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Research Paper Engineering

Simulation and Analysis of Unified Power Quality Conditioner for Power Quality Improvement Using UVTG

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ABSTRACT *Nowadays, the quality of electric power supply has improved a lot by the use of power electronics based equipments. This power electronics based equipments plays a greater role in eradicating the power quality problems such as Harmonic Distortion, Current Transient etc. But the conventional power quality based equipment does not give 100% output in power quality. Therefore it is necessary for the power engineers to develop a dynamic and most advanced solution to these power quality problems. So they find a most promising solution to this problem is Unified Power Quality Conditioner (UPQC). UPQC deals with both load current and supply voltage imperfection. The UPQC is a combination of series and shunt active power filters connected in cascade via a common DC link capacitor. The series APF is mainly used for compensate voltage related problems like Voltage harmonics distortion, Voltage Sag/Swell, Interruption. Whereas, the shunt APF is used for current related problems like Current harmonics distortion, Transient Current. The UPQC is working with Unit Vector Template Generation based control technique. The simulation results of a three-phase Unified Power Quality Conditioner (UPQC) using Unit Vector Template Generation based control techniques have been carried to compensate voltage and Current related Problem.*

KEYWORDS : UNIT VECTOR TEMPLATE GENARETION I, pi control method, upqc technic, Comparison of SERIES and SHUNT.

INTRODUCTION

There are mainly two types of solution of voltage harmonics problem are passive filters and active filters. Passive filters are not always responding correctly as nature of power system condition change. Active power filters exploit the latest generation of power semiconductor devices. With improvements in power and control circuits, active filters are becoming a viable alternative to passive filters. There are following types of active power filters:

1. Series active power filter
2. Shunt active power filter
3. Hybrid active power filter
4. Unified power quality conditioner

(1) series active power filter

Figure . shows a system configuration of a single-phase or three-phase series active filter is mainly used for compensate various types of voltage related problems. The series active filter is connected in series with the utility supply voltage through a three-phase transformer or three single-phase transformers. The series active filter is also consists of series converter with a dc capacitor and passive low pass filter. LC filter is mainly used to eliminate high frequency switching ripples on generated converter output voltage. The series active filter is controlled on the basis of the following manner:

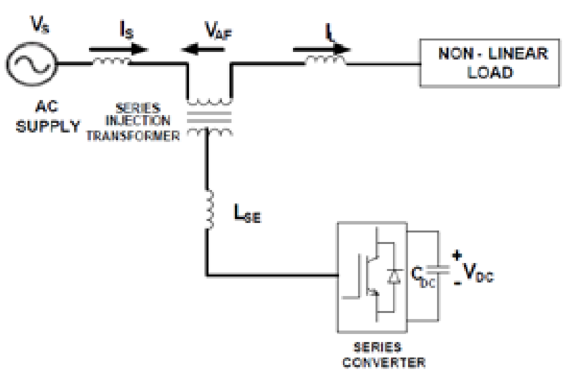

Fig . Line diagram of series active filter

(2) Shunt Active Power Filter

Figure shows a system configuration of a single-phase or three-phase shunt active filter is mainly used for compensate various types of current related problems. The shunt active filter with or without a transformer is connected in parallel with the nonlinear load. The shunt active filter is also consists of shunt converter with dc capacitor and shunt inductor. Shunt inductor (LSH) is mainly used to interface shunt converter into the network and also help in smoothing the current wave shape. The shunt active filter is controlled on the basis of the following manner:

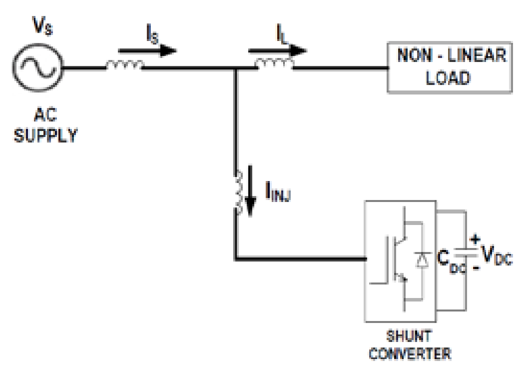

Fig . Line diagram of shunt active filter

(3) Hybrid Filter

The hybrid filters are combination of shunt or series type active filter and the passive filter. Here, figure shows the hybrid filters which are the combination of series active filter and shunt passive filter. Using these types of filter the KVA rating of the active filter is significantly reduces and also cost of active filter is reduce because of less rating of converter switches and dc link capacitor. Passive shunt LC filter is mainly used to eliminate lower order harmonics.

