

Single Phase d-q Transformation using as indirect Control Method for Shunt Active Power Filter

Sachi Sharma¹

¹Research Scholar (M.E), LDRP-ITR College, Gandhinagar, India

[Email-spark_sachi@yahoo.com](mailto:sachi@yahoo.com)

Abstract— A single-phase shunt active power filter is used mainly for the elimination of harmonics in single-phase AC networks. In this paper a single-phase shunt active power filter based on, an indirect control technique is designed and simulated. This control technique is achieved by phase shifting the input signal(voltage/current) by $\pi/2$.The overall action of the shunt active power filter to eliminate the harmonics created by a non-linear load on the source side is discussed in this paper and the output of the shunt active power filter is verified using MATLAB/Simulink software.

Keywords— Harmonics, Single Phase Shunt Active Power Filter,

1. Introduction

Because of the tremendous advantage of power electronic based devices/equipment they play a vital role in the modern power processing .As a result these devices/equipment draws non-sinusoidal current from the utility side due to their nonlinearity .So in addition to the reactive power supply a typical distribution system has to take care of the harmonics also[C]. These power quality concerns made the power engineers to think about the devices which reduces the harmonics in the supply line [E,F].Such devices are known as active power filter/power conditioners which are capable of current/voltage harmonic compensation. Active power filters are classified into shunt , series and hybrid active power filters which can deal with various power quality issues [A,E]. One of the major advantage of the APF's are they are adaptable to changes in network and load fluctuations and it consumes only less space compared with the conventional passive filters[H]. Nowadays power quality issues in single phase system is more than three phase due to the large scale uses of non-linear loads and also due to the increase in newly developed distributed generation systems like solar photo voltaic, small wind energy systems etc in single phase network [A,G].Reactive power and current harmonics are significant while considering a single-phase network, which are major concerns for a power distribution system, because these issues leads to other power quality troubles. In this paper a single-phase shunt active power filter based on indirect control technique for generating the reference signal is used. In this paper section (2) detailing about single-phase shunt active power filter, section (3) gives an idea about the indirect control strategy which is then followed by the simulation study and conclusions.

2. Single-Phase Shunt Active Power Filter

In this topology the active power filter is connected in parallel to the utility and the non-linear load. Pulse width modulated voltage source inverters are used in shunt active power filter and they are acting as a current controlled voltage source. The compensation for current harmonics in shunt active power filter is by injecting equal and opposite harmonic compensating current (180 degree phase shifted).As a result the harmonics in line get cancelled out and source current becomes sinusoidal and makes it in phase with source voltage .With the help of control strategies reference signals are generated and which then compared with the source current to produce the gating signals for the switches.. For the reference signal generation there are different control strategies like instantaneous active reactive power theory (pq theory) developed by Akagi [K] ,Parks d-q or synchronous reference frame theory[D].

These control strategies are mainly focused on three phase systems [I]. The three phase pq theory is made applicable to the single phase systems by the work of Liu [J] by phase shifting an imaginary variable which is similar to voltage or current signals by 90 degree. Later this concept extended to single phase synchronous d-q reference frame by Zhang [B].

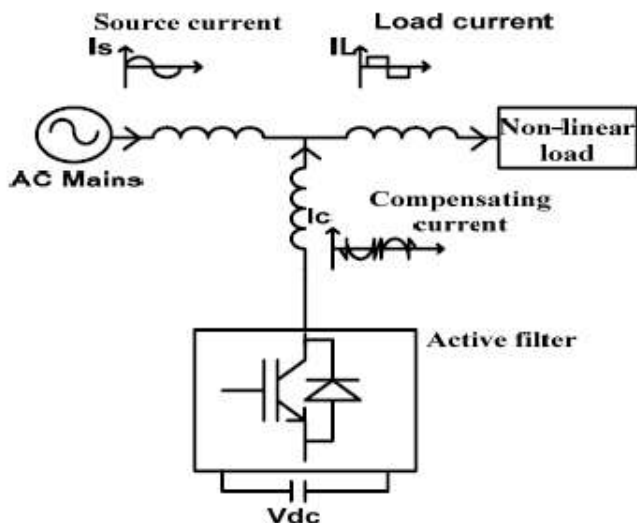


Figure 1: Principle of shunt active power filter.

