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Study of Harmonic based Indirect Current Controlled in Shunt Active Filter Using Slide Mode Controller

Kalpana.S, P.K.Dhal

Abstract— This paper investigates better power quality by using an indirect current controlled in shunt active filter (APF). The proposed technique of APF is based on a voltage source inverter (VSI). The VSI is divided by two loops i.e the voltage control loop and the current control loop. The voltage control loop is regulated the DC link capacitor voltage and the current control loop uses sliding mode control to shape the source current such that it is in-phase with the input voltage. The presence of harmonics and reactive power, it will be caused an additional power loss. The advantage of APF is that the reference current for power quality improvement is generated from the DC link capacitor voltage. Computer simulations are carried out on a sample power system to demonstrate the effectiveness of the proposed approach in suppressing the harmonics. This work proposes a sliding mode controller based single phase shunt active filter for Non-linear load. The proposed design system with control scheme is analyzed in computer simulation using MATLAB/SIMULINK scenario.

Index Terms— shunt active filter, indirect current control, sliding mode control.

I. INTRODUCTION

The Harmonic distortion is one of the important factors of power quality problems in power systems. The ac power supply feeds different kind of linear and non-linear loads. The non linear loads produce harmonics and reactive power related problems. This harmonics and reactive power cause poor power factor and distort the supply voltage. The current harmonics create problems in power systems such as malfunctions in sensitive equipment and the harmonic voltage drops across the network impedance that result in poor power factor. Traditionally these problems are solved by passive filters. But these passive filters introduce tuning problems. One of the most popular is the shunt active power filter [1]-[2]. It is mainly a voltage source and connected in parallel with the non-linear loads. Conventionally, a shunt active filter is controlled in such a way as to inject harmonic and reactive compensation currents based on calculated reference currents. The injected currents are meant to cancel the harmonic and reactive currents drawn by the nonlinear loads. Recently, sliding mode controller has generated a great deal of interest in various applications. It has been introduced in the power electronics field. The advantages of sliding mode controllers over the conventional PI controller are that it does not need an accurate mathematical model [3]-[4]. It can work with imprecise inputs can handle nonlinearity and may be more robust than the conventional PI controller. So the sliding mode controller is useful for minimization of harmonics and improvement of power quality. It is not a new issue rather than various authors have introduced some innovative methodologies. The most important observation from the work reported by various researchers for power quality improvement is the Design of active power filter under 'fixed load' conditions or for loads with slow and small variation [5]-[6]. There is the need to design an active power filter, which is capable of maintaining the total harmonic distortion (THD) under variable load conditions.

II. INDIRECT CURRENT CONTROLLED BASED SHUNT ACTIVE POWER FILTER

The voltage source inverter of a single phase indirect current controlled shunt active power filter is shown in figure1.

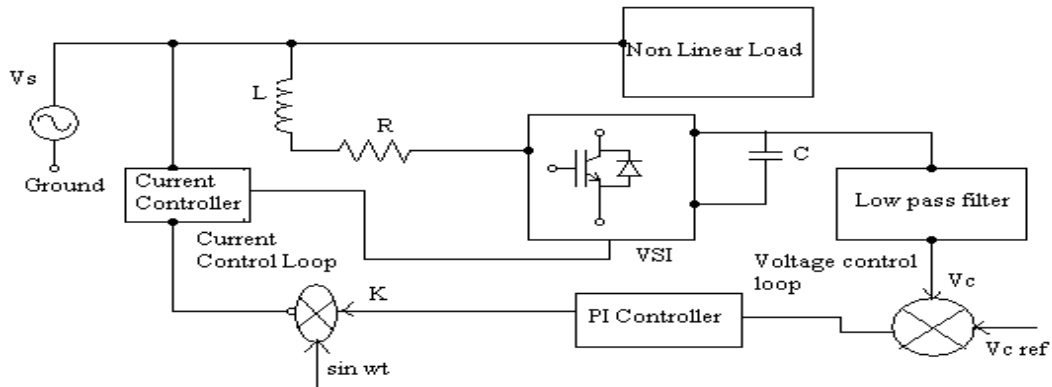


Fig 1. Indirect current controlled in shunt active power filter

The voltage source inverter is controlled to produce a fundamental terminal voltage in phase with the AC system voltage. When the fundamental inverter terminal voltage is more than the rms value of AC system source voltage V_{source} , a leading current is drawn from the AC system. When the inverter terminal is less than V_{source} , a lagging current is drawn from AC system [7]-[8]. The magnitude of the inverter terminal voltage depends on the DC link capacitor voltage V_c . So by controlling the gate signals of the switches, the inverter terminal voltage can be made to lag or lead the AC system voltage. The real power flows into or out of the inverter circuit. By suitable operation of above figure2, a compensating voltage V_{comp} having a fundamental component V_{comp1} is generated at the output of the inverter. When $V_{comp1} > V_{source}$, it will be leading current with respect to V_{source} , It will be drawn and the inverter supplies reactive power to the system. When $V_{comp1} < V_{source}$, it will be lagging current and it supplies leading reactive power to the system. When $V_{comp1} = V_{source}$, it will be no current. It will flow into or out of the system. The reactive power can be controlled by compensating voltage.

