Simulation a shunt active power filter using MATLAB/Simulink

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3 authors, including:

Musa Yusup Lada
Technical University of Malaysia Malacca

Md Hairul Nizam Talib
Technical University of Malaysia Malacca

Simulation a Shunt Active Power Filter using MATLAB/Simulink

Musa Yusup Lada, Ismadi Bugis and Md Hairul Nizam Talib
Faculty of Electrical Engineering,
Universiti Teknikal Malaysia Melaka,
Karung Berkunci No. 1752, Durian Tunggal, 76109 Melaka

***Abstract*— Along with increasing demand on improving power quality, the most popular technique that has been used is Active Power Filter (APF); this is because APF can easily eliminate unwanted harmonics, improve power factor and overcome voltage sags. This paper will discuss and analyze the simulation result for a three-phase shunt active power filter using MATLAB/Simulink program. This simulation will implement a non-linear load and compensate line current harmonics under balance and unbalance load. As a result of the simulation, it is found that an active power filter is the better way to reduce the total harmonic distortion (THD) which is required by quality standards IEEE-519.**

***Index Terms*—APF, d-q theorem, THD, Power Quality, ADS, Instantaneous Power theory**

I. Introduction

Harmonic is defined as "a sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency". Harmonic is turnout of several of frequency current or voltage multiply by the fundamental voltage or current in the system. Previous technique used to compensate load current harmonics is L-C passive filter; as a result the filter cannot adapt for various range of load current and sometimes produce undesired resonance.

In electrical power supply there are many nonlinear power loads drawing non-sinusoidal current. Non-sinusoidal current will pass through the different kind of impendence in the power system and produce voltage harmonics. This will affect to the power system components especially sensitive equipment [1], [2]. Paper by Mark McGranaghan Says that "The increasing use of power electronics-based loads (adjustable speed drives, switch mode power supplies, etc.) to improve system efficiency and controllability is increasing the concern for harmonic distortion levels in end user facilities and on the overall power system" [3].

The harmonic standard was invigilated with IEEE Standard 519. The objective of this standard is to provide general harmonic evaluation procedures for different classes of customer such as industrial, commercial and residential. The IEEE 519 also illustrated methods for evaluating of harmonic control at the customer level and on the utility system. Expert devices such as ovens that produce heat are commonly sensitive to harmonics. There are many problem caused by harmonics in the power system and electrical loads such as a Disturbance to Electrical and Electronics Devices, Higher Losses, Extra Neutral Current, Improper Working of Metering Devices, De-Rating of Distribution Equipment and Resonance Problem [1], [2], [3].

II. Active filter

Active filter have been designed, improved, and commercialized in past three decades. They are applicable to compensate current-based distortions such as current harmonics, reactive power and neutral current. They are also used for voltage-based distortion such as voltage harmonics, voltage flickers, voltage sags and swells and voltage imbalances [1].

They are two categories of active filter such as single-phase and three-phase. Three-phase active filters may be with or without neutral connection and single phase active filters are used to compensate power quality problems caused by single-phase loads such as DC power supplies. Three-phase active filters are used for high power nonlinear loads such as adjustable speed drive (ASD) and AC to DC converters [1], [3].

Based on topologies, they are two kinds of active filter such as current source and voltage source active filters. Current source active filters (CSAF) employ an inductor as the DC energy storage device as shows in Fig. 1. In voltage source active filter (VSAF), a capacitor acts as the storage element as shows in Fig. 2. Between these two topologies,

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All the authors are with Faculty of Electrical Engineering and Power Electronic and Drives Department, Universiti Teknikal Malaysia Melaka, Malaysia (e-mail: musayl@utem.edu.my)

VSAF are inexpensive, lighter, and easier to control compare to CSAF [1], [3]. There are types of connection that can be used for active filter such as shunt active filter, series active filter, parallel active filter, and hybrid active filter [3].

