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Comparison of Different Filters for the Improvement of Power Quality

Authors

Kavya Mittal[1], Ankita Kosti[2]

[1]M.Tech Student, S.R.I.T., Jabalpur (M.P)

Email: *kavyamittal89@gmail.com*

[2]Assistant Professor, Department of Electrical Engineering, Jabalpur (M.P)

Email: *ankitakosti@gmail.com*

Abstract

This paper basically deals with the purpose to increase the reliability of power system and improve the Power Quality (PQ) by using Hybrid Filter which hence also improves the Total Harmonic Distortion (THD) as per IEEE-519 Standard limits. The proposed filter estimates and mitigates the harmonics in power transmission systems because of non-linear loads. So, by using Hybrid Power Filter, THD will be checked and is compared with the THD obtained without using filter. In this paper I will also compare the results of different filters. The Simulation is performed and the results are realized in Simulink / MATLAB environment.

Keywords: *hybrid filter, IEEE- 519 harmonic standard, power quality, total harmonic distortion.*

Introduction

Harmonics are polluting the power distribution system because of the rapid widespread use of non-linear devices such as furnaces, computer power supplies, adjustable speed drives (ASD's) etc in industrial or residential applications. These harmonics not only lead to current and voltage stress but are also responsible for other effects such as capacitor failure, electromagnetic interference and many other more losses and disturbances. IEEE-519 Standard restricts the maximum level of harmonics tolerance of a supply system. For this harmonic compensation, filters are very much essential and widely used. These hence improve the power quality and hence increase the reliability of the distribution system [1]-[4].

The compensation of the harmonics which are disturbing the power quality of a distributed system can be achieved by using various types of filters. Some of these filters which help in the power quality improvement are Passive Filters (PF), Active Power Filters (APF) and hybrid power filters (HPF) [5]. PF and APF possess some advantages and disadvantages, but hybrid active power filters contain their advantages but not their disadvantages.

Passive filter has been used traditionally for the compensation of harmonic distortion due to the harmonic contents in industrial power systems but due to some drawbacks such as dependency of their performance on the system impedance, resonance problem, and absorption of harmonic current of nonlinear load, which will lead to further propagation of harmonics throughout the power system.

Passive filters have been most commonly used to limit the flow of harmonic currents in distribution systems they are usually custom designed for the application. However, their performance is limited to a few harmonics and they can introduce resonance in the power system. The passive filters use reactive storage components, namely capacitors and inductors. Among the more commonly used passive filters are the shunt LC filters and the shunt low pass LC filters. They have some advantages such as simplicity, reliability, efficiency and cost. Among the main disadvantages are the resonances introducing din to the ac supply; the filter effectiveness, which is a function of

overall system configuration; and the tuning and possible detuning issues. These drawbacks are overcome with the use of active power filters.
APFs can be further categorized into two types:

(i) Series APFs and (ii) Shunt APFs.

Series active power filter, is the series connected filter which protects the consumer from the inadequate voltage supply 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, since no energy storage (battery) is necessary and the overall rating of the components is smaller. The series active filter injects voltage component in series with the supply voltage and therefore can be regarded as a controlled voltage source, compensating voltage sags and swells on load side.
Shunt active power filter, with a self controlled dc bus, has 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 by180^{o}
The shunt active filter shown in Fig. is a current controlled voltage source inverter (VSI), which is connected in parallel with the load. It is controlled in such a way to generate the required reactive and harmonic currents of the load. The shunt active filter shown in Fig.1 is a current controlled voltage source inverter (VSI), which is connected in parallel with the load. It is controlled in such a way to generate the required reactive and harmonic currents of the load.
Figure1.shows the connection of a shunt active power filter and Figure2.show the active filter works to compensate the load harmonic currents.

