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Power Quality Improvement by using Shunt Active Power Filter

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Abstract: This paper presents the performance analysis of shunt active power filter using UVT(Unit V ector Template) method. This shows how to reduce or eliminate the various power quality issues for a three-phase balanced and unbalanced composite load i.e. (linear load and non-linear load) by using shunt active power filter. The governing method used to reduce the various power quality issues is UVT method for both three-phase balanced and unbalanced composite load. The various power quality issues are – harmonic compensation, reactive power compensation and improvement of power factor. Simulation results are tabulated for both three-phase balanced and unbalanced composite load.
Keywords: Balanced and Unbalanced Load, Reactive Power Compensation, Shunt Active Power Filter, THD, UVT

I. INTRODUCTION

Due to the extensive usage of power electronic based equipment for both domestic and industrial purpose there is a rise in power quality issue. The power quality issue is a major concern across the world. But the power electronic based equipment that is used for domestic and industrial purpose consists of both linear and non-linear loads. This power electronic based equipment mainly consists of non-linear loads that lead to power quality issues. Especially, due to increase in demand of non-linear load there is a decrease power quality. Some of the power quality issues are harmonics, reactive power demand, power factor, signaling voltages, voltage fluctuations, voltage dips and interruptions, voltage balance, power frequency variations etc. Examples of non-linear loads are computers, fax machines, printers, PLCs, refrigerators, televisions. One of the major power quality issues is harmonics. And apart from harmonics reactive power compensation is also the major quality issue that leads to disturbances in power systems. For these power quality issue we use filters. Based on the efficiency, the most widely used filter is active power filter. This filter does not compensate harmonics but also the reactive power compensation is also met. Due to which the source rms current is constant. Different configurations of active power filters have been developed. In this paper, shunt active power filter is used. The governing method used for both three-phase balanced and unbalanced composite load is UVT method i.e. (Unit Vector Template method). Here the power quality issues are analysed.

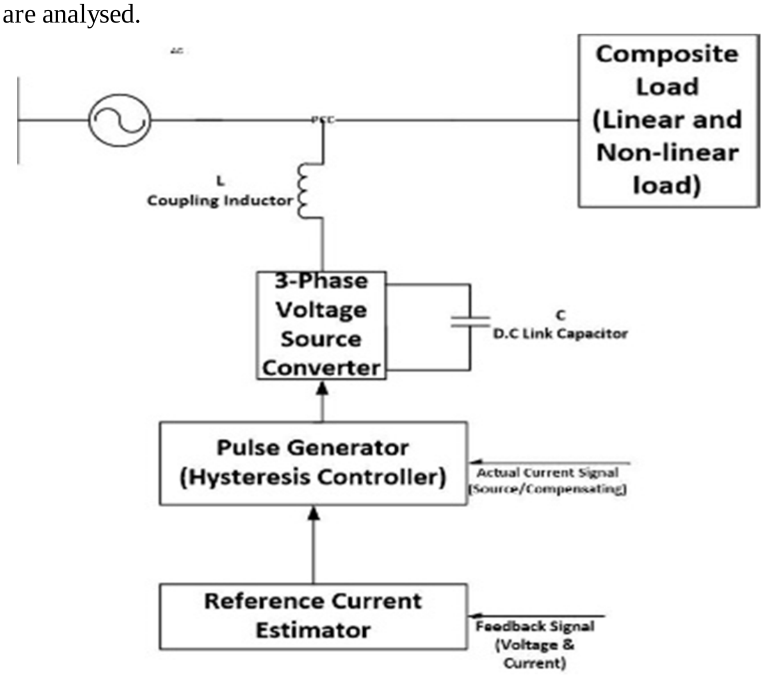

Fig.1. Basic Structure Of Shunt Active Power Filter

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II. SHUNT ACTIVE POWER FILTER

The basic structure of a shunt active power filter is shown in the above figure (1). Here the source is assumed to be both three-phase balanced and unbalanced load that is connected to a composite load i.e. (both linear and non-linear load). At the point of common connection a coupling inductor is connected. The function of coupling inductor is to reduce the ripple current. The filter used is a 2-level three-phase voltage source converter which is connected in parallel with a D.C link capacitor. For balanced load i.e. for a three-phase three-wire system a three-leg IGBT based voltage source converter is used. For unbalanced load i.e. for a three-phase four-wire system a four-leg IGBT based voltage source converter is used. A D.C link capacitor is used in parallel with three-phase voltage source converter. The function of D.C link capacitor is the smooth operation of shunt active power filter. To generate the pulses for the three-phase voltage source converter a pulse generator is used. The pulse generator consists of a hysteresis controller. The control algorithm discussed here is Unit Vector Template method.