3. Indirect Control Technique

3.1 Single-phase d-q transformation

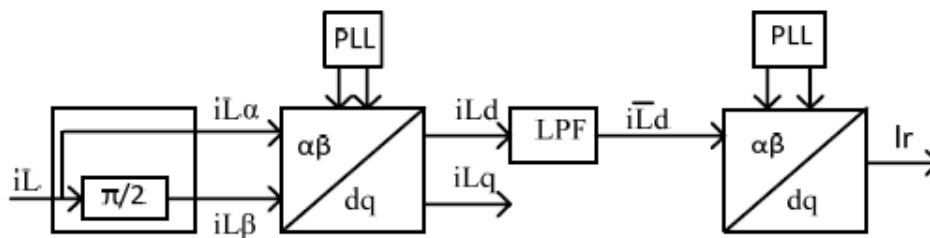


Figure 3: Reference signal generation using single-phase d-q transformation.

A single-phase system can directly convert into $\alpha\beta$ frame without any matrix transformation. An imaginary variable obtained by shifting the original signal (voltage/current) by 90 degrees and thus the original signal and imaginary signal represent the load current in $\alpha\beta$ co-ordinates.

$$\begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} = \begin{bmatrix} i_L(\omega t + \theta) \\ i_L(\omega t + \theta + \pi/2) \end{bmatrix} \quad (1)$$

From second equation we can write as

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & -\cos(\omega t) \\ \cos(\omega t) & \sin(\omega t) \end{bmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} \quad (2)$$

From i_{Ld} and i_{Lq} we can derive fundamental active, fundamental reactive, harmonic active, and harmonic reactive by using appropriate filters. The DC components i_{Ld}^- , i_{Lq}^- are obtained by using LPF and AC components i_{Ld}^+ , i_{Lq}^+ are obtained by using HPF.

Here we are using the DC component for the generation of reference current hence it is called indirect method. The load requires only fundamental active part of the source current.

$$\begin{bmatrix} i_{Ld}^* \\ i_{Lq}^* \end{bmatrix} = \begin{bmatrix} i_{Ld}^- + 0 \\ 0 + 0 \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & -\cos(\omega t) \\ \cos(\omega t) & \sin(\omega t) \end{bmatrix}^{-1} \begin{bmatrix} i_{Ld}^* \\ i_{Lq}^* \end{bmatrix} \quad (4)$$

In order to obtain a constant DC voltage across the active filter the term i_{DC} is added to the above equation.

$$\begin{bmatrix} i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & \cos(\omega t) \\ -\cos(\omega t) & \sin(\omega t) \end{bmatrix} \begin{bmatrix} i_{Ld}^- + i_{DC} \\ 0 \end{bmatrix} \quad (5)$$

Therefore the reference signal is

$$i_{s\alpha}^*(\omega t) = \sin(\omega t)(i_{Ld}^- + i_{DC}) \quad (6)$$

The generated reference current is used for making gating pulses to the inverter switches which further inject the compensating current into the line