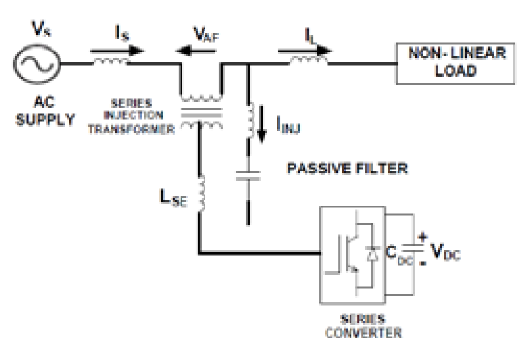

Fig . Line diagram of hybrid active filter

(4) Unified Power Quality Conditioner

The schematic diagram of unified power quality conditioner (UPQC) is shown in figure . Unified power quality conditioner is a combination of series active filter and shunt active filter connected in cascade via a common dc link capacitor. The UPQC is mainly used to compensate both voltage and current related problems. The main objectives of shunt active filter are to compensate for the reactive power demanded by the load, to eliminate the harmonics from the supply current, and to regulate the DC link voltage. The main objectives of series active filter are to compensate voltage harmonics, voltage imbalances, voltage flicker, sags, swells etc.

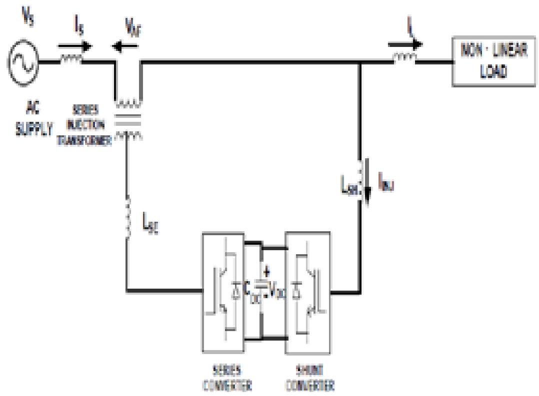

Figure 2.9 Line diagram of unified power quality conditioner

II. Unit Vector Template Generation Technique for the Series Active Filter

A simple control algorithm based on UVTG is used to control the series APF of proposed topology. The series is controlled in such a way that it injects voltages (via, vib and vic), which cancel outs the distortions present in the supply voltages (vsa, vsb and vsc), thus making the voltages at PCC (vla, vlb and vlc) perfectly sinusoidal with the desired amplitude. In other words, the sum of supply voltage and the injected series filter voltage makes the desired voltage at the load terminals. The control strategy for the series APF as shown in the Fig .

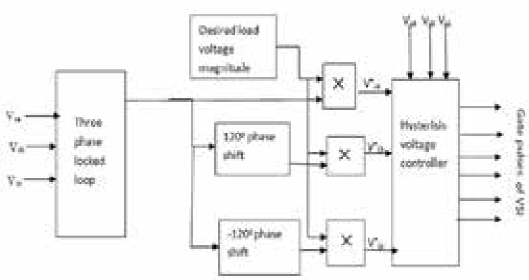

Fig . Control Scheme of UVTG in Series APF

Three-phase distorted supply voltages are sensed and given to PLL which generates two quadrature unit vectors (sin*wt,* coswt). The in-phase sine and cosine outputs from the PLL are used to compute the supply in phase, 120^0 displaced three unit vectors (ua, ub and uc) using eqn.(1) as

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & -\frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} \sin\theta \\ \cos\theta \end{bmatrix} \quad \ldots\ldots\ldots\ldots (1)$$

