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COMPARATIVE ANALYSIS OF POWER QUALITY IMPROVEMENT WITH PQ THEORY & DC LINK CONTROL SCHEME OF NON-LINEAR LOAD BY USING SHUNT ACTIVE POWER FILTER

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Abstract*— A Comparative Analysis of Power Quality improvement with PQ Theory & DC Link Control Scheme of Non-Linear Load by using Shunt Active Power Filter was proposed in this paper. A shunt active power filter(SAPF) based on PQ Theory & with DC link voltage hysteresis current control was used with the help of MATLAB software. The proposed active power filter was applied to three phase power system with 415V voltage and 50Hz frequency AC supply connected to a non-linear load. The result shows that the shunt active power filter with PQ Theory produces lower Total Harmonic Distortion(THD) than the active power filter with DC Link voltage hysteresis current control.

***Keywords*— MATLAB, THD, SAPF, CONTROLLER, APF, DC.**

I. INTRODUCTION

In recent years, when globalization increases the requirement of power also increased. In the domestic load such as compact fluorescent lamp (CFL) , television, personal computer, inverter and several electronics devices. Different non-linear loads are used in industries such as variable frequency drives, converter etc. The existence of such non-linear load causes the load current distortion and it also affects on the power quality. In the power electronics equipment due to the switching action the delay effect is introduced. This results in harmonics and THD. For solving the power quality problem shunt active power filter (Shunt APF) is used to compensate source current harmonics as well as to eliminating voltage harmonics. The author proposed to develop fuzzy controller to analyse the performance of instantaneous real active and reactive current control strategy for extracting reference currents of shunt active filters under balanced, unbalanced non-sinusoidal conditions[1].the study of active filter configuration control strategies, selection of components other economic and technical consideration and their selection for specific application was covered[2]. In this paper the author present active harmonic filter which is capable to reduce the harmonics of the power system, the shunt active power filter is best suited for the compensation of total harmonic distortion [3]. it has proposed in three-phase active filter for harmonics and reactive power compensation, the three phase 415v,50hz supply given to the system the harmonics will reduces from the system [4]. The author shows that active power filters are developed for compensating harmonics and reactive power simultaneously they provide the function of FFT analysis which is very useful to calculate total harmonic distortion in source current[5]. a control algorithm for a three-phase hybrid power filter is proposed by the author the control strategy is based on the vectorial theory dual formation of instantaneous reactive power [6]. Modern active filters and traditional passive filter is used in the system which is able to reduce the harmonics in the system [7]. The three phase 3 wire series active filter is used for compensating the harmonics and reactive power [8]. In this paper Compensation strategies for shunt active-filter control method used for improving the power factor of the system [9]. A novel harmonic power filter was proposed in which the control technique is based on the instantaneous reactive power theory for improvement of the power factor and to reduce total harmonic distortion to standard limits[10].

This paper shows that a comparative analysis between two control technique for power quality improvement.

II. SYSTEM MODEL

ACTIVE POWER FILTER MODELLING

The principle of operation of active power filter is based on the injection of the current harmonics required by the load. Basically active power filter generates a current equal and opposite in polarity to the harmonic current drawn by the non-linear load and injects to the point of common coupling (PCC). Pure active power filter can be classified into two types according to their circuit configurations are as:

I. Series active power filter
II. Shunt active power filter

I. SERIES ACTIVE POWER FILTER CIRCUIT CONFIGURATION

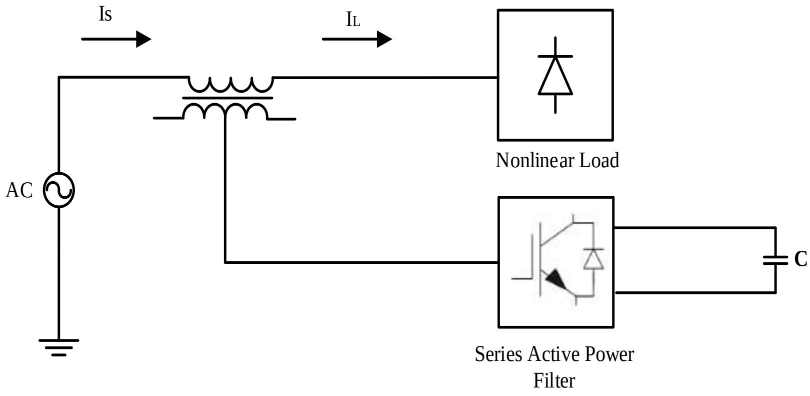

Fig.1: Schematic diagram of series active power filter.

