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Active Power Filter Techniques for Harmonics Suppression in Non Linear Loads

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Abstract: the growth in electronic devices applications increasing the non linear loads in power systems because most of these devices involve uses regulated power supply such as SMPS, Choppers etc. but because of the non linearity involved with the controlling process it produces undesired harmonics and reactive components which causes the heating, vibration electromagnetic interference etc. hence to mitigate these problems many methods are suggested such as use of passive LC filters and other controlled active power filters (APF) with different controlling algorithms and topologies. In this paper we presents the study & analysis of various active techniques used for suppression of harmonics. The matter and discussion performed in this paper may be used for system designer for adopting the best filter according to operating conditions and requirements.

Keywords: Active Power Filters (APF). Harmonic Distortion, Hybrid Power Filters.

1. Introduction

Electronically controlled devices are more suitable device than the transformer based devices for the AC to AC or AC to DC converters generally used for voltage regulation or controlling of induction motors and other devices because of lower cost, fast and simple controllability, smaller size. The main drawback of such systems that they produce the unwanted harmonics which could cause serious problems such as excessive heating, vibrations, lowering the power factor and electromagnetic interference. Now even these drawbacks it's a preferable choice because of its advantages as discussed in previous paragraph. Hence the designers search many ways to overcome the problems involve with it while maintaining its advantages intact, some of them are very simple and works like LC filters and some involves complex algorithms with active switching devices and microprocessors in this paper we are presenting the analysis of some active techniques used for this purpose and try to conclude their most appropriate application area.

2. Active Power Filters

To reduce the harmonics conventionally passive L–C filters were used and also capacitors were employed to improve the power factor of the ac loads. But the passive filters have several drawbacks like fixed compensation, large size and resonance problem. To mitigate the harmonics problem, many research work development are developed on the active power (APF) filters or active power line conditioners [5].

The active power filter (APF) is a popular approach for cancelling the harmonics in power system. The main component in the APF is the control unit. The control unit is mainly divided into two parts as follows [1].

1. **Harmonic Extraction Technique:** Harmonic extraction is the process in which, reference current is generated by using the distorted waveform. Many theories have been developed such as p-q theory (instantaneous reactive power theory), d-q theory, frieze controller, PLL with fuzzy logic controller [3],

neural network etc.. Out of these theories, more than 60% research works consider using p-q theory and d-q theory due to their accuracy, robustness and easy calculation.

2. **Current Modulator:** Current modulator is mainly used to provide the gate pulse to the active power filter (Inverter). There are many techniques used for giving the gating signals to PWM VSI such as sinusoidal PWM, triangular PWM, hysteresis current controller, adaptive hysteresis current controller, space vector modulation and space vector with hysteresis current controller etc. The above described two control techniques (harmonics extraction technique and current modulator technique) are main research focus of many researchers in the recent years. It may be noted that either harmonics extraction technique or the current modulator can be used individually or both at a time. Apart from these two techniques, most of the research works are directed also in dealing with multi-level inverter control problems.

2.1. Topologies of Various Active Power Filters

APLC's are basically categorized into two types, namely, single phase (two-wire connection), three-phase (three wire and four-wire connection) configurations to meet the requirements of the nonlinear loads in the distribution systems. Single-phase loads, such as domestic lights, TVs, air conditioners, and laser printers behave as nonlinear loads and cause harmonics in the power system [6]. Many configurations, such as the active series filter [5], active shunt filter [5-6], and combination of shunt and series filter has been developed [5]. The above mentioned APLC's either based on a current source inverter (CSI) with inductive energy storage or voltage source inverter (VSI) with capacitive energy storage devices.

2.3. Control techniques used for Active Power Filter

Designing a suitable controller for an APF is very important. A number control strategies such as instantaneous reactive power theory, synchronous frame d–q theory [6], synchronous detection method [3], notch filter and fuzzy logic controller [5] method are used in the development of three-phase AFs and the gate pulses are generated by current control technique like sinusoidal pulse width modulation (SPWM), triangular PWM, hysteresis current control technique [2].

2.4. Digital Controller for Active Power Filter

Advancement in Microelectronics has motivated new directions for APF design starting from the use of analog and digital components to microprocessors, microcontrollers, digital signal processors (DSP's) and FPGA implementation. Further, these developments have made it possible to use different control algorithm such as proportional integral (P-I), fuzzy logic etc. for improving the steady state and dynamic performance of APFs. By implementing this performance, response as well as the cost is efficient compare to the analog one.

