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A Study of Modern and Traditional Filters Using Active and Passive Devices Filters

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ABSTRACT

Modern active filters have several functions, different from traditional passive filters: harmonic filtering, dampening, isolation and termination, reactive power controls, load balancing, voltage-splash reduction and/or their combinations. Significant cost reductions have inspired manufacturers to market active filters in power semiconductors and signal processing devices. This paper covers general pure active filters and hybrid active filters for the harmonic filtering and the conventional passive filtering of three-step diodes.

1. Introduction

Since their basic operating principles were firmly established in the 1970s [1–5], active harmonic filters

– active filters,1 for short – have attracted the attention of power electronics researchers/engineers who have had a concern about harmonic pollution in power systems [6–14]. Moreover, deeper interest in active filters has been spurred by

– The emergence of semiconductor switching devices such as IGBTs (insulated-gate bipolar transistors) and power MOSFETs (metal-oxide-semiconductor field-effect transistors), which are characterized by fast switching capability and insulated-gate structure,

– the availability of digital signal processors (DSPs), field programmable gate arrays (FPGAs), analog-to-digital (A/D) converters, Hall-effect voltage/current sensors, and operational and isolation amplifiers at reasonable cost.

Modern active filters are superior to conventional passive filters with condensers, inductors and/or resistors in filtering performance, smaller in physical size and more flexible in application. Nevertheless, in contrast with passive filters, even today the active filters are significantly lower in cost and operational loss. Effective air-conditioner filters are also known as "active power filters," "active power line conditioners," "active power efficiency conditioners," "static var compensators," etc. Passive filters are also known as "active control filters." In other words, power conditioning is not just harmonic filtration, they also include the harmonic damping, harmonic separation, harmonic termination, reactive power control for power correction & voltage regulation, load balance, voltage flicker reduction and/or comb flashes; it is also used as a power supply unit for harmonic filtration. The word 'power conditioning'

Single-phase active filters and tri-phase active filters may be divided. Research has been carried out on single-stage active filters, which resulted in technical literature. Active single phase filters are, however, substantially less critical than active three phase filters because single-phase filters are restricted to low-power applications other than electric traction or rolling equipment. The active filters can also be classified in terms of their circuit configuration into pure active filters and hybrid active filters. Many pure active filters may use either the PWM (PWM), which is equipped with a dc condenser or the current-source converter with a dc inductor as a power circuit. Today the voltage source converter is more cost-effective, physical size and reliable than the current source converter. Active hybrid filters consist of PWM converters and passive elements, such as condensers, inductors, and/or resistance, with single to multiple voltage sources. For harmonic filtration, the hybrid filters are more attractive than the pure filters, especially for high power applications, from both a viable and economic perspective.

Pure and hybrid active filters along with conventional passive filters are listed in this paper. Both pure and hybrid filters offer a wide variety from the consumer to research and development filters. We draw on the latest developments in power electronics, which involves circuits of conversion, semiconductor power tools, analog / digital processing of signals, voltage / current sensors, and control theory. Active filters also act as a powerful bridge in electrical engineering between power electronics and power engineering. The basic circuit configurations and operating principles of the pure active filters intended for power conditioning are therefore taken into account. In addition to harmonic filtering of low- and medium-voltage diode correctivators, the theory, design and filtering efficiency of lower-cost transforming filters will also be emphasized. Finally, this paper gives some examples of practical pure and hybrid active filters, including the 300-kVA pure active filter installed in a water-processing plant, and the 21-MVA active filter using the 4.5-kV 1.5-kA IEGTs (injection-enhanced gate transistors) for voltage-flicker reduction of electric ac arc furnaces.

2. Voltage Harmonics In Power Systems

Harmonic-producing loads.

Non-linear loads produced by non-sinusoidal currents are known as defined and unidentified loads from three phase sinusoidal voltages. Usually, high-speed diode or thermistor rectifiers, cyclo converters and arc furnaces are known as harmonic output loads, since electricity providers in many cases identify individual nonlinear loads built by high-speed appliance systems. Each load produces a great deal of harmonic current. High-power users who mount their own harmonic load output loads on power distribution systems may decide the point of common connection (PCC). In addition, the amount of harmonic current drawn by an individual consumer can be determined.