Figure1 shows the voltage harmonic filtering in case of single-phase and three-phase diode rectifier with a capacitive DC load. The series active power filter is connected in series with the power supply.

- Instantaneous supply current is detected by controller.
- Harmonic currents are extracted from the source of supply current by means of Digital Signal Processing.
- This reduces the supply harmonics significantly.

II. SHUNT ACTIVE POWER FILTER CIRCUIT CONFIGURATION

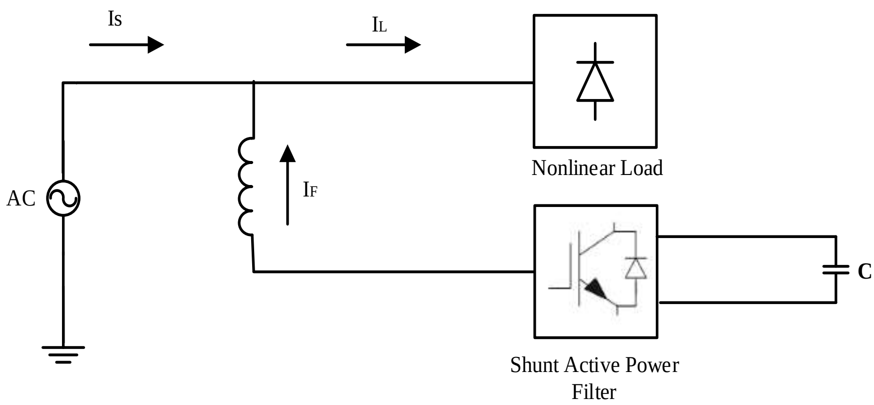

Fig.2: Schematic diagram of a shunt active power filter.

The operation of the shunt active power filter is shown in Figure2, is investigated for the general case. The DC load can be treated as AC motor driven by a voltage source Pulse Width Modulation (PWM) inverter. The Single phase active filter method uses power electronics for produce harmonic current components with 180 degree phase shift to the harmonic current components generated from non-linear loads.

Shunt active power filter has been connected in this control technique in parallel with the harmonic generating load.

- The instantaneous load current is observed by the current controller.
- The detected load current, harmonic current is separate out with the help of DSP.
- For cancel out the harmonic current, Active power filter draws compensating current from utility supply of the system.

III. PROPOSED METHODOLOGY

In this paper we proposed there are two techniques for Comparative Analysis of Power Quality improvement with PQ Theory & DC Link Control Scheme of Non-Linear Load by using Shunt Active Power Filter for reducing the source current and Total Harmonic Distortion are as follows:

1-FIRST CONTROL TECHNIQUE – SHUNT ACTIVE POWER FILTER BASED ON P-Q THEORY

To understand the system configuration and control circuit for shunt active power filter, its model and implementation has been done by using MATLAB/SIMULINK software platform with referring the control strategy shown in Figure 3.