The computed three in-phase unit vectors then multiplied with the desired peak value of the PCC phase voltage (V*lm), which becomes the three-phase reference PCC voltages as:

$$\begin{bmatrix} v^*_{la} \\ v^*_{lb} \\ v^*_{lc} \end{bmatrix} = V^*_{lm} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad \ldots\ldots\ldots\ldots (2)$$

The computed voltages from reference voltages from eqn. (2) are then given to the hysteresis voltage controller along with the sensed three phase PCC voltages (vla, vlb and vlc). The output of the hysteresis controller is switching signals to the six switches of the VSI of series APF. The hysteresis controller generates the switching signals such that the voltage at PCC becomes the desired sinusoidal reference voltage

III. Unit Vector Template Generation Technique for the Shunt Active Filter

The control algorithm for shunt APF consists of the generation of three-phase reference supply currents (i*sa, i*sb and i*sc) and it is depicted in Fig.. This algorithm uses supply in-phase; 120o displaced three unit vectors computed in eqn. (3). The amplitude of the reference supply current (I* sp) is computed from the comparison of average and the reference value of the dc bus voltage of the back to back connected VSIs results in voltage error, which is fed to a proportional integral (PI) controller. The output of the PI controller is taken as the reference amplitude (I*sp) of the supply currents. The three in-phase reference supply currents are computed by multiplying their amplitude (I* sp) and in-phase unit current vectors as:

$$\begin{bmatrix} i^*_{sa} \\ i^*_{sb} \\ i^*_{sc} \end{bmatrix} = I^*_{sp} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix}$$

The computed three-phase supply reference currents are compared with the sensed supply currents and are given to a hysteresis current controller to generate the switching signals to the switches of the shunt APF which makes the supply currents fallow its reference values. In this control scheme, the current control is applied over the fundamental supply currents instead of the fast changing APF currents, thereby reducing the computational delay and number of required sensor. In addition to this, no extra control is required for the mitigation of source neutral current.

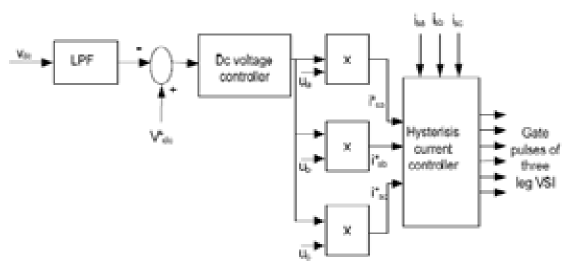

Fig . Control Scheme of UVTG in Shunt APF

IV. Hysteresis Control Technique for Series Active Filter

There are various types voltage-controlled pulse width modulation (PWM) techniques available among all of them hysteresis controllers offer inherent simplicity in implementation and excellent dynamic performance.

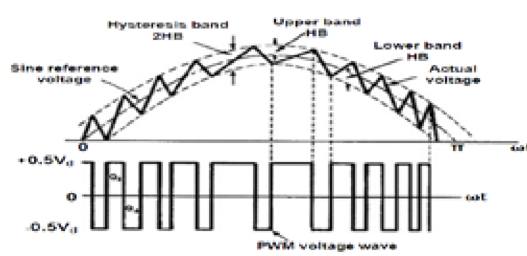

Fig. Hysteresis voltage control technique

Hysteresis-band PWM is basically an instantaneous feedback voltage control technique of PWM where the actual voltage continually tracks the command voltage within a hysteresis band. Figure explains the operation principle of hysteresis band PWM for a half bridge inverter. The control circuit generates the sine reference voltage wave of desired magnitude and frequency, and it is compared with actual voltage wave. As the voltage exceeds an upper hysteresis band, the upper switch in half bridge is turned off and lower switch is turned on. As a result, the output voltage transition from $+0.5V_dV_d$, and $-0.5V_dV_d$, and the voltage starts to decay. In same way as voltage crosses the lower band limit, the lower switch is turned off and the upper switch is turned on. In comparison with other control technique hysteresis voltage control has a very fast response and simple operation but the disadvantage of this method is variable switching frequency. The hysteresis band voltage control for series active power filter is used to generate the switching pattern of the inverter. There is various voltage control methods proposed for active power filter configurations; but the hysteresis voltage control method is proven to be the best among other voltage control methods, because of 39 quick voltage controllability, easy implementation and unconditioned stability. The hysteresis band voltage control is robust, provides excellent dynamics and fastest control with minimum hardware.