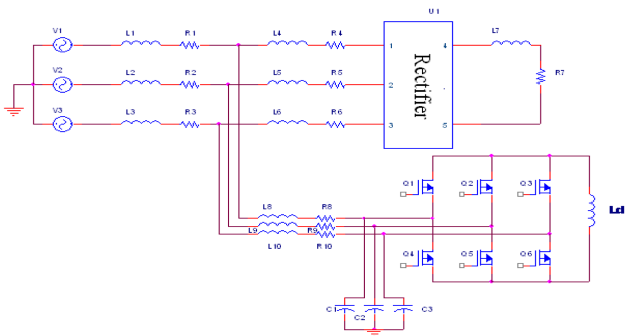

Fig. 1. A typical three-phase current source active filter (CSAF)

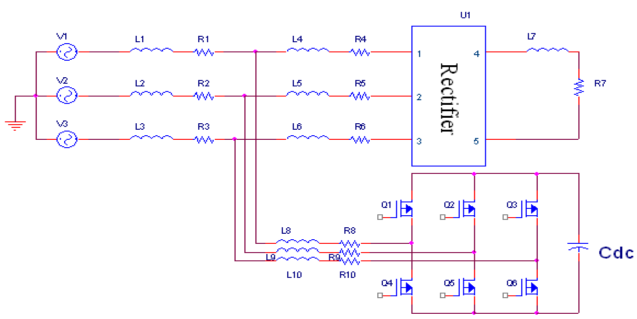

Fig. 2. A typical three-phase voltage source active filter (VSAF)

A shunt active filter is capable of removing harmonics from the supply of commercial and industrial sites. Simon Round and friends use the new technique based on sinusoidal subtraction by using active filter to make an inverter which is more responsive to the harmonics [4].

According to the research by mark McGranaghan, one of the serious problems facing on active filter design is to figure out the active filter rating that is required to compensate harmonics from particular load. He used a parallel-connected active filter for his research due to this topology able to limit of the harmonics cancellation provided and the size can be selected accordingly to achieve any desired level of cancellation. One good things of using parallel-connected active filter is that it can provide enough compensation so that the load or filter compensation will be within some specified guidelines for harmonic generation. Fig. 3 shows the diagram illustrating component of shunt connected active filter with the waveform showing cancellation of harmonics from an ASD load [3].

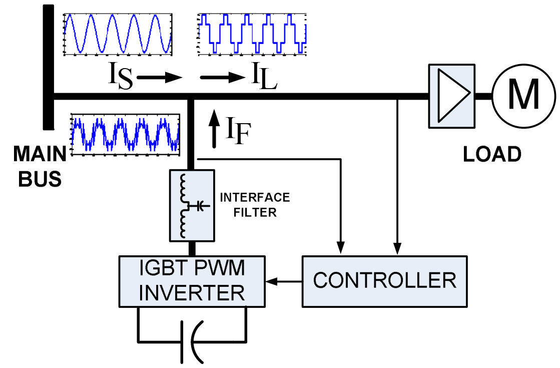

Fig. 3. Diagram illustrating component of shunt connected active filter with the waveform showing cancellation of harmonics from an ASD load.

III. Instantaneous Power Theory

The instantaneous power theory or p-q theory was introduced by *Akagi* in 1983. This method uses algebra transformation also know as Clarke transform for three phase voltage and current. The three phase voltage and current are converted into α-β using eq. (3) and eq. (4), where i_{abc} are three phase line current and v_{abc} are three phase line voltage.

$$i_{\alpha\beta o} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} i_{abc} \tag{3}$$

$$v_{\alpha\beta o} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} v_{abc} \tag{4}$$

Refers to p-q theory, the active power and reactive power for three phase system might be given as shown in eq. (5) and eq. (6).

$$p = v_\alpha i_\alpha + v_\beta i_\beta + v_o i_o \tag{5}$$

$$q = v_\alpha i_\beta - v_\beta i_\alpha \tag{6}$$

For system that do not have a neutral connection, the zero sequence does not exist and the mathematical equation will be presented in matrix form as shown in eq. (7).