III. ANALYSIS OF SLIDING MODE CONTROLLER IN SHUNT ACTIVE POWER FILTER

The proposed indirect current controlled shunt APF is shown in figure 1. It has two control loops, the voltage control loop and the current control loop. The voltage control loop is regulated the average value of the DC link capacitor voltage V_c . It is sensed DC link capacitor voltage which is sent to a low pass filter (LPF) to remove the ripples present in it. The voltage thus obtained is compared with a reference DC voltage $V_{c(ref)}$ and the error is fed to a PI controller. The output of the PI controller is the amplitude (k) of the current, which is used to derive the reference current [9]-[10]. The derived reference current is compared with the source current in the current control loop for generating gate signals for the switches of the voltage source inverter (VSI) of the APF. Sliding mode control has been used in the current control loop of the proposed APF as shown in figure 2.

The sliding mode controller is used to reduce the harmonic and ease to implement. The sliding mode controllers have a property of operating at infinite and varying switching frequency such that state variables of the system follow the required trajectory. The various techniques have been proposed in sliding mode controlled active power filters to control the switching frequency. It is mainly based on hysteresis modulation. In the proposed active power filter system, a pulse width modulation based sliding mode controller is being used to fix the switching frequency at a constant value. So the harmonic content in the source current is reduced significantly shown in MATLAB simulation scenario [11]. From the above figure2 is to make the source current follow reference source current a sliding surface which is defined as

$$S = (I_{source} - I_{source}^*) + \lambda \int (I_{source} - I_{source}^*) \quad (1)$$

Where S = sliding mode surface, I_{source} = source current, I_{source}^* = reference source current and λ = sliding mode co-efficient.

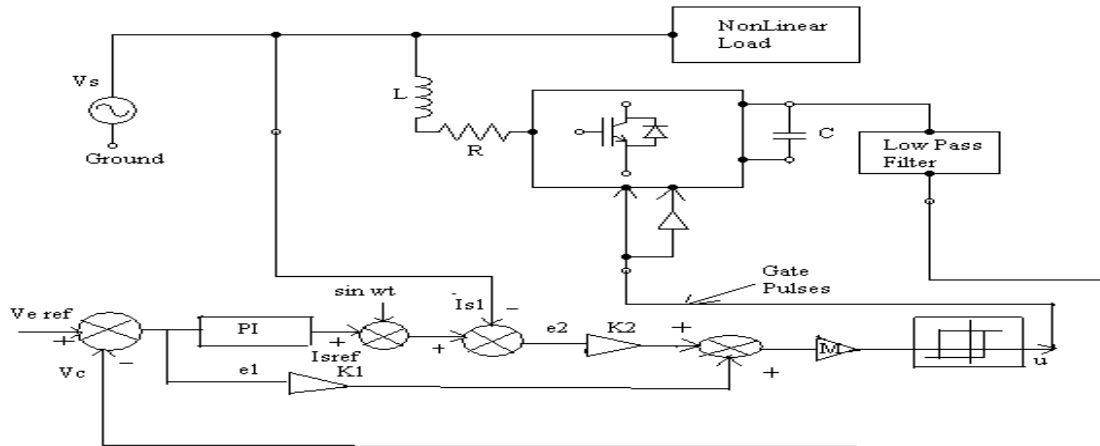


Fig 2 Sliding mode controller in shunt active filter

The concept is applied in MATLAB/SIMULINK and better result is obtained as shown in simulation figures. After design of the sliding mode surface, the next important aspect is to check for existence condition for sliding mode to exist in the vicinity of the sliding surface. It is possible only when the tangent to the state trajectory is made to direct towards the sliding surface [12]-[13]. In general actual trajectory lies above the sliding surface, it can say $S > 0$. The actual trajectory lies on the sliding surface, it can say $S = 0$. Finally actual trajectory lies below the sliding surface, it can say $S < 0$. When $S > 0$, $I_{source} > I_{source}^*$. It is to bring the trajectory on to the sliding surface. So the extra amount current must be used to charge the capacitor. Similarly when $S < 0$, $I_{source} < I_{source}^*$. When the sliding mode control exists, the reachable condition should be satisfied. This can be written as mathematically

$$\lim_{s \rightarrow 0} s \cdot S \cdot S^* < 0 \tag{2}$$

The above condition can be satisfied by controlling the sign of S^* . It is possible with proper control of the switches, the discrete control law which maintain the state trajectory on the sliding surface $S = 0$. It can expressed as

$$U = \begin{pmatrix} 1 & \text{if } S > 0 \\ -1 & \text{if } S < 0 \end{pmatrix} \tag{3}$$

From the figure1 to get $I_{source} = I_{line} + I_{comp}$. (4)

Also it can written as $I_{source}^* = I_{line}^* + I_{comp}^*$. (5)

$$\frac{dI_{line}}{dt} = \frac{1}{L}(V_{source} - I_{line}R - V_C U) \tag{6}$$

Here considering equation (1), (4), (5) and (6), it will get

$$\frac{1}{L}(V_{source} - I_{line}R - V_C U) - \frac{dI_{line}^*}{dt} + \lambda(I_{source} - I_{source}^*) \tag{7}$$

From equation (8) it can be obtained

$$U_{eq} = \frac{1}{V_C} (V_{source} - I_{line}R - L \frac{dI_{line}^*}{dt} + \lambda L (I_{source} - I_{source}^*)) \quad (8)$$

