# A Review Paper on Power Quality Improvement by Harmonics Reduction Using Shunt Active Power Filter With p-q & d-q Current Control Strategy

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***Abstract:*** With the widespread use of power electronics devices such as rectifier, inverter etc. in power system causes serious problem relating to power quality. One of such problem is generation of current and voltage harmonics causing distortion of load waveform, voltage fluctuation, voltage dip, heating of equipment etc. Also presence of non-linear loads such as UPS, SMPS, speed drives etc. causes the generation of current harmonics in power system. They draw reactive power components of current from the AC mains, hence causing disturbance in supply current waveform. Thus to avoid the consequences of harmonics we have to compensate the harmonic component in power utility system. Among various method used, one of the effective method to reduce harmonic in power system is the use of Shunt Active Power Filter (SAPF). This Paper gives detail performance analysis of SAPF under two current control strategy namely, instantaneous active and reactive power theory (p-q) and synchronous frame reference theory (d-q) and their comparative analysis to justify one of the method better over other. In both method a reference current is generated for the filter which compensate either reactive power or harmonic current component in power system. In this paper, a current controller known harmonic current controller is described which is used provide corrective gating sequence of the IGBT inverter and thus helps to remove harmonics component.

***Keywords**: Shunt Active Power Filter (SAPF), Harmonics, Active Filter, passive Filter.*

## I. INTRODUCTION

Power electronic switching device in conjunction with nonlinear loads causes serious harmonic problem in power system due to their inherent property of drawing harmonic current and reactive power from AC supply mains. They cause voltage unbalance and neutral currents problem in power system. With the distortion of current and voltage waveform due to presence of harmonic effect the power system equipment that are connected to maintain steady and reliable power flow in the power system. Major effects include overheating, capacitor failure, vibration, resonance problem, low power factor, overloading, communication interference and power fluctuation. Thus to improve the performance it is required to eliminate harmonics from power utility system [1]. One of the method used for elimination is the use of shunt active power filter (SAPF) in which a reference current is generated to remove distortion from the harmonic currents. Shunt active power filter continuously monitor the harmonics current and reactive power flow in the network and generate reference current from distorted current waveform. Thus dynamic closed loop action of SAPF helps the reduction of harmonics and compensation of reactive power in real time basis with little time delay. SAPF can be used with different current control strategy such as d-q method, fuzzy logic controller, p-q method, neural networks etc. which is helpful in removing effective harmonic from power system. Harmonic pollution is mostly common in low voltage side due to wide use of nonlinear loads (UPS, SMPS, Rectifier etc.), which is undesirable as it cause serious voltage fluctuation and voltage dip in power system. So it required to eliminate undesirable current and voltage harmonics and to compensate the reactive power to improve the performance and operation of the power system. The use of traditional passive filter in removing harmonics is not that much effective because their static action and no real time action or dynamic action is taken for the removal of harmonics. But the shunt active power filter on the other hand gives promising results when compared with conventional active and passive filters. This project basically shows the comparison between two current control strategy [8] i.e. synchronous frame reference method and instantaneous active-reactive power method

## II. LITERATURE REVIEW

### [1] Shunt Active Power Filter

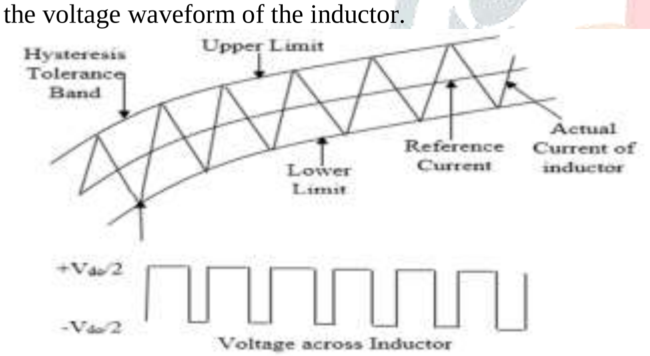
As the name portrays the shunt dynamic force channel (SAPF) are associated in corresponding to the force framework network any place a wellspring of symphonious is available. Its primary capacity is to counteract the consonant or non-sinusoidal current produce because of essence of nonlinear burden in the force framework by creating a current equivalent to the symphonious current however off inverse stage for example with 180o stage shift w.r.t to the consonant current. For the most part SAPF utilizes a current controlled voltage source inverter (IGBT inverter) which creates repaying current (ic) to remunerate the symphonious segment of the heap line current and to keep source current waveform sinusoidal. Compensating harmonic current in SAPF can be generated by using different current control strategy to increase the performance of the system by mitigating current harmonics present in the load current.