If it is compared to the total current system , a single low-power Diode rectifier produces a inimitable amount of harmonic current. But a large amount of harmonics can be made in the power distribution system through multiple low energy diode rectifiers. A low power, harmonic-production load is usually considered a low-power diode corrector as the utility device for electrical appliances. Unidentified loads have so far been given less attention than identified loads. Applied to regulate current and voltage harmonic levels at present are harmonic regulations or guidelines like IEEE 519-19 92, IEC61000, etc. Currently. The main goal of the legislation or guidelines is the implementation of best practice at minimal social costs in power plants and in equipment design.

Voltage THD and 5th-harmonic voltages.

Tables 1 & 2 show the total harmonic distortion (THD) maximum and minimum values of a standard power system, which were calculated in October 2001 in the Japanese voltages and the most dominant 5thharmonic voltage. Remember that Japanese power supply systems are usually integrated into their 6,6 kV distribution networks with three-phase ungrounded systems without neutral line. For high voltage power transmission systems, harmonic voltages and the resulting voltage THD are generally lower than in the power transmission system of 6,6 kV. The main reason is the increase in the efficiency of the short-circuit by the creation and interconnenctions of high voltage power transmission systems. With regard to distribution systems, the maximum value of the 5th harmonic voltage for a commercial area has exceeded the permitted level of 3%, taking into account Japanese guidelines.

Under light-weight conditions in the night, the machine in Japan reaches 7 percent. I have also pointed to another big trend. In the secondary of a power transformer installed in the substation, the 5th harmonic Voltage rises with 6.6-kV bus, while at night, under light-charging conditions, it decreases with a 77-kV bus in the primary. These observations based on actual measures suggest that, as a result of serial and / or parallel harmonic resonance between the line inductors or shunt condensers for power-factor correction installed on the distribution system, the 5th harmonic voltage on the 6,6kV bus at night is due to "harmonic amplitude." This means that harmonious compensation as well as harmonic damping are a viable and efficient way of solving harmonic emissions in electricity distribution systems. Electrical utilities will also be liable in all power delivery networks for harmonic damping. The harmonic currents in their own devices must be controlled within defined limits by individual customers and end users.

Table 1

Voltage THD and 5th-Harmonic Voltage in a High-Voltage Power Transmission System

	Over 154 kV		154–22 kV	
	THD	5th-harm.	THD	5th-harm.
Max	2.8%	2.8%	3.3%	3.2%
Min	1.1%	1.0%	1.4%	1.3%

Voltage THD and 5th-Harmonic Voltage in a 6.6-kV Power Distribution System

	6.6 kV			
	Residential		Commercial	
	THD	5th-harm.	THD	5th-harm.
Max	3.5%	3.4%	4.6%	4.3%
Min	3.0%	2.9%	2.1%	1.2%

3. Traditional Passive Filters

Circuit configurations.

Passive filters made up of condensers, inductors and/or resistors can be categorized into tuned filters and filters. Parallel to the nonlinear loads such as diode / thyristor rectifiers, electric arc furnaces etc., they are connected. The configurations of the passive filters in a per-phase basis are shown in Figures 1 and 2. In the three-phase high-power thyristor rectification system a combination of four single-tuned filters was used to rectify the fifth, 7th, 11th and 13th harmonic frequencies, and a high-pass second-order filter tuned around the 17th harmonic frequency. The installation of such a passive filter near a nonlinear load ensures low-impedance paths for specific harmonic frequencies and thus remove the dominant harmonic currents from the load. Each single-tuned filter's current value of the low-impedance path is influenced by the filter's Q quality factor that determines the tuning's sharpness. A value of Q normally ranges from 20 to 100. Although a High-Pass secondary filter offers good filtering efficiency in a wide frequency range, its basic frequency loss is higher than its equivalent single-tuned filter.

The added advantage of passive filters is to obtain a correction of inductive loads by power-factor. In many cases, but not in all cases, this function gives passive filters an advantage.

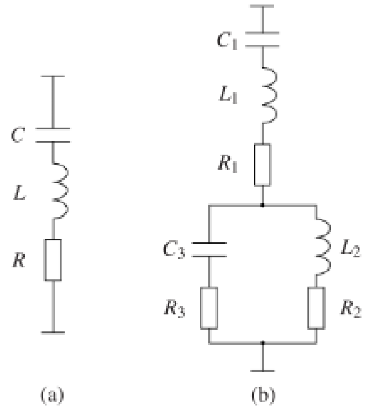

Fig. 1. Passive tuned filters: (a) single tuned, and (b) double tuned

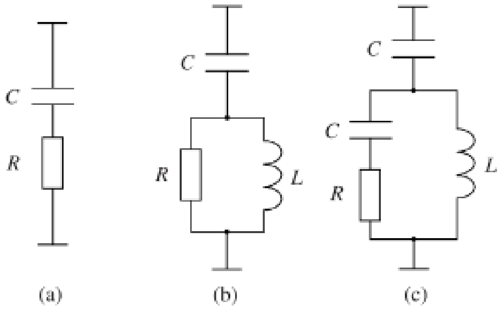

Fig. 2. Passive high-pass filters: (a) first-order, (b) second-order and (c) third-order

Consideration to installation.

