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Enhancement of Power Transfer Capability Using UPFC with Shunt and Series FACTS Controllers

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ABSTRACT

Flexible AC Transmission Systems as a key building block of transmission level smart grids have shown effective functionalities in promoting the system operation security and service reliability. The electrical power quality is affected by many factors like harmonic pollution due to non-linear loads such as large thyristor power converters, rectifiers and the voltage/current flickering due to arc furnaces and also the sag and swell creation due to the switching of the loads. This paper presents the simple control design and simulation scheme for a unified power flow controller (UPFC) to assist in reducing total harmonics distortion. This device contains the integration of a shunt active filter together with a series active filter in a back to back configuration to simultaneously compensate the supply voltage and the load current. To overcome this problem, the paper proposes supplementing the pi controller feedback loop comprised of an identifier. UPFC that consists of two back-to-back inverters requires bulky and often complicated zigzag transformers for isolation and reaching high power rating with desired voltage waveforms. The proposed topology has been analyzed for reduction of harmonics sag compensation using shunt and series voltage source converter in MATLAB/Simulink Environment.

Keywords: Total Harmonic Distortion (THD), Shunt Controller, Series Controller, Voltage Source Converter (VSC), Pulse Width Modulation (PWM), Sag Compensation

1. INTRODUCTION

The flexible ac transmission system (FACTS) is a new technology, based on power electronics, to enhance power system capability through the ability of high-speed electronic control of ac transmission line parameters [1]. The sources of problems can be disturb the power quality are power electronic devices, arcing devices, load switching, large motor starting, embedded generation, sensitive equipment, storm and environment related damage, network equipment and design. The solution to improve the energy quality (PQ-Power Quality) at the load side is of great important when the production processes get more complicated and require a bigger liability level, which includes aims like to provide energy without interruption, without harmonic distortion and with tension regulation between very narrow margins [2-4]. In order to overcome these consequences and to provide the desired power flow along with system stability and reliability, installations of new transmission lines are required. Moreover, installation of new transmission lines with the large interconnected power system are limited to some of the factors like economic cost, environment related issues.

The Unified Power Flow Controller (UPFC) is a typical FACTS (Flexible AC Transmission Systems) device that is the most sophisticated and complex power electronic equipment and has emerged for the control and optimization of power flow and also to regulate the voltage in electrical power transmission

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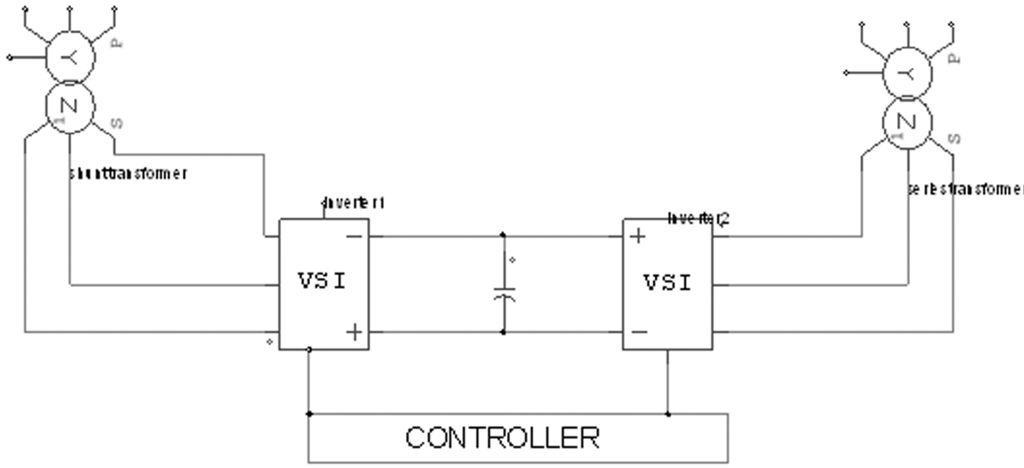

Figure 1: Schematic Circuit Diagram of UPFC

system [5]. 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 technology of power system utilities around the world has rapidly evolved with considerable changes in the technology along with improvements in power system structures and operation. The ongoing expansions and growth in the technology, demand a more optimal and profitable operation of a power system with respect to generation, transmission and distribution systems [6]. The schematic diagram of UPFC conventional circuit configuration is shown in figure 1.

Demand in electricity conduct with restricted building of new transmission facilities has caused today's interconnected power systems to be overloaded. Previously, power system stabilizers (PSS) installed at generator locations were used to damp such system oscillations. However, PSSs are localized stabilizers and hence best suited for damping local oscillatory modes in the power system. Since inter-area modes are related to the dynamics of an inter-connected power system, damping control method means for transmission paths evolved [7-9]. The advancements in high-power semiconductors led to the advent of flexible AC transmission systems (FACTS) technology. The first one consider as series control mode provides the reference input is a simple VAR request that is maintained by the control system regardless of bus voltage variation. The second one represent the shunt voltage control mode gives idea about the shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value with a defined slope characteristics the slope factor defines the per unit voltage error per unit of inverter reactive current within the current range of the inverter [10-12].

Recently, [13-14] many changes have been implemented electric power utilities all over the world. So, we have to improve method in the matter of the power system. This is global trend and similar structural changes have adaptation to new generation patterns will also necessities adaptation and require occurred elsewhere in other industries. Moreover, the flexibility of power system can be increased. The power has responded the technology of flexible AC transmission system or some of which may have achieved maturity within the industry whilst some others are yet in the design stage FACTS [15]. In this paper presents the reduction total harmonic distortion at sag compensation of power transmission system based UPFC using shunt and series voltage source converter. However, it is important to include the switching characteristics especially when studying the interaction of the converters and the power system in response to system faults. Thus, in this work the UPFC converter is modeled in MATLAB-SIMULINK using a two-level, six-pulse voltage sourced converter (VSC) topology with the thyristor firing pulses generated through a pulse width modulation (PWM) switching technique.