3.Designing of Active Power Filter

To cancel the harmonics and compensate the reactive power APF is the suitable solution. The APF concept is to use an inverter to inject currents or voltages harmonic components to cancel the load harmonic components. The more usual configuration is a shunt APF to inject current harmonics into the point of common coupling (PCC). The APF can be installed in a low voltage power system to compensate one or more loads; thus, it avoids the propagation of current harmonics in the system. The developments of different control strategies give APF to a new location. As APF compensate the reactive power and cancel the harmonics, it is also called as active power line conditioners (APLC). The three main aspects of an active power conditioner are:

- The configuration of power converter (the scheme and the topology of converter and the electronics device used)
- The control strategy (the calculation of APLC control reference signals)
- The control method used (how the power inverter follows the control reference)

3.1. Configuration of Active Power Filters

APF's can be classified based on converter type, topology, and the number of phases. The converter type is mainly two types.

- Voltage source inverter (VSI)
- Current source inverter (CSI)

The topology of active power filter is classified in to three types.

- Series active power filters
- Shunt active power filters
- Hybrid active power filters

Finally based on the phases the APF mainly two types.

- Two-wire (single phase) system.
- Three or four-wire three-phase system.

3.3. Voltage Source Inverter (VSI)

In voltage source inverter (VSI) the dc voltage always has one polarity, and the power reversal takes place through reversal of dc current polarity. For reasons of economics and performance, VSI's are often preferred over current source inverter (CSI) for flexible ac transmission (FACTS). Since the direct current in a VSI flows in either direction, the converter valves have to be bidirectional, and also, since the dc voltage doesn't reverse, the turn off device need not to have reverse voltage capability. IGBTs, MOSFETs etc may have parallel reverse diode built in as a part of complete integrated device suitable for voltage source inverter. Figure 1 topology of the VSI. On the dc side, voltage is unipolar and is supported by capacitor. This capacitor is large enough to at least handle a sustained charge or discharge current that accompanies the switching sequence of the converter valves and shifts in phase angle of the switching valves without significant change in the dc voltage.

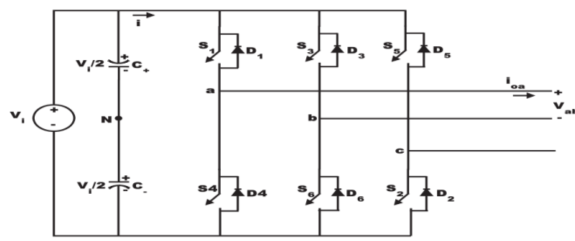

Figure 1: Basic topology of a voltage source inverter.

3.4. Current Source Inverter (CSI)

A current-sourced inverter (CSI) is characterized by the fact that the dc current flow is always in one direction and the power flow reverses with the reversal of dc voltage. Basically there are three types of CSI i.e. Diode inverter, Line-commutated inverter, Self commutated inverter. For flexible AC transmission (FACTS) application self commutated inverter is preferred and basically it is based on turn off devices (MOSFET, IGBT etc.), in which commutation of current from valve to valve takes place with the device turn-off action and provision of ac capacitors, to facilitate transfer of current from valve to valve. Whereas, in a voltage sourced converter the commutation of current is supported by a stiff dc bus with a dc capacitor. The figure 2 shows the topology of CSI [2][5].

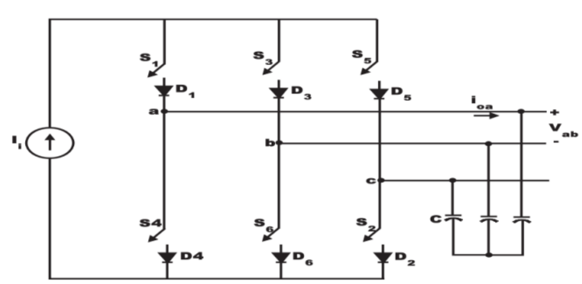

Figure 2: Basic topology of a current source inverter

3.3. Series Active Power Filter

Figure 3 shows the connection scheme of a series APLC. It is connected to the power system through coupling transformer. The compensation voltage is used to cancel the voltage harmonics of load.

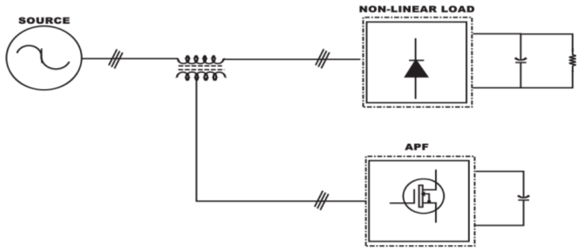

Figure 3: A series APLC scheme

The performance scheme of series APLC is shown in figure 3. The APLC supplies a compensating voltage as in Figure 3.1. These harmonic components cancel the voltage harmonics of the load. After the compensation, the source voltage will be sinusoidal bas shown in Figure 3.1 [6-7].

