International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

Active Power Filter for Harmonics Compensation in Single Phase Power Lines

Savita N. Patil
Department of E&TC Engg.
MET's, Institute of Engineering,
Bhujbal Knowledge City,
Nashik-422003

Dr. P. H. Zope
Ph.D., ME Electronics(Digital Electronics)
Department of Post Graduate E&TC Engg.
SSBT's College Of Engineering and Technology Bambhori,
Jalgaon

***Abstract*— Active filtering of electric power has now become a mature technology for harmonic compensation in single phase power line generated by loads. Harmonics are multiples of the fundamental frequency distortion found electrical power, subject to continuous disturbances. These harmonics are created by the usage of increased devices such as UPS system, rectifiers, filters etc. Large harmonic current in a circuit will result in greater voltage distortion that leads to greater power loss, greater temperature rise and abnormal operation of switching devices. To mitigate the harmonic and improve the power quality an optimum design of appropriate filter is needed [1]-[2]. The topology of the filter is based on a single-phase voltage source inverter (VSI) with four MOSFET or IGBT semiconductor switches. In this project active filters are employed to mitigate the harmonic content. The pulse-width-modulated (PWM) technique is then used to generate the required gate drive signals to the full- bridge VSI. A low-pass filter is also incorporated in the output of the inverter to provide a sufficient attenuation of the high switching ripples caused by the VSI. This paper deals with the hardware implementation, MATLAB simulation (simulink) of active power filter for harmonics compensation in single phase power line. A comparative study on harmonic content before and after to engagement of filters also done.**

Index Terms— **Active power filters, active power line conditioners, harmonics compensation, power quality.**

I. INTRODUCTION

Service reliability and quality of power have become growing concerns for many facility managers, especially with the increasing sensitivity of electronic equipment and automated controls. There are several types of voltage fluctuations that can cause problems, including surges and spikes, sags, harmonic distortion, and momentary disruptions. They occur frequently when there are large numbers of personal computers (single phase loads), uninterruptible power supplies (UPSs), variable frequency drives (AC and DC) or any electronic device using solid state power switching supplies [3]-[4] to convert incoming AC to DC. Loads create harmonics by drawing current in abrupt short pulses, rather than smooth sinusoidal manner. Harmonics can cause sensitive equipment to malfunction and other problems, including overheating of transformers and wiring, and reduced power factor. Harmonics are the multiple of fundamental frequency, and whereas total harmonic distortion is the contribution of all the harmonic frequency currents to the fundamental. Harmonics are the by-products of modern electronics. Evaluating the life-cycle costs and effectiveness of harmonics mitigation technologies can be very challenging—beyond the expertise of most industrial facility managers. After performing the proper measurement and analysis of the harmonics problem, this type of evaluation requires an analysis of the costs of the harmonics problem (downtime of sensitive equipment, reduced power factor, energy losses or potential energy savings) and the costs of the solutions. The terms "linear" and "non-linear" define the relationship of current to the voltage waveforms. A linear relationship exists between the voltage and current, which is typical of an across the line load. A non linear load has a discontinuous current relationship that does not correspond to the applied voltage waveform. All variable frequency drives cause harmonics because of the nature of the frontend rectifier [4],[5].

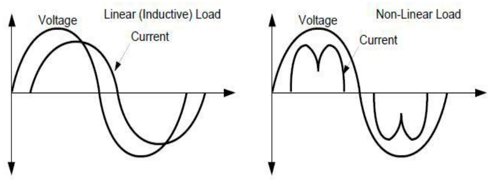


Fig1: Difference between Linear and Non-Linear Loads

II. PWM INVERTER

2.1Block Diagram of inverter

Inverters converts DC signal into AC signal. The function of an inverter is to change a dc input to a symmetrical ac output voltage of desired magnitude and frequency [1].

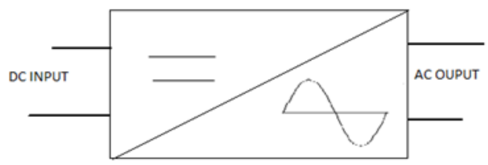


Fig2: Block Diagram of inverter

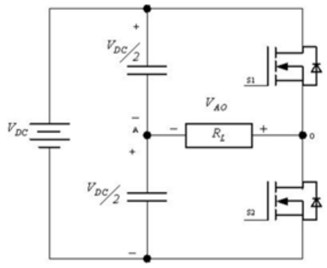
2.2 Classification of inverter

- Single-phase inverter.

