



Active Filters: A Review

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ABSTRACT

Passive filters have some drawbacks which make them undesirable, such drawbacks include resonating with the system impedance, bulkiness in size, heavyweight, sensitiveness to variation of system parameters and fixed harmonic compensation among others. Active filters or active harmonic Filters (in full) overcome the shortcomings of passive filters and as such are generally preferred over their passive counterparts. This paper discusses active filters and their classifications as well as applications.

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INTRODUCTION

Active Filters, sometimes referred to as active power filters, are also called active power line conditioners, active power quality conditioners, and sometimes self-commutated Static Var Compensators (SVCs), Active harmonic filters (Akagi, 2005), etc. The active filter is a general name applied to a group of power electronic circuits that utilize power switching devices and energy storage circuits which are passive, such as inductors and capacitors (El-Habrouk *et al.*, 2000). They are generally designed to eliminate harmonics in the power system. They can mitigate second (2nd) to fiftieth (50th) order harmonics, in some cases even higher, reducing the THD value to less than 5% as required by IEEE standard 519 of 2014 (Kalair *et al.*, 2017). They are generally preferred to their passive counterparts, this is because of the drawbacks of the passive filters such as bulkiness, weightiness, mistuning, etc. (Musa *et al.*, 2017; Saribulut *et al.*, 2011; Hussien & Pinkal, 2014).

Active filters over the past half-century have evolved, having different configurations, numerous strategies of control as well as a variety of solid-state devices. The numerous uses of active filters include elimination or mitigation of voltage and current harmonics, regulation of terminal voltage, voltage flicker suppression etc. The aforementioned uses can be achieved either singly or in combination, which depends on control strategy, configuration and requirements that have to be selected appropriately (Singh *et al.*, 1999).

ACTIVE FILTER TYPES

Active filters can be classified under three headings namely; type of converter, topology and according to phases (Singh *et al.*, 1999)

CONVERTER TYPE

Active filters are classified based on converter type into two; Voltage Source and Current Source.

Voltage Source Inverter

Voltage Source Inverter (VSI) utilizes a capacitor for storage of DC at the converter DC side (Zouidi *et al.*, 2006; Akagi, 1994) as seen in Figure 1, the pulse width modulation (PWM) bridge is made of six switches, which are all controllable and made of Insulated Gate Bipolar Transistors (IGBTs), each switch has a diode in anti-parallel for reverse voltage blocking

(Routimo *et al.*, 2007). Generally, the two types of inverters i.e. voltage and current source are alike to power circuits utilized in AC motor drives. They differ though in the sense that these two (current source and voltage source) are used in active filters and act as a source of non-sinusoidal voltage or current as the case may be (Akagi, 2005; Massoud *et al.*, 2004). Figure 1 shows a voltage source inverter

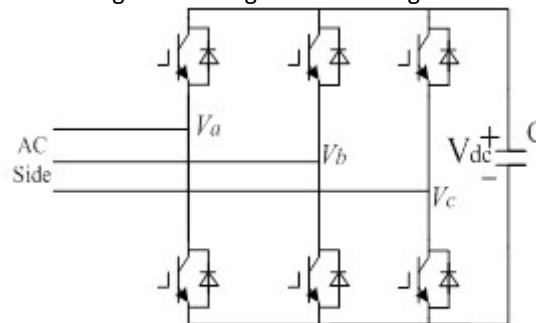


Figure 1: Voltage Source Inverter

Voltage source inverters are preferred and used more than current source inverters because they are higher in terms of efficiency, cheaper in terms of cost and smaller in terms of size (Akagi, 1994), particularly referring to the DC link capacitor used in VSI, and the DC inductor used in the CSI (Akagi, 2005; Saribulut *et al.*, 2011). The DC link voltage used for a 400V mains is mostly 700-750V (Routimo *et al.*, 2007).

Another advantage of VSI over CSI is that the IGBT modules available in the market have a diode in them inherently, with anti-parallel connection, meaning IGBT in itself does not require to provide reverse capability blocking on its own, hence more flexibility in device design, while for CSI, there is a need for connecting a reverse blocking diode in series with the traditional IGBT (Akagi, 2005).

In VSI, the DC voltage of the storage capacitor has to be larger than the

peak supply voltage, at least 1.5 times to be exact, moreover, the DC link capacitor should be sufficiently large to ensure limiting of the DC link voltage ripple (Vardar, 2011).