TABLE □
System Parameters

Nonlinear load (A 3 phase diode bridge rectifier with RL load) A-Phase RL load B-Phase RL load	R = 30 Ω, L = 10 mH R=30 Ω, L=10 mH R=10 Ω, L=5 mH
Linear Load	P = 100W, Q = 10 / 20 kVAR
DC Link Capacitor	3000 µF
Reference Capacitor Voltage (V_{dc})	700 V
Coupling Inductor (L_c)	3.5 mH

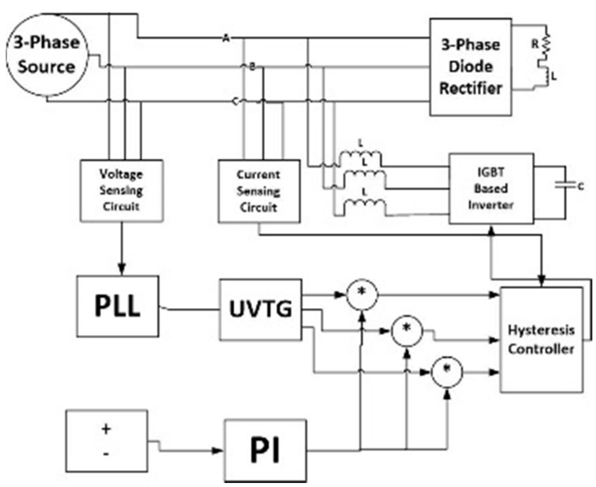
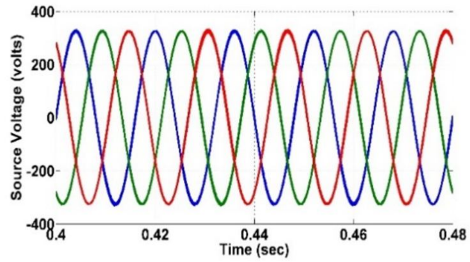


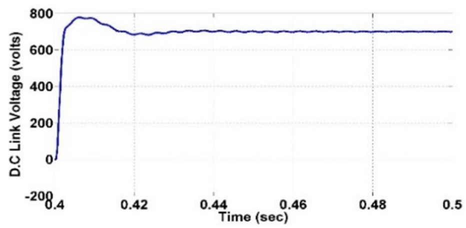
Fig. 2. Unit Vector Controller

III. UNIT VECTOR CONTROLLER

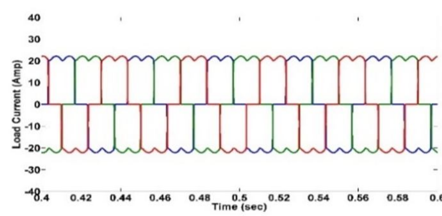
1) *Balanced Load:* A schematic block diagram of a three-phase balanced load is shown in the above figure (b). A three-phase source is connected to a three-phase composite load. The composite load consists of a non-linear load and a linear load. Non-linear load introduces harmonics and linear load causes reactive power demand. A three-phase voltage sensing circuit is connected to the PLL (Phase Locked Loop). By using PLL three unit's sine vectors are generated displaced by 120 degrees at each other. The output of PI controller and unit sine vector are multiplied to generate reference source currents i.e. $I_{sa}^*, I_{sb}^*, I_{sc}^*$. Here active filter used is a two-level three phase IGBT based voltage source converter connected to the mains at PCC (Point of Common Connection) through a coupling inductor. The function of coupling inductor is to reduce the ripple current of compensating current being injected at PCC. For generating the switching pulses for the converter a hysteresis controller is used where reference source currents are being compared with actual source I_{sa}, I_{sb}, I_{sc}.


