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Review Paper on Modern Active, Passive and Hybrid Filters for Harmonic Mitigatation

KEYWORDS filters, electronic circuit, harmonics, distribution system, frequency, bandwidth

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ABSTRACT *Filters of some sort are essential to the operation of most electronic circuits. Generally harmonic filters referred as active and passive filters. One of the most common methods for control of harmonic distortion in industry is the use of passive filtering techniques that make use of single-tuned or band-pass filters. The more sophisticated active filtering concepts operate in a wide frequency range, adjusting their operation to the resultant harmonic spectrum. In this way, they are designed to inject harmonic currents to counterbalance existing harmonic components as they show up in the distribution system. Hybrid filters are a combination of passive and active filtering schemes. This paper focus on application of several active and passive filters for mitigation of harmonics.*

INTRODUCTION

The intensive use of power converters and non-linear loads has contributed for the deterioration of the power quality, and this factor affects critical processes, resulting in substantial economical losses. Therefore the development of equipments capable to mitigate problems that affect electrical installations is of great interest [1] [2]. Traditionally, Passive filter has been used to eliminate the harmonic in power system due to its low cost and high efficiency. A passive filter shows the low impedance at the time of tuning to absorb current harmonic and has a good compensation performance. However, passive filter has the disadvantage of depending on the parameters of power system, susceptible to the load and power system resonant and the characteristic change due to aging. In addition, passive filter usually is designed with fixed parameters, which cannot be lightly adapted for the different operation condition.

Modern active filters are superior in filtering performance, smaller in physical size, and more flexible in application, compared to traditional passive filters using capacitors, inductors and/or resistors. The term "power conditioning" used in this paper has much broader meanings than the term "harmonic filtering." Active power filter has been developed to overcome the disadvantages of passive filter and can provide flexible and reliable compensation, but is not a cost-effective solution due to the high operation cost.

Moreover, the active filters can be classified into pure active filters and hybrid active filters in terms of their circuit configuration. Hybrid active filters consist of single or multiple voltage source, PWM converters and passive components such as capacitors, inductors and/or resistors. The hybrid filters are more attractive in harmonic filtering than the pure filters. [3–10].

HARMONIC VOLTAGES IN POWER SYSTEM

The increasing use of nonlinear loads in residential, commercial as well as industrial sector is keeping harmonic distortion in distribution networks.[11]

Table 1 shows the maximum and minimum values of total harmonic distortion (THD) in voltage and the most dominant 5th harmonic voltage in a typical power system in Japan, which were measured in October 2001 [12]. The individual harmonic voltages and the resulting voltage THD in high-voltage power transmission systems tend to be less than those in the 6.6-kV THD in voltage and 5th harmonic voltage in high voltage power transmission system tend to be less than those in the 6.6-kV power distribution system. The primary reason is that the expansion and interconnection of high-voltage power transmission systems has made the systems stiffer with an increase of short-circuit capacity. For the distribution system, the maximum value of 5th-harmonic voltage in a commercial area has exceeded its allowable level of 3%, considering Japanese guidelines, while the maximum voltage THD was marginally lower than its allowable level of 5%.

TABLE - 1

THD in voltage and 5th harmonic voltage in a high voltage power transmission system and medium voltage distribution system [13]

	Over 187 kV		154-22 kV	
	THD	5th harmonic	THD	5th harmonic
Maximum	2.8%	2.8%	3.3%	3.2%
Minimum	1.1%	1.0%	1.4%	1.3%
6 kV				
	Residential area		Commercial area	
	THD	5th harmonic	THD	5th harmonic
Maximum	3.5 %	3.4 %	4.6%	4.3%
Minimum	3.0 %	2.9 %	2.1 %	1.2%

The 5th-harmonic voltage increases on the 6.6-kV bus at the secondary of the power transformer installed in a substation, whereas it decreases on the 77-kV bus at the primary, under light-load conditions at night. These observations based on the actual measurement suggest that the increase of 5th harmonic voltage on the 6.6-kV bus at night is due to "harmonic amplification" as a result of series and/or parallel harmonic resonance between line inductors and shunt capacitors for power-factor correction installed on the distribution system.

HARMONIC MITIGATION TECHNIQUES

PASSIVE FILTERS

Passive filters are the most commonly used filters in industry.

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Passive filters can be found under following category:
Single-tuned filters High- (or band-) pass filters (first, second, and third order) The design of a passive filter requires a precise knowledge of the harmonic-producing load and of the power system.