The switching logic is formulated as follows:

$$V_L = V_L^* - HB \quad (4.4)$$

$$V_L = V_L^* + HB \quad (4.5)$$

Where, V_L = actual load voltage

V_L^* = reference load voltage

HB = hysteresis band and S1, S2, S3, S4 are switches of voltage source inverter.

V . Hysteresis Control Technique for Shunt Active Filter

There are various types current controlled pulse width modulation (PWM) techniques available among all of them hysteresis controllers offer inherent simplicity in implementation and excellent dynamic performance. Hysteresis-band PWM is basically an instantaneous feedback current control technique of PWM where the actual current continually tracks the command current within a fixed hysteresis band. Figure 3.6 explains the operation principle of hysteresis band PWM for a half bridge inverter. The control circuit generates the sine reference current wave of desired magnitude and frequency, and it is compared with actual current wave.

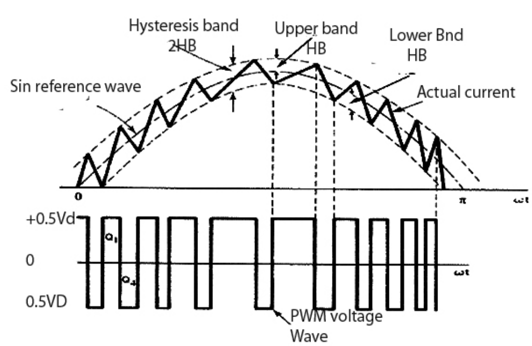

Fig. Hysteresis current control technique

As the current exceeds an upper hysteresis band, the upper switch in half bridge is turned off and lower switch is turned on. As a result, the output voltage transition from +0.5 Vd, and -0.5Vd, and the current starts to decay. In same way as current crosses the lower band limit, the lower switch is turned off and the upper switch is turned on. The main disadvantage of this method is variable switching frequency. To solve the problem of variable switching frequency so, adaptive hysteresis current control technique is applied. The switching frequency is not fixed in hysteresis current control technique, so, it was introduced the concept of the average switching frequency. The hysteresis band current control for active power filter is used to generate the switching pattern of the inverter. There are various current control methods proposed for active power filter configurations; but the hysteresis current control method is proven to be the best among other current control methods, because of quick current controllability, easy implementation and unconditioned stability. The hysteresis band current control is robust, provides excellent dynamics and fastest control with minimum hardware.

The switching logic is formulated as follows:

Is = I*s – HB (3.6)

Is = I*s + HB (3.7)

Where, Is = actual source current

I*s = reference source current

HB = Hysteresis band and S1, S2, S3, S4 are switches of voltage source inverter.