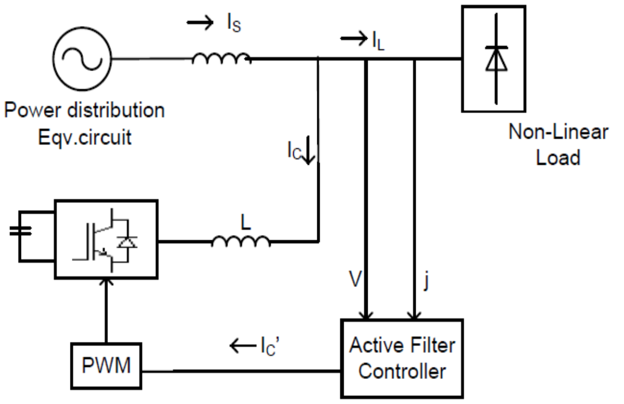

Fig.1. Shunt Active Power Filter Topology

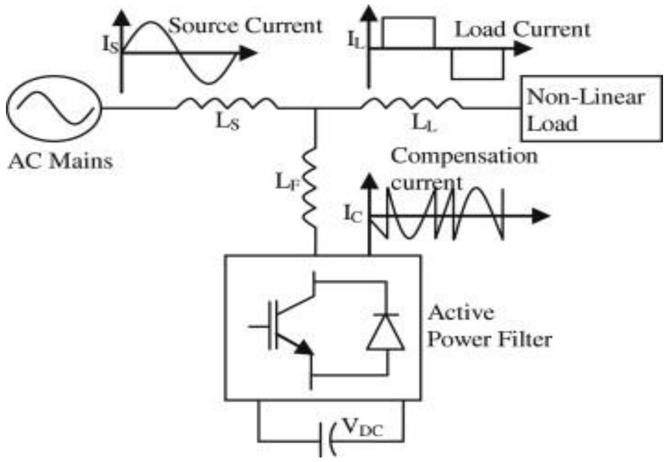

Fig.2. Compensation of load harmonic currents by using Shunt Active Power Filter

But it has also some draw backs like high initial cost and high power losses due to which it limits the rewide application, especially with high power rating system [3]. To minimize these limitations, hybrid power filter have been introduced and implemented in practical system applications. Shunt hybrid filter is consists of an active filter which is connected in series with the passive filter and with a there phase PWM inverter. This filter effective lymitigates the problem of a passive and active filter. It provides cost effective harmonic compensation, particularly for high power nonlinear load [6]. Different control techniques are present for the compensation of the harmonic currents. Some of them are Synchronous Reference Frame (SRF) transformation, instantaneous power (p-q) theory etc where high pass filters (HPFs) are used or extracting harmonic components of the source current from the fundamental components[7].

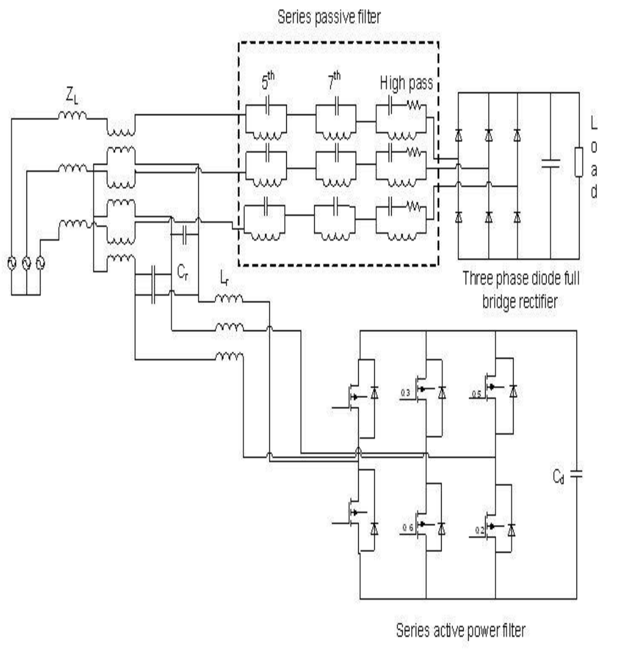

Fig.3. Compensation of load harmonic currents by using Hybrid Active Power Filter

This paper presents the configuration of different types of filters for the power quality improvement. Then different control strategies including *pq* method [8], *dq* method [9] are presented. Final section present simulation results that are conducted in MATLAB/Simulink environment and under various non-ideal mains test scenarios. Then a comparison of the methods is made for various conditions.

2. Extraction Methods of Harmonic Current

A. *Instantaneous Reactive Power Theory (pq Method):*

This method is also known as *pq* method. Most APFshave been designed on the basis of instantaneous reactive power theory or *pq* method for the calculation of the desired compensation current. This theory was first proposed by Akagi and co-workers in 1984 [10].

The p-q theory is based on a set of instantaneous powers defined in the time domain. The three-phase supply voltages (*ua*, *ub*, *uc*) and currents (*ia*, *ib*, *ic*) are transformed using the Clarke (or α-β) transformation into a different coordinate system yielding instantaneous active and reactive power components. This transformation may be viewed as a projection of the three-phase quantities onto a stationary two-axis reference frame.

B. Synchronous ReferenceTheory (d-q Method)

In this method, called also the method of instantaneous currents *id*, *iq*, the load currents aretransformed from three phase frame reference *abc* into synchronous reference in order to separate the harmonic contents from the fundamentals [11]. It gives better performance even in the case where the three phase voltage is not ideal.