2. MODEL OF UNIFIED POWER FLOW CONTROLLER

The UPFC is designed for compensation of AC power transmission systems. It gives functional workability to answer many of the problems facing the power delivery industries. UPFC can be able to maintain synchronic or individually all the parameters affecting power flow in the power system network. The main reason behind the wide spreads of UPFC are ability to power flow bi-directionally maintaining well regulated DC voltage, work ability in the wide range of operating conditions. This is based on the second or latest generation of FACTS technology. This FACTs device combines the two features of two VSC. Basically these devices are voltage source converters (VSC). A current injected UPFC model for improving power system dynamic performance was developed. It has represented by an equivalent circuit with a shunt current source and a series voltage source converter. The basic schematic diagram of UPFC is shown in figure 2.

The series inverter is 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. So, this inverter will exchange active and reactive power with the line. The series inverter electronically provides the reactive power, 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 Vdc 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. The proposed UPFC topology represent the circuit diagram is shown in figure 3.

The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, shunt current into the transmission line. The shunt inverter can be controlled in two different modes such as VAR control mode and Automatic Voltage Control Mode. In this mode of operation explained the reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, Vdc is also required. Similarly, the automatic voltage control mode described the shunt inverter

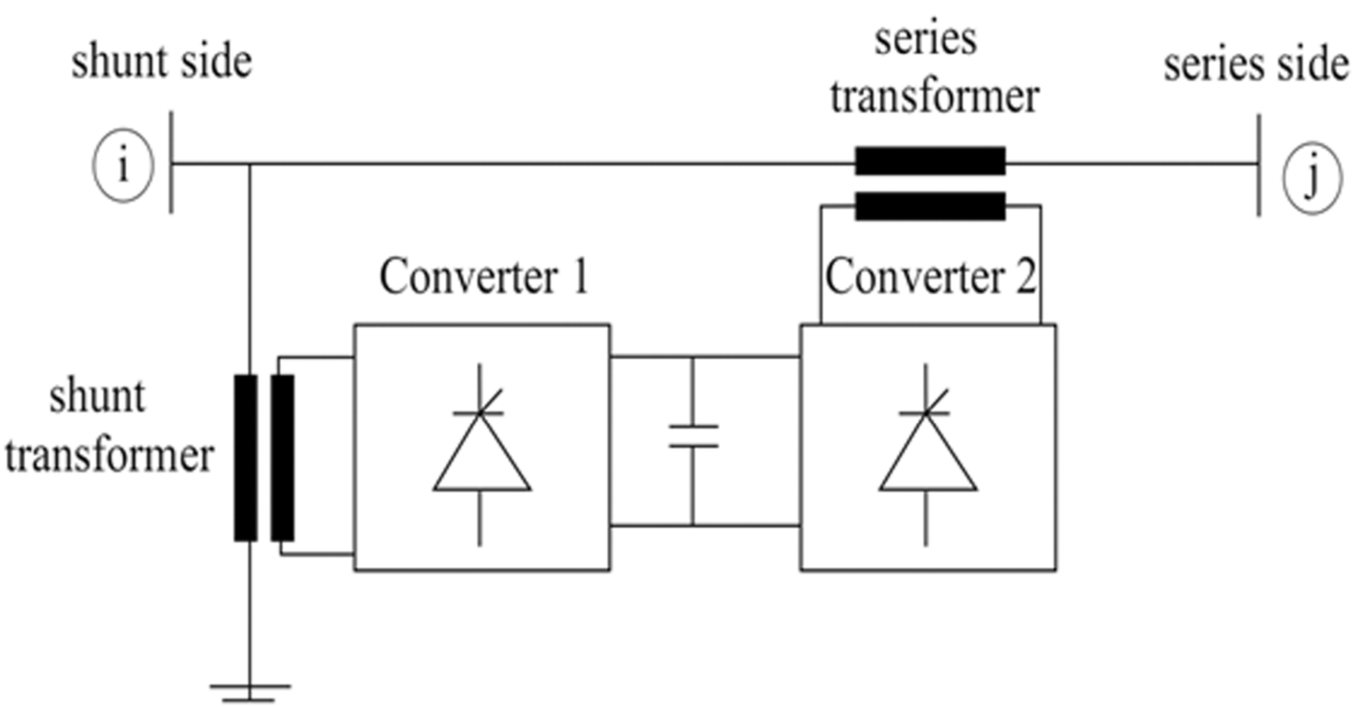

Figure 2: Basic Schematic Diagram of UPFC

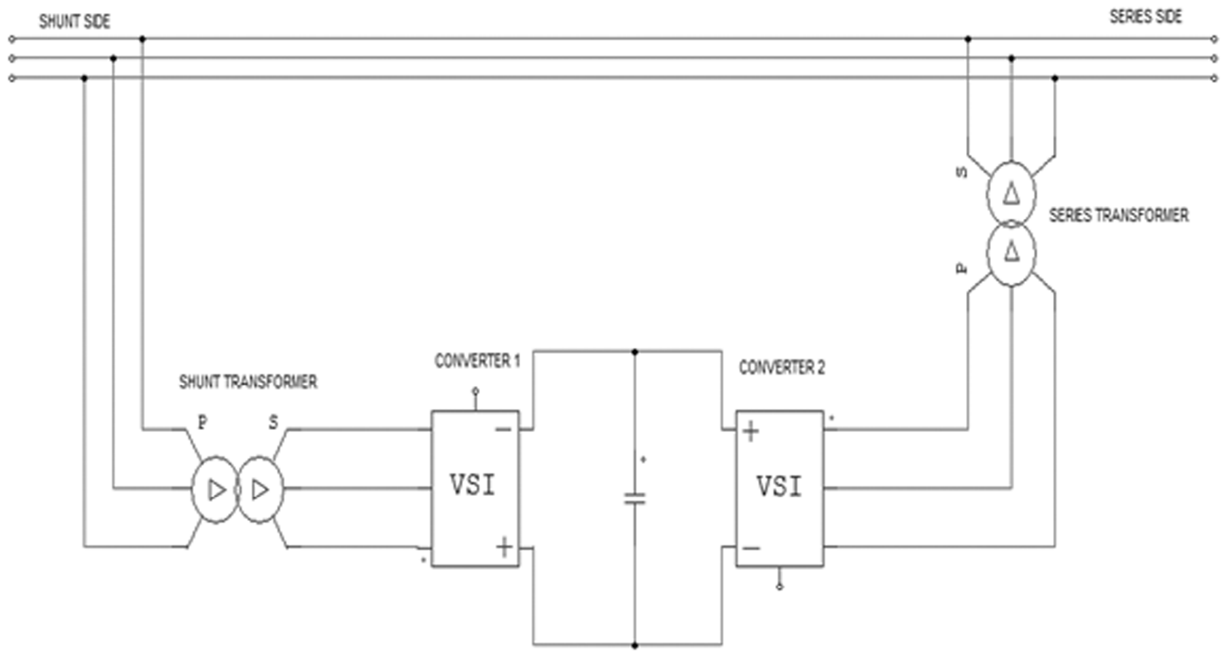

Figure 3: Proposed Overall UPFC Configuration

reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line.

3. CONFIGURATION OF POWER FLOW WITH UPFC