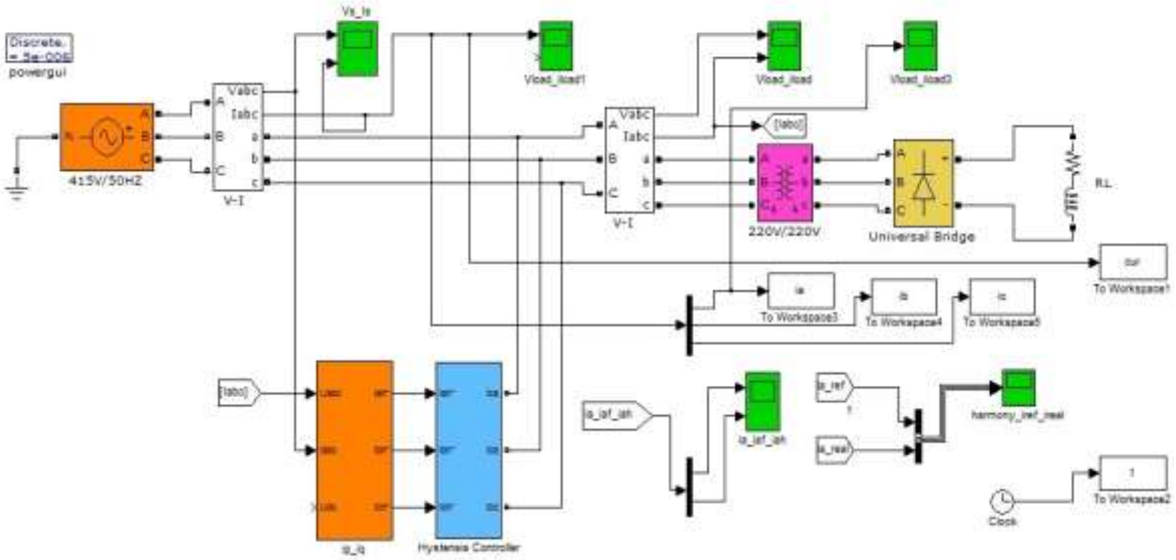

Fig.3 : Simulink model of shunt active power filter based on p-q theory for RL load.

The following figure shows a Simulink model where shunt active power filter based on p-q theory is connected at the input end of the system. In this experiment a bridge rectifier connected to parallel RL combination is considered as non-linear load, since the main source of harmonics are is non-linear loads. Total harmonic distortion was analyzed for current harmonics for different values of switching bandwidth of hysteresis controller. a three phase 415 V AC supply connected to a non linear load. Here non-linear load is RL load connected to a diode rectifier. It is well known that a non-linear load is the main source of harmonic current generation, therefore a power-gui block is also added in the simulation model so as to analyse amount of harmonics produced due to given non-linear load. Shunt active power filter concept uses power electronics to produce harmonic current components generated from non-linear loads. The shunt active power filter is based on the principle of injection of harmonic currents into the AC system of the same amplitude but opposite in phase to that of load harmonics.

In simple terms, it can be expressed as:

Let's assume that the load current as combination of fundamental load current and harmonic current which can be expressed as

$$I_l = I_f + I_h \qquad \text{… (1)}$$

Where, I_l is fundamental component and I_h is harmonic current

Active filter current is given by

$$I_{af} = I_h \qquad \text{… (2)}$$

Supply current is given by

$$I_s = I_l - I_{af} \qquad \text{… (3)}$$

Solving further

$$I_s = I_f + I_h - I_h$$

$$I_s = I_f \qquad \text{… (4)}$$

thus theoretically it is shown that harmonics are completely compensated by shunt active power filter.

2-SECOND CONTROL TECHNIQUE – SHUNT ACTIVE POWER FILTER WITH DC-LINK-VOLTAGE HYSTERESIS CURRENT CONTROL

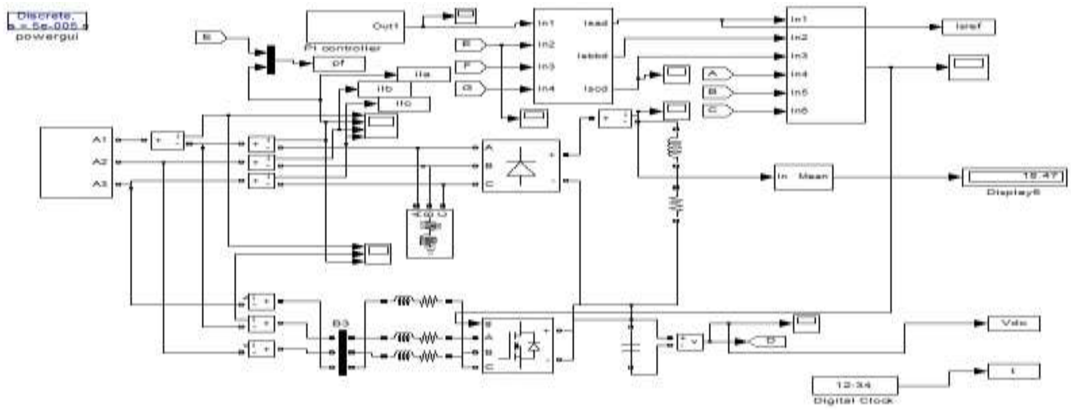

Fig.4: Simulink model of shunt active power filter with DC link voltage hysteresis current control.