**[2] Instantaneous Real and Reactive Power Theory (p-q method).**

This theory takes into account the instantaneous reactive power arises from the oscillation of power between source and load and it is applicable for sinusoidal balanced/unbalanced voltage but fails for non-sinusoidal voltage waveform. It basically 3 phase system as a single unit and performs Clarke's transformation (a-b-c coordinates to the α-β-0 coordinates) over load current and voltage to obtain a compensating current in the system by evaluating instantaneous active and reactive power of the network system.

**[3] Hysteresis Current Controller.**

Hysteresis current control method is used to provide the accurate gating pulse and sequence to the IGBT inverter by comparing the current error signal with the given hysteresis band. As seen in figure the error signal is fed to the hysteresis band comparator where it is compared with hysteresis band, the output signal of the comparator is then passed through the active power filter to generate the desired compensating current that follow the reference current waveform.
Asynchronous control of inverter switches causes the current of inductor to vary between the given hysteresis band, where it is continuously compare with the error signal, hence ramping action of the current takes place. This method is used because of its robustness, excellent dynamic action which is not possible while using other type of comparators.
Switching frequency can be easily determined by looking at the voltage waveform of the inductor.




The voltage across inductor depends on gating sequence/gating pulse of IGBT inverter which is again dependent on the current error signal of the hysteresis controller. Variable frequency can be obtained by adjusting the width of the hysteresis tolerance band.

**[4] Synchronous Reference Frame theory (d-q method)**

Another method to separate the harmonic components from the fundamental components is by generating reference frame current by using synchronous reference theory. In synchronous reference theory park transformation is carried out to transformed three load current into synchronous reference current to eliminate the harmonics in source current. The main advantage of this method is that it take only load current under consideration for generating reference current and hence independent on source current and voltage distortion. A separate PLL block it used for maintaining synchronism between reference and voltage for better performance of the system. Since instantaneous action is not taking place in this method so the method is little bit slow than p-q method for detection and elimination of harmonics.

**[5] Harmonics.**

Total Harmonic Distortion (THD) is a measure of the effective value of the distorted sinusoidal waveform's harmonic components. Normally, total harmonic distortion is used to relate with voltage harmonic distortion. However, total harmonic distortion is also used to calculate current harmonic distortion in a power system . The following equation is used to measure and calculate THD in a power system:

$$\text{THD} = \sqrt{\frac{\sum_{h2}^{\infty} M_h^2}{M1}}$$

Where:
Mh : Individual harmonic component
M1 : Fundamental component
M : Be either current or voltage

**[6] Source of Harmonics**

Harmonics are usually defined as periodic steady state distortions or deterioration of original voltage and/or current waveforms in power systems where frequency of harmonic wave is an integral multiple of fundamental frequency. Major sources of voltage and current harmonic generation in power system are

- Controlling action of power electronic devices such as chopper, inverter etc. cause imbalance in power system leading to harmonic generation.
- Non-linear load such as UPS, SMPS, battery charger.
- Power electronic converter such as high-voltage direct-current power converters, traction and power converters, wind and solar-powered dc/ac converters etc. [5] cause harmonic generation owing to their energy conversion and controlling action.
- Heating material in ac/dc converters acts as a nonlinear load whose controlling action produces harmonics [5] due to inherent property of high reactive power requirement.

**[7] Effect of Harmonics**

Harmonics may cause interference and disturbance in power systems network. Some of the major problems include:

- Harmonic currents present in the power system causes heating of equipment, such as transformers and generators and give huge copper loss.
- In generators owing to multiple zero crossings of distorted current waveform causes voltage instability and voltage fluctuation.
- Since frequency of harmonic current is different from that of fundamental may cause improper breaker and switch operation which is undesirable.