Source Voltage (volts)
Time (sec)

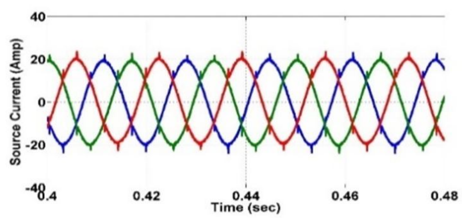
(a)


D.C Link Voltage (volts)
Time (sec)

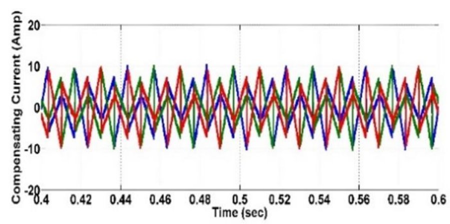
(b)


Load Current (Amp)
Time (sec)

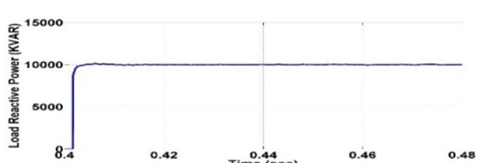
(c)


Source Current (Amp)
Time (sec)

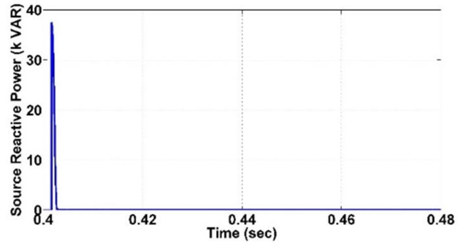
(d)


Compensating Current (Amp)
Time (sec)

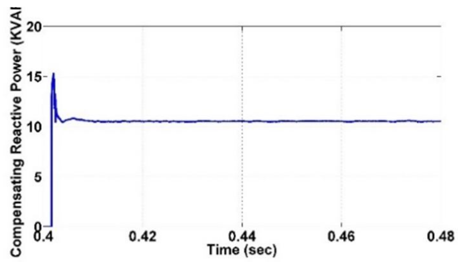
(e)


Load Reactive Power (KVAR)
Time (sec)

(f)



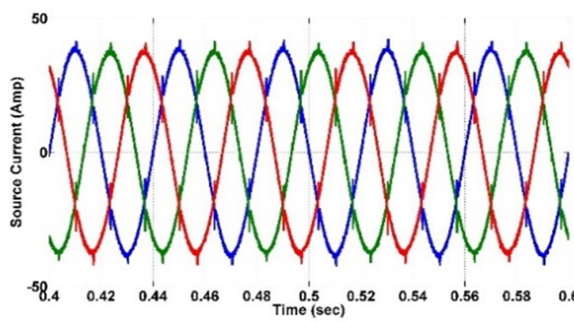
(g)



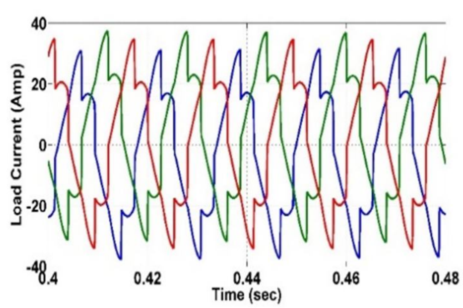
(h)

Fig. 3. Simulation Results Of Apf Using Unit Vector Template Method For Balanced Three-Phase Load (A). Source Voltage (V_{ph}). (B). Dc Link Capacitor Voltage (V_{dc}). (C). Load Current (I_l) (D). Source Current (I_s) (E). Compensating Current (I_c) (F). Load Reactive Power (Q_l). (G). Source Reactive Power (Q_s). (H). Compensating Reactive Power (Q_c)

2) *Unbalanced Load:* Two Single-Phase Non-Linear Load Are Connected To Phase A And Phase B. The Uvt Controller For Unbalanced System Is Similar To Balanced Case With Some Modifications. For Unbalanced Case Three Phase Four Leg Inverter Is Used Where Fourth Leg Is Connected To The Neutral Line Between Source And Load. The Fourth Leg Can Be Controlled For Neutral Current Compensation. The Reference Neutral Current Is Generated By Summation Of Three Reference Source Current. It Is Compared With Actual Neutral Current In Hysteresis Controller To Generate The Switching Pulse For The Fourth Leg Of The Inverter.