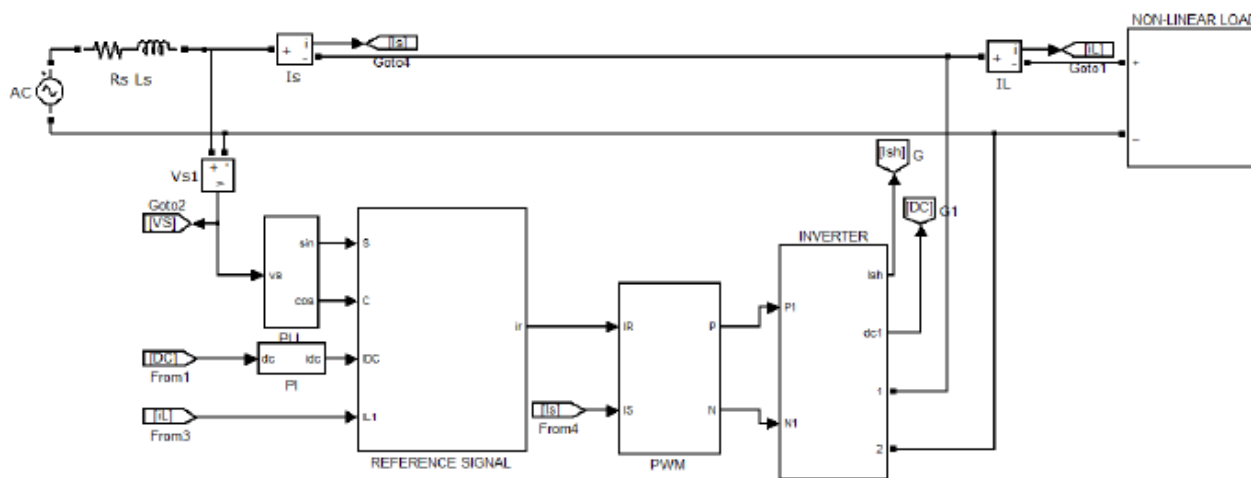
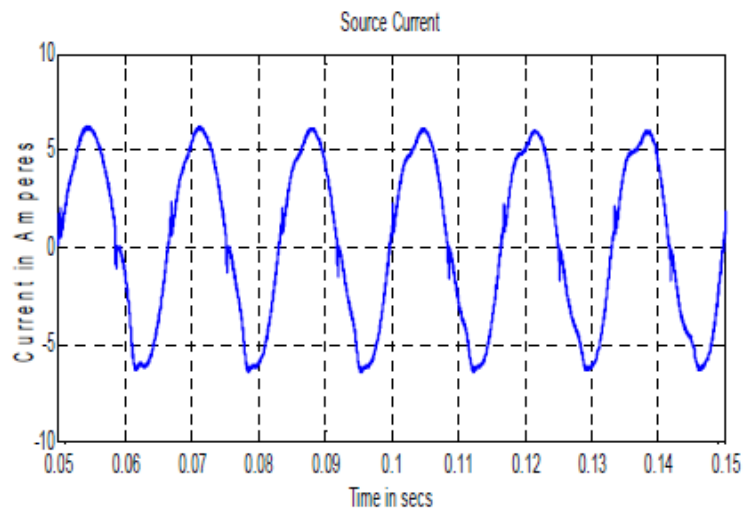
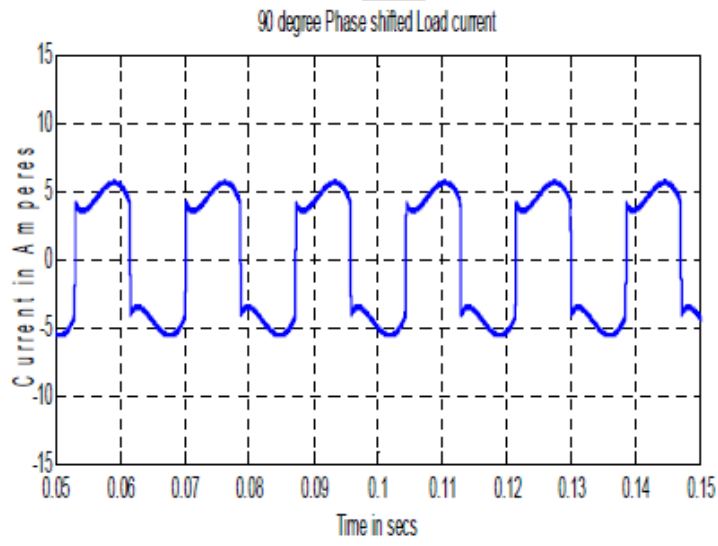
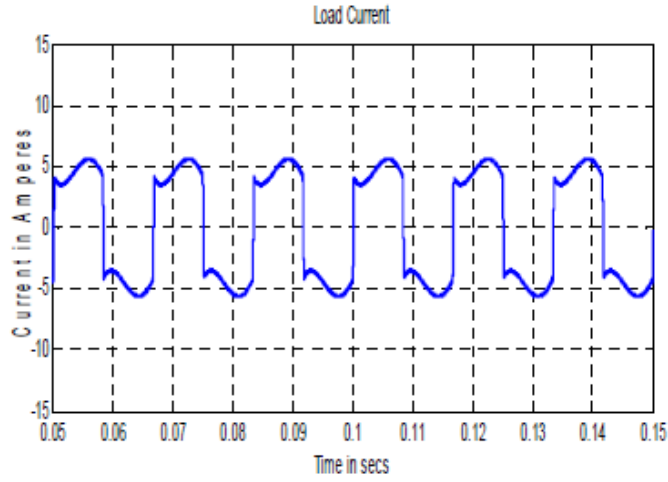