Now U_{eq} is continuous and lies between 0 and 1. From equation (8), it can be written as

$$0 < \frac{1}{V_C} (V_{source} - I_{line}R - L \frac{dI_{line}^*}{dt} + \lambda L (I_{source} - I_{source}^*)) < 1 \quad (9)$$

IV. SIMULATIONS RESULTS AND DISCUSSIONS

To validate the system performance overall active power filter is computer simulated using MATLAB software. The total harmonic distortion (THD) of all voltage and current wave forms are measured as shown in figures below. In RL load, the total harmonic distortion (THD) reduces when number of cycle increases. The number of cycle 5, fundamental frequency 50 HZ and maximum frequency 1KZ, the THD is 9.05. In RC load, the number of frequency 5, fundamental frequency 50 HZ and maximum frequency 1KZ, the THD is 8.86. Similarly same number of cycle for RLE load is 4.99.

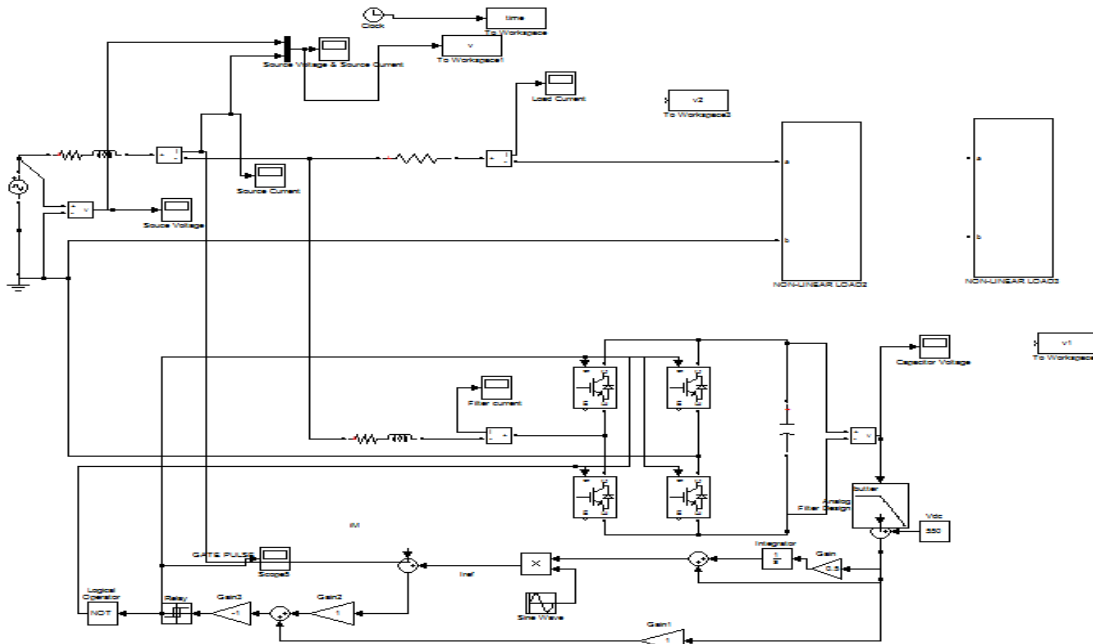


Fig 3 single phase shunt active filter with RL Load

In the figure 3, the single phase ac source is connected to the RL load. The shunt active filter is injected into the line and output voltage is controlled. The capacitor dc voltage is obtained by voltage control loop.

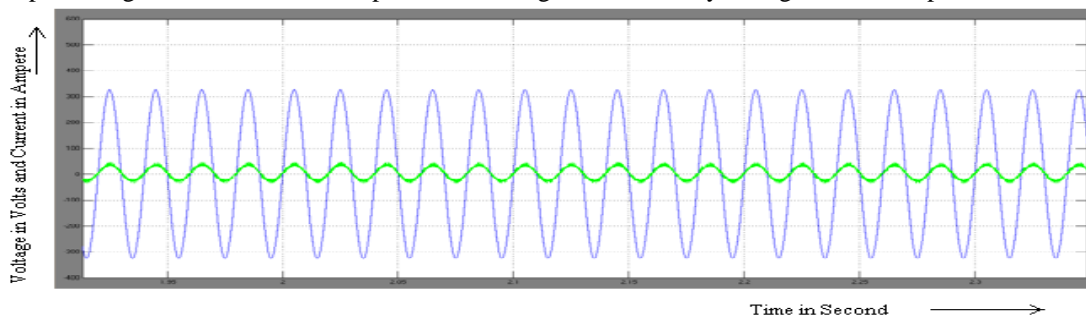


Fig 4 source voltage (V) and source current (A) in input sides of RL load



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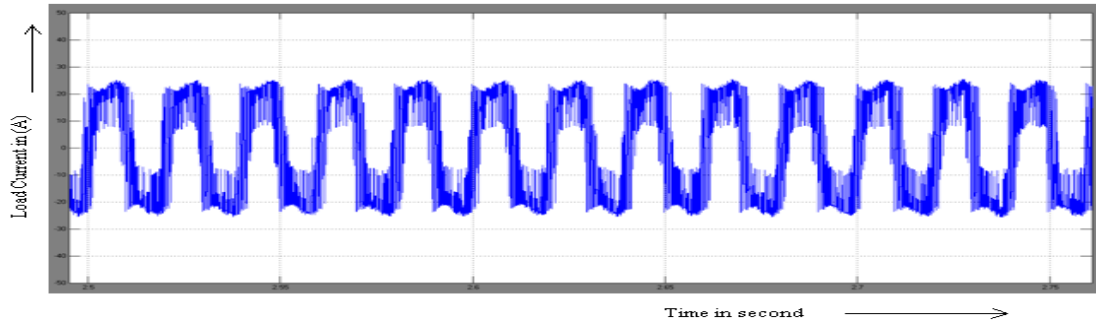