- Three-phase inverters.

2.3 Single-phase inverter:

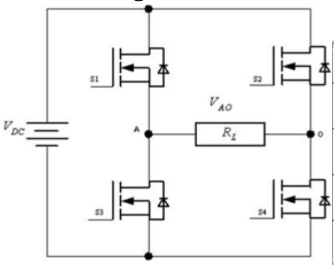
- Single Phase Half Bridge Inverter



S_1	S_1	V_{Ao}
ON	OFF	+VDC/2
OFF	ON	-VDC/2

Fig3: Single-phase Half Bridge inverter

- Single Phase Full Bridge Inverter



S1	S2	S3	S4	VA	Vo	VAo
ON	OFF	OFF	ON	+VDC/2	-VDC/2	VDC
OFF	ON	ON	OFF	-VDC/2	+VDC/2	-VDC
ON	OFF	ON	OFF	+VDC/2	-VDC/2	0
OFF	ON	OFF	ON	-VDC/2	+VDC/2	0

Fig4: Single-phase Full Bridge inverter

III. HARMONICS

3.1 What are harmonic?

Harmonics are voltage and current frequencies riding on top of the normal sinusoidal voltage and current waveforms. Usually these harmonic frequencies are in multiples of the fundamental frequency, which is 60 hertz (Hz) in the U.S. and Canada. The most common source of harmonic distortion is electronic equipment using switch-mode power supplies, such as computers, adjustable-speed drives, and high-efficiency electronic light ballasts[5].

3.2 Problem with harmonic

Any distribution circuit serving modern electronic devices will contain some degree of harmonic frequencies. The harmonics do not always cause problems, but the greater the power drawn by these modern devices or other nonlinear loads, the greater the level of voltage distortion. Potential problems (or symptoms of problems) attributed to harmonics include:

- Malfunction of sensitive equipment
- Random tripping of circuit breakers
- Flickering lights
- Very high neutral currents
- premature failure of transformers and uninterruptible power supplies (UPSs)
- Reduced power factor

3.3 Solution to Harmonics problem

There are two basic choices: to reinforce the distribution system to withstand the harmonics or to install devices to attenuate or remove the harmonics. Second strategies for attenuating harmonics, from cheap to more expensive, include passive harmonic filters, isolation transformers, harmonic mitigating transformers (HMTs), the Harmonic Suppression System (HSS) from Harmonics Ltd, and active filters [5].

3.5 Types of filters involved in harmonic compensation:

Filters are often the most common solution that is used to mitigate harmonics from a power system. Unlike other solutions, filters offer a simpler inexpensive alternative with high benefits. There are three different types of filters each offering their own unique solution to reduce and eliminate harmonics. These harmonic filters are broadly classified into passive, active and hybrid structures. The choice of filter used is dependent upon the nature of the problem and the economic cost associated with implementation [5].

3.5 What is Total Harmonic Distortion?

Total Harmonics distortion is complex and often confusing concept to grasp. However, when broken down into the basic definition of harmonics and distortion, it becomes much easier to understand. Harmonics have frequency that is integral multiple of waveform's fundamental frequency. For example, given a 60Hz fundamental waveform, the 2nd, 3rd, 4th, and 5th, harmonics components will be at 120Hz, 180Hz, 240Hz and 300Hz respectively. This, harmonics distortion is the degree to which a waveform deviates from its pure sinusoidal values as a result of summation of all these harmonic elements. The ideal sine wave has zero harmonic components. In that case, there is nothing to distort this perfect wave.

Total harmonic distortion, or THD, is the summation of harmonics components of the voltage or current waveform compare against the fundamental component of the voltage or current wave:

$$THD = \frac{\sqrt{(V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2)}}{V_1} * 100\%$$

The formula above shows the calculation for THD on a voltage signal. The end result is a percentage comparing the harmonics components to the fundamental component of signal. The higher the percentage, the more distortion that is present on the mains signal.

IV. FILTER

4.1Passive Filters:

Passive filter consisting of a bank of tuned LC filters and/or a high- pass filter have been broadly used to suppress harmonics because of a low initial cost and high efficiency[5][6]. However, passive filters have the following disadvantages:

- Source impedance strongly affects filtering characteristics.
- Parallel resonance between a source and a passive filter cause amplification of harmonic currents on the source side at specific frequencies.