A simple inductive reaction in a range of harmonic low-ordre frequencies may represent the background system impedance viewed above the point of installation of a passive filter. A passive filter can sink different harmonic currents from other nonlinear loads on a single feeder and/or from the power supply upstream of the passive filter.3 this will make the passive filter overloaded and inefficient. The passive filter can then sink in a lower frequency than any tuned frequency. Until building a passive filter, engineers will carry out comprehensive studies on the probability of harmonic resonance and case by case overload. These investigations can, however, be accompanied by relatively high technical costs.

In order to achieve component tolerance and changes, the final design of a passive filter should also permit. Initial tolerance levels usually within 5 per cent, for example, and their fluctuations are due to temperature and other operational conditions.

4. Pure Active Filters For Power Conditioning

Pure active filters can be classified into shunt (parallel) active filters and series active filters from their circuit configurations. At present, shunt active filters are more preferable than series active filters in terms of form and function, and therefore series active filters are suitable exclusively for harmonic filtering.

Circuit configurations of shunt and series active filters.

Figure 3 shows a single-phase or three-phase shunt active filter system configuration for harmonic current filtering with a dc load capacitive single or three-phase diode right. This active filter is one of the most important device configurations for various types of active pure and hybrid filters. The dc load can, in many cases, be regarded as an Ac engine powered by a PWM inverter voltage source. In parallel with the harmonic load, this active filter, with or without a transformer is associated. On the basis of "feed-forward" the active filter can be controlled:

– The controller detects the instantaneous load current iL.

– It extracts the harmonic current iLh from the detected load current by means of digital signal processing.

– The active filter draws the compensating current iAF (= −iLh) from the utility supply voltage vS, so as to cancel out the harmonic current iLh.

Note that the ac inductor Lac, which is installed at the ac side of the diode rectifier, plays an important role in operating the active filter stably and properly

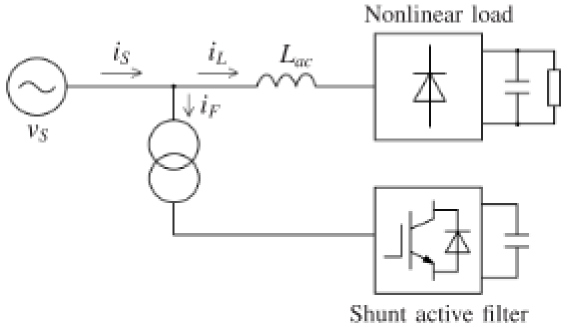

Fig. 3. Single-phase or three-phase shunt active filter

Figure 4 shows a system configuration of a single-phase or three-phase series active filter for harmonic-voltage filtering of a single-phase or three-phase diode rectifier with a capacitive dc load. The series active filter is connected in series with the utility supply voltage through a three-phase transformer or three single-phase transformers. Unlike the shunt active filter,the series active filter is controlled on the basis of the following “feedback” manner:

– The controller detects the instantaneous supply current iS.

– It extracts the harmonic current iSh from the detected supply current by means of digital signal processing,

– The active filter applies the compensating voltage vAF (= KiSh) across the primary of the transformer. This results in significantly reducing the supply harmonic current iSh when the feedback gain K is set to be enough high.

The above considerations suggest that “dual” relationships exist in some items between the shunt active filter and the series active filter.

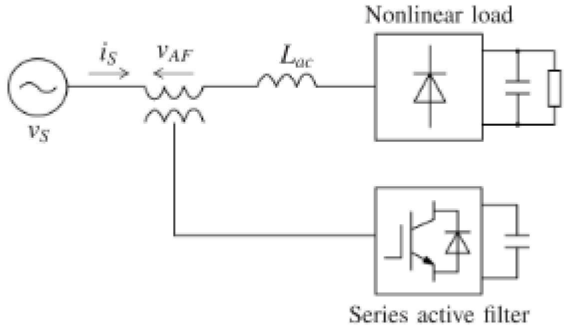

Fig. 4. Single-phase or three-phase series active filter

Three-phase voltage-source and current-source PWM converters.