Fig 5 load current (A) in output side

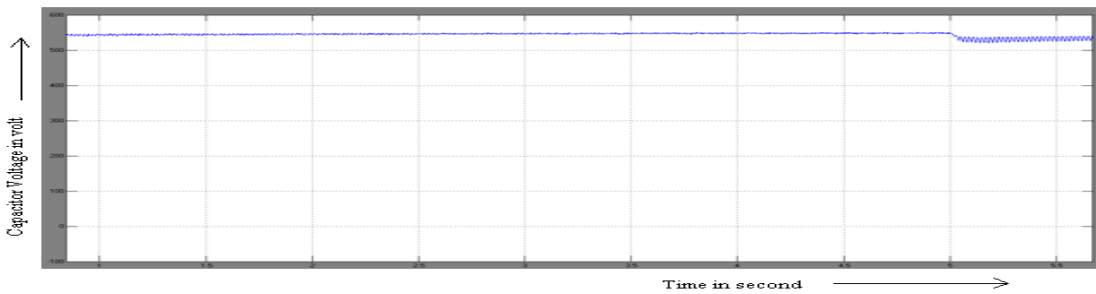


Fig 6 capacitor voltages in volt

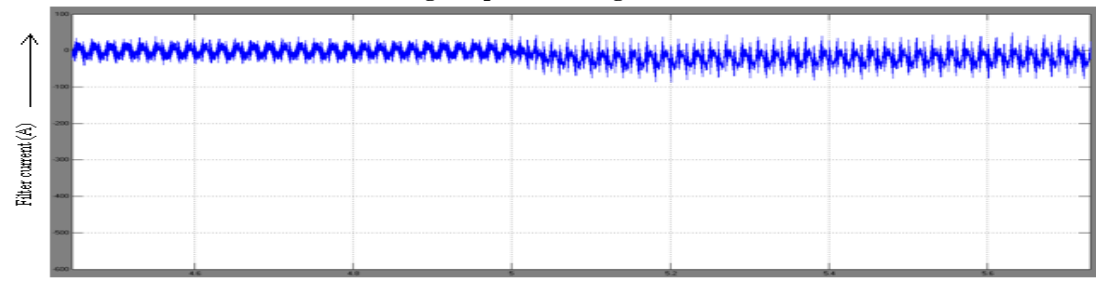


Fig 7 filter current (A) in shunt active filter

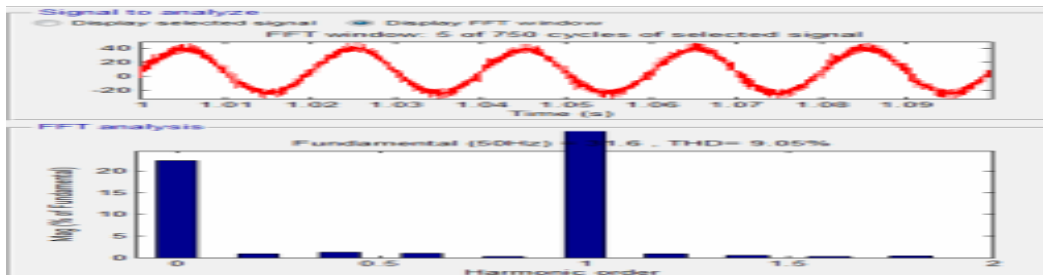


Fig 8 THD in shunt active filter with RL load for 5 cycles

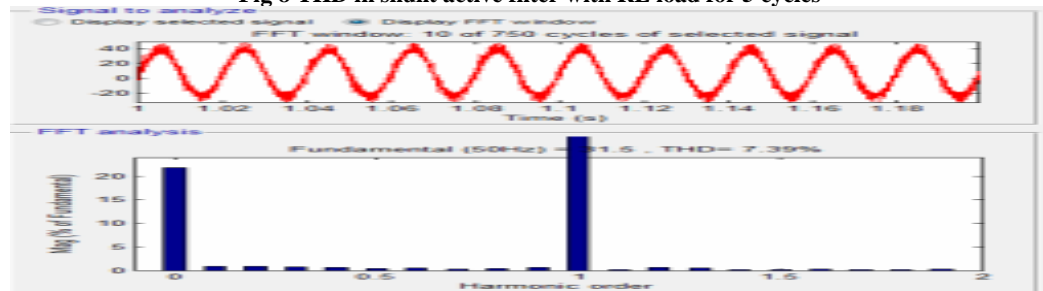


Fig 9 THD in shunt active filter with RL load for 10 cycles

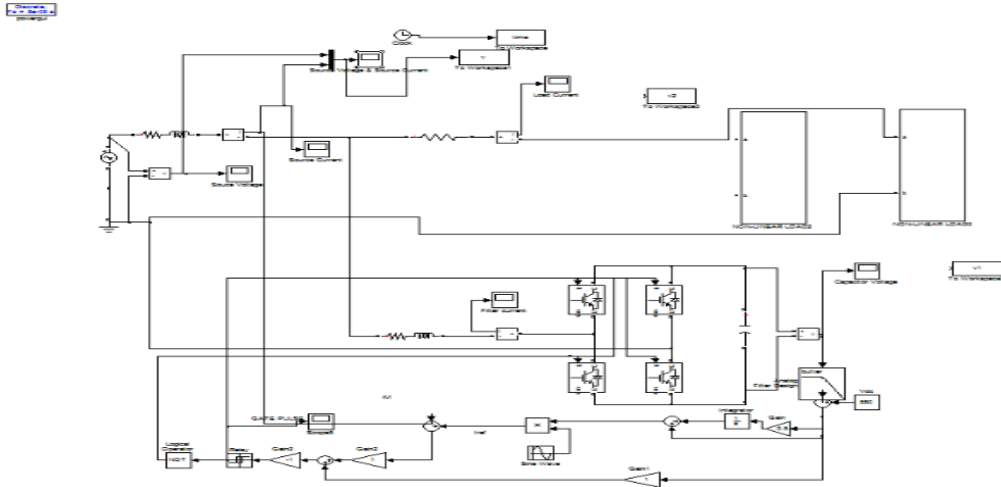


Fig 10 single phase shunt active filter with RC Load

In the figure 10, the single phase ac source is connected to RC load and shunt active filter is injected into the line. So the output voltage is controlled.