**[8] Harmonic Mitigation Techniques**

Harmonic elimination techniques are used to improve the power system performance with some objectives

- To improve the system power factor and to compensate the reactive power.
- To maintain a particular THD limit in current harmonic distribution.
- Hence various devices and equipment serves the purpose of harmonic elimination from power system. Some of widely used equipment are:

- Line reactors (Inductive reactor)
- Isolation transformers (provide isolation of high power circuit from low power circuit)
- K-Factor or harmonic mitigating transformers
- Phase shifting transformer
- Harmonic filters

But mostly current harmonic filters are used to reduce current harmonics in power system. There are generally two types of harmonic filters are present: i) passive filter and ii) active filters.

**[9] Passive Filter**

It is a combination of series/parallel connection of passive elements such as capacitors, inductors and/or resistor. They provide a low resistance path for the harmonic current to flow owing to the formation of resonance at that particular harmonic frequency. Hence harmonic current is diverted through passive filter network and system current becomes distortion free. Likewise distortion in voltage waveform is also removed. For bypassing the current effective means of connection is connecting the passive filter in parallel with the load. In order to improve power factor passive filters are designed as capacitive filter so that it correct the current displacement factor and provide reactive power to the load.

Different variety of passive filters such as single tuned, double tuned, high pass and c-type filters are used for harmonic mitigation purpose but among them most commonly used filter is single tuned filter. It comprises of series combination of inductor and capacitor which provide low impedance for tuned harmonics while resonating at tuning frequency.

**[10] Advantages of Passive Filters**

Although passive filters doesn't eliminate harmonics to a greater extent yet it is used due to some prominent features which are described as under:

- They are simpler to configure and construct.
- Low initial & maintenance cost (compared to APF)
- Shunt passive filters of capacitive nature provide reactive power to the nonlinear load and on the other hand improve power factor by improving current displacement factor.
- Lowering of THD in line current to a permissible limit can be possible by use of passive filter.

**[11] Active Filter**

An active filter consists of serial/parallel array of arrangement of both active and passive components and it is a type of analog electronic filter. Basic building block of active filter are Amplifiers. Thus filter performance and response is improved by the use of amplifiers instead of inductors that are used in passive filter for the same purpose. Active filter have dynamic response and thus can remove current distortion, current harmonics etc. faster than passive filter. It can also be used for reactive power compensation and also for voltage based distortions such as flickering, voltage dip, unbalancing. It uses PWM techniques to remove load unbalancing and neutral shifting problems. There is no possibility of resonating condition as tuning of frequency isn't taking place in active filtering, so the power system network remain more stable during operation. Unlike passive filter, there performance doesn't depends on system parameters and its topology.

**[12] Operation of Active Filters.**Active Filter generate compensating current signal by continuously monitoring the load current with the help of some algorithm such as p-q theory, d-q transform, sliding mode control, DSP based algorithm etc. Now the generated compensating current is used to generate the switching pulse and switching sequence of IGBT inverter with the help of hysteresis controller or any other type of current controller. The inverter then generate the required harmonic current for the load through charging and discharging of DC link capacitor and injected into the system through coupling transformer with a phase difference to compensate the reactive power coming from the AC mains.

Major types of Active filters are: i) Series AF, ii) Shunt AF and iii) Hybrid AF.

**[13]Advantages of Active Filters**

- Widely compensated the THD in source current waveform.
- Only a single filter can be able to eliminate all the unwanted harmonics.
- Resonance condition is absent which increase the stability of power system.
- Filter characteristics changes with load variation due to dynamic response of the filter.

**[14]Instantaneous Power Calculation.**
The crucial part of SAPF which calculates the compensation currents. These currents are calculates using "P-Q theory. This Constant power control strategy was the first strategy developed for Active power filters by Akagi et al. in 1983.This theory uses Clarke's transformation which consists of real matrix that transform three phase 'V' or 'I' into αβγ stationary reference frames.

## V. CONCLUSION

After study it is also seen, that harmonic is compensated to a greater extent while using d-q control strategy instead of p-q i.e. the THD of source current is almost reduces by half while using the d-q method. Since gate driver card and data acquisition card is not available, we are unable to complete the experimental setup and validate the result coming from simulation. In future it is possible to find a better way than d-q current control method to eliminate harmonics in power utility system with maintaining reliability and stability of the system by using PWM based current controller.

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