The figure 4 shows the Simulink model of shunt active power filter with DC Link voltage hysteresis current control for investigations on power quality improvement of non-linear load which consists of supply source, loads and some other control blocks for generation of gate signals.

Here non-linear load is RL load connected to a diode rectifier. The DC link voltage is compared with reference voltage and is passed through a PI controller to generate the reference current magnitude; this scheme has been explain in figure 4.

IV. SIMULATION RESULTS

In this section shunt active power filter responses are presented in steady state and transient state condition. During this simulation shunt active power filter is used in Butterworth filter with compensated time (t = 0.04 sec).

SIMULATION RESULTS WITHOUT USING ANY FILTER

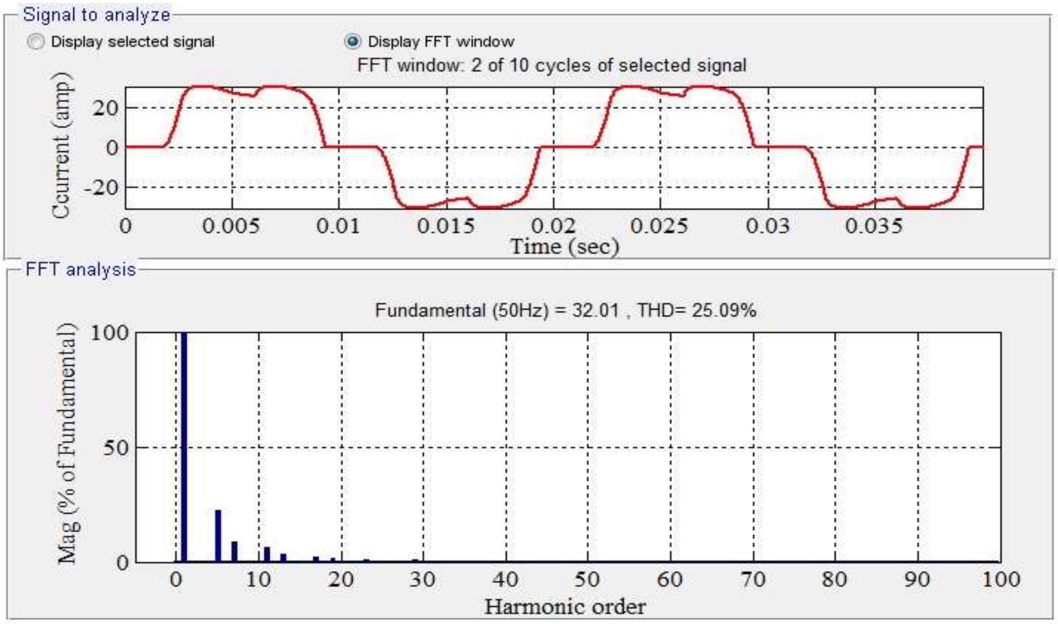

Fig.5: Source current and Total Harmonics Distortion (THD) before compensation.

As it is seen from the above figure that without any compensation for non-linear loads the source current Total Harmonics Distortion (THD) is 25.09% which is very highs.