Current Source Inverter

Current Source Inverter (CSI) unlike the VSI, has a diode placed in series with each IGBT, being a unidirectional switch for reverse voltage blocking (Zouidi *et al.*, 2006). CSI acts as a source of non-sinusoidal current to meet the requirement of harmonic current for a nonlinear load (Singh *et al.*, 1999; Massoud *et al.*, 2004). It is equipped with a DC inductor for energy storage at AC side of the converter. Since a series diode is needed with every IGBT switch for reverse voltage blocking, this leads to more complicated design and fabrication (Akagi, 2005).

It should be ensured that the inductor DC should be greater than or at least equals

the compensating current's peak value.

Figure 2 shows a current source inverter.

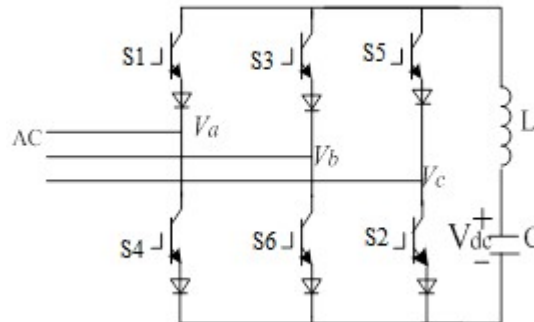


Figure 2: Current Source Inverter

Number of Phases

Active filters are classified into three under the heading, which is two-wire and three-wire active filters (Singh *et al*).

Two-wire active filters

This is a single-phase classification which consists of only a live wire and the

neutral. It could be used for shunt, series and heating, which is two-wire and four-wire active filters (Singh *et al*). It can also be used independent of the source for the inverter, be it voltage source or current source. A typical example is shown in Figure 3

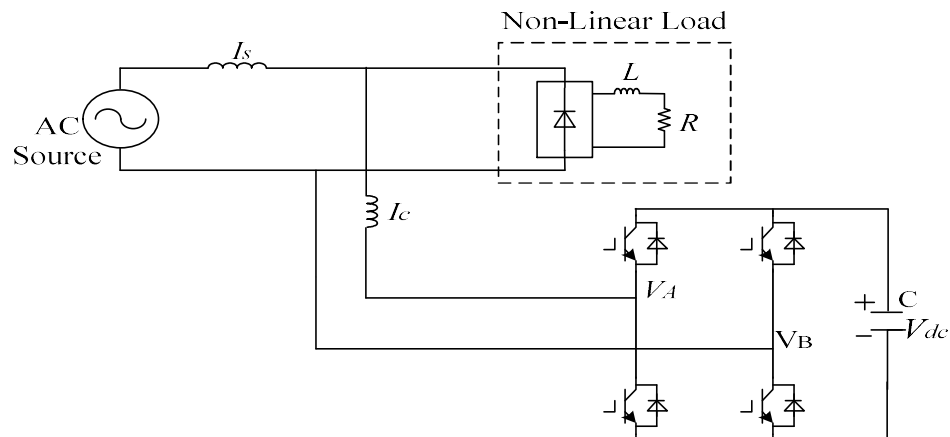


Figure 3: Two Wire Active Filter

Three-Wire Active Filters

These utilize all three live wires without a neutral. Solid-state power converters find many applications in three-phase, a three-wire system of nonlinear

loads, like adjustable speed drives (ASDs), for which of late, many ASDs incorporate in their designs, active filters, in their front end designs. Figure 4 shows a three-wire active filter.