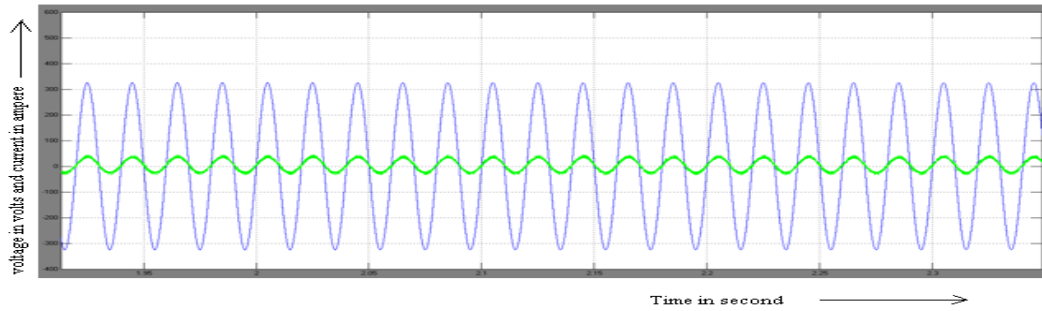


Fig 11 source voltage (V) and source current (A) in input sides of RC load

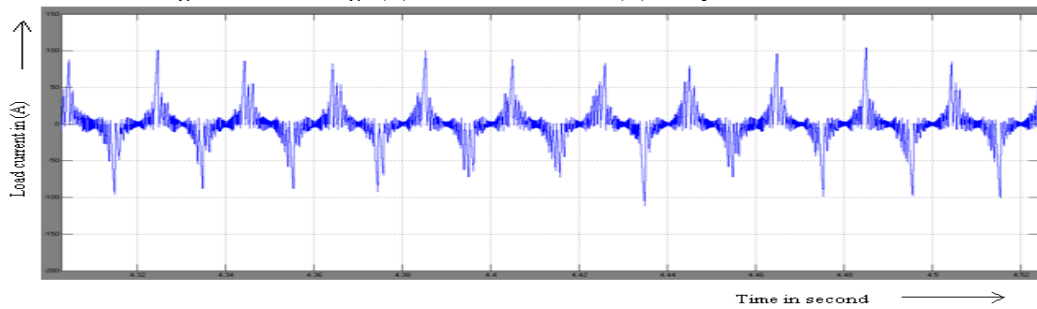


Fig 12 load current (A) in output side

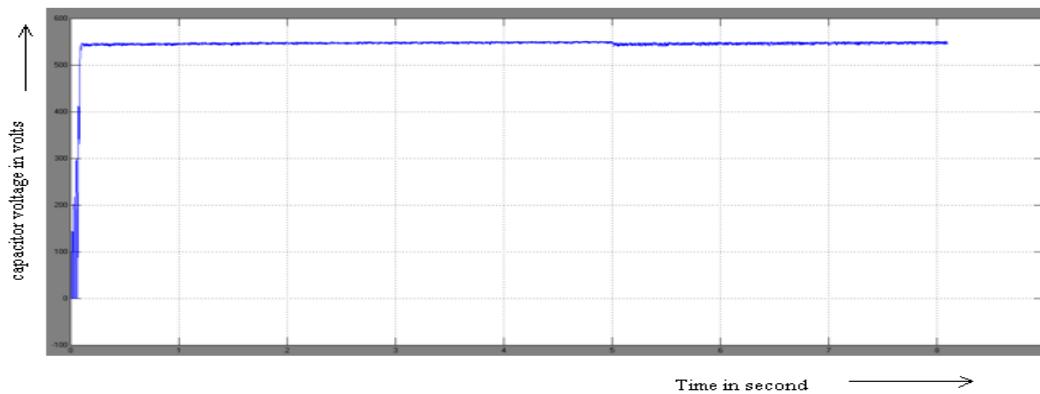


Fig 13 capacitor voltages in volts

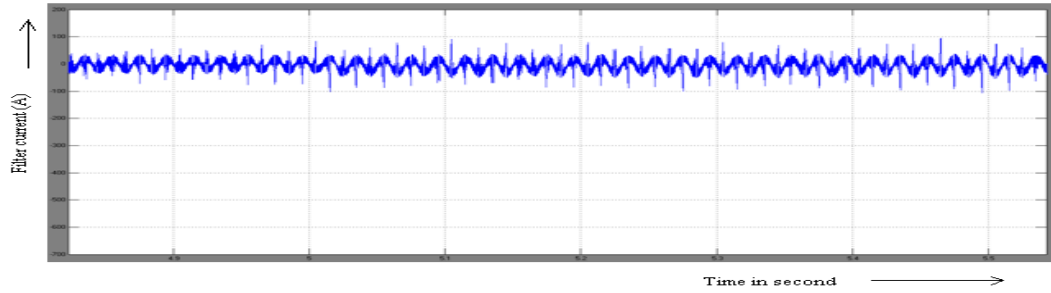


Fig 14 filter current (A) in shunt active filter

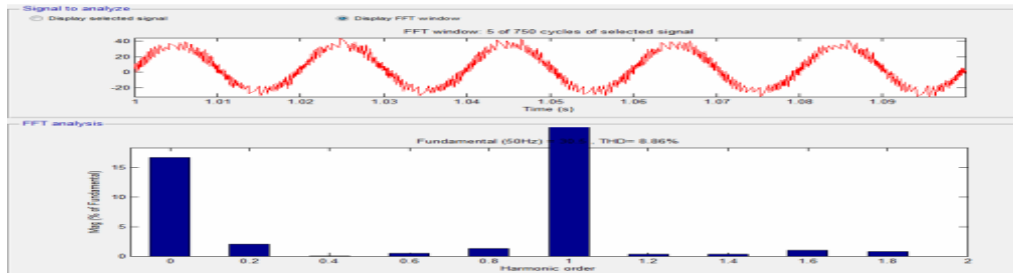