- A passive filter may fall into series resonance with a source so that voltage distortion produces excessive harmonic currents flowing into the passive filter

4.2 Active Filters:-
Active filters use amplifying elements, especially op amps, with resistors and capacitors in their feedback loops, to synthesize the desired filter characteristics. Active filters can have high input impedance, low output impedance, and virtually any arbitrary gain. They are also usually easier to design than passive filters.

4.2.1Advantages of active filter over passive filter:-
1) Active filter do not resonate with the system where as passive filters resonate with system.
2) They can work independently of the system impedance characteristics and therefore they can be used in very difficult circumstances where passive filters cannot operate successfully because of parallel resonance problems [5].
3) They can address more than one harmonic at a time and fight with other power quality problems also
4) They can be programmed to correct harmonics as well as power factor.

4.2.2Disadvantages of Active Filter over Passive Filter:
1) Active filters cost more than the passive filters
2) Active filters cannot be used for small loads in a power system.

V. CONFIGURATIONS

AF's can be classified based on converter type, topology, and the number of phases. The converter type can be either CSI or VSI bridge structure. The topology can be shunt, series, or a combination of both. The third classification is based on the number of phases, such as two-wire (single phase) and three- or four-wire three-phase systems.

5.1 Classification of active filter:-
5.1.1 Shunt active filter:-
The shunt active power filter, with a self controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters compensate load current harmonics by injecting equal but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180º. [3],[7].

- Eliminate Current Harmonics
- Reactive Power Compensation
- Balancing Unbalanced Current

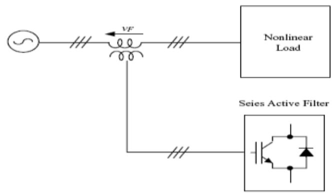


Fig5: Series active filter

5.1.2 Series active filter:-
Series active power filters were introduced by the end of the 1980s and operate mainly as a voltage regulator and as a harmonic isolator between the nonlinear load and the utility system. The series connected filter protects the consumer from an inadequate supply voltage quality. This type of approach is especially recommended for compensation of voltage unbalances and voltage sags from the ac supply and for low power applications and represents economically attractive alternatives to UPS. The series active filter injects a voltage component in series with the supply voltage and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on the load side[3],[7].

- Eliminate voltage Harmonics
- Regulate and Balance the Terminal Voltage
- Damp out Harmonics Propagation[12]

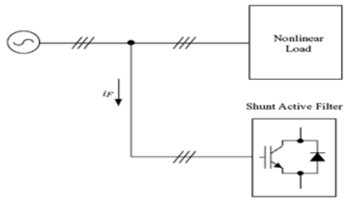


Fig6: Shunt active filter

VI. CONTROL STRATEGIES

Control Strategy is the heart of the APF and is implemented in three stages. In the first stage, the essential voltage and current signals are sensed, to gather accurate system information. In the second stage, compensating commands in the terms of current and voltage levels are derived based on control methods and APF configurations. In the third stage of control the gating signal for the solid-state devices of APF are generated using PWM. Development of compensating signals either in the terms of voltage or currents is the important part of APF control and affects their rating and transients, as well as steady-state performance. The control strategies to generate compensation commands are based on frequency-domain and time-domain correction techniques.

VII. SIMULATION RESULTS

7.1System without active power filter:
In modern electrical system there are various types of load as the system supplies power to the different types of load such as

a. Commercial loads: single phase power supplies, fluorescent lightning, adjustable speed drives.
b. Industrial loads: three phase power converters, DC drives, AC drives, arcing devices, saturable devices [9]-[10].
Due to such sources of harmonics, they produces harmonic distortion which effects the imperative equipment like capacitors, transformer, motors, telecommunication, impact on energy and demand metering[2]. The system without filter in Fig7. has many distortions which are blamed for many power quality disturbances with high frequency component, it increases closer to the load. Mostly harmonics are occurred in a steady state condition and are integer multiple of the frequency.

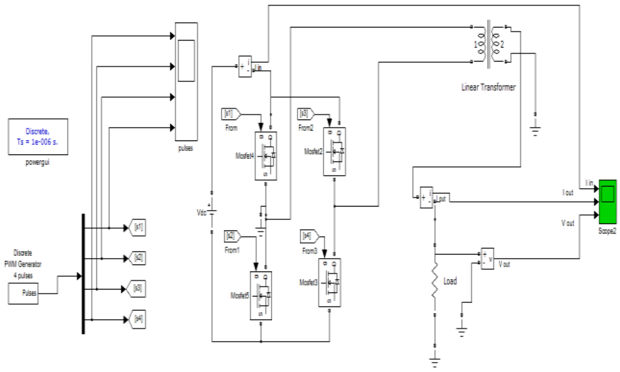


Fig7: Simulation diag. without active power filter.

