002.
[11] M. S. El-Moursi and A. M. Sharaf, "Novel controllers for the 48-pulse VSC STATCOM and SSSC for voltage regulation and reactive power compensation," IEEE Trans. Power System, vol. 20(4), pp. 1985–1997, Nov. 2005.
[12] J. Rodriguez, J. S. Lai, and F. Z. Peng, "Multilevel Inverters: A survey of topologies, controls and applications," IEEE Trans. Industrial Electronics, vol. 49, no. 4, pp. 724–738,Aug. 2002.
[13] C. k. Lee, J. S. K. Leung, S. Y. R. Hui, and H. S. H. Chung, "circuit level comparison of STATCOM technologies", IEEE Trans. Power Electronics, vol.18, no.4, pp.1084-1092, July 2003.
[14] S. Baskar, N. Kumarappan and R. Gnanadass," Switching Level Modelling and Operation of Unified Power Flow Controller", Asian Power Electronics Journal, vol.4, No.3, December 2010.
[15] S. Limyingcharoen, U. D. Annakkage, and N. C. Pahalawaththa, "Effects of Unified Power Flow Controllers on Transient Stability", IEEE Proceedings Generation Transmission and Distribution, 145(2), 1998, pp. 182–188.

G.Shasikala received the B.E. Degree in Electrical and Electronics Engineering from Adhiyamaan College of Engineering, Hosur, University of Madras, Chennai, India and Post-graduation in Power Electronics & Drives in Annai Mathammal Sheela Engineering College Namakkal. Anna University, Coimbatore, India. Now She is working as a Assistant Professor in Er. Perumal Manimekalai College of Engineering, Hosur.