Fig 15 THD in shunt active filter with RC load for 5 cycles

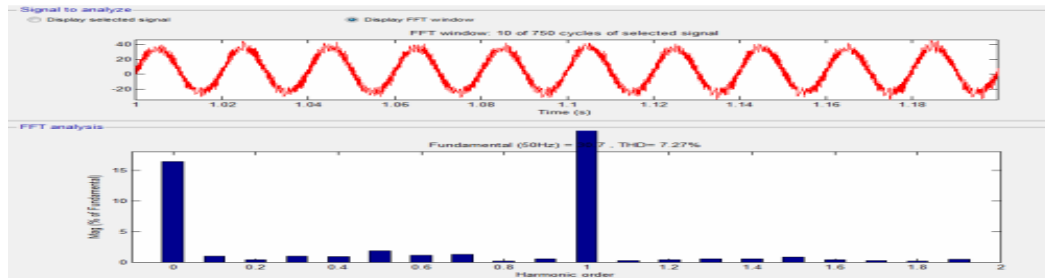


Fig 16 THD in shunt active filter with RC load for 10 cycles

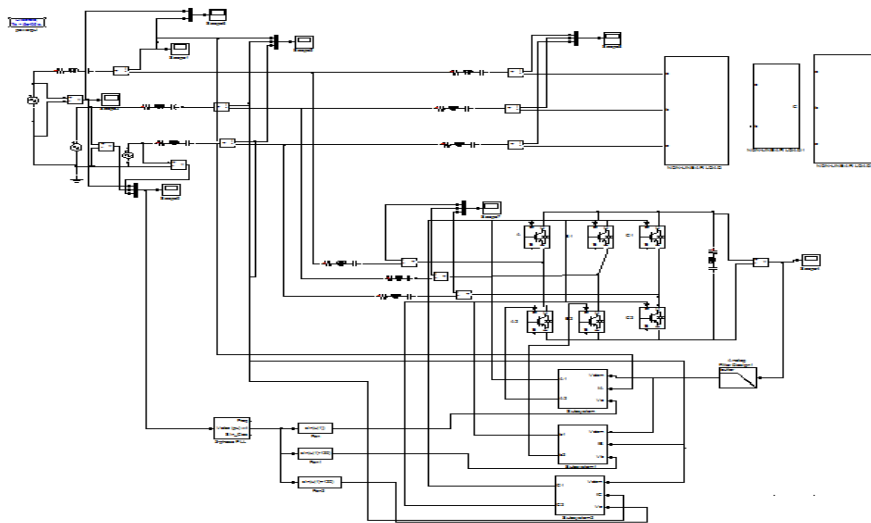


Fig 17 three phase shunt active filter with RLE Load

In the figure 17, the three phase ac source is connected to RLE load. The shunt active filter is injected into the line.