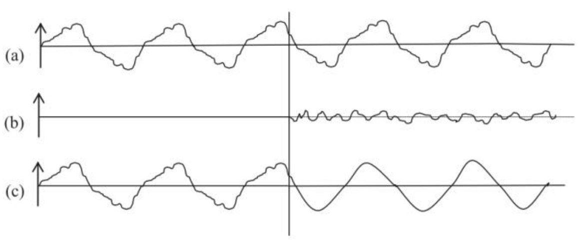

Figure 3.1: Performance schemes of series active power filter.

3.4 Shunt Active Power Filter

The more usual APLC configuration is the shunt or parallel connection. Figure 4 shows the basic scheme of the connection, where the MOSFET switching device represents the APLC power block. The loads with current harmonics can be can be compensated by this APLC configuration [2].

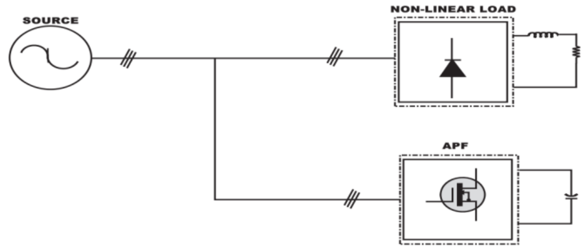

Figure 4: A shunt APLC scheme.

3.5 Hybrid Active Power Filter

To reduce the cost of the static compensation, combination of static and passive filters is called as hybrid active power filter. The passive filters are used to cancel the most relevant harmonics of the load, and the active filter is dedicated to improving the performance of passive filters or to cancel other harmonics components. As a result, the total cost decreases without reduction of efficiency. Fig.5.1, 5.2 and 5.3 shows the more usual hybrid topologies [2].

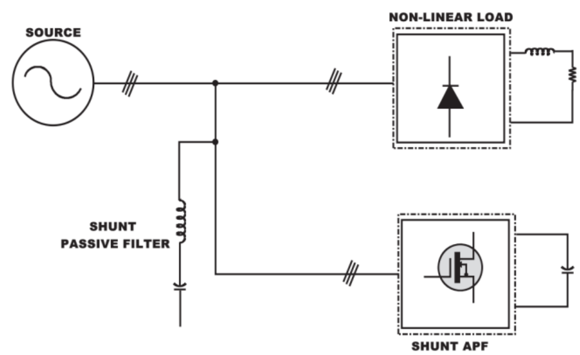

Figure 5.1: Hybrid filter with a shunt passive filter and a shunt active filter

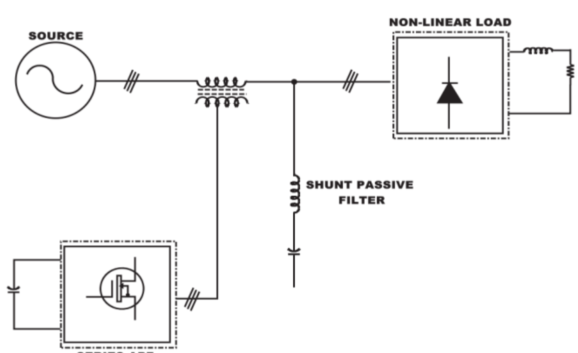

Figure 5.2: Hybrid filter with a shunt passive filter and a series active filter

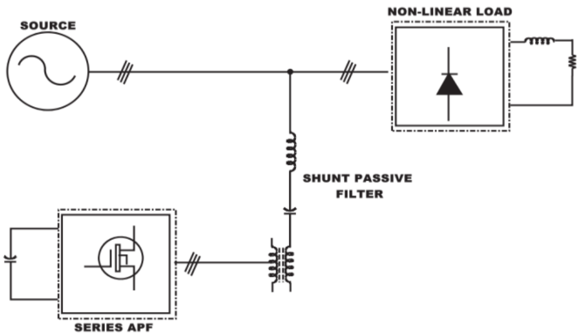

Figure 5.3: A shunts passive filter and a shunt active filter and an active filter in series with it.

3.6. Two-Wire (Single Phase) System

Two-wire (single phase) system is available in three mode of configuration (active series, active shunt and combination of both). Also available according to converter configuration i.e. current source PWM with inductive energy storage elements and voltage source PWM with capacitive dc-bus energy storage elements.

3.7. Three or Four-Wire Three-Phase System

There are several nonlinear loads with three phase configuration. In three phase four wire systems with unbalanced loads, it is possible to use three single phase inverters as an APLC power circuit. The main objective is to compensate the phase by phase. In general, in four wire power systems, it is usual to use APLCs with three phase configurations. I n this case, a split capacitor will be necessary in the DC side [3].

4. Conclusion

This paper has described different topologies of APF and the merits and demerits of the each topology are explained. It is shown that shunt active power filter is suitable for eliminating the current harmonics.

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