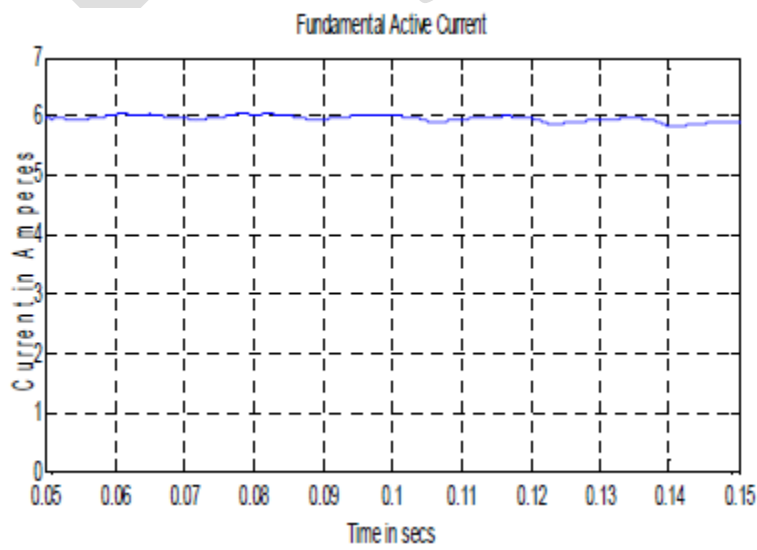
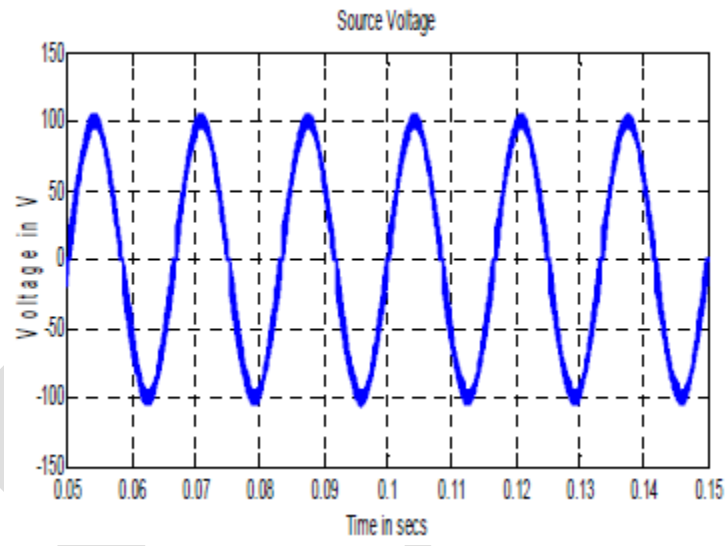
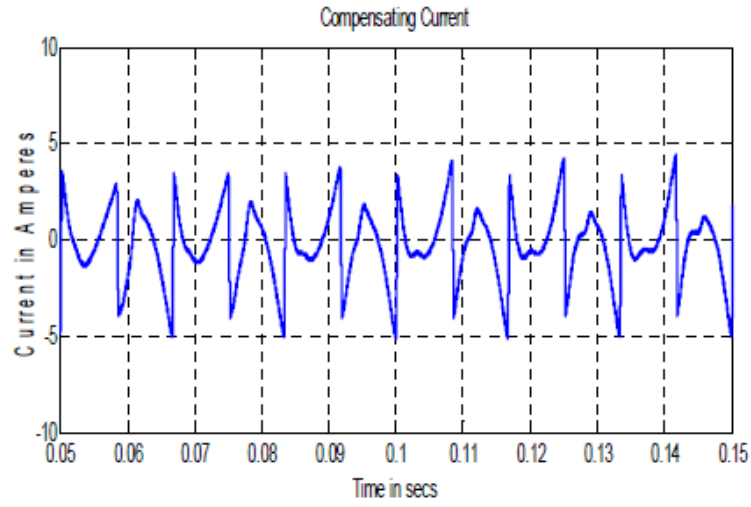