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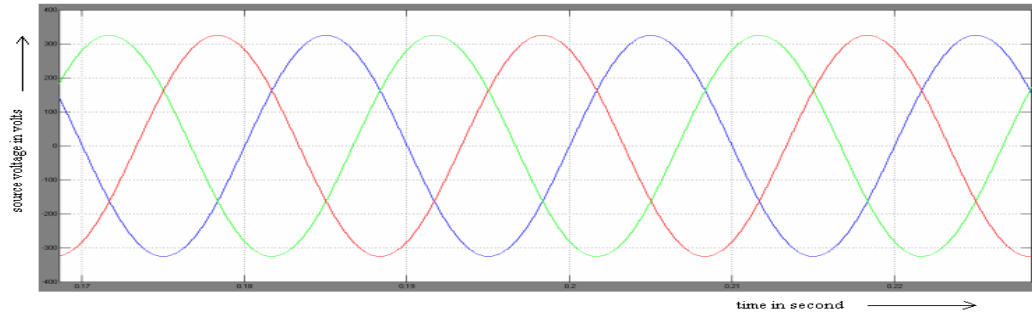


Fig 18 three phase source voltages in volt

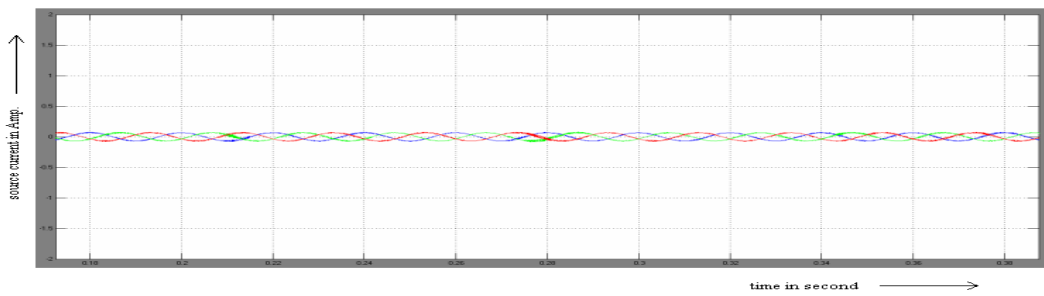


Fig 19 three phase source current in ampere

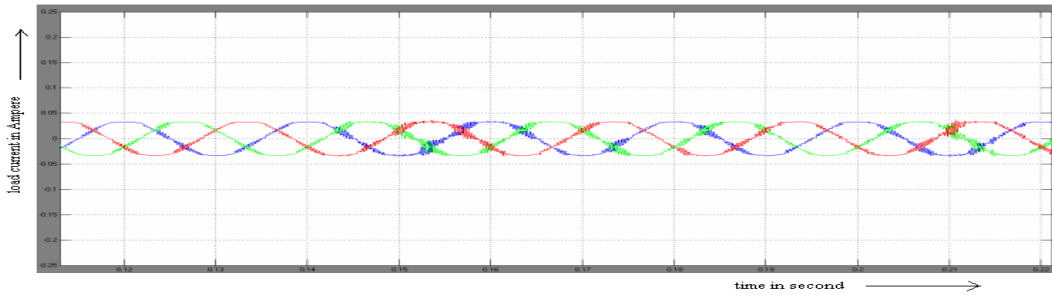


Fig 20 three phase load current in ampere

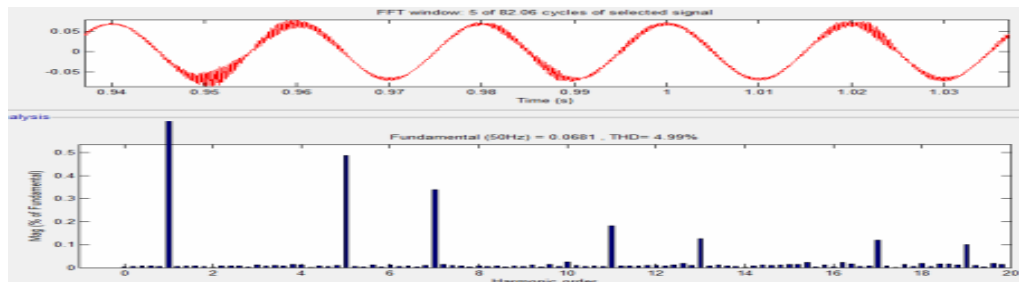


Fig 21 THD in shunt active filter with RLE load for 5 cycles

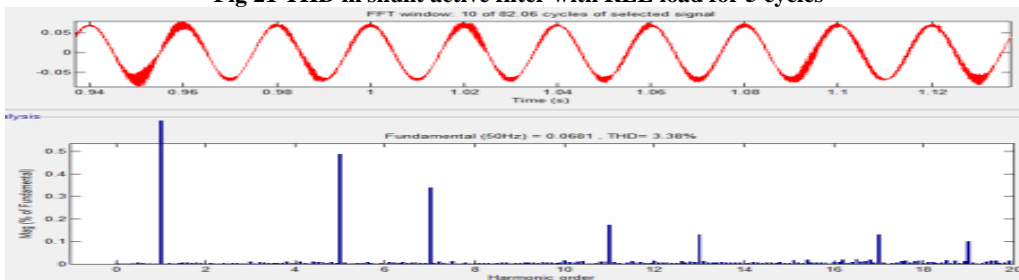


Fig 22 THD in shunt active filter with RLE load for 10 cycles



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Table.1 THD in different load

| No. of Cycles | Fundamental of Frequency | Maximum Frequency | %THD for RL load | %THD for RC load | %THD for RLE load |
|---------------|--------------------------|-------------------|------------------|------------------|-------------------|
| 5 | 50 | 1KHZ | 9.05 | 8.86 | 4.99 |
| 10 | 50 | 1KHZ | 7.39 | 7.27 | 3.38 |

