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Mitigation of Harmonics Using Three-Phase Four-Wire Shunt Active Power Filter

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Abstract: With the abundant increase of power electronic equipments and the application of various non-linear devices, the distortion in current due to various power quality problems affects the grid to a wider extent. This has lead to a greater focus on harmonic current compensation in recent years which can be attained by the use of active power filters. Active filters are sophisticated power electronic devices which can overcome power quality problems. This study focuses on the mitigation of harmonics by using shunt active filter. Active power filter is an efficient power electronic device being used for eliminating power quality problems. It can compensate harmonics with varying amplitude and frequency and can overcome the shortage of passive filter effectively.

Key words: Shunt active power filter, Instantaneous Reactive Power theory, harmonics, Three Phase Four Wire System, total harmonic distortion, hysteresis controller

INTRODUCTION

Use of non-linear loads and devices in power systems are growing very rapidly which pose power quality problems to a greater extent. These loads inject harmonic currents into the power system. Harmonics are sinusoidal voltages or currents having frequencies that are integral multiples of the supply frequency. Greater concerns have been expressed by industries which have equipment or processes that are sensitive to distortion on the supply voltage which affect their plant operation and productivity. Effect of high level of voltage or current harmonics can cause transformer heating, high current in neutral conductor and distorted voltage waveform. Capacitors are sensitive to harmonic voltage while transformers are sensitive to current harmonics.

Filters are often the most common solution that is used to mitigate harmonics from a power system. Unlike other solutions, filters offer a simpler inexpensive alternative with high benefits. There are different types of filters each offering their own unique solution to reduce and eliminate harmonics. The choice of filter used is dependent upon the nature of the problem and the economic cost associated with implementation. The increased severity of power quality problems and other problems associated with the passive filters such as large size and weight, higher cost, fixed compensation and resonance problems with loads and networks has required a focus on a power electronic solution that is active filters. This study focuses on shunt active power filters which are used for harmonic mitigation based on Instantaneous Reactive Power theory. Shunt Active Power Filter (SAPF) is economical and easy to control.

SHUNT ACTIVE POWER FILTERS-PRINCIPLE

Active power filters are explored for executing different power conditioning function simultaneously along with harmonic elimination due to increase in non-linear and unbalanced load at the point of coupling (Akagi, 1996). Shunt active power filter compensate current harmonics by injecting equal but opposite harmonic compensating current (Yanbo *et al*., 2006). In this case, the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered a harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non linear load and the active power filter as an ideal resistor. The neutral wire is connected with midpoint of DC side bus and it provides the access for neutral wire current. The shunt active power filer comprises of subsystems to calculate reference current for current tracking and driver circuit along with the inverter.

DESIGN OF SHUNT ACTIVE POWER FILTER

The basic block diagram of shunt active power filter is shown in Fig. 1. Due to the consideration of three phase four wire systems, the zero sequence current component

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must be calculated and subtracted from the three phase current. The three phase current without zero sequence component can be evaluated using the instantaneous reactive power theory (Czarnecki, 2006). The method of reference current calculation (Mahajan *et al*., 2012) is explained as follows: Let i_a, i_b and i_c be the load currents. The zero sequence component of three phase current is given by:

$$i_o = \frac{i_a + i_b + i_c}{3} \quad (1)$$

Now the zero sequence component of current is subtracted from the three phase current to obtain $i_{a'}$, $i_{b'}$ and $i_{c'}$ which comprises of only positive and negative sequence components:

$$i_{a'} = i_a - i_o \quad (2)$$

$$i_{b'} = i_b - i_o \quad (3)$$

$$i_{c'} = i_c - i_o \quad (4)$$

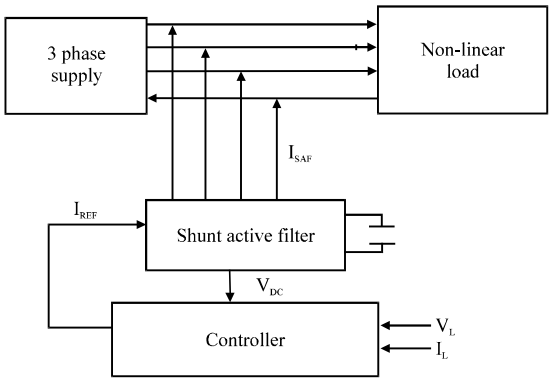

Fig. 1: Basic block diagram of shunt active power filter

Now, $i_{a'}$, $i_{b'}$, $i_{c'}$ are transformed using α-β transformation and i_p and i_q are obtained by the use of low pass filters (Czarnecki, 2006). Then, the fundamental positive sequence components of current, i_{af}, i_{bf} and i_{cf} are obtained by inverse transformation. Then, the reference currents can be obtained as follows:

$$i_a^* = i_a - i_{af} \quad (5)$$

$$i_b^* = i_b - i_{bf} \quad (6)$$

$$i_c^* = i_c - i_{cf} \quad (7)$$

In order to produce the compensation current to eliminate the harmonics, shunt active power filter recognises the harmonic component of load current (Aredes and Watanabe, 1995; Xiaoqing and Zhaoan, 1997). Then, the opposite polarity of harmonic component of load current acts as the instructional current $i_c^{\#}$ (Asquerino and Revuelta, 2002). So, by injecting the opposite polarity of harmonic current into the line, harmonics are reduced to a greater extent. For the control circuit of shunt active power filter hysteresis controller (Juhai, 2012) is used by which PWM signals are generated. These PWM signals control the on and off of main filter circuit.