SIMULATION RESULTS BY USING SHUNT ACTIVE POWER FILTER WITH P-Q THEORY CONTROL TECHNIQUE

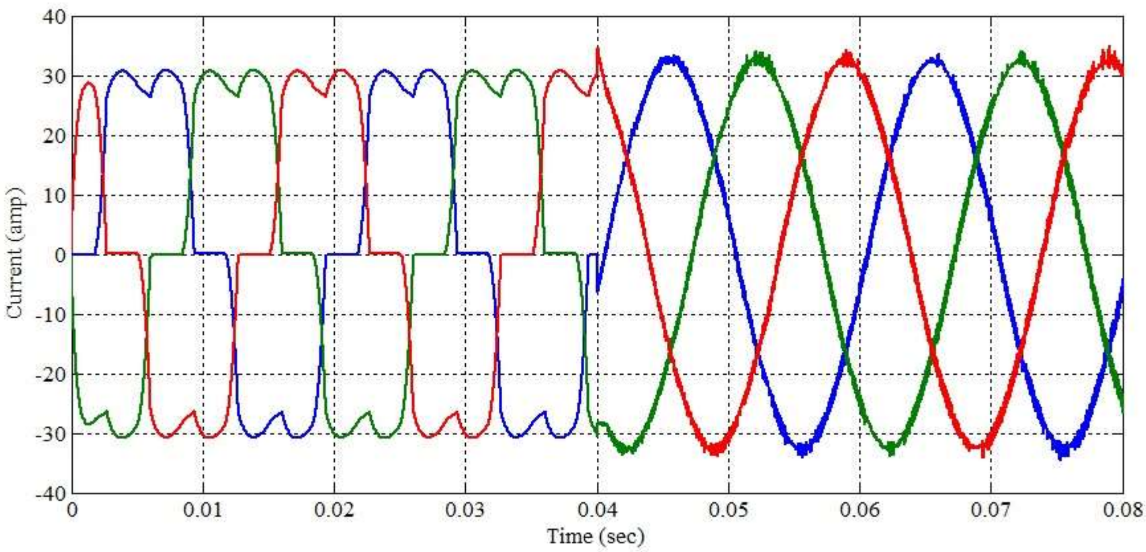

Fig.6: Three phase load current waveform.

As figure shows that the current non-linear load is reach in harmonics and it gets compensated at the time (t = 0.04 sec), at this particular time shunt active power filter comes into the picture for harmonic reduction.

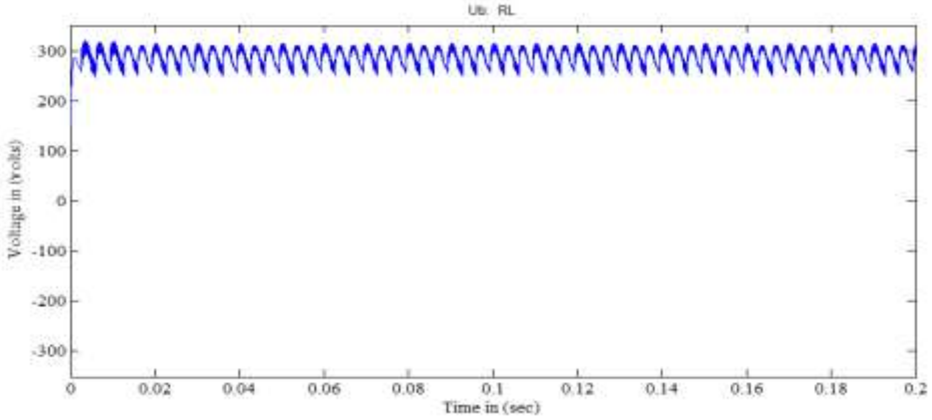

Fig.7: Simulation voltage waveform for RL load.

The following figure shows the reference current ($I_{ah\ ref}$, $I_{bh\ ref}$, $I_{ch\ ref}$) waveforms which is to be compare with actual currents (I_{ah} I_{bh} I_{ch}) of Active Filters as shown in figure below.

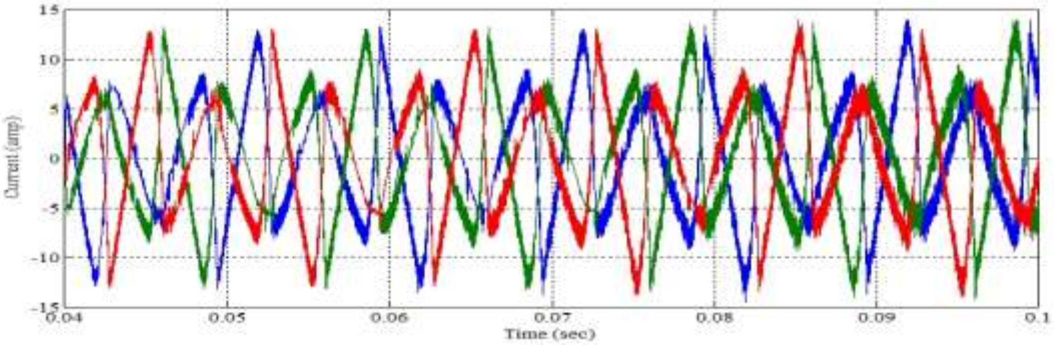

Fig.8: Actual current waveforms for Shunt Active Power Filter with p-q theory.