VI.SIMULATION AND ANALYSIS OF SERIES APF

1. Simulation of Series APF

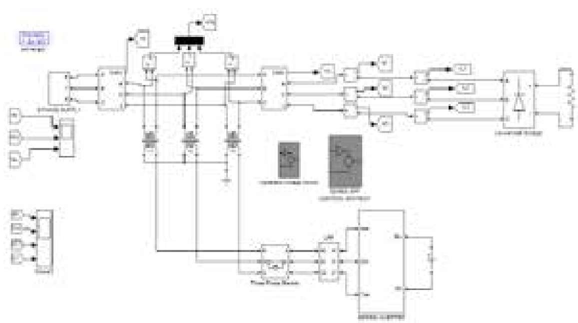

Fig. Simulink model of series APF

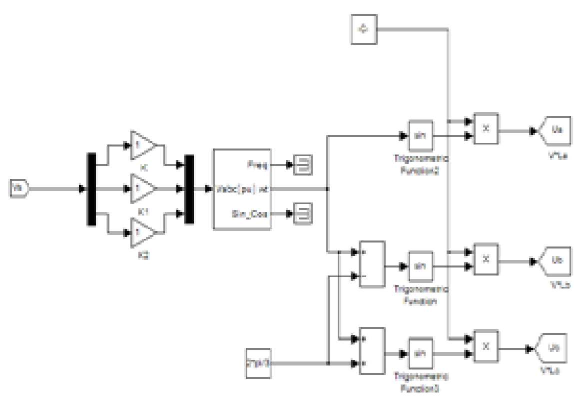

Fig. Simulink model of control scheme for series APF

2. with Filter Simulation Results

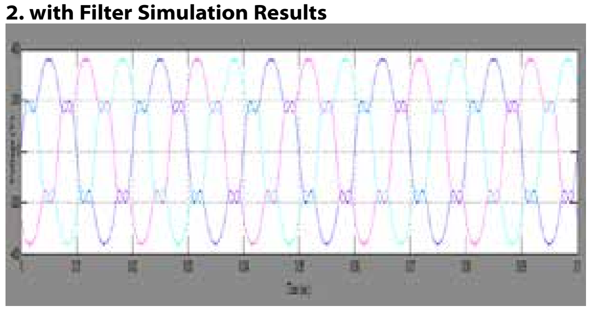

Fig. Source Voltage

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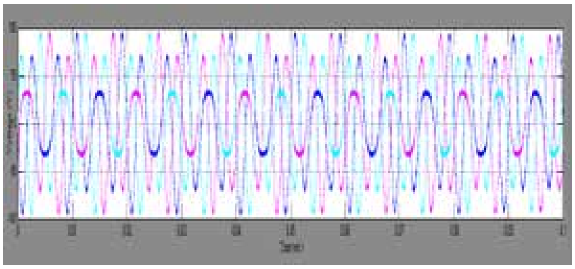