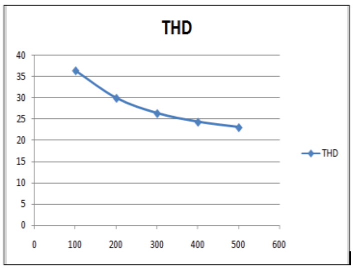


Fig8: THD% Vs Load graph.

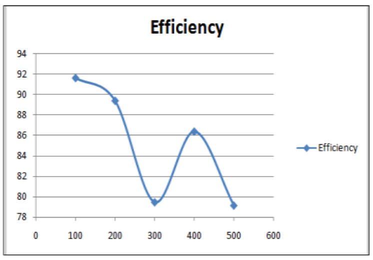


Fig9: Efficiency Vs Load graph.

7.2 System with active power filter:

In single phase power line, by using active power filter, injecting harmonic compensate and thereby reducing THD and improve the power factor. Active filtering of electric power has now become a mature technology for harmonic compensation[9]-[10].

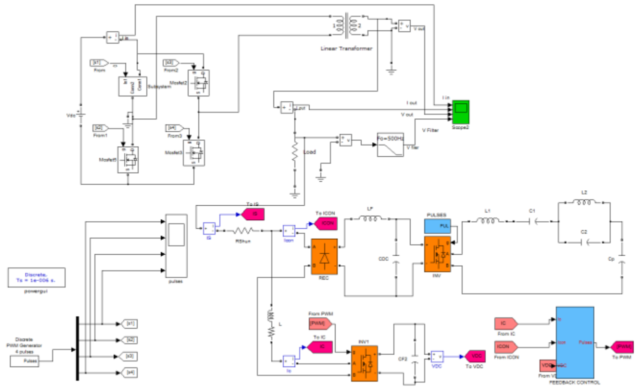


Fig10: Simulation diag. with active power filter.

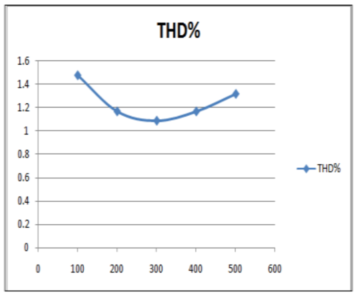


Fig11: THD% Vs Load graph.

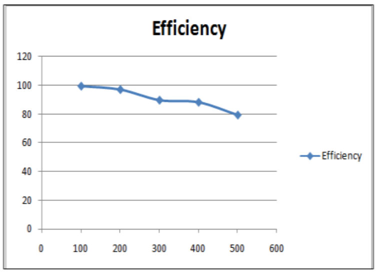


Fig12: Efficiency Vs Load graph.

7.3 Comparative study on Harmonic content before and after Active Filters

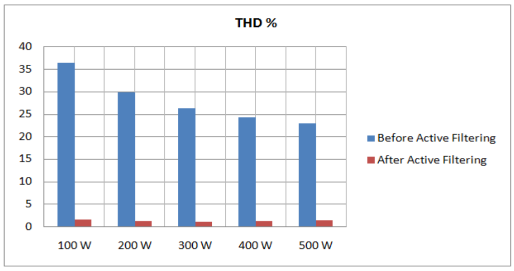


Fig13: Comparative study on THD% before and after Active Filters

VIII. CONCLUSION

A single phase active filter based on control technique is used in this paper. Active filter is found effective in injecting harmonic compensate and thereby reducing THD and improve the power factor of the line. By using Active Filter, Total Harmonics Distortion (THD) present in Inverter is reduced from 36.47% to 1.48%. As result THD compensation achieved successfully in simulation using MATLAB software. It is also noticed that a constant voltage appears across the DC-link capacitor which helps the smooth functioning of the voltage source inverter.

REFERENCES

[1] Hideaki Fujita and Hirofumi Akagi, "A Practical Approach to Harmonic Compensation in power systems – Series Connection of Passive and Active Filters", IEEE transactions on industrial applications , vol. 27, no.6, Nov / Dec-1991.