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{7}$$

Active and reactive power can be separated into two parts which are AC part and DC part as shown in eq. (8) and eq. (9). In order to get the DC part of the active and reactive power, the signals need to be filtered using low-pass filter. The low-pass filter will remove the high frequency component and give the fundamental part.

$$p = \overline{p} + \widetilde{p} \tag{8}$$

$$q = \overline{q} + \widetilde{q} \tag{9}$$

Then according to p-q theory the active power is represented by DC part of α-β reference current, which is rearranged as shown in eq. (10).

$$i_{\alpha\beta}{}^{*} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \tag{10}$$

Therefore three phase actual current reference for active filter might be given as shown in eq. (11)

$$i_{abc}{}^{*} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} i_{\alpha\beta}{}^{*} \tag{11}$$

IV. Simulation Result

Shunt voltage source active filter simulation has been done by using MATLAB/Simulink with referring the control strategy shown in Fig. 4. This simulation uses a capacitor as a storage element and all components are assumed to be ideal.

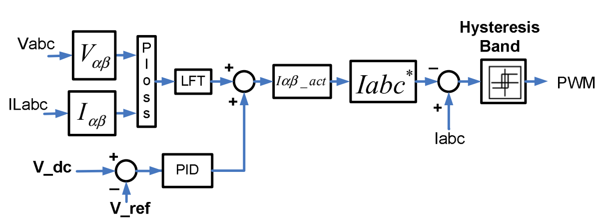

Fig. 4. Control strategy

Fig. 5 shows the modeling an active filter which is consisting of three phase power supply with 240Vrms 50Hz and with 120º phase different angle, active filter circuit, non-linear load and controller switching strategy for the filter. Fig. 6 shows the switching scheme controller for Active Filter which consist of algebra transformation of two phase to three phase, three phase to two phase transformation and hysteresis band.

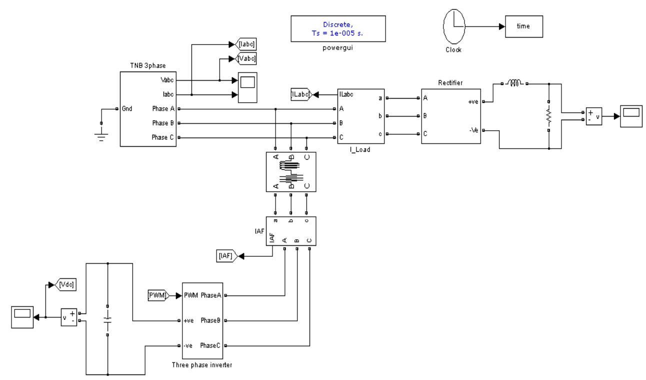

Fig. 5. Simulink model an active filter

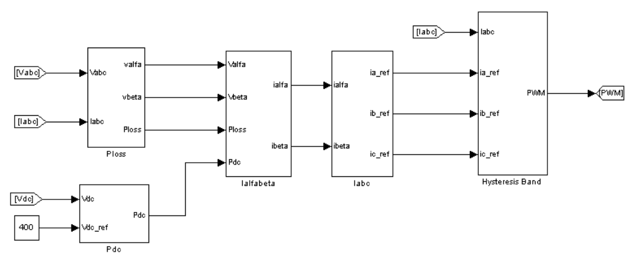

Fig. 6. Switching scheme controller for active filter

Active filter is connected to three phase voltage supply via non-negligible transmission impendence as shows in fig. 2, and wave shape of the three phase voltage source is shown in Fig. 7. Simulation is performed on three phase balanced non-linear load which are three phase diode rectifier 3kVA and supplying the DC voltage to purely resistive load. As a result, the three phase load current will appear as shows in Fig. 9. Fig. 8 shows the three phase line current which is almost in sinusoidal form. The active filter current shows in Fig. 10.