The performance of the UPFC injection model is tested on the two area four generator power system. The injection model of the UPFC is placed at the beginning of the lower line between buses 8 and 12 in order to see the influence on the power flow through that line as well as on the bus voltages. Injection model of the UPFC is described in the static part of the analysis, where the power injection model is used. However, for a dynamic analysis, due to model requirements, current injection model is more appropriate. The single line diagram of UPFC is shown in figure 4. In the past, a majority of literature such as the ones described

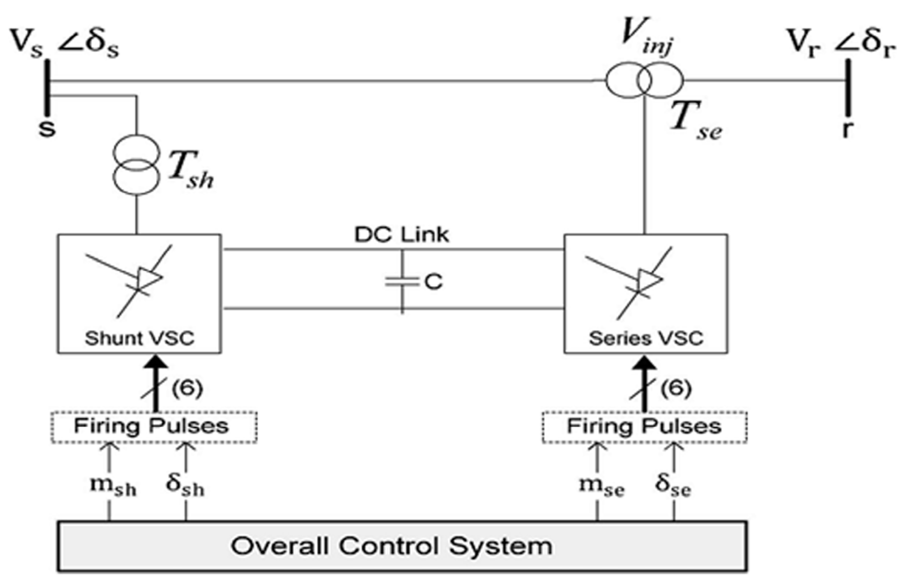

Figure 4: UPFC Based Single Line Diagram

have modeled the UPFC as a series reactance with a set of active and reactive nodal power injections or by two ideal voltage sources. Such models were primarily chosen for their mathematical simplicity where the converter switching characteristics were ignored.

A UPFC consists of two identical converters, the shunt VSC and the series VSC connected in shunt and series with the ac transmission network, respectively. Each converter is connected to the ac system through corresponding coupling transformers, Tsh and Tse and are operated from a common dc link supported by a dc capacitor. It primarily provides the real power demanded by the series VSC from the ac system via the common dc link. This is made possible by keeping the dc link capacitor, C charged at all times, replicating an energy source for real power exchange. It also acts as an independent reactive power compensator thereby maintaining the system bus voltage at a specified value. With its four control inputs, the UPFC can be commanded to force an appropriately varying line power to effectively damp power oscillations.

The UPFC should operate in the automatic power flow control mode keeping the active and reactive line power flow at the specified values. It is found that there is an improvement in the real and reactive powers through the transmission line when UPFC is installed. The power flow arrangement of electric circuit diagram is shown in figure 5. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. In power system transmission, it is required to maintain the voltage magnitude, phase angle and line impedance. Consequently, to control power flow over designated transmission line and enhancement of power system stability FACTS devices are used in modern power system network. Transient Stability is improved and faster steady state is achieved. Hence, congestion is less by improving transient stability.