Fig. Transformer Injected Voltage

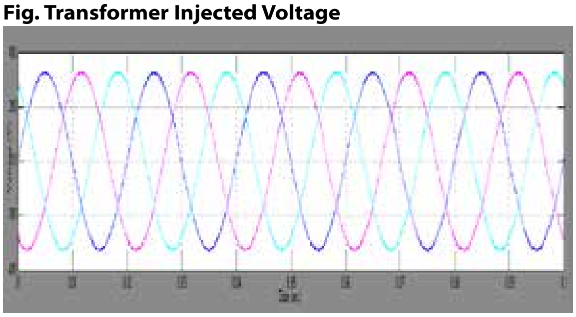

Fig. Load Voltage

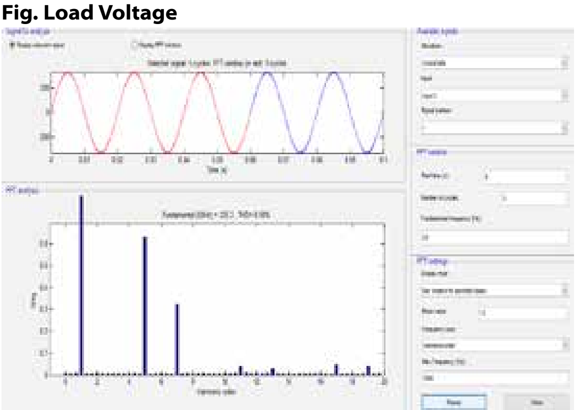

Fig. Load Voltage with %THD for Phase A

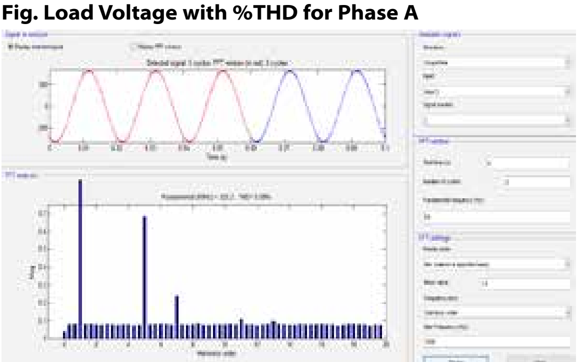

Fig. Load Voltage with %THD for Phase B

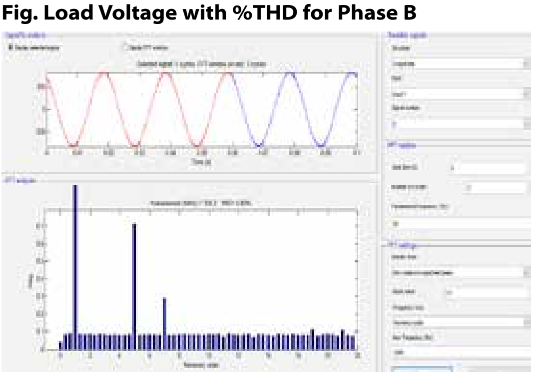

Fig. Load Voltage with %THD for Phase C

3. Simulation of Shunt APF

A number of simulations have been performed to check the working of the shunt active power filter under various non-linear loadings (w.r.t connection of the loads at the PCC) and nonideal supply. The analysis of the results shows that the working of the active filter is very satisfied to compensate the harmonics under unbalanced and distorted conditions of distribution supply.

The simulation results of different models discussed in this work in addition to different parameters of grid and filter. The simulation results are shown and discussed. Different grid conditions will be discussed and results will be compared. The comparison includes the extraction methods, VSI control theories, DC voltage control, in addition to the function under non ideal system conditions.