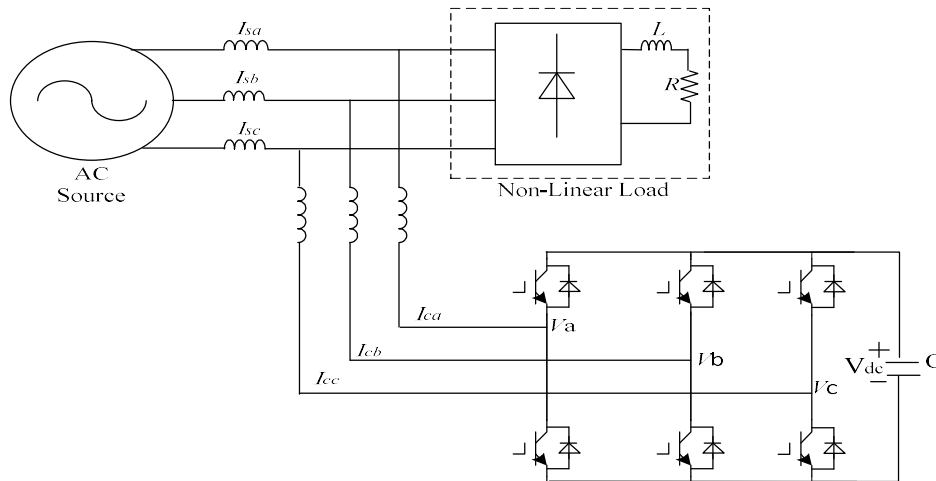


Figure 4: Three-wire Active Filter

Four Wire Active Filters

Many domestic loads are single-phase, whose supply comes from three-phase mains that have a neutral cable. This system has such disadvantages as the cause of high neutral current, unbalance, reactive power and harmonic burdens. In trying to reduce the aforementioned problems of the two-wire system, the four-wire system was

introduced. So many variations and topologies have been developed, such as shunt active type with current source inverter, and another, which is voltage fed, active series type and also a hybrid, which comprises of active series and passive shunt (Singh *et al.*, 1999). Figure 5 shows a four-wire configuration.

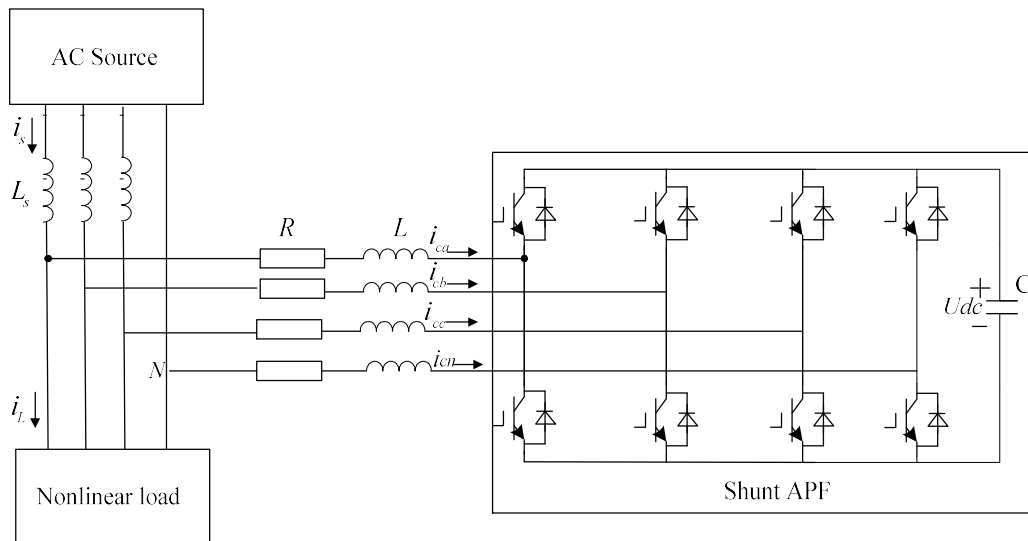


Figure 5: Four-Wire Active Filter

Topology Based Classification

Based on topology, Active filters are classified into series, shunt, hybrid and Unified Power Quality Conditioner (UPQC)

Series Active Filters

This type of filter forms a series connection with the supply mains just before the load; this is achieved through a matching transformer. They are generally used for voltage harmonics mitigation, and for balancing or regulating the load's or line's terminal voltage. Other applications

include reduction of negative sequence voltage, voltage regulation on three-phase systems (Singh *et al.*, 1999). Series active filters are not used as much as its shunt counterpart, this is because of some drawbacks such as having to handle high currents, this consequently leads to rising in current rating, and as a result, larger in physical size. An advantage they possess though is that they are best for mitigation of voltage harmonics and three-phase voltage balancing. A series of active filter configuration is shown in Figure 6.