Figure 4: Simulink model of proposed shunt active power filter.

4. Simulation Study

The proposed single-phase shunt active power filter using indirect control strategy is simulated in simpower system toolbox in MATLAB software. Here a 60Hz source is connected to the non-linear diode rectifier load. Due to the non-linearity in the load the source current is distorted and the THD content is about 38.90%. When the shunt active power filter is connected in between source and load which injects thenegative harmonic compensating current into the line and the source current regain its sinusoidal nature , the power factor is much better than without the filter and the THD content is improved to 9.65%.





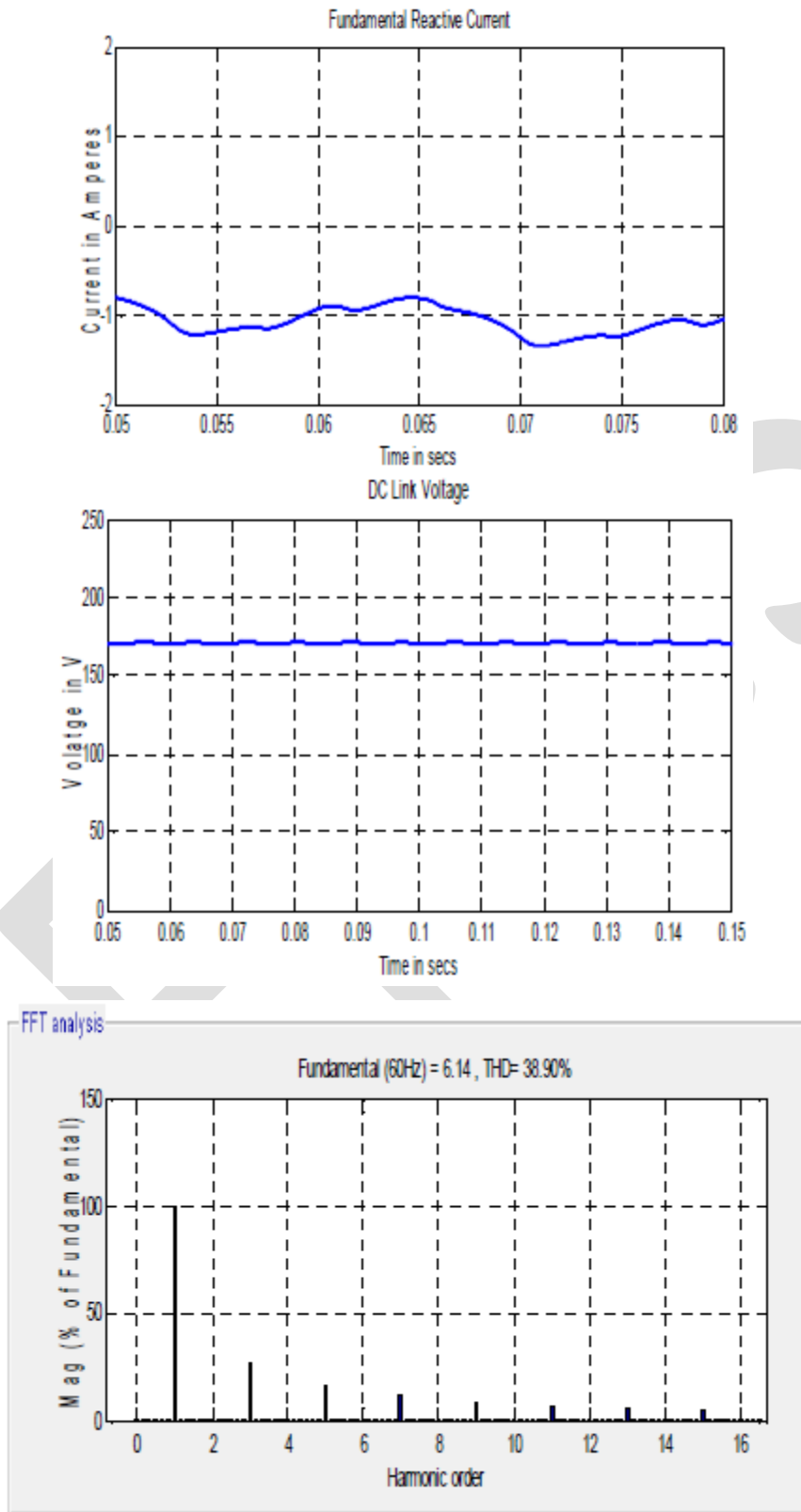


Figure 5: FFT analysis of distorted source current.

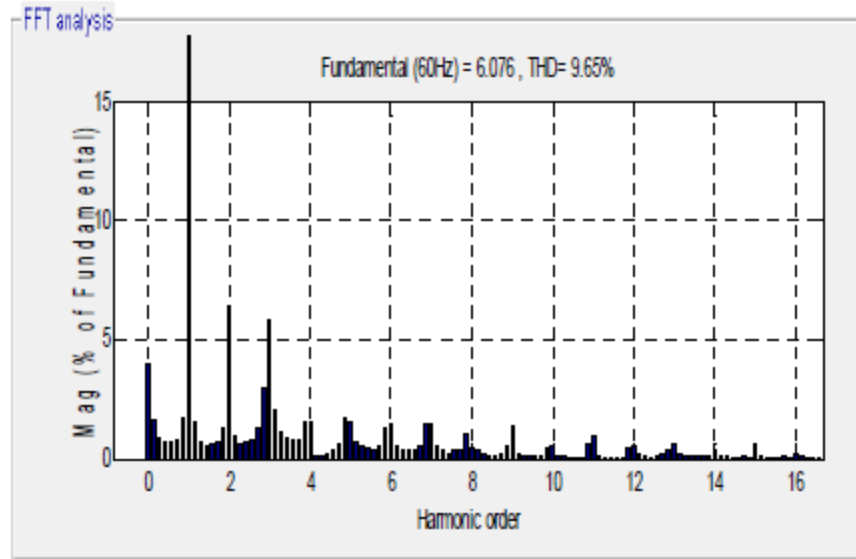


Figure 6: FFT analysis of source current after compensation.

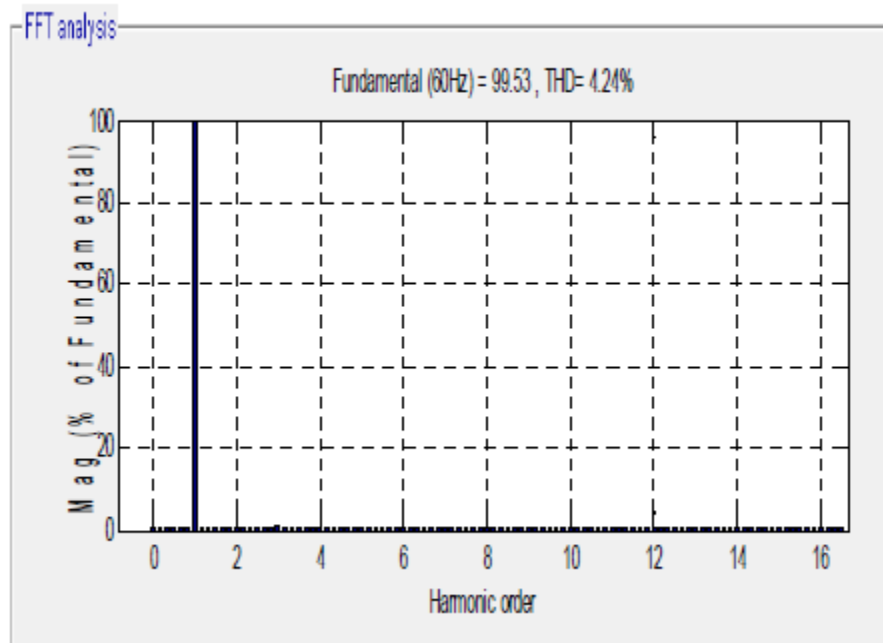


Figure 7: FFT analysis of source voltage.

