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Comparative Analysis of Harmonic Filter on the Basis of Power Quality Parameters

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Abstract:*Today with the advancement in power electronic domain, the majority of the loads are non-linear in nature. All these kinds of load give rise to the harmonics, which in turn can affect the power quality of the system. To filter out these unwanted harmonics there are various practices carried out through passive, active and hybrid solutions. The choice of the filters depends according to the loads and their requirement. As per necessity, active and passive filters are preferred to fulfill the power quality requirement as per IEEE-519 standard. In this paper, a prototype of single-phase and three-phase passive filter for 4A and 10A harmonic current has been proposed.*

Keywords–*Non-linear, power quality***,** *passive filter, active power filter, IEEE-519 standard*

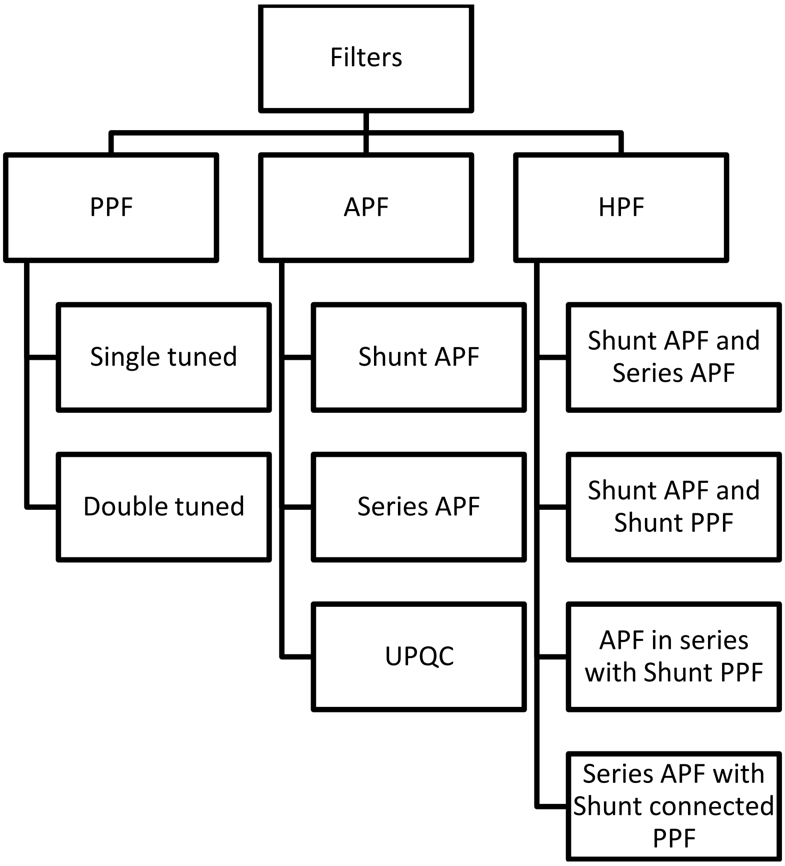
I. Introduction

Recent developments in the power electronics field, there is a huge increase in nonlinear loads in our electricity distribution system. This has increased the value of harmonics present in the system which calls for finding a better solution to mitigate this problem [1]. Power quality (PQ) is basically defined as the analysis, measure and improvement in the voltage to maintain that voltage to be sinusoidal with specified magnitude and frequency as per the requirement [2]. PQ can be analyzed from the source side and is defined as the ability of the generator in generating power at 50 Hz [3]. One of the major PQ issues is the harmonics present in the system. Harmonics are defined as the integral multiple of the fundamental frequency (50Hz/60Hz) [4].Harmonic currents affect supply systems and may create serious problems like a malfunction of equipment, power losses, and resonances. Harmonic currents are caused mostly by the AC to DC conversion, mostly used in both home and industry applications.The solid-state equipment like Variable frequency drive (VFD), Variable speed drive (VSD) generates harmonics by drawing non-sinusoidal current from source. If harmonics are present into the system then they may degrade the system stability. Thus there is a need to reduce the harmonic distortion as per IEEE-519 standard [5]. In order to mitigate these harmonics from the system some mitigation devices like Passive power filters (PPF), Active power filters (HPF), Hybrid power filters (HPF), UPQC, DSTATCOM, and other alternatives have already been developed [6]. The PPF uses passive elements like a capacitor, inductor etc. These are the most economical and robust type of filters.Mostly these filters deal with the harmonics, because of their low initial cost and simplicity. The drawbacks associated with these filters are their fixed compensation characteristics and resonance across source or with load [7]. APF are more complex and costlier as compare to PPF but are in existence as they overcome certain disadvantages of them [8]. HPFis the combination of both APF and PPF and comprises the benefits of both the filters with reduced cost.

