

Single Phase Active Harmonic Filters for Harmonic Elimination

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Abstract: With advancement in technology, there has been an increase in usage of power electronic converters/loads for various industrial applications and process automation. Power electronic loads inject harmonic currents into the utility causing overheating of power transformers and neutral wires, unpredictable performance of protection systems etc. In addition, electric resonances in such loads can also cause other undesirable phenomena like voltage fluctuations, radio frequency interference (RFI) etc. To mitigate these undesirable effects, a new generation of power electronics converter (Active Filters) is being considered. Technical review of recent trends in the area of active filters is presented in this paper. Finally, this paper discusses the trends in the design of active filters and the factors affecting them.

Keywords: Harmonics, Active filter, multilevel inverter, series and hybrid filters

1. Introduction

Technology advancement in last three decades has led to increase in usage for power electronic converters for various industrial, commercial and residential applications [1]-[4]. These static converters draw non sinusoidal currents and hence polluting the utility supply due to the characteristics and non-characteristic harmonics generated by them. Harmonics have adverse effect on the power system network and result in

- ∞ Overheating of neutral conductors, bus bar, lug connections, motor control and switchgear, which may affect current interrupting capabilities
- ∞ Circuit breaker nuisance tripping, malfunction of on-board breaker electronics, excessive arcing, improper fuse operation or nuisance blown fuse interruption (artificial heating, or “skin effect”)
- ∞ AC motor torque pulsation, voltage sags, notching; DC adjustable speed drives creating high inrush currents

- ∞ Overheating in transformers and cable systems, insulation (dielectric) breakdown
- ∞ Power factor capacitors becoming overloaded, potential for resonance conditions
- ∞ Meter, protective relaying, control and other communication and measurement instrumentation devices (including ground fault detection and digital displays) malfunctioning or providing a faulty reading, mal operation of electronic components and other equipment [5]-[7]
- ∞ Lifespan of equipment may reduced, potential for premature failure, downtime increased, higher maintenance costs, increase for potential loss of specific production line or process, interruption in operations, or catastrophic loss.

The standard regulations, like the IEEE 519 limits the harmonics at the service entrance, enforce to limit the harmonic pollution.

Passive filters are classical solution to the harmonics and poor power factor problem. Passive filters are also known for their large sizes, resonance problems at other than tuned frequencies, poor performance with variation in input frequency etc. Although passive filters are cost effective solutions but still its disadvantages limits its usage for specific applications [8]. A unity power factor topology is a better solution compared to passive filter but it also has its own limitation for application in telecom applications, wherein multiple loads are connected on same bus.

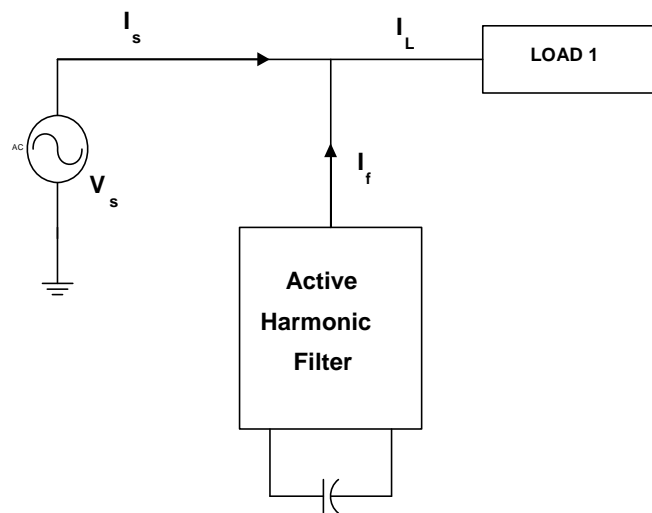


Fig 1. Shunt Active Power Filter block diagram

A shunt active filter shown in figure 1 below is an alternate solution to mitigate harmonics generated by the non linear loads. Along with elimination of harmonics,

this APF also provides reactive support to the system, hence improving the system power factor.

Three phase active filters are thoroughly studied and are popular solutions to nonlinear load problems. The principles of active filtering techniques [9]-[13] were proposed in 1970's but it took almost a decade to practically implement active filter as a solution to avoid harmonic contamination. Today various active filter topologies [14]-[20], with different control schemes are available depending on the type of problem. It is generally found that single phase loads pollute the bus more compared to the three phase bus. Triplen harmonics are also generated due to these single phase loads. Limiting standards for harmonics viz IEEE 519 and also the Utilities emphasize on the elimination of harmonics at the point of common coupling (PCC) as shown in fig 2 and recommend the connection of active filter at PCC.

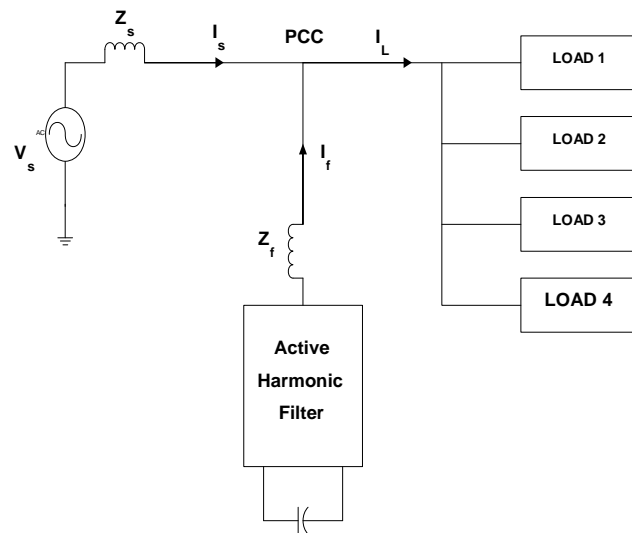


Fig 2. Three phase shunt active filter connected as per IEEE 519

This means that the harmonics flows within the power system network still even if it is mitigated at PCC. This may affect the neutral conductors and other critical loads. For the developed and always growing IT industry, tool making industries, small scale engineering industries most of all the loads are single phase in nature. They may be feeder supplying a network of computers or single phase drives. These nonlinear loads are major culprit of generating harmonics and poor power factor. This paper proposes a simple technique for elimination of harmonics at these low levels.