Table 1: Performance of indirect control technique for 1Ø SAPF.

Condition	THD (%)
	Source Current(I_s)
Without Filter	38.90
With Filter	9.65

5. ACKNOWLEDGEMENT

A colossal number of people have directly or indirectly helped me at different levels of me to successfully accomplish it. It is their relentless support and care that has got me through this memorable journey of our life. So, here I would like to express our sincere gratitude towards them.

I am grateful to all faculty members of Electrical Engineering Department, LDRP Institute of Technology & Research. I also thank our Head of Electrical Engineering Department, Prof. H. N. Prajapati for providing the necessary infrastructure to carry out the paper work at the institute. Last but not least, we would like to express thanks to the Almighty GOD and our families without whose blessings the successful accomplishment of this seminar could not have been possible. I will always remember and cherish each and every one who has helped me to bring the project to this level.

6. Conclusion

A single phase shunt active power filter based on indirect control technique is used in this paper. Using this control strategy reference signal is generated successfully. The shunt active power filter is found effective in injecting harmonic compensating current and thereby reducing the source current THD and improves the power factor of the line. The THD is reduced from 38.90% to 9.65% after compensation. It is also noticed that a constant voltage appears across the DC-link capacitor which helps the smooth functioning of the voltage source inverter. The shunt active power filter output is verified successfully with the help of MATLAB software.

REFERENCES:

- [1] V Khadikar, A Chandra and B N Singh (2009), "Generalised single-phase p-q theory for active power filtering: simulation and DSP-based experimental investigation", IET Power Electronics, Vol. 2, No. 1, pp. 67-78.
- [2] R Zhang, M Cardinal, P Szczesny and M Dame (2002), "A grid simulator with control of single-phase power converters in D-Q rotating frame," in proc. IEEE Power Electronics Specialists Conference (PESC), vol. pp. 1431-1436.
- [3] M Gonzalez, V Cardenas and F Pazos (2004), "D-Q transformation development for single-phase systems to compensate harmonic distortion and reactive power," in Proc. IEEE Power Electronics Congress, pp. 177-182.
- [4] S Golestan, M Joorabian, H Rastegar, A Roshan and J.M. Guerrero (2009), "Droop based control of parallel-connected single phase inverters in D-Q rotating frame," in Proc. IEEE Industrial Technology, pp. 1-6.
- [5] B Singh, K Al-Haddad and A Chandra (1999), "A Review of Active Power Filters for Power Quality Improvement", IEEE Transactions Ind. Electro. Vol 45, no. 5, pp. 960-971.
- [6] M El-Habrouk, M K. Darwish and P Mehta (2000), "Active power filters a review", in Proc. Of IEE-Elect. Power Appl, vol. 147, no-5, pp. 403-413.
- [7] Kunjumammed L.P, Mishra M.K (2006), "Comparison of single phase shunt active power filters algorithm", proc. Annu. Conf. IEEE Power India.
- [8] Mohammad H Rashid (2007), "Power Electronics Handbook: Devices Circuits and Applications" Elsevier 2e. Single-Phase Shunt Active Power Filter Using Indirect Control Method 89
- [9] H Akagi, Y Kanazawad and A Nabae (1984), "Instantaneous reactive power compensators comprising switching devices without energy storage Components", IEEE Trans. Ind. Appl, Vol. 20, no-3, pp 625-630.

- [10] J Liu, J Yang and Z Wang(1999),”A new approach for single –phase harmonic current detecting and its application in a hybrid active power filter,”inproc.Annu.Conf.IEEE.Indist.Electronics.Soc(IECON99),vol 2,pp,849-854.
- [11] A Vectorial Approach for Generation of Optimal Current References for Multiphase Permanent-Magnet Synchronous Machines in Real Time Xavier Kestelyn, Member, IEEE, and Eric Semail, Member, IEEE
- [12] A Vectorial Approach for Generation of Optimal Current References for Multiphase Permanent-Magnet Synchronous Machines in Real Time Xavier Kestelyn, Member, IEEE, and Eric Semail, Member, IEEE

IJERGS