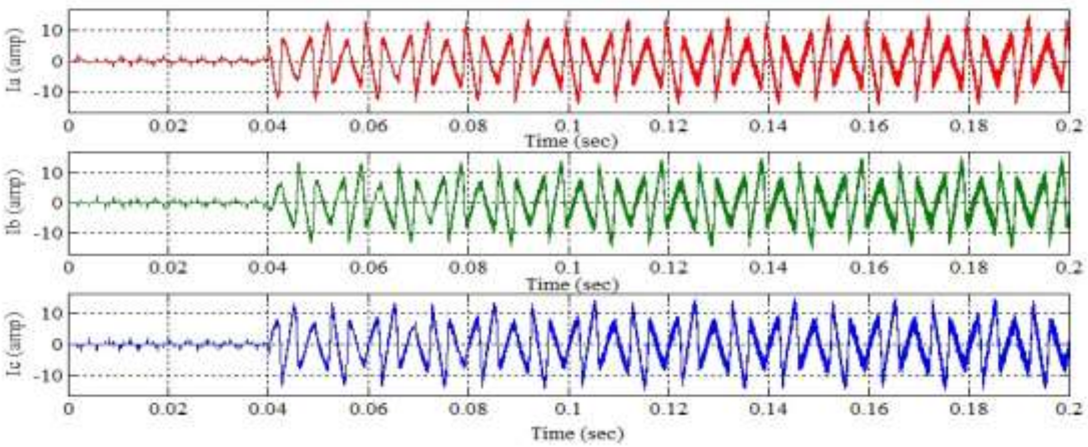

Fig.9: Compensated three phase current waveforms of Shunt Active Power filter.

Above figure shows the compensated currents of the shunt active power filter with p-q theory for the three phase system.

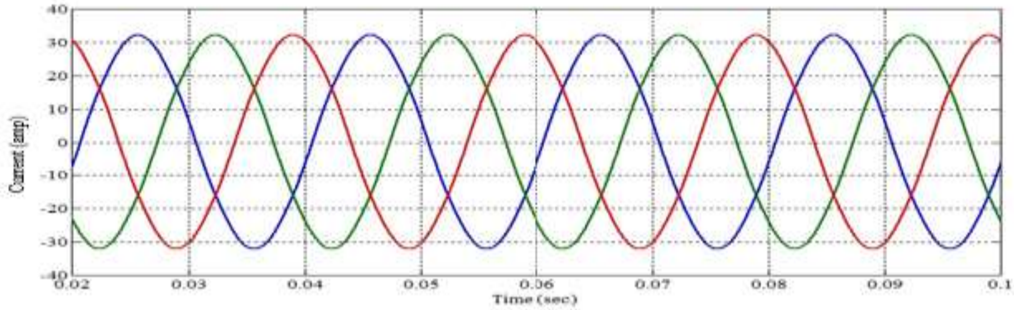

Fig.10: Three phase source current waveform.

This figure shows the three phase current which are obtain after Park's Transformation the Phase Locked Loop (PLL) which are compared with actual currents (I_{abc}) to generate (I^*_{ah} I^*_{bh} I^*_{ch}) these are the reference currents for shunt active power filter (SAPF).

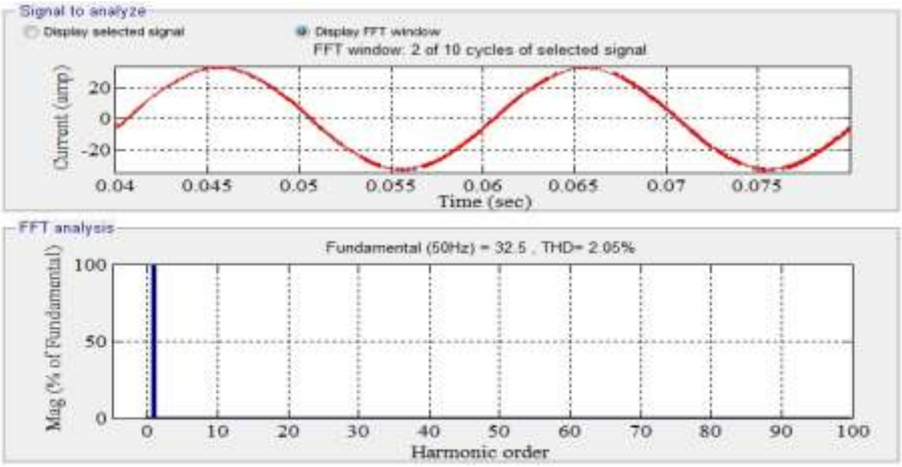

Fig.11: Source current and THD in case of Shunt Active Power Filter with p-q theory.