2. Methodology

There are two possible approaches for single phase AHF for use in system. They are:

- A) Usage of one AHF for each harmonic generating load. The rating of such a system will be very less and hence the advantages of using high switching frequencies can be gained that lead to high performance with compact models. Flow of harmonics in the system is stopped and hence the chance of interference of harmonics with other loads is nullified. **Figure 3a** shows usage of individual single phase AHF. However it is not commercially viable solution to use individual AHF per load.
- B) **Figure 3b** shows a commercially viable solution that is practically possible also. Fig. 3 shows multiple single phase feeders connected to three phase source. A single AHF can be used per feeder to compensate for harmonics and reactive power. The rating of AHF can be reasonable and the advantage here is that if one feeder AHF fails still the % THD increase or effect on system PF is not significant. Also the Harmonic currents are confined to one feeder only to overall performance of system is improved.

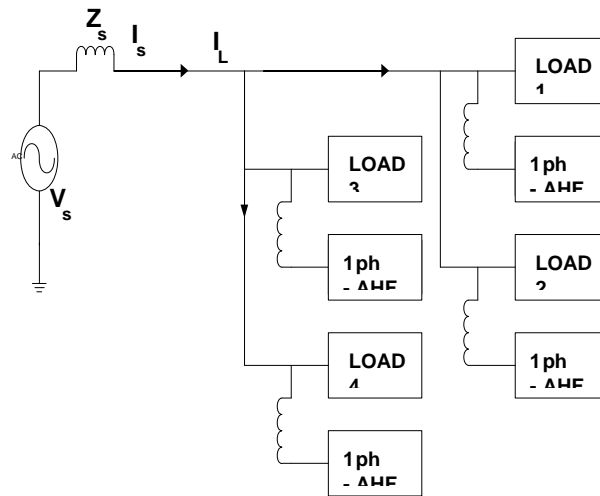


Fig 3a. Single-phase shunt active filter used for individual load

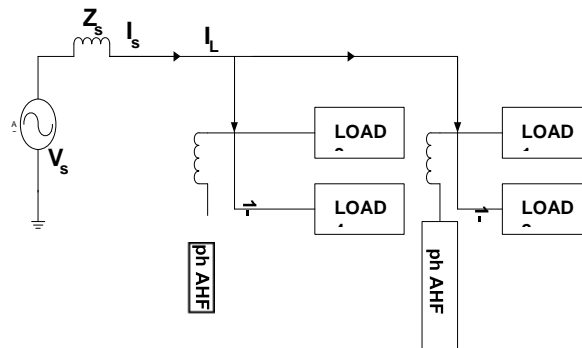


Fig 3b. Single-phase shunt active filter used for small feeders

The single phase active filter has been studied and designed for feeder level applications. The rating of single phase AHF developed range from 10 kVA for distributed computer loads for IT centers and to 5 to 25 kVA for industrial applications.

3. Control scheme for Single Phase AHF

IGBT based full bridge voltage source inverter with a DC capacitor and a coupling inductor is used as single phase active power filter. **Fig 4** shows a single phase active power filter connected in shunt to AC mains. For the calculation of reactive and harmonic components of the AC mains current, the load current is sensed using a current transformer.

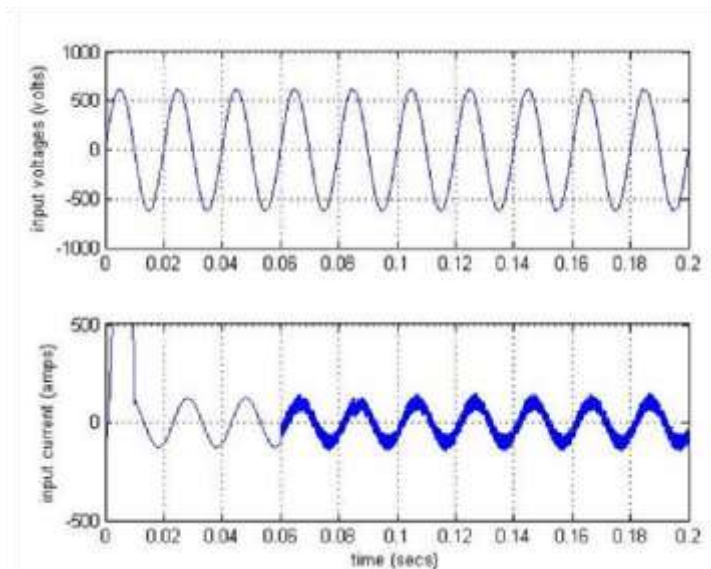


Fig 7. Source Voltage and current waveforms for lagging loads

4. Conclusion

In this paper a single-phase active power filter employed to correct the power factor of groups of loads is presented. The full-bridge voltage source inverter controlled through the sensor of the AC load current is used as the active filter. Sine multiplication theory is implemented using microcontroller. Theoretical analysis results of the active filter compensating for a group of loads validates the analysis. The main characteristics of the presented active filter are: the employed control technique is very simple and easy to implement, the AHF is able to compensate for the fundamental load current phase displacement and the load current harmonic distortion, a high power factor is achieved. Though the proposed control technique has a drawback of slow initial response time

i.e. one cycle for start of compensation but it is very efficient, cost effective and simple to implement for small distributed networks.

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