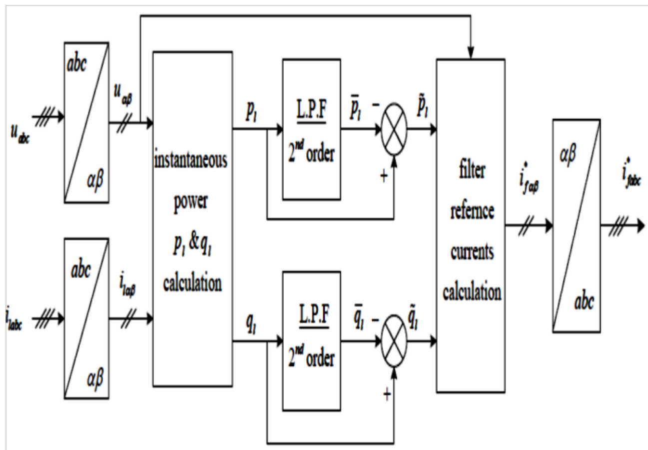

Fig.4. Principle of instantaneous active and reactive power theory.

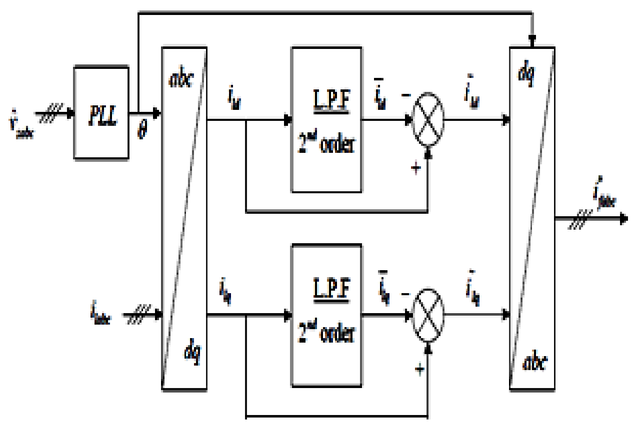

Fig.5. Principle of the synchronous reference method

3. Simulation Response

The proposed system is simulated using MATLAB/ SIMULINK. This section shows some important results for power quality improvement before filter and after filter.

Fig.6. shows the source voltage waveform using PQ method. Figure shows the effect of load variation.

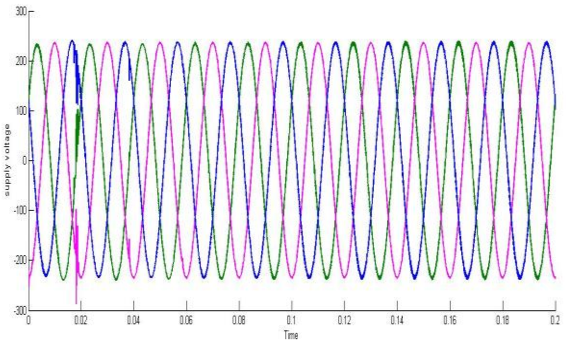

Fig.6. Supply Voltage

Fig.6. shows the source current waveform before filter.

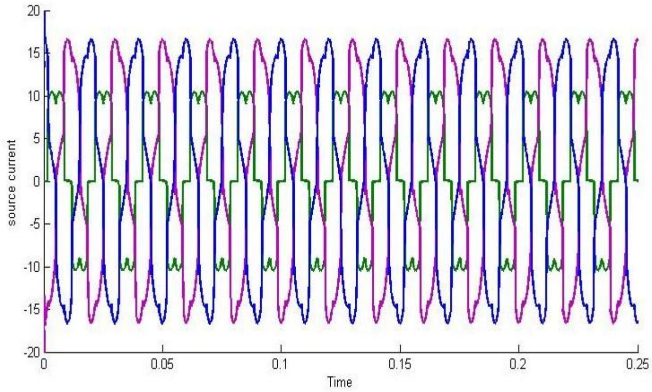

Fig.7. Source Current before Filter

Following figure.8, shows the THD analysis before filter which is found to be many more times as per IEEE-519 standard limits.

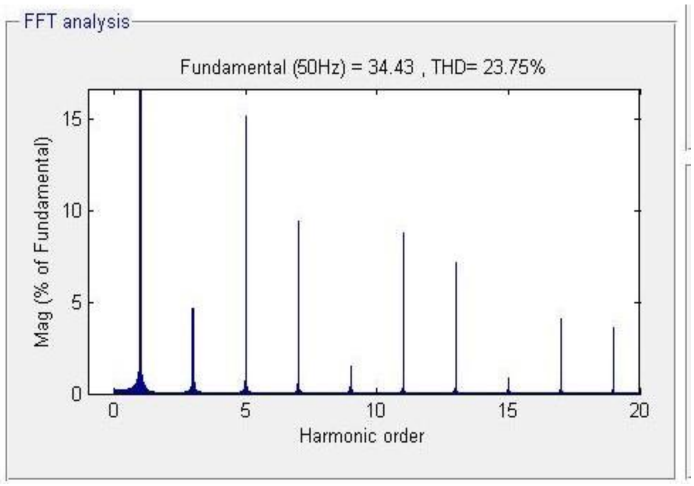

Fig.8. THD of Source Current Before Filter

On applying different filters, the following THD results are realized.