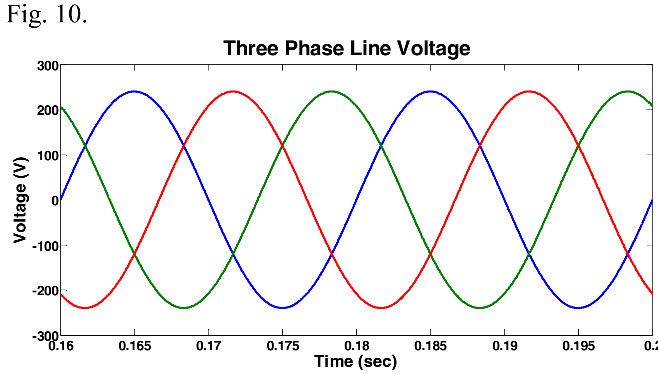

Fig. 7. Three phase line voltage

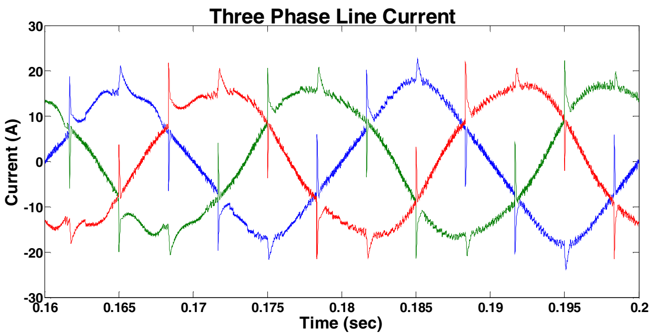

Fig. 8. Three phase line current

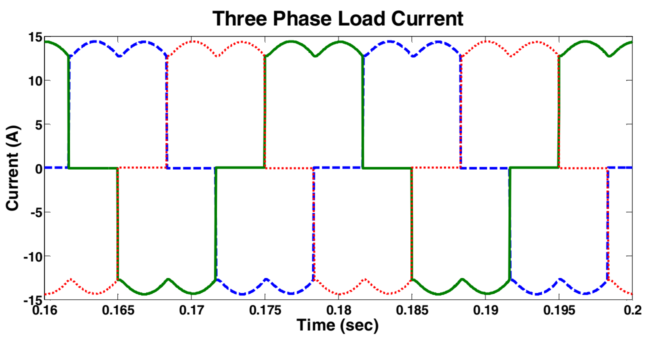

Fig. 9. Three phase load current

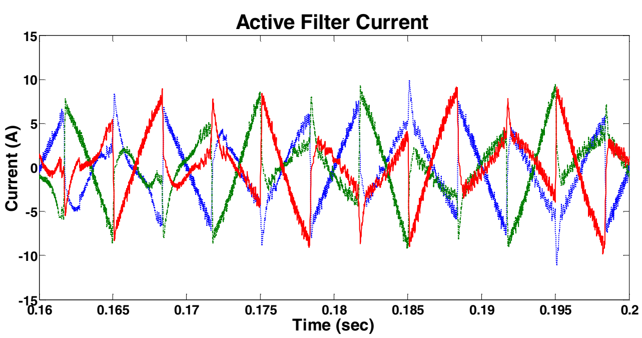

Fig. 10. Active filter current

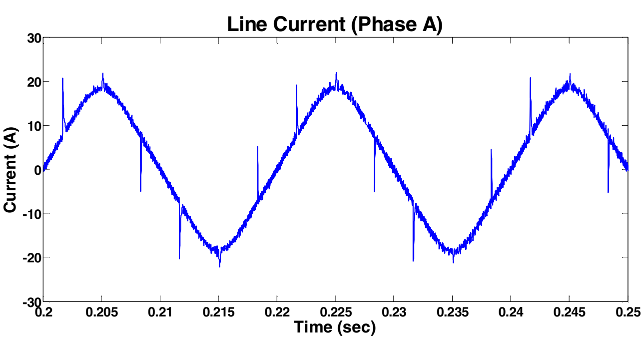

Fig. 11. Line current for phase A

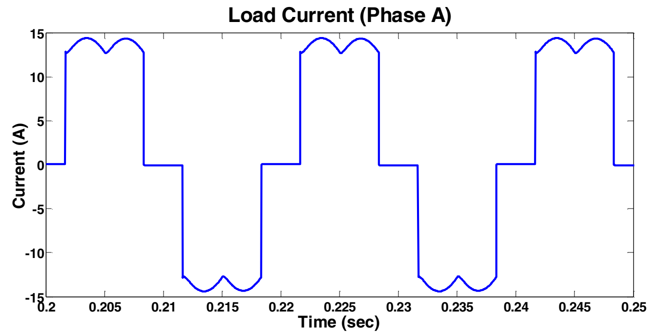

Fig. 12. Load current for phase A

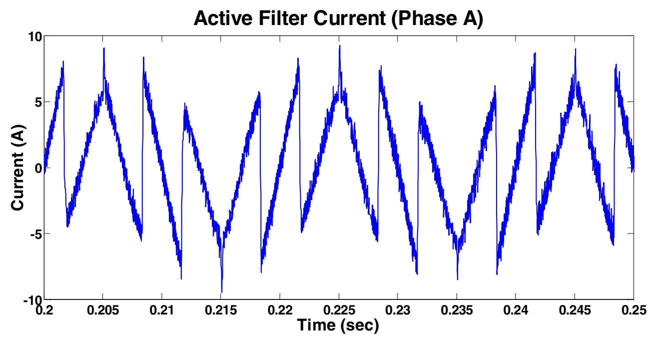

Fig. 13. Active filter current for phase A

From THD for line current and load current as shown in Fig. 14 and Fig. 15, it can be said that the effectiveness of the active filter in compensating for harmonic components will reduce the THD from 30.76% to 12.68%. This means that the THD of line current satisfies IEEE-519 standard.