(a)



(b)

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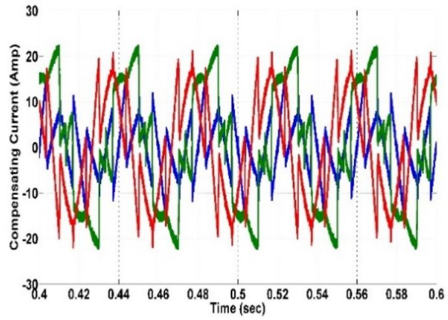

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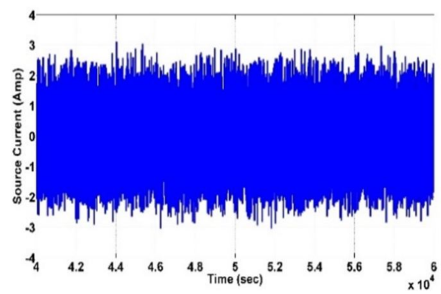

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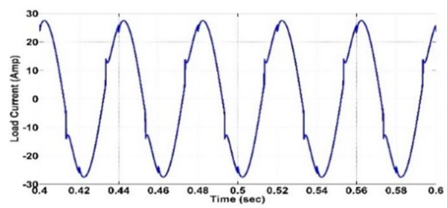

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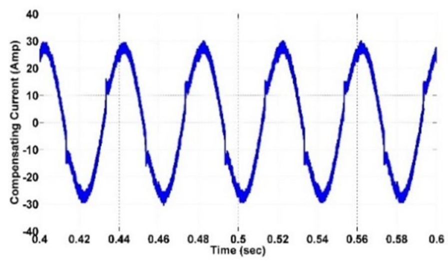

(f)

Fig. 4. Simulation Results Of Apf By Using Unit Vector Template Method For A Three-Phase Unbalanced Load (A). Source Current Is (B).Load Current (Il) (C). Compensating Current.(Ic) (D). Source To Neutral Current (Isn) (E). Load To Neutral Current(Iln). (F). Compensating Neutral Current(Ic).

TABLE □
THD Of Source Current

Load type	Without APF	With APF
Nll (Balanced)	33.07%	4.1%
Nll + Ll (Unbalanced)	23 %	3.5%

IV. RESULTS AND DISCUSSION

By using the system parameters i.e. tabulated in table 1 various simulation results of APF using UVT method for a three- phase balanced and unbalanced load are shown in fig.3 and fig.4. Fig. 3. (a) shows three-phase balanced source voltage. Fig. 3. (b) shows the D.C link capacitor voltage where the reference voltage is maintained constant. Fig. 3. (c) shows three-phase balanced load current since the load is balanced. Fig. 3. (e) shows compensating current where the compensation of harmonics are introduced due to non-linear load. Fig. 3. (f) shows the load reactive power at load power demand 10 kw. It is successfully compensated by shunt active power filter. The source is not responsible for supplying any reactive power as seen in fig. 3. (g). The compensating reactive power is same as load reactive power. Thus, shunt active power filter is providing 100% reactive power compensation. Fig. 4. (e) shows the load neutral current is compensated by compensating neutral current in fig. 4. (f). Fig. 4. (d) shows source neutral current is zero.

V. CONCLUSION

An Active Power Filter Based On Unit Vector Template Controlling Technique Is Presented in this paper. Two important power quality parameters are analyzed in detail, namely, current harmonic and reactive power compensation which in turn affects the input side power factor. THD for only non-linear load reduces from 33.07% to 4.1%. THD for only non-linear and linear load reduces from 23% to 3.5%. Reactive load demand at 10kw is been compensated by the filter. Thus, it is clear that along with harmonic suppression, reactive power compensation can be performed in a controlled manner.