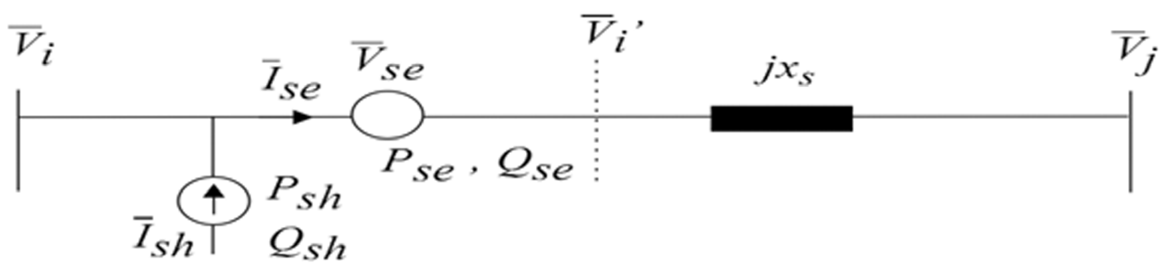

Figure 5: Electric Circuit Diagram for Power flow

4. DESIGN OF BACK TO BACK CONVERTER CONTROLLER

The shunt converter is used to improve reactive power of the line .so; we can provide voltage regulation at connection line. In this converter, one is act as STATCOM and another one act as SSSC. It can be observe the reactive power and regulate the voltage level. SSSC is used to regulating the current in power transmission line. It has two control mode consists such as VAR control mode and automotive voltage control mode. The block diagram of controller organization of UPFC model is shown in figure 6.

With the development of power systems especially the opening of electric energy markets, it becomes more and more important to control the power flow along the transmission line, thus to meet the need of power transfer. On the other hand the fast development of power electronic technology has made UPFC a promising part for future power system needs. This device is an advance power system device capable of providing simultaneous control of voltage magnitude, active and reactive power flows in an adaptive fashion.

4.1. Series Controller

The Series controller is used to generate the gate pulse for series converter and also injected in series side in transmission line. The UPFC connection of two VSC which is shunt and series VSC connected with grid line. The proposed converter is connected to the AC system through two transformers T_{shunt} and T_{series}

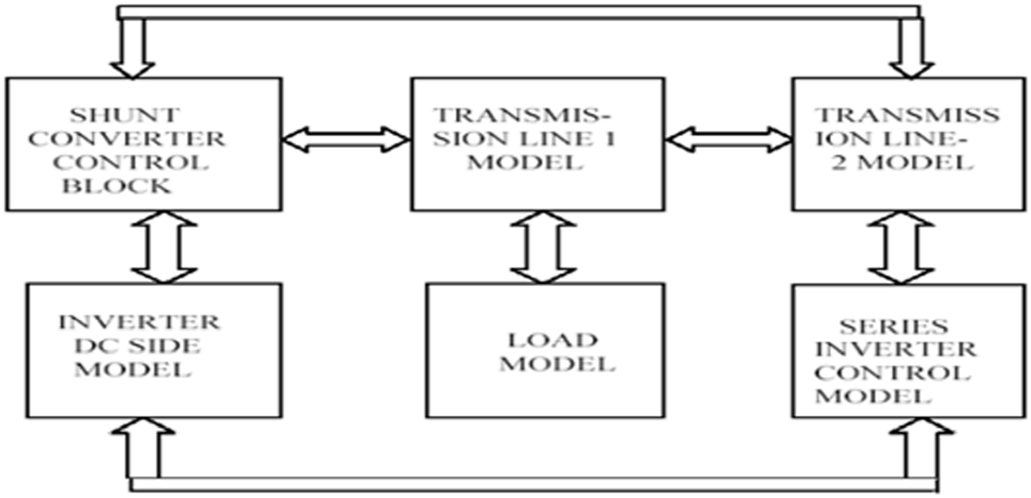

Figure 6: UPFC controller organization model

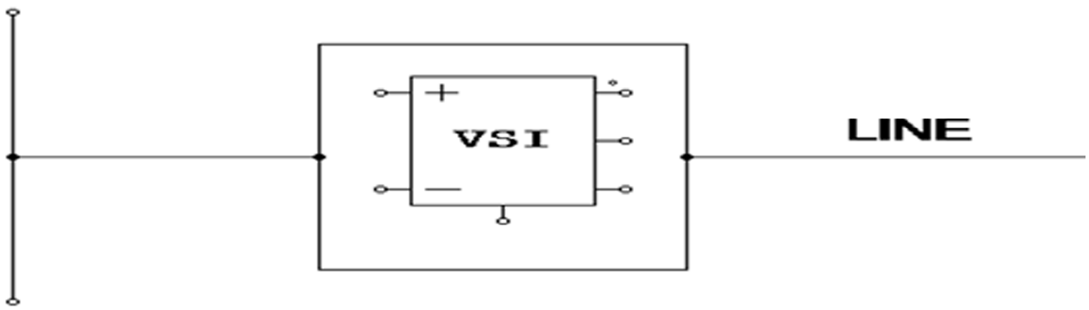

Figure 7: Series Controller act as Static Synchronous Series Compensator

respectively. Also, it can be operated from common dc link support by dc capacitor. The series controller is acts as Static Synchronous Series Compensator (SSSC) shown in figure 7.

4.2. Shunt Controller

Shunt controller is implementing the current in phase with voltage the transmission line. Series controller is connected with line in transmission line the voltage and current is in phase and absorbing variable reactive power. The shunt and series VSCs can be operated in different control modes where a particular mode is chosen depending upon the application objective. The d-q control method suggested is adopted wherein the desired $P_{desired}$ and $Q_{desired}$ are compared with the measured line flows, P_{meas} and Q_{meas} and the corresponding deviations in real and reactive power (ΔP and ΔQ) are used to drive the d-q components (Vd and Vq) of series injected voltage. The shunt controller is act as Static Synchronous Compensator (STATCOM) shown in figure 8.