The voltage source PWM converter, fitted with a dc condenser, is shown in Figure. There are two types of power circuits for the 3-stage active filter. 5(a) and a PWM converter with dc inductor, shown in the figure. 5(a) Fifth (b). The power circuits for ac motor drives are similar. Nevertheless, they vary in behaviour, as active filters function as non-sinusoidal sources of current or voltage. The author prefers the voltage source to the PWM converter, since the PWM converter voltage source is more effective, cost efficient and physical smaller, especially when compared between the dc condenser and the DC inducer.

The IGBT module now available on the market is also more suitable for the PWM converter from voltage sources because each IGBT has a free-wheeling diode. This means the IGBT needs not to provide itself with the reverse blocking capability, thereby making the production of the system more robust than the reverse blocking IGBT in terms of conductivity and switching losses and short-circuit capable. On the other hand, the PWM converter requires a traditional IGBT connection and a reverse blocking diode in series, as shown in Fig. In the current source. 5(b) or reverse-blocking IGBT which leads to more complex equipment design and manufacture without reverse blocking capability and slightly worse device characteristics than the standard IGBP. Indeed, most active filters in Japan are equipped with the voltage source PWM converter, which is equipped with the DC condenser as a power circuit.

The authors describe active filters with a PWM converter voltage source and a PWM converter with current sources, with a focus on contrasts from different viewpoints.

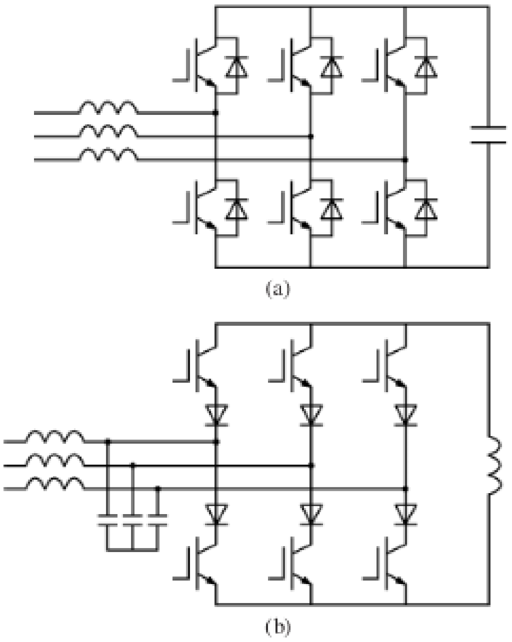

Fig. 5. Power circuits applicable to three-phase active filters: (a) voltage-source PWM converter and (b) current-source PWM converter

Three-phase pure active filters.

Figure 6 shows an active three-stage shunt filter 's detailed circuit configuration. A three-phase PWM converter with dc condenser, control circuit, and a filter for rip-overs consists of the following three components. This controlling circuit is based in conjunction with operational and insulation amps for analog signal processing, Hall-effect Voltage / Current Sensors, DSP, FPGAs and A / D Converters for digital signal processing and a state of the art DSP. For the active filter you can sum up the desired system characteristics as follows:

– The voltage-source PWM converter with a current minor loop should provide the capability of controlling the compensating current iAF with a frequency bandwidth up to 1 kHz. This leads to harmonic filtering in a range of the most dominant 5th-harmonic current to the 25th-harmonic current. The carrier frequency of the PWM converter is desirable to be as high as 10 kHz.

– For the lowest possible amplitude and phase error, the control system will extract the harmonic current iLh in the observed load current iL not only in steady states, but also in transient states. As for three-phase active filters, the instantaneous active and reactive power theory or the so-called “ p-q principle, ”[9, 10], and the d-q transformation are typically applied to their control circuits for harmonic extraction. The three-phase voltage v in the circuit of the p-q theory must be included, as shown in Figure. 6. The d-q transformation includes a phase-locked-loop (PLL) to match the transformation of the frequency with the phase of the line. Note that the p-q theory includes concepts that are broader than the d-q process.

– The small-rated switching-ripple filter designed appropriately should be connected in parallel as close as possible to the voltage-source PWM converter. The task of the small rated filter is to eliminate switching ripples caused by PWM operation from the compensating current if .

The filter active in Fig. Active. 6 still is called "pure active filter," since there is no capabilities for mitigating the domestic 5th and 7thharmonic currents of the diode rectifier with the small rating switching-rippling filter. Built a suitable dc-voltage feedback loop allows the dc voltage to be defined and changed without power supply [13].