PQ is calibrated in scale of frequency deviation, voltage, and current of supply system.Combination of fundamental, third, fifth, and many more harmonics create the deformation of power waveform. The result is non-sinusoidal current and voltage which affect the system.
The PQ issues due to harmonics may lead to the following consequences:

- Elevation of noise, vibration and rotor heating in machines
- Overvoltage through the resonance
- Interference with ripple control system
- De-rating and dielectric breakdown in cables
- Noise on voice frequency telephone lines
- Failure of customer's equipment's

II. Filter Topologies



1) Passive power filter (PPF): The PPF provides a low impedance path to the unwanted harmonics. They are classified as:

- Single tuned PPF
- Double tuned PPF

Single tuned filters are designed to mitigate a single harmonic. These filters are basically used to mitigate lower order harmonics while double tuned filters are designed to mitigate two harmonics for which it is designed. The designing of passive filter is described below:

Designing of single tuned passive filter

The designing criteria for single tuned passive filters include:
The inductive reactance (X_L) is calculated as:

$$X_L = \frac{V_L}{I_L} \quad (1)$$

Where,$V_L = voltage\ across\ inductor$, $I_L = current\ flowing\ through\ inductor$

Then value of inductor (L) is calculated as:

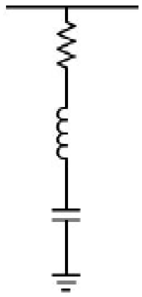
$$L = \frac{X_L}{2 \times \pi \times f} \quad (2)$$

The value of X_L at nth harmonic is given as:

$$X_L = 2 \times \pi \times nf \times L \quad (3)$$

Equating the value of $X_L = X_C$ at nth harmonic
Now finding the value of capacitor (C) for fine tuning of the filter:

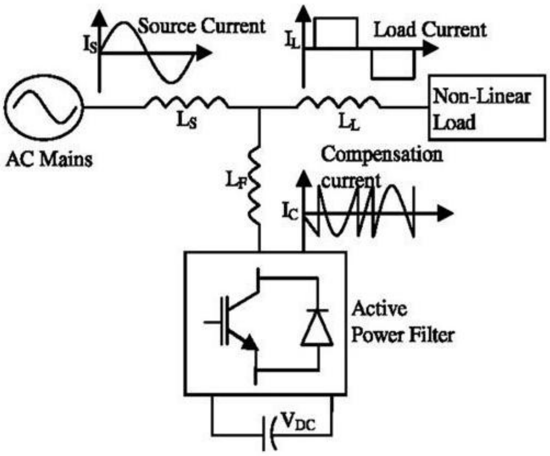
$$C = \frac{1}{2 \times \pi \times nf \times X_C} \quad (4)$$



2) **Active power filter (APF):**PPF has serious drawbacks, namely large parameter tolerance, aging and dependence of the filtering characteristic as a function of the grid impedance. These problems are the main driving forces for the development of APF. The APF is a Voltage Source Inverter (VSI) which injects the compensating current or voltage based on the network configuration. It was proposed around 1970. But the recent advancement in power electronics technology, along with the theory of instantaneous active and reactive power which was presented in 1983, APF's are an up-to-date solution with fast switching devices, low power loss, and fast digital processing devices at an affordable price.

Depending on the circuit configuration and function, APF‟s are divided into three types:-

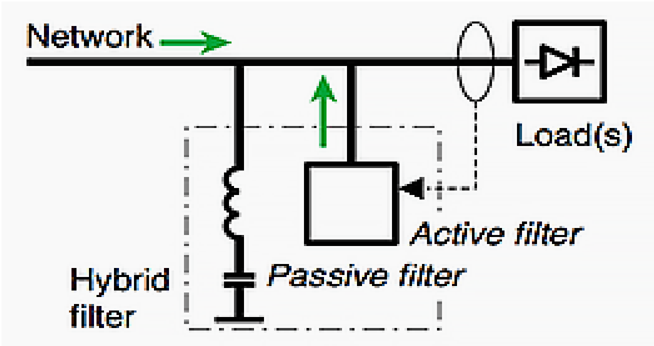
- Shunt Active Power Filter
- Series Active Power Filter
- Unified Power Quality Conditioner (UPQC)



3) Hybrid power filter (HPF):APF mitigate harmonics with much better efficiency and accuracy but require higher converter ratings and their cost is relatively higher than passive filters. This disadvantage excludes them from usage in cost-sensitive applications. To minimize this disadvantage, various types of hybrid topologies were presented and successfully implemented in recent years.The HPF is the combination of both APF and PPF. They have the advantage of both of these. These topologies mitigate the harmonic currents pretty well, while their cost is considerably reduced compared to a pure active power filter solution.