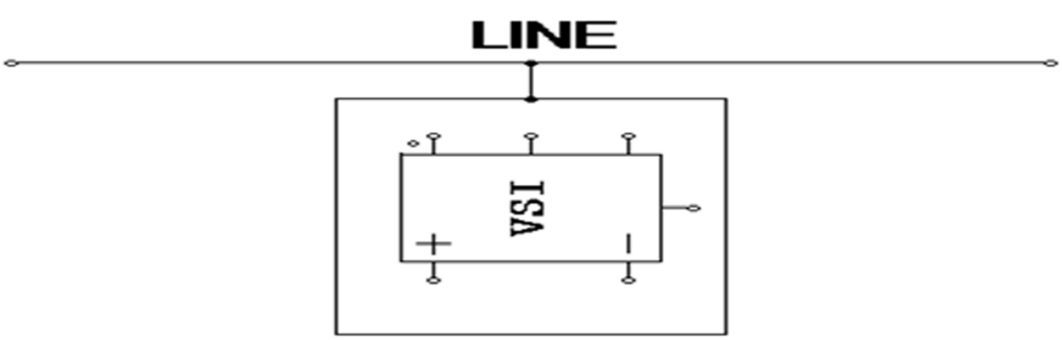

Figure 8: Shunt Controller act as STATCOM

5. SIMULATION RESULTS

Here, simulation circuit diagram and results are given below. The Simulink is simulated using MATLAB/ Simulink. In fig. 9 is proposed simulation circuit diagram is mentioned. In fig.10 and fig.11 are controller of shunt and series. In fig.12 and 13 is input sag voltage and current mentioned here. In fig 14 and 15 are mention below sag compensation of voltage and current. In fig.16 is mentioned THD is mentioned.