Before compensation source current THD = 25.09%
After compensation source current THD = 2.05%
Figure 11 represents the source current waveform and Total Harmonics Distortion in case of shunt active power filter with p-q theory which is shows the frequency spectrum of the source current before and after the performance of shunt active power filter is shown. It is clear from the figure that the application of a shunt active power filter removes the harmonics of the current and the source current synchronizes with the voltage and current.

SIMULATION RESULTS BY USING SHUNT ACTIVE POWER FILTER WITH DC-LINK-VOLTAGE HYSTERESIS CURRENT CONTROL

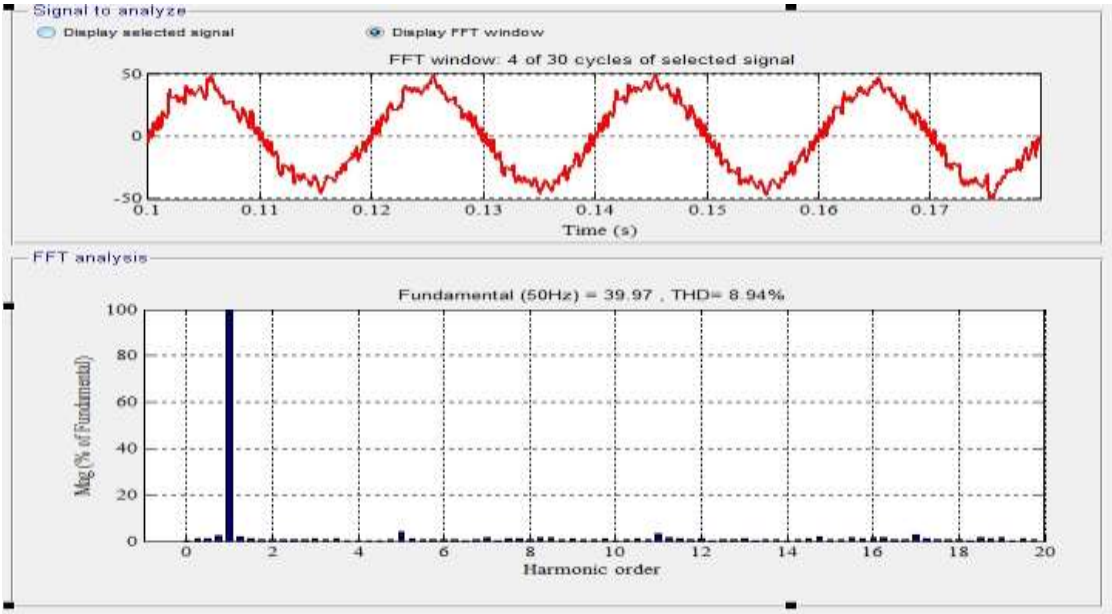

Fig.12: Source current waveform and THD in case of Shunt Active Power Filter with DC Link voltage Hysteresis current control.

Figure 12 represents the source current Total Harmonics Distortion in case of shunt active power filter with DC link voltage hysteresis current control which shows the frequency spectrum of the source current before and after the performance of shunt active power filter with DC link voltage hysteresis current control. As shown, the application of shunt active power filter removes the harmonics of the current and the source current synchronizes with the voltage and current.
The following figure shows the source current waveform and the harmonics for a hysteresis controller at bandwidth (= 0.2), as it can be seen from the figure that the Total Harmonics Distortion of source current is (THD=8.94%), since hysteresis current controller operates at variable switching frequencies therefore higher order harmonics enter into the current waveform

SYSTEM PARAMETERS

The system parameters which are to be considered for the " Comparative analysis of power quality improvement with PQ Theory and DC Link control scheme of non-linear load by using shunt active power filter" is given below in Table1.