[2] Giampaolo Buticchi, Luca Consolini, and Emilio Lorenzani, "Active Filter for the Removal of the DC Current Component for Single-Phase Power Lines", IEEE Transactions on power electronics Jan- 2011.

[3] Bhim Singh, Kamal Al-Haddad, "A Review of Active Filters for Power Quality Improvement" IEEE Transaction on industrial electronics, vol. 46, no. 5, october 1999.

[4] Paolo Mattavelli and Fernando Pinhabel Marafão, "Repetitive-Based Control for Selective Harmonic compensation in Active Power Filters", IEEE transactions on industrial electronics, vol. 51, no.5, Oct-2004.

[5] C.Nalini Kiran, Subhransu Sekhar Dash, S. Prema Latha, "A Few Aspects of Power Quality Improvement Using Shunt Active Power Filter", International Journal of Scientific & Engineering Research Volume 2, Issue 5, May-2011

[6] D. Infield, P. Onions, A. Simmons, and G. Simmons, and G. Smith, "Power quality from multiple grid-connected single-phase inverters" IEEE Transaction on Power Delivery, vol. 19, no. 4, pp. 1983-1989, Oct. 2004.

[7] T.kavitaha, k. ratnaraju, "Novel method for power quality improvement using active power filter" International Journal of Computer Trends and Technology- volume3Issue3- 2012

[8] Michael C. Pacis, Jesus M. Martinez Jr., and Jaypee V. Tecson, "Modelling and Simulation of Active Power Filters for Harmonic Compensation, Voltage Sags and Swells Mitigation and Power Factor Correction", Proceedings of the World Congress on Engineering and Computer Science 2010, Vol II WCECS 2010, October 20-22, 2010, San Francisco, USA.

[9] Bhakti I. Chaughule1 , Amit L. Nehete2 , Rupali Shinde3, "Reduction In Harmonic Distortion Of The System Using Active Power Filter In Matlab/Simulink", International Journal of Computational Engineering Research,Vol, 03,Issue, 6.

[10] M. Cirrincione, M. Pucci, G. Vitale, and A. Miraoui, "Current harmonic compensation by a single-phase shunt active power filter controlled by adaptive neural filtering," IEEE Transactions on Industrial Electronics, vol. 56, no. 8, pp. 3128 –3143, Aug. 2009.

[11] Chennai Salim1 and Benchouia Mohamed Toufik2, "Intelligent Controllers for Shunt Active Filter to Compensate Current Harmonics Based on SRF and SCR Control Strategies", International Journal on Electrical Engineering and Informatics - Volume 3, Number 3, 2011.

[12] Anzari M1, Rejil Chandran2 and Arun Kumar R3, "Single-Phase Shunt Active Power Filter Using Indirect Control Method", Advance in Electronic and Electric Engineering ISSN 2231-1297, Volume 3, Number 1 (2013), pp. 81-90 © Research India Publications

[13] Paolo Mattavelli, "A Closed-Loop Selective Harmonic Compensation for Active Filters", IEEE transactions on industrial applications , vol. 37, no.1, Jan /Feb 2001.

[14] P. H. Zope, Ajay Somkuwar, "Design and Simulation of Single phase Z-source inverter for utility interface", International Journal of Electrical Engineering & Technology (IJEET) ISSN 0976-6553 (online), (Sep - Oct 2010), Volume 1, Number 1, pp 114-130.

[15] P. H. Zope, Prashant Sonare, "Simulation and Implementation of control strategy for Z-source inverter in the speed control of Induction Motor", International Journal of Electrical Engineering & Technology (IJEET) ISSN 0976-6553 (online), Volume 3, Issue 1, January- June (2012), pp. 21-30

[16] P. H. Zope, A. J. Patil, Ajay Somkuwar," Performance and Simulation Analysis of Single-Phase Grid Connected PV System Based on Z-Source Inverter", 2010, IEEE Conference PEDES-2010-Power India, Digital Object Identifier: 10.1109/PEDES.2010.5712436, Print ISBN: 978-1-4244-7782-1

[17] P. H. Zope , K. S. Patil, Prashant Sonare, « Development of Single Phase Z-source Inverter Using ARM7 for Speed Control of Induction Motor", Second International Conference on Control, Communication and Power Engineering 2011-CCPE Nov-2011, Proc. published by Springer, V.V. Das and N. Thankachan (Eds.): CIIT 2011, CCIS 250, pp. 440–443, 2011, © Springer-Verlag Berlin Heidelberg 2011.