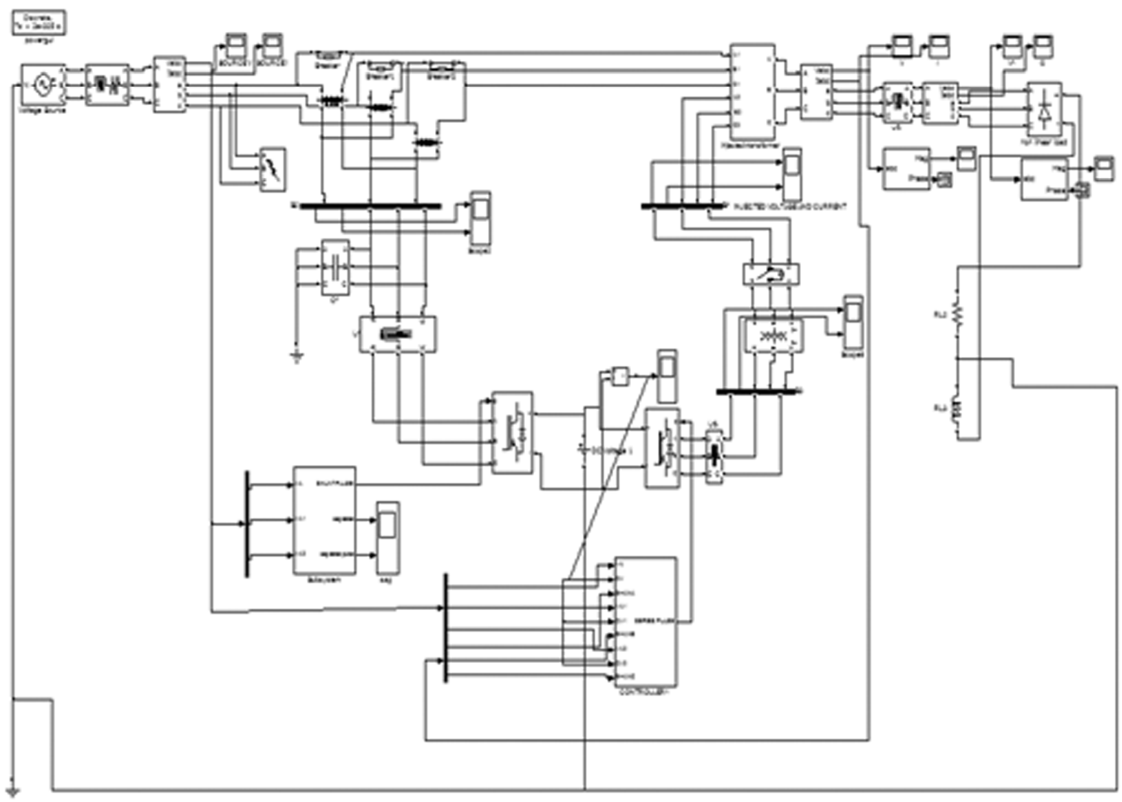

Figure 9: Simulink model of overall topology

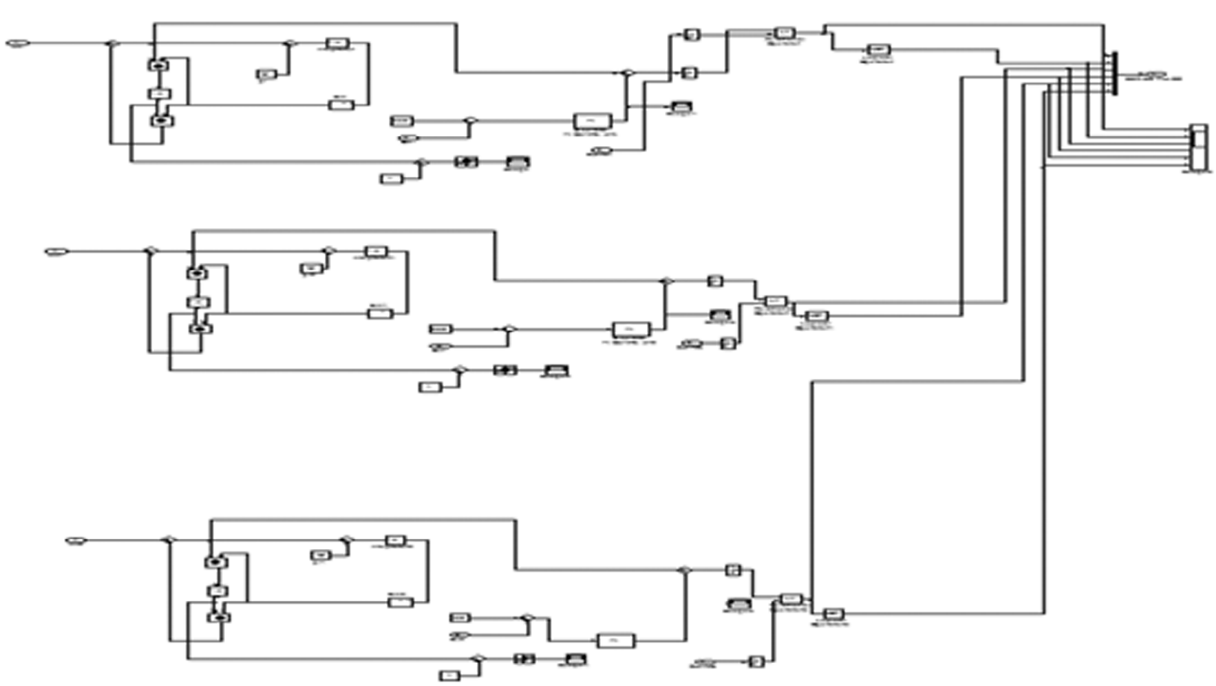

Figure 10: Control structure of Series Converter

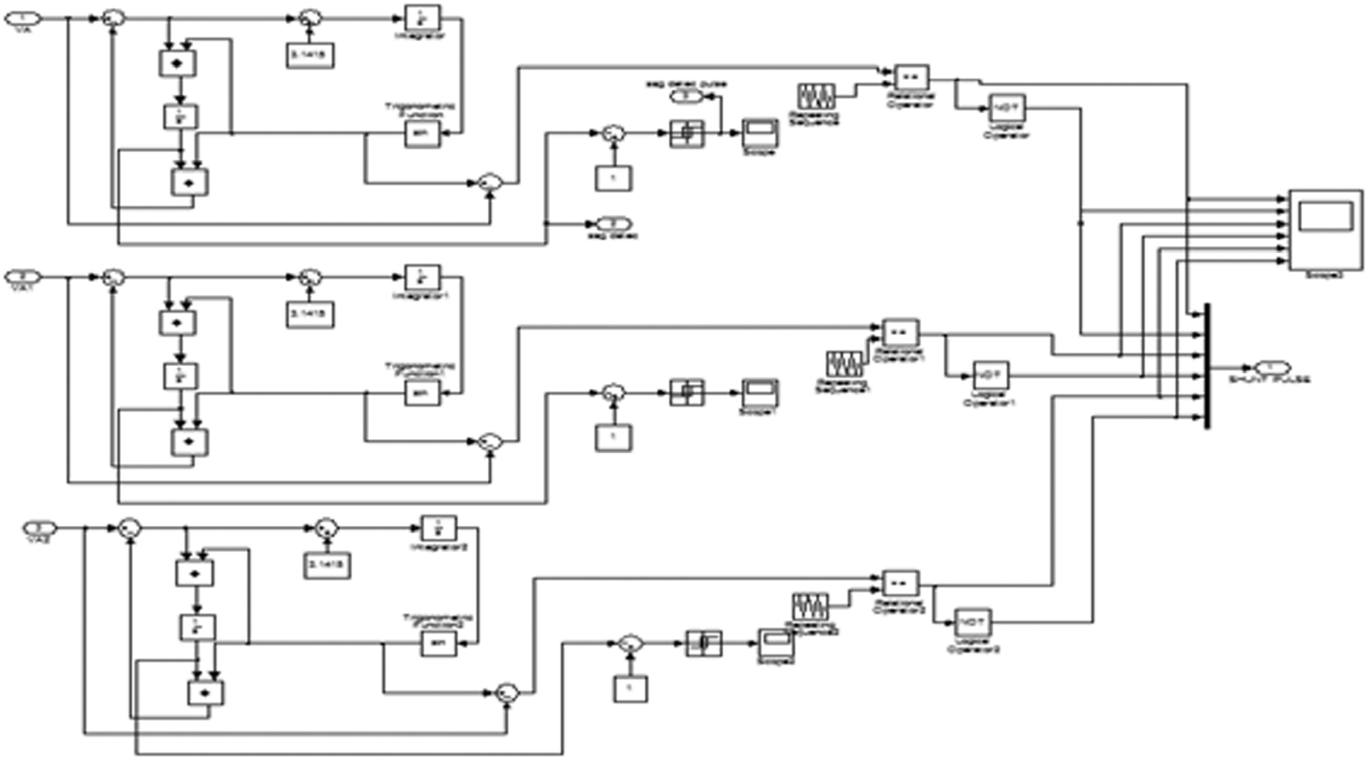

Figure 11: Control Strategy of Shunt Converter

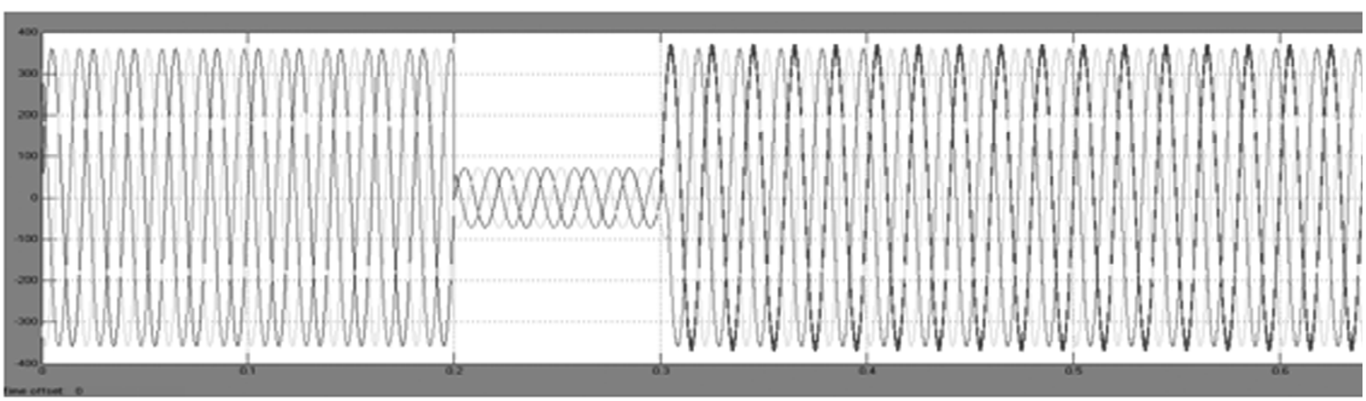

Figure 12: Input Sag Voltage Waveform

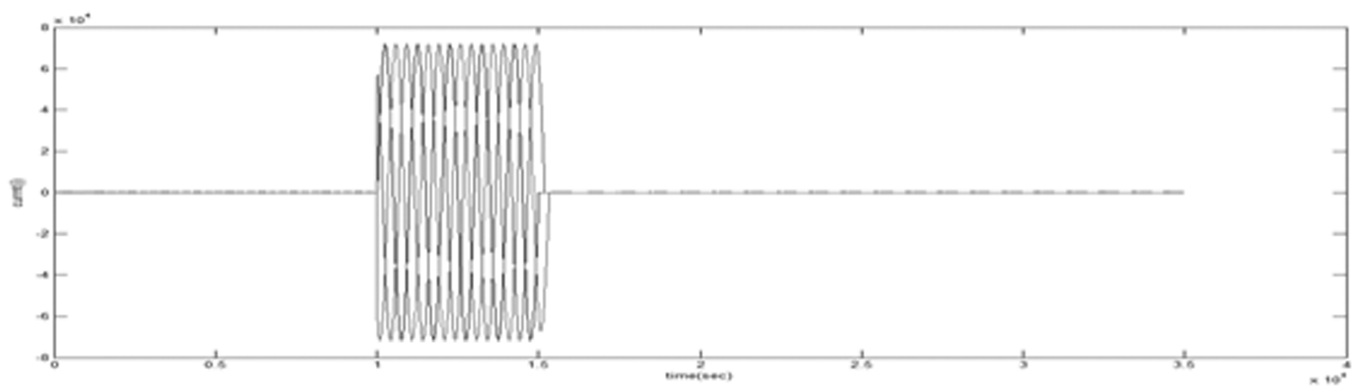

Figure 13: Input Sag Current Waveform

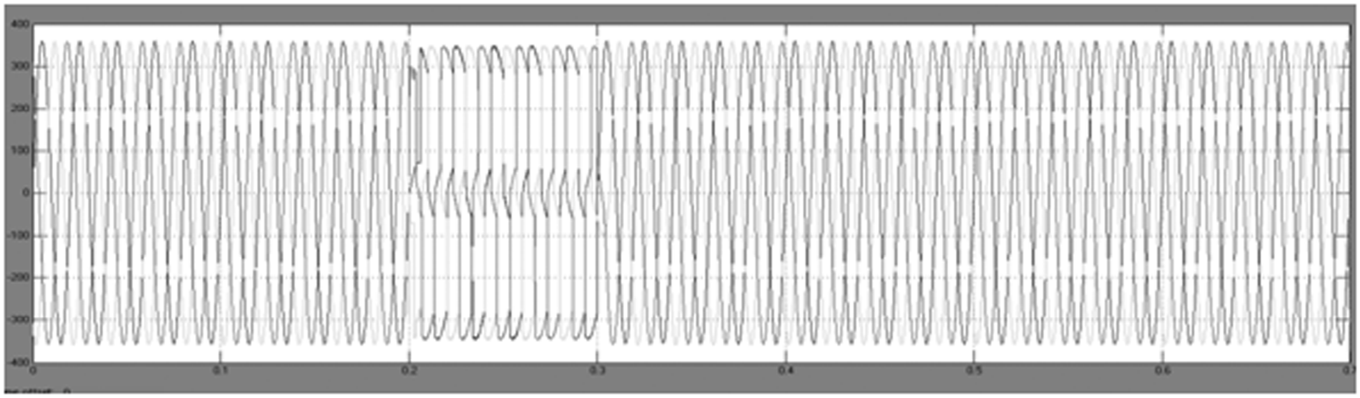

Figure 14: Output Sag Compensated Voltage Waveform

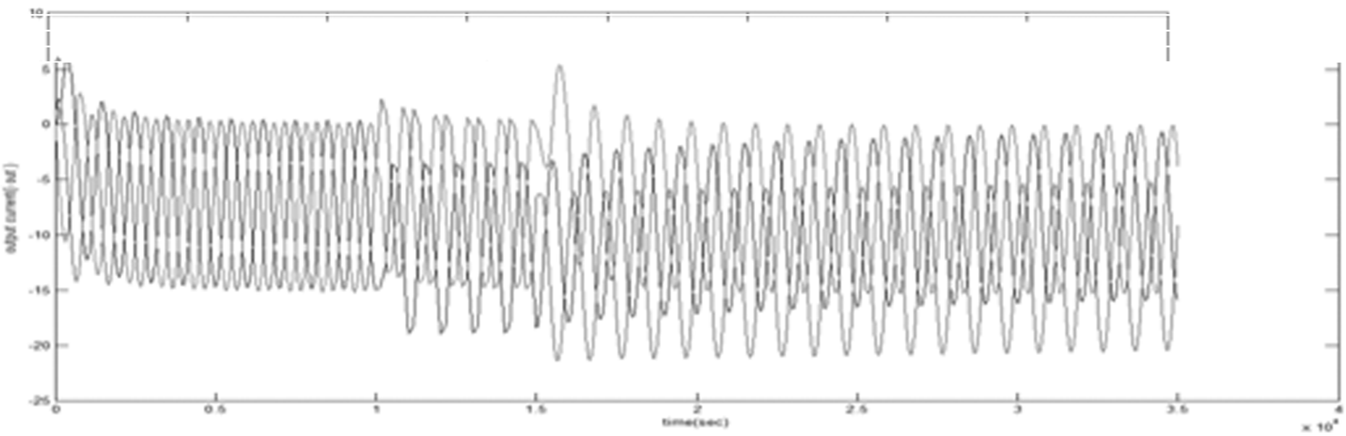

Figure 15: Output Sag Compensated Current Waveform

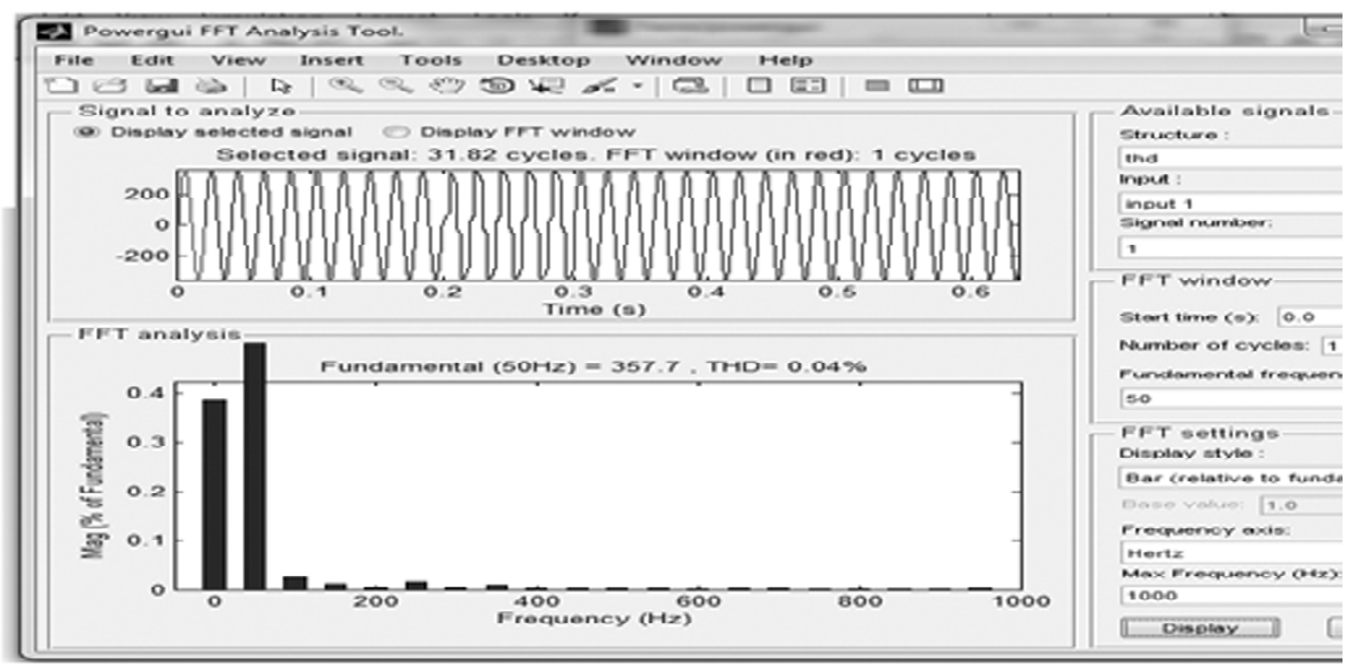

Figure 16: FFT analysis of Output Side

6. CONCLUSION

Wide area control signals taking into account issues such as communication delays are being investigated. The three phase system based UPFC topology has been analyzed using Matlab software. This proposed controller is used to provide the dynamic control of shunt and series converter operation of UPQC for compensation of fault condition. The configuration of unified power quality conditioner (UPQC) consists of back-to-back connection of two three-phase active power filters (APF) with a common dc link. Here, one of the APF is connected in parallel with the utility called as parallel active power filter (PAPF). In addition, the proposed controller is capable of adapting to different system configuration and could be extended for any other type of FACTS device. Also, the several devices consider as UPFC, STATCOM and SSSC controllers in large power system configuration for achieving optimum power oscillation damping without affecting individual device performance. The UPFC system is performed as well as THD reducing which occurred 0.04% the effectiveness intended for installation on a transmission line. It is used to control the real and reactive power in transmission line.

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