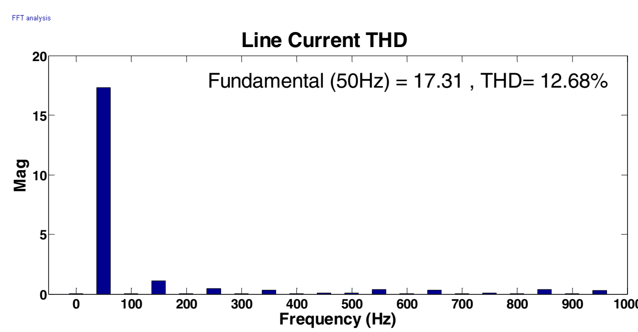

Fig. 14. THD for line current

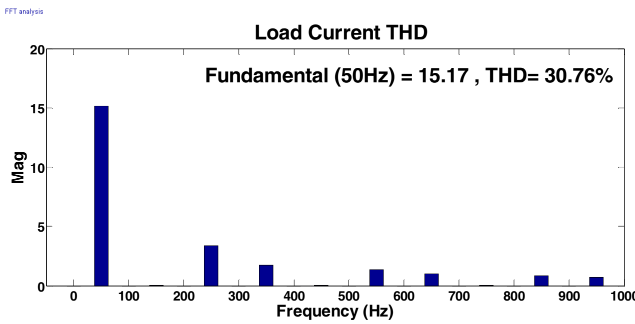

Fig. 15. THD for load current

V. Conclusion

The Increasing usage of non-linear load in electrical power system which will produce the current and voltage harmonics, and associate harmonics problem in power system become more serious and directly affecting the power quality. Conventional way of harmonics elimination by using passive filter might suffer from parasitic problem. It has been shown that three phase active filter based on p-q theory can be implemented for harmonic mitigation and power factor correction. Harmonics mitigation carried out by the active filter meets the IEEE-519 standard requirements.

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