The dc condenser can generally be considered from theoretical standpoint as an energy storage element. The active filter however is typically not regarded in practical terms as an energy storage device, since the volume of energy contained in the dc condenser is considerably smaller than in a battery or a superconducting magnetic belt. In other words, it does not depend on their circuit configuration, but mainly on whether their storage capacity is small or large, for terminology to differences between the active filter and the power storage system.

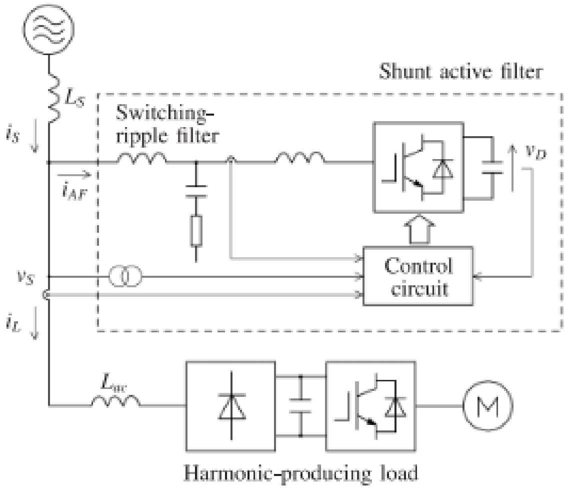

Fig. 6. Single-line system configuration of a three-phase active filter

Trends in pure active filters.

Due to the high cost and performance rivalry among Japanese manufacturers, a strong market for pure active filters for power conditioning has grown. The costs of power semi conducers (IGBTs), auxiliary components and integrated digital control circuits are currently being reduced , making pure active filters affordable. The actual market price of active filters however depends heavily on buying conditions. For instance, pure active filters in a range of 10 to 400 kVA have been marketed at Fuji Electric. in Japan. A working filter can directly be mounted on a low voltage industrial energy system with a voltage range of 200 to 440 V. But, when it is mounted on a medium-voltage power network, another active filter needs a step-down transformer. Active filters expand into and transport electrical utilities, industries, office buildings, hospitals, water services and practical applications.

References are a shunt active filter for installation on a system with a harmonic amplification due to series and/or parallel resonance values between line inductions and power-factor correction capacitors. The active filter based on voltage detection at the point of installation is regulated in such a way that the outer circuit shows infinite impedance at the fundamental frequency, and that harmonic frequencies show low resistance. When the active filter is mounted at the end of a radial distribution feeder, harmonic damping throughout the distribution feeder is performed successfully. It suggests, like a 50-degree terminator mounted on the end of the signal transmission line that the active filter serves as a harmonic terminator.

An active three-phase series filter consisting of three single-phase H-bridge conversion systems with 10 kHz PWM carrier frequency and a small high frequency dc condenser. The dc terminal of the active filter is connected to the dc terminals of an accident rectifier with a dc condenser and thus forms a specific dc condenser between the active filter and the diode rectifier. A three-phase experimental system with an output of 200 V, 20 kW and 50 Hz has confirmed the satisfaction of the filtering performance.

5. Conclusion

Classified in pure active filters and hybrid active filters based on the latest electronics technology. In his mind the reader can ask this simple question: "What's preferable, a pure active filter or an active hybrid filter? "Happily or unfortunately, engineering has no flexible cost and performance technology, and is based on a balance between cost and performance. Therefore, the author depends on the functions of active filters intended for installation to provide a comprehensive answer to the question.

A pure active filter offers a number of functions, such as harmonic filters, damping, load balance, load balancing, reactive power control, voltage control, voltage-flicker decreases and/or combinations. The pure active filter is well suited for the "power conditioning" of nonlinear loads like electric bow furnace, and utility / industrial feeding systems. The "Power Conditioning" feature can be described as "Energy Conditioning." An active hybrid filter, on the other hand, consists of an active filter and a unique-specific filter directly connected without transformer in series. This hybrid filter is dedicated to the 'harmonic' filtering of three-phase diode rectifier because, while it has a theoretical point of view, it does not have a functional reactive power control capability.

Active filters for power conditioning have already been put on the market by some producers. Yet they will aim to reduce costs , increase filtration performance and boost performance in order to compete well with conventional passive filters. In addition, truthful manufacturers should speed up active filter installation in proximité of non-linear cargoes, in addition to harmonic guidance or recommendations. In turn, the active filters would save more because of the large-scale production economy. A feedback loop of this kind would encourage the broad acceptance of active filters to solve harmonic pollution and improve energy quality.

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