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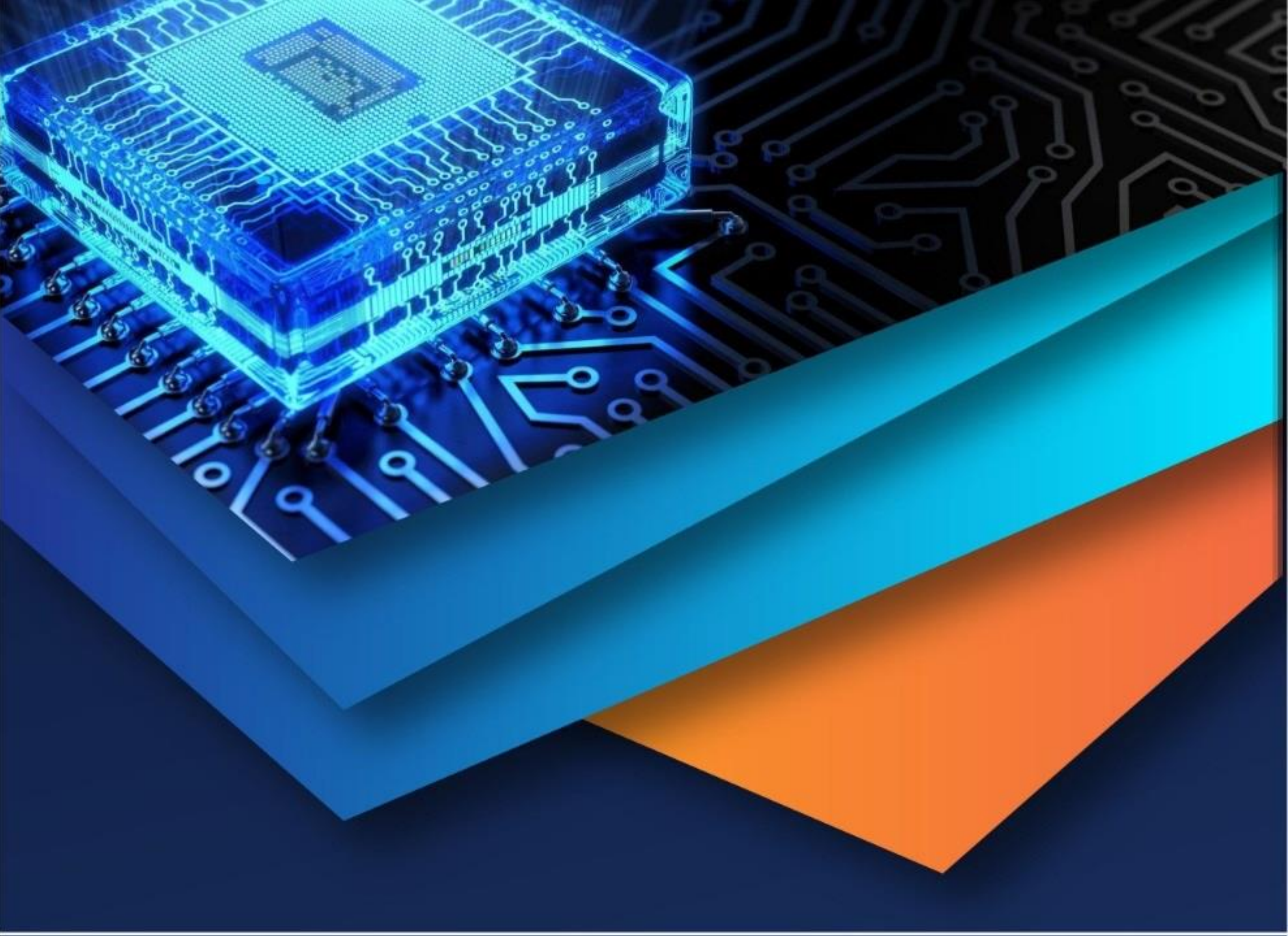

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