It is observed that from figure 8 and figure 9 for RL load, the total harmonic distortion (THD) are reducing at constant frequency at 50 HZ and maximum frequency 1KHZ and also in RC load from figure 15, figure 16 and RLE load from figure 21, figure 22. It is observed that total harmonic distortions are reducing significantly.

V. CONCLUSION

The implementation of indirect control technique applied to sliding mode controller based shunt active power filter has been presented. It is also analyzed in improvement of power quality in MATLAB software. The novel sliding mode control is proposed in reference current tracking to reduce the tracking error. It can be done proper combinations of fixed frequency sliding mode current control in shunt active power filter. The dynamic response of shunt active power filter system helps to reduce harmonic content in source current in different cycle with RL and RC load. The simulation results confirmed that the designed a shunt active power filter in indirect current control technique with slide mode controller has better result in harmonics. The future work can be carried out using fuzzy based sliding mode controller.

REFERENCES

- [1] R.Mohanty, "Indirect current controlled shunt active power filter for power quality improvement," Electrical power and energy systems, 62(2014), pp.441-449.
- [2] Rajesh K Patjoshi and Kamala Kanta Mahapatra, "Performance comparison of direct and indirect current control techniques applied to a sliding mode based shunt active power filter", Annual IEEE India conference (INDICON) 2013.
- [3] Soumya Rajan Mahapatra and Pravat kumar Ray, "A fixed switching frequency adaptive sliding mode controller for shunt active power filter system", IEEE TENCON – 2014 Proceeding 22-25 October 2014.
- [4] M.Angulo, D. A.Ruiz-Caaballero, J.Lago, M. L. Heldwein, S.A.Mussa, "Active power filter control strategy with implicit closed-loop current control and resonant controller", IEEE Trans.Ind.Electron, vol.60, no.7, pp2721-2730, July 2013.
- [5] V.S.Bandal and P.N.Madurwar, "Performance analysis of shunt active power filter using sliding mode control strategies", 12th international workshop on variable structure systems, march 2012.
- [6] B.Cheng, P.Wang and Z.Zhang, "Sliding mode control for a shunt active power filter", In proceedings of the 3rd international conference on Measuring technology and Mechatronics automation (ICMTMA'11), vol.3,pp 282-285, 2011.
- [7] P.karuppanan.S.R.Prusty, K.K.Mahapatra, "Adaptive- hysteresis current controlled based active power filter for power quality enhancement", SEISCON, pp.1-6, 2011.
- [8] D.Stanciu, M.Teodorescu, A.Florescu and D.A.Stoichescu, "Single phase active power filter with improved sliding mode control", In Proceeding of the 17th IEEE international conference on automation, quality and testing, robotics (AQTR'10),pp. 15-19, may 2010.
- [9] H.Wang, Q.Li, Y.Gong and Y.Duan, "An adaptive sliding mode control methodology applied to shunt active power filter", In Asia-pacific power and energy engineering conference (APPEEC'10), March 2010.
- [10] J.Matas,Luis Garcia de Vicuna,J.Miet,J.M.Guerrero,M.Castilla, "Feedback linearization of single phase active power filter via sliding mode control", IEEE Trans.Power Electron,vol.23,no.1,pp 116-125,jan 2008.
- [11] D.Nedelijkovic,M.Nemec,K.Drohnic and V.Ambrozic, "Direct current control of active power filter without filter current measurement", In Proceeding of the international symposium on power electronic, electrical drives, automation and motion(SPEEDAM'08),pp.72-76,2008.
- [12] G.K.Gingh, A.K.Singh and R.Mitra, "A simple fuzzy logic based robust active power filter for harmonics minimization under random load variation", Electric power systems research, vol.77, no.8, pp.1101-1111, 2007.



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[13] L.H.Tey and Y.C.Chu, "Improvement of power quality using adaptive shunt active filter", IEEE Trans. On power delivery, vol.20, pp.1558-1568, 2006.

AUTHOR BIOGRAPHY



Kalpana.S is M.Tech Power Electronic student of Vel Tech Dr.RR&Dr.SR Technical University, Chennai. She has completed her Bachelore degree from Multi Tech Engineering College, Avadi. Her area of interest power electronics application to power system and power quality.



Dhal.P.K. has received his M.E. degree (power systems) from Thiagarajar College of Engineering under Madurai Kamaraj University, Madurai. He received his Ph.D degree from Sathyabama University, Chennai. He is currently working as Associate professor in Electrical & Electronics Engineering Department at Vel Tech DR.RR&DR.SR Technical University, Avadi, Chennai. He published technical papers in International & National Journals and Conferences. His area of interest is power electronics application to power system, power quality, and power system stability. He is member in ISTE & IEEE.