Table1. Specification for Test System

COMPONENETS	SPECIFICATIONS
AC Source	V_s = 415V, f = 50Hz
Non-linear Load	R_L = 40Ω, and L_L = 30mH

TOTAL HARMONIC DISTORTION (THD) WITH DIFFERENT SCHEMES

The Comparisons of Total Harmonic Distortion (THD) with different schemes are given below in Table 2.

Table2. Comparisons of Total Harmonic Distortion (THD) with different schemes

MATLAB MODEL	SOURCE CURRNT Total Harmonic Distortion (THD)
Without Filter	THD = 25.09%
With Shunt Active Power Filter with p-q theory control technique	THD = 3.17% THD = 2.57% THD = 2.05%
With Shunt Active Power Filter with DC link voltage Hysteresis current control	THD = 8.94% THD = 6.62%

Now it is clear from the table2 that by using the shunt active power filter with p-q theory the Total Harmonic Distortion (THD) of the source current has been reduced from 25.09% to 2.05%. And in the case of Shunt Active Filter with DC link voltage hysteresis current control the source current Total Harmonic Distortion (THD) has been reduced from 25.09% to 6.62%. So the shunt active power filter with p-q theory control scheme is the better scheme for reducing the harmonics for the non-linear load.

V. CONCLUSION & FUTURE SCOPE

In this paper, a comparative analysis of currents harmonics and their consequences on the electrical systems has been discussed. In addition to the study of different proposed solutions for the problem of harmonics, the literature studies claim that the shunt active power filter represents an efficient solution for the compensation of harmonics produced by the non-linear loads. A shunt active power filter has been investigated for power quality enhancement/improvement. Hysteresis controller based shunt active power filter are implemented for harmonic and reactive power compensation of the non-linear load. The Total Harmonic Distortion (THD) of the source current by using the shunt active power filter with p-q theory is 2.05% which is below the harmonics limit imposed by IEEE standard.

FUTURE SCOPE

1. Further development of SIMULINK model can be done using different control schemes such as fuzzy logic control and PI or sliding mode control and then comparison can be done for all the control schemes.
2. Experimental investigations can be done on shunt active power filter and hybrid filter by developing a prototype model in the laboratory to verify the simulation results.
3. The prototype model can also be implemented using different control schemes.
4. The prototype model can be practically implemented on various loads in industrial and commercial purposes such as drives.
5. The results of simulated model may be validated by developing the hardware of this model.

REFERENCES

[1] IEEE-519, IEEE Recommended for Practices and Requirements for Harmonic Control & compensation in Electricl Power Systems, 1992.

[2] Al-Haddad, K.; Chandra, A., "A review of active filters for power quality improvement," Industrial Electronics, IEEE Transactions on, vol.46, no.5, pp.960-971, Oct 1999.

[3] H. Akagi, Active Harmonic Filter, & Harmonic current compensation Proceedings of the IEEE, Vol. 93, No.12, pp. 2128-2141, 2005.

[4] Kamal Al-Haddad & Ambrish Chandra, "A New simple Control Strategy for 3-phase Active Filter for Harmonics and Reactive Power Compensation" IEEE Trans. on Power Systems, Vol. 46, No. 5, pp. 133 – 138, Oct-1999.

[5] H. Akagi and A. Nabae, "Active filters and energy storage systems operated under non-periodic conditions", IEEE Power Engineering Society Summer Meeting, 2: 965-970, (2000).

[6] S. P. Litran and Salmeron,"Improvement of the electrical power quality by using of series active Filter & shunt passive filters", IEEE Transaction on power delivery, vol.25, no.2, April 2010.

[7] Akagi H., "Modern active filters and traditional passive filters", Bulletin of the Polish Academy of Sciences, Technical Sciences, 54: 255-269, (2006).

[08] Cavallini, G. C. Montanari. "Compensation Strategies for Shunt Active-Filter Control". IEEE Trans. on Power Electronics, Vol. 9, No. 6, pp. 587-593, Nov. 1994.

[09] Akagi, H., New Trends in Active Filters for Improving Power Quality, Power Electronics, Drives and Energy Systems for Industrial Growth, Proceedings of the 1996 International Conference on, 417 – 425, vol.1, (1996).

[10] F. Z. Peng, H. Akagi, and A. Nabae, "A novel harmonic power filter," in Proc. IEEE/PESC, pp. 1151–1159. Apr. 1988.