Because passive filters always provide reactive compensation to a degree dictated by the volt ampere size and voltage of the capacitor bank used, they can in fact be designed for the double purpose of providing the filtering action and compensating power factor to the desired level. If more than one filter is used — for example, sets of 5th and 7th or 11th and 13th branches — it will be important to remember that all of them will provide a certain amount of reactive compensation.

ACTIVE FILTERS

The active filter uses power electronic switching to generate harmonic currents that cancel the harmonic currents from a nonlinear load. The active filter configuration investigated in this paper is based on a pulse-width modulated (PWM) voltage source inverter that interfaces to the system through a system interface filter as shown in Figure 2. In this configuration, the filter is connected in parallel with the load being compensated. Therefore, the configuration is often referred to as an active parallel filter. Figure 2 illustrates the concept of the harmonic current cancellation so that the current being supplied from the source is sinusoidal.

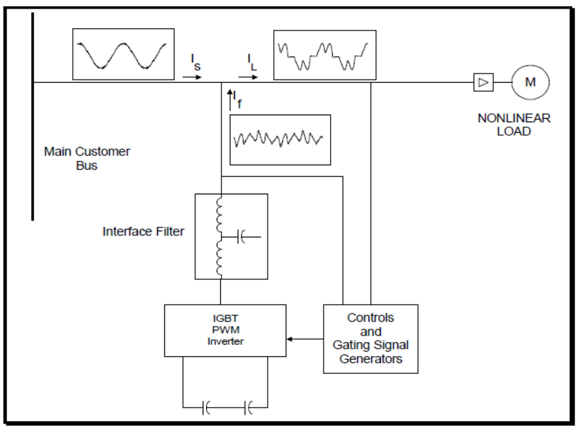

Figure 2 shunt connected active filter

The active filter does not need to provide any real power to cancel harmonic currents from the load. The harmonic currents that to be cancelled show up as reactive power. Reduction in the harmonic voltage distortion occurs because the harmonic currents flowing through the source impedance are reduced.

Therefore, the dc capacitors and the filter components must be rated based on the reactive power associated with the harmonics to be cancelled and on the actual current waveform that must be generated to achieve the cancellation.

The driving voltage across the interfacing inductance determines the maximum di/dt that can be achieved by the filter. This is important because relatively high values of di/dt may be needed to cancel higher order harmonic components.

HYBRID ACTIVE FILTERS

The hybrid active power filter topology is shown in Fig.3, which consists of a three-phase pulse width modulation (PWM) voltage-source inverter (active power filter, APF) and the passive filter connected in series to APF through coupling transformer. Generally, the active power filter acts as a controlled voltage source and force the harmonic current into the hybrid active power filter.

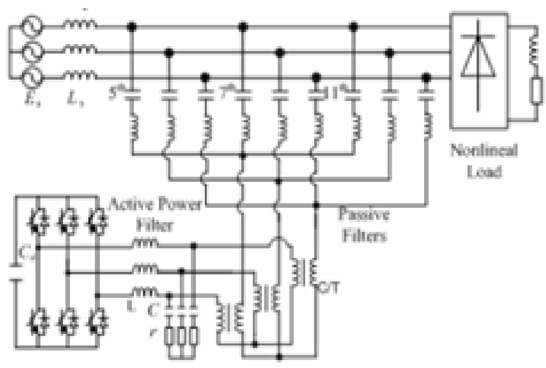

Figure 3 Hybrid active filter configuration

In order to eliminate harmonic of the system current, the active power filter is controlled as a current controlled voltage source. The active power filter imposes a voltage signal VAPF that forces load harmonic current flow into the passive filter, thus improving its compensation performance in despite of the variation in the tuned frequency of the passive filter. The voltage reference of active power filter is equal to

$$V_{APF}^{*} = K \cdot I_{sh} \qquad [1]$$

Where, K is the harmonic compensation gain. Suppose utility voltage is pure sinusoidal, the relation between the utility harmonic current and the load harmonic current is obtained which can be used to denote the filtering characteristics of hybrid active power filter.

$$\frac{I_{sh}}{I_{Lh}} = \frac{Z_F}{Z_S+Z_F+K} \qquad [2]$$

CONCLUSIONS

Active filters based on leading-edge power electronics technology can be classified into pure active filters and hybrid active filters. A pure active filter provides multiple functions such as harmonic filtering, damping, isolation and termination, load balancing, reactive-power control for power-factor correction and voltage regulation, voltage-flicker reduction, and/or their combinations. Using hybrid approach it is possible to improve significantly the filtering performance of a shunt passive filter when combine with a small series active filter. The hybrid filter is exclusively used for mitigation of harmonics of three-phase diode rectifiers.

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