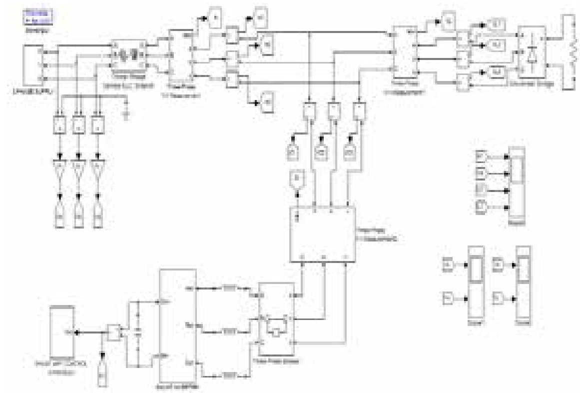

Fig. Simulink model of shunt APF

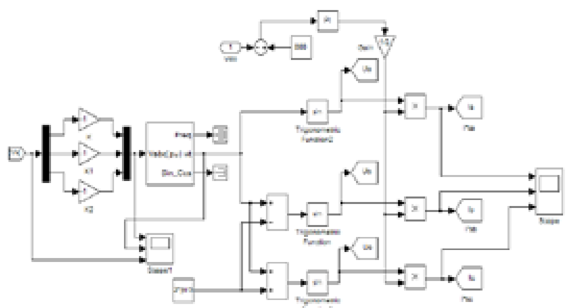

Fig. Simulink model of control scheme for shunt APF

4. With Filter Simulation Results

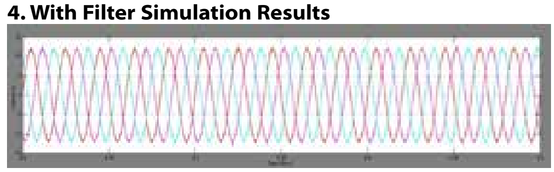

Fig. Source Current

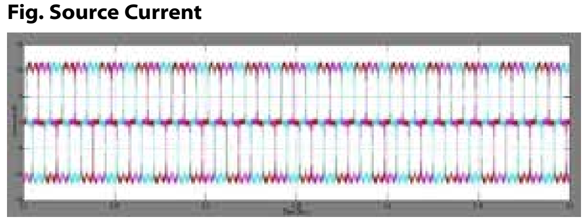

Fig. Load Current

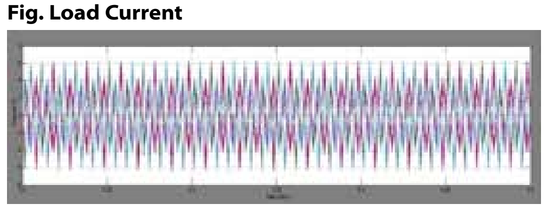

Fig. compensate Current

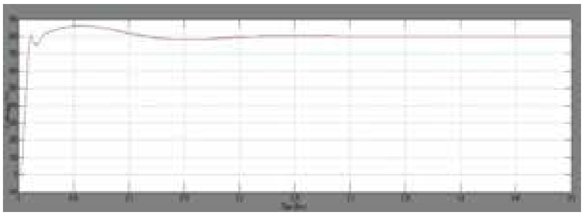

Fig. DC Link Voltage

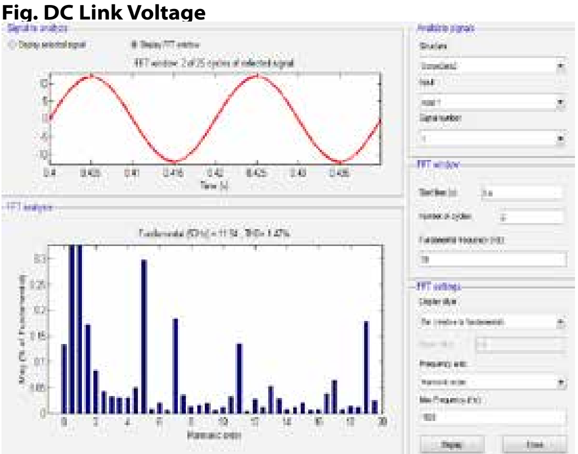

Fig. Source Current with %THD for Phase A

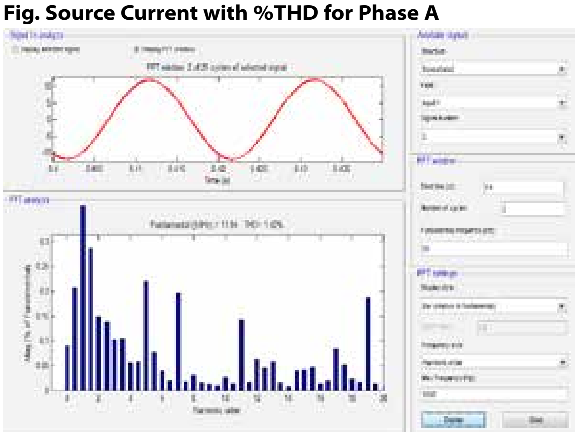

Fig. Source Current with %THD for Phase B

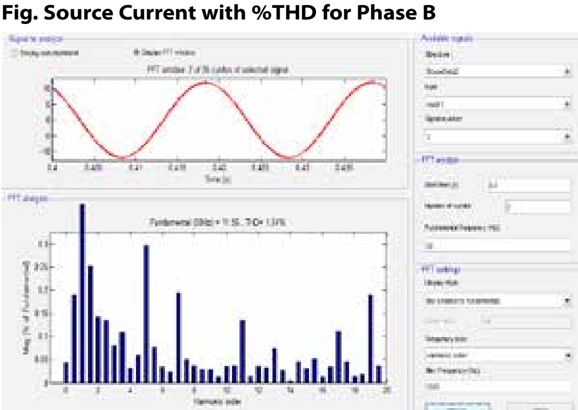

Fig. Source Current with %THD for Phase C

VII.CONCLUSION

The Unified Power Quality Conditioner consisting of two voltage source inverters with a common DC link. It can simultaneously perform the tasks of Series and Shunt Active Power Filters. Here, I have done series & shunt active filters simulation in it can compensate power quality problems like, voltage & current harmonics simultaneously.

It is concluded that series & shunt active power filter is powerful, reliable and cost effective solution to suppress the voltage & current related problems. Unit vectore template generation theory is the simplest and effective method. In the series active power filter by using uvtg theory during voltage harmonics condition the THD of load voltage is reduced from 22.36% to 0.60%. In the shunt active power filter by using uvtg theory during voltage harmonics condition the THD of source current is reduced from 28.42% to 1.47%.

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