There are different hybrid filters based on the circuit combination and arrangement. They are-

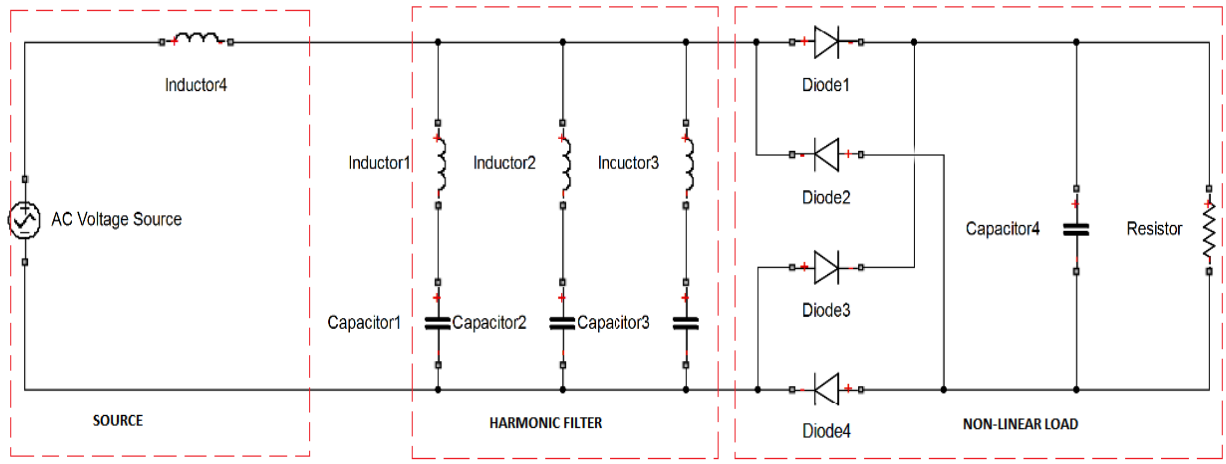
- Shunt Active Power Filter and Series Active Power Filter
- Shunt Active Power Filter and Shunt Passive Filter
- Active Power Filter in series with Shunt Passive Filter
- Series Active Power Filter with Shunt Passive Filter



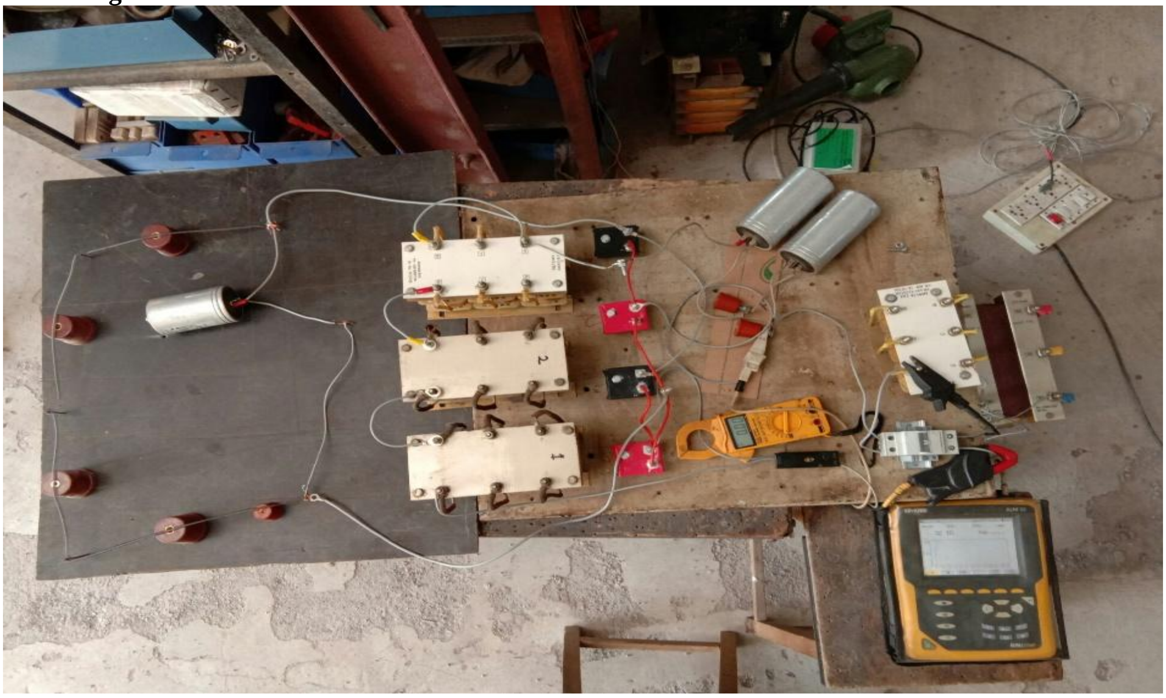
III. Practical implementation of single tuned PPF