(a) *By using passive filter:*

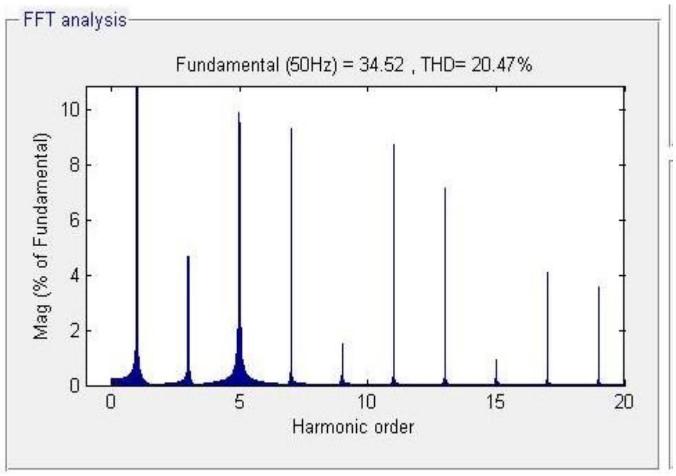

Fig.9. THD of Source Current After using Passive Filter

(b) *By using active filter:*

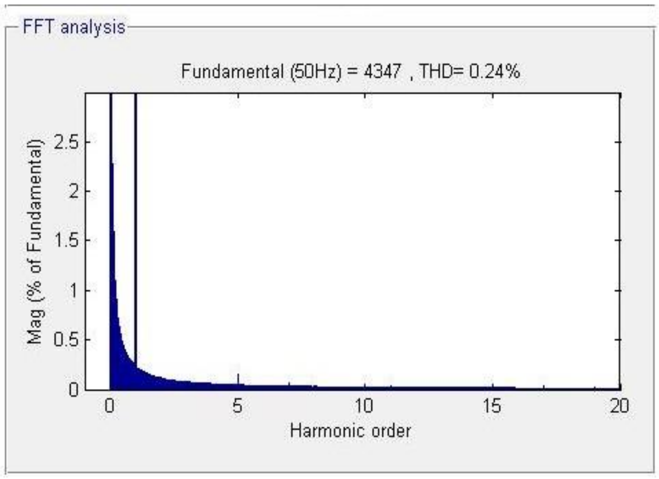

Fig.10. THD of Source Current After using Active Filter

(c) *By using hybrid filter:*

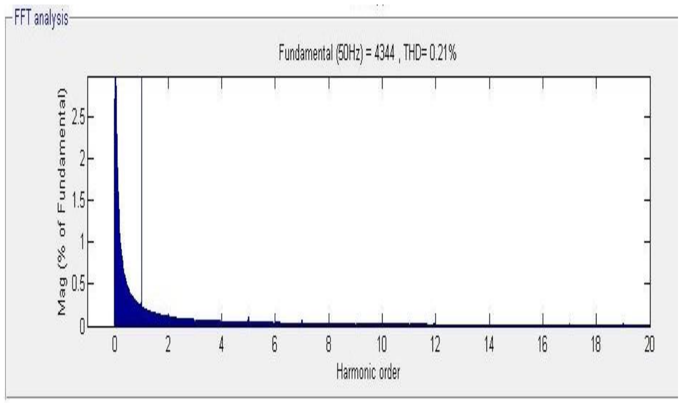

Fig.11. THD of Source Current After using Hybrid Filter

It is clear from the above THD simulation response that the distortion gets minimized after using filters.

4. System Parameters

The details of the parameters used in system are given in Table I.

TABLE. I.

Supply System	Line Voltage (r.m.s. value)	200V
	Line Frequency	50 Hz
	Source inductance, Ls	0.02mH
	AC inductor to the rectifier	0.02mH
Active Filter	V_{dc}(V)	650
	C_{dc}(μF)	1600
	L_c(mH)	5.05
Passive Filter	C_f(μF)	80.2
	L_f(mH)	5.05
Nonlinear load 1	R_L(Ω)	10
	L_L(mH)	10
Nonlinear load 2	R_L(Ω)	10
	L_L(mH)	10

5. Conclusion

In this paper, different types of filters are introduced for the reduction of the load harmonics which further leads to the power quality improvement of a distributed system. On the basis of simulation results performed in MATLAB/Simulink environment, it is concluded that Hybrid Filter gives best response in the minimization of THD over passive filter and active filter. Hence it can be concluded that hybrid filter plays a very important role in power quality improvement.

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