SIMULATION CIRCUITS AND RESULTS

In this study, three phase four wire shunt active filter has been simulated using MATLAB Software using non linear loads. The simulation circuit and results are shown from Fig. 2-8. The simulation results clearly show that the total harmonic distortion is reduced and within IEEE standards.

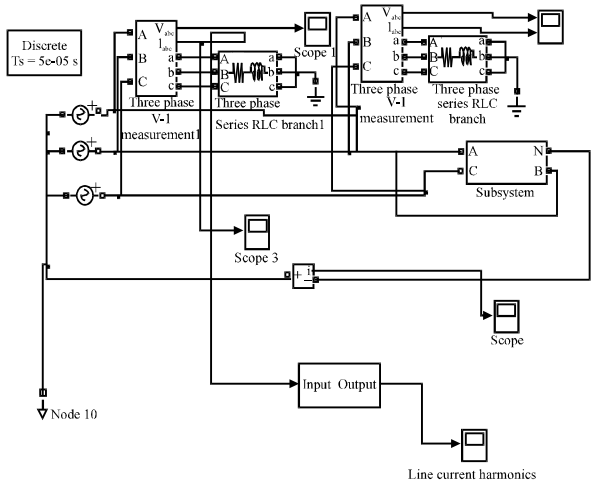

Fig. 2: System without shunt active filter

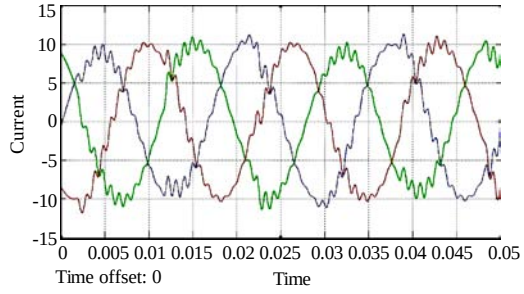

Fig. 3: Line current without shunt active filter

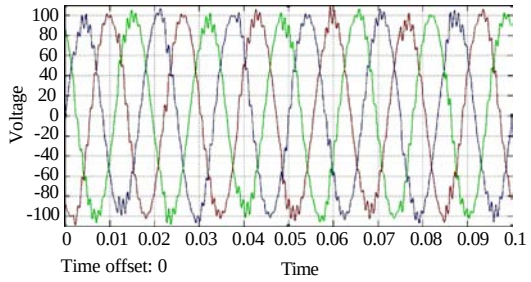

Fig. 4: Line voltage without shunt active filter

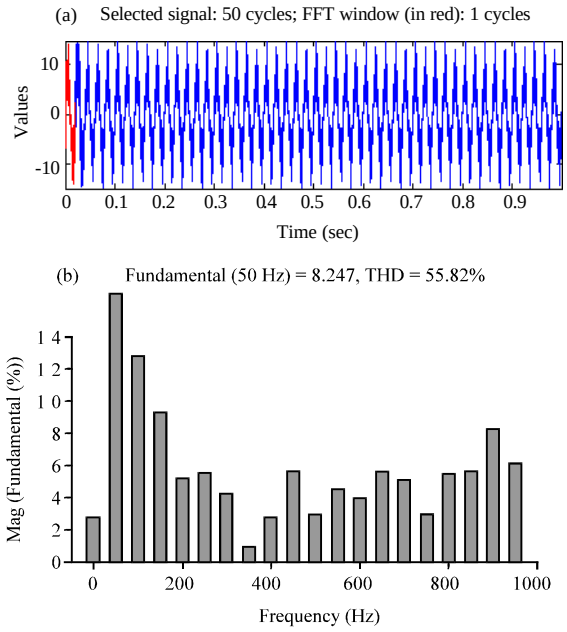

Fig. 5: a, b) THD of line current without shunt active fiter