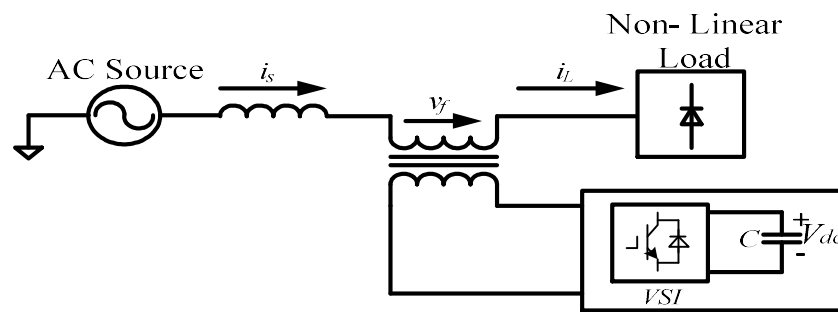


Figure 6: Series Active Filter Configuration

Shunt Active Filters

Also referred to as parallel active filters, are the most important and have a range of applications in the industry, unlike its series counterpart, it is connected in

parallel with the supply mains just before the load via the point of common coupling (PCC) for current harmonics mitigation as shown in Figure 7

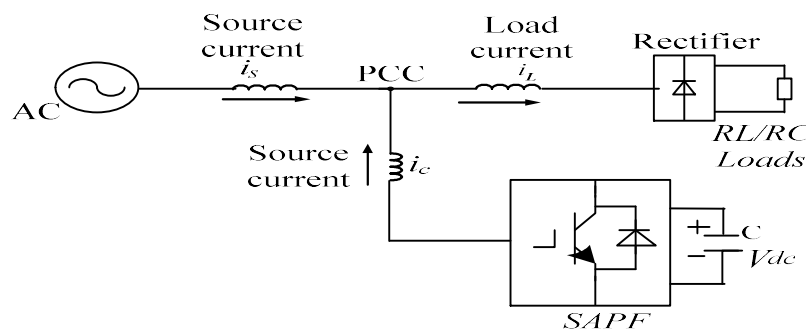


Figure 7: Shunt Active Filter Configuration

Apart from current harmonic mitigation, shunt active power filters also find applications in compensation of reactive power, and for balancing of unbalanced currents. Current harmonics are usually introduced by nonlinear loads, as such; shunt active filter is used at the load end. They inject a current, equal but opposite in phase to cancel out harmonic components of the nonlinear load at the Point of Common Coupling (PCC) (Singh *et al.*, 1999).

Hybrid Filters

Different configurations and types of filters have been proposed by

researchers for solving the different problems arising from nonlinear loads. But as you would have it, the acceptability of active filters by users have been limited in practical situations, this is because of their high ratings and cost considerations. For these reasons, hybrid filters have been developed, which are cost-effective in solving various problems arising from nonlinear loads. Hybrid filters are simply filters that utilize a combined active and active, active and passive or passive and passive filters for solving power quality issues (Singh *et al.*, 2004). Figure 8 is a diagram showing a hybrid filter

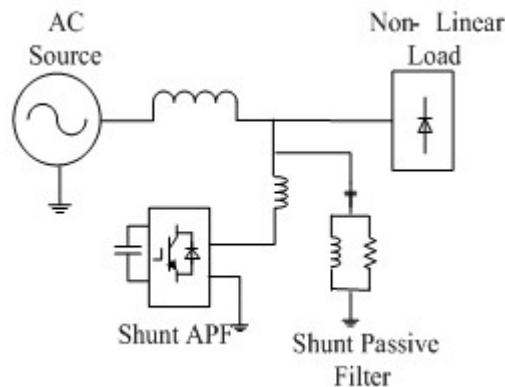


Figure 8: Hybrid Filter Containing Shunt Active and Shunt Passive

Unified Power Quality Conditioner

Unified power quality conditioner (UPQC) combines both series active filters and shunt active filters; it utilizes two VSIs, one of which is connected to a supply line via series connection and the other via the parallel connection. The two VSIs are as well connected to a DC storage capacitor. It can perform both current and voltage harmonic mitigation. For attenuation of current harmonics, a series voltage in proportion to line current is introduced, to eliminate any voltage dip or flicker, the series voltage and the voltage at the PCC are added to provide a buffer. The UPQC

can also operate in these two modes simultaneously.

CONCLUSION

This work has presented an extensive review of active filters. It has stated the drawbacks of passive filters which include resonance, bulkiness, weight and fixed compensation, which are well overcome by active filters. Furthermore, it has discussed the classification of active filters under topology, many phases and converter type. Active filters are classified according to their topology as series, shunt, hybrid and UPQC, according to phases as



two, three and four-wire, and according to converter type as VSI and CSI.

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