For designing any type of filter requires a detailed harmonic analysis report. For developing this prototype A KRYKARD ALM-32 Power Quality Analyzer has been used. The measurements are taken at the intervals of 20secs. Then data is analyzed on the basis of the percentage of each harmonic frequency in the power supply waveform. The percentage of harmonics is verified with the IEEE-519 standard. The harmonics which exceed the standard are targeted for bringing it to the permissible level. To generate required harmonics at the load side, a capacitor, and a resistor used in parallel. To design passive filter, first of all, a suitable inductor is selected then inductive reactance is compared with capacitive reactance at the tuned harmonic frequency which needs to be eliminated. Thus the rating of the capacitor is obtained and selected. This capacitor is connected in series with the inductor to form a passive filter. The passive filter is connected across the phase and neutral. Inductors are added in series with phase line to increase the source impedance and to divert the harmonics to low impedance path offered by a passive filter. Final measurements are taken to verify the elimination of harmonics and until the harmonics are obtained under the permissible levels, the above parameters of passive elements are varied.

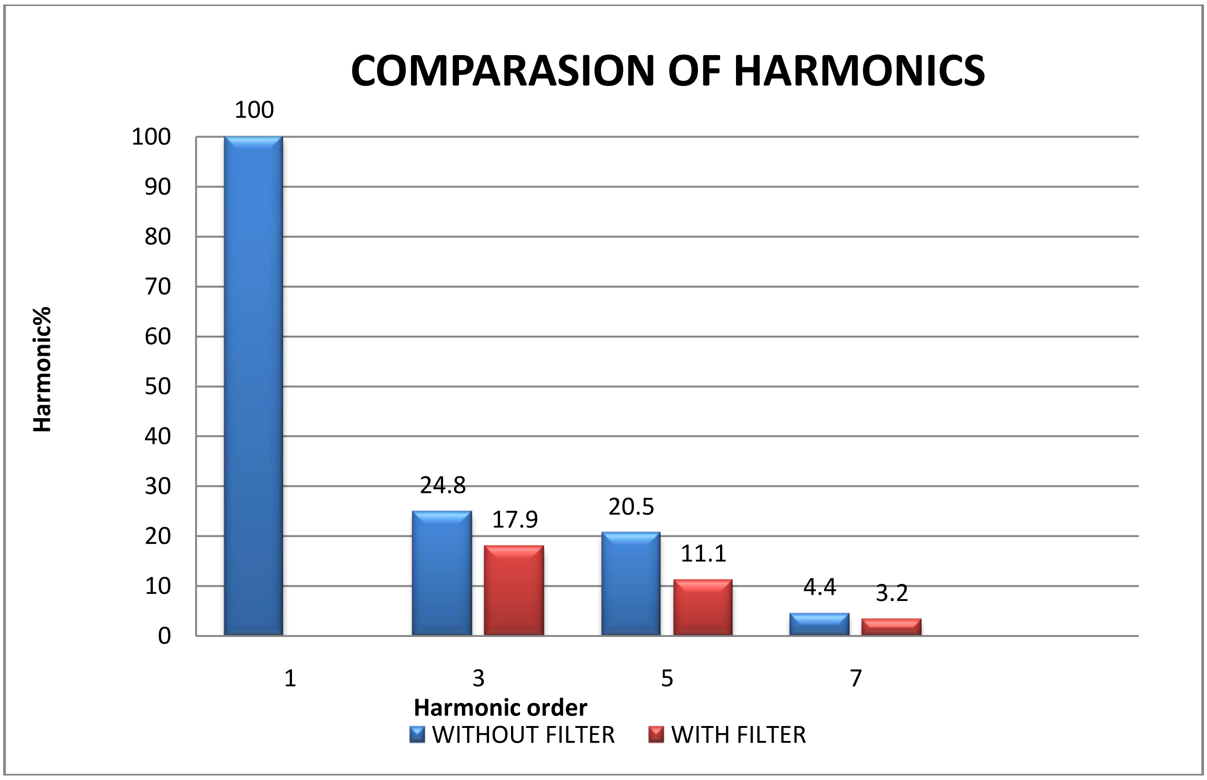
Line Diagram



Circuit Diagram



IV. Results



V. Conclusion

In this paper comparative analysis of various harmonic filters are done on the basis of power quality parameters. It reveals that in case of transients, passive filters are not suitable in which case active filters are found to be suitable. High voltage rating active filter is not economic which is thus replaced by passive filters. In order to obtain desired harmonic elimination, the best solution is the use of hybrid power filters which is a combination of the passive and active power filter. Hybrid power filter overcomes the demerits of passive power filter as well as an active power filter. Hence the hybrid power filter is dominant over the other harmonic power filters.

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