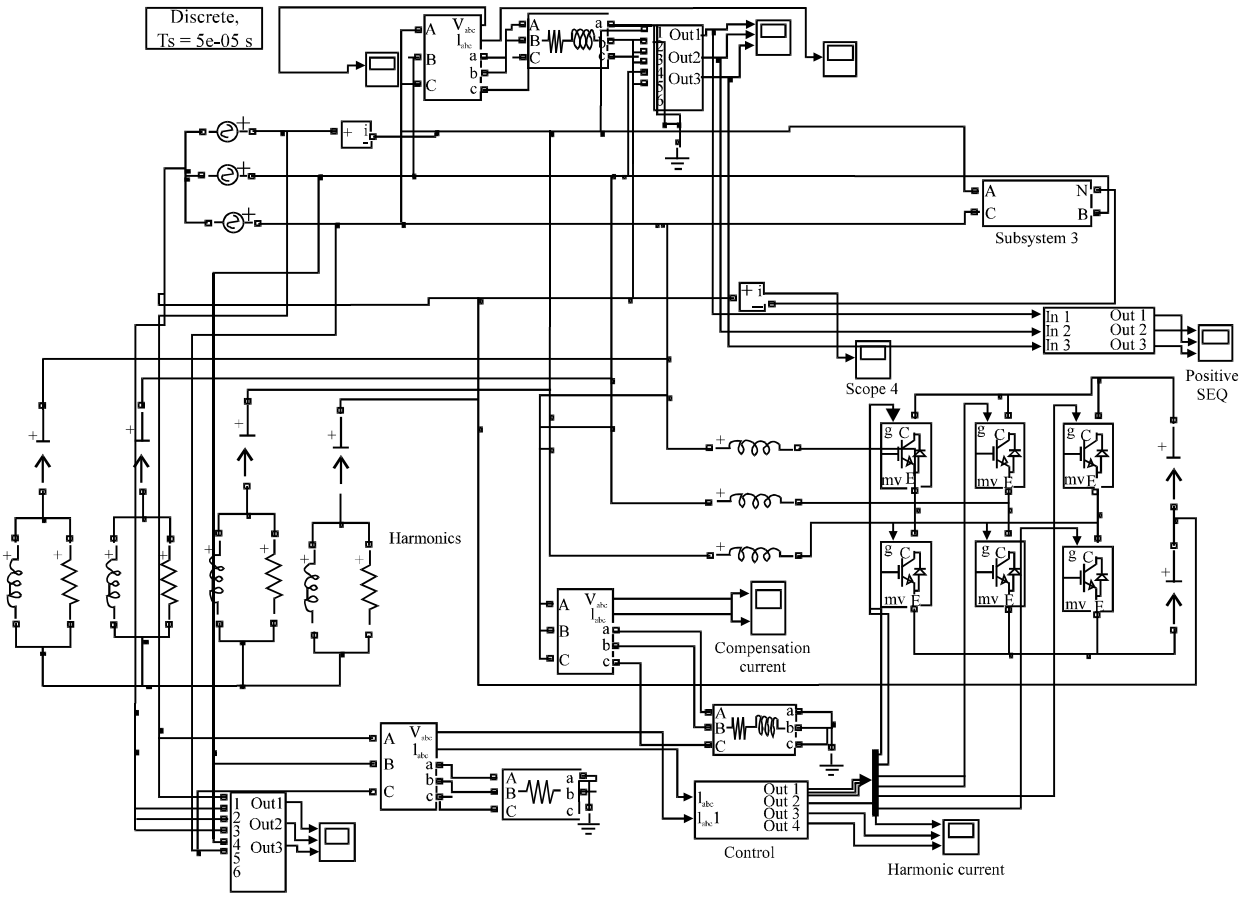

Fig. 6: System with shunt active filter

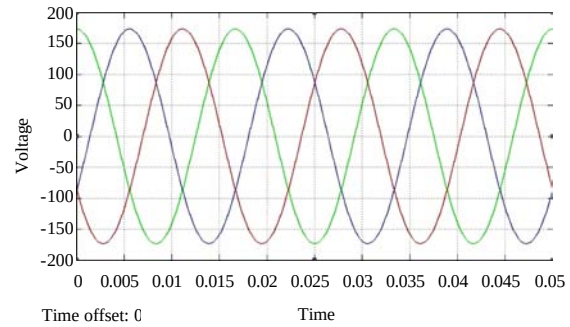

Fig. 7: Source voltage with shunt active filter

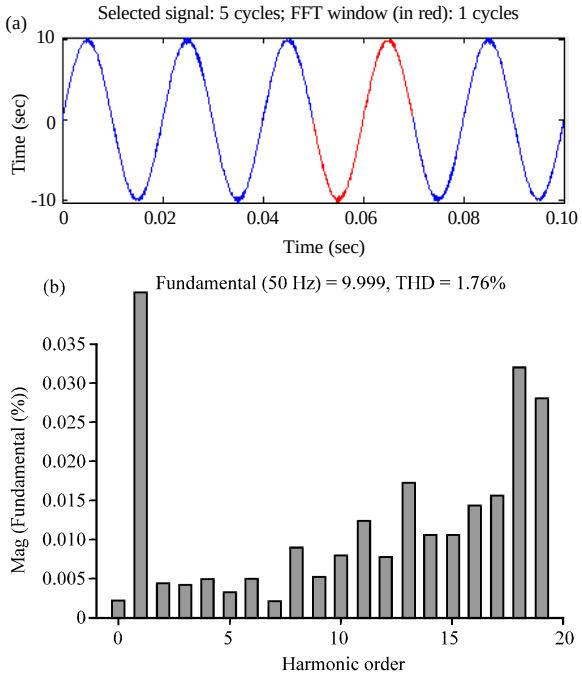

Fig. 8: a, b) THD of line current with shunt active filter

CONCLUSION

Due to the development of power electronics technology nowadays huge amount of disturbances has been introduced in the line. Using shunt active power filter is an efficient method to reduce the total harmonic distortion introduced in the line current. The simulation results clearly show that the distortion in the line current has been controlled effectively.

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