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Reduction of Selective Harmonics using Shunt Active Power Filters

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Abstract:- This paper describes a new approach to design voltage source converter based on shunt active power filter (APF) to reduce the harmonics. The design approach uses a selective harmonic elimination method. In this approach certain harmonic current components of load are compensated by the active power filter. The proposed selective harmonic elimination approach has been implemented using a voltage source converter based on active power filter for the elimination of current harmonics considering six pulse rectifier load. Simulation and field test results have shown that selective harmonic elimination method can be successfully applied to a voltage source converter based on active power filter for reduction of harmonics.

Index Terms *—Active filters, harmonic distortion, pulse width modulated power converters, power quality (PQ).*

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I. INTRODUCTION

Proliferation of nonlinear loads has increased the problems related to power quality (PQ) issues. Power quality problem is defined as voltage, current or frequency deviations. A growing power quality concern is harmonics distortion. Harmonics are caused by the non-linearity of customer loads. In recent years, active power filters has been developed to suppress harmonics generated by static power converters. A flexible and versatile solution to power quality is offered by active power filters. Currently they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filter always operates in conjunction with shunt passive filters in order to compensate load current harmonics [2] - [4]. Since shunt active power filters can be used for harmonic mitigation independent of passive filters is considered in this paper for analysis and implementation.

A. Active Power Filter System

Active power filters compensate current harmonics by injecting equal but opposite harmonic compensating current. In this case, shunt active power filter operates as a current source injecting the harmonic components generated by the load.

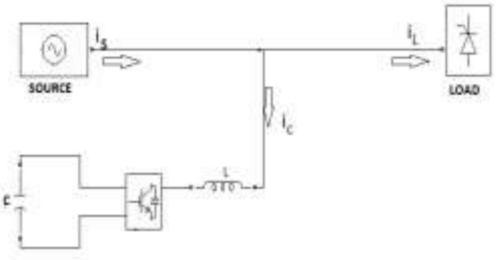

Fig. 1. Shunt Active Power Filter

An APF can be installed in the point of common coupling(PCC) of an ac system to compensate load. Once installed, the current harmonic circulation to the system is limited. Nowadays, APF development allows its application to compensate the reactive power, the negative sequence currents and the harmonic currents. So the APF's are generally named active power line conditioners (APLC). The parameters to define an APLC are the circuit configuration at power converter and the control strategy(the way to obtain the reference signal) [5]. The control strategy used for APF is based on instantaneous reactive power theory [6] and d-q transformation [7] as described in next section.

II. CONTROL STRATEGY

A. Instantaneous Reactive Power Theory

The phase voltages u_a, u_b, u_c and the pulse converter currents i_{Pa}, i_{Pb}, i_{Pc} are transformed into phase voltages u_α, u_β and pulse converter currents $i_{P\alpha}$, $i_{P\beta}$ respectively by using instantaneous reactive power theory. It is given in matrix equation (1) and (2).

$$\begin{bmatrix} u_\alpha \\ u_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_{P\alpha} \\ i_{P\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{Pa} \\ i_{Pb} \\ i_{Pc} \end{bmatrix} \quad (2)$$

The instantaneous real power p_L and the instantaneous imaginary power q_L on the load side can be defined using equation (3),

$$\begin{bmatrix} p_L \\ q_L \end{bmatrix} = \begin{bmatrix} u_\alpha & u_\beta \\ -u_\beta & u_\alpha \end{bmatrix} \begin{bmatrix} i_{P\alpha} \\ i_{P\beta} \end{bmatrix} \quad (3)$$

Using equation (3) compensating reference current can be obtained as shown in equation (4).

$$\begin{bmatrix} i_{P\alpha} \\ i_{P\beta} \end{bmatrix} = \begin{bmatrix} u_\alpha & u_\beta \\ -u_\beta & u_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p_L \\ q_L \end{bmatrix} \quad (4)$$

p_L and q_L having average and oscillating components. It can be written as,

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$$p_L = \bar{p}_L + \tilde{p}_L \quad (5)$$

$$q_L = \bar{q}_L + \tilde{q}_L \quad (6)$$

The α-phase six pulse load current $i_{P\alpha}$ is divided into the following components:

$$i_{P\alpha} = \frac{u_\alpha}{u_\alpha^2 + u_\beta^2}\bar{p}_L + \frac{-u_\beta}{u_\alpha^2 + u_\beta^2}\bar{q}_L + \frac{u_\alpha}{u_\alpha^2 + u_\beta^2}\tilde{p}_L + \frac{-u_\beta}{u_\alpha^2 + u_\beta^2}\tilde{q}_L \quad (7)$$

p^* and q^* are given by

$$p^* = -\tilde{p}_L \quad (8)$$

$$q^* = -\tilde{q}_L \quad (9)$$

$\bar{p}_L$ is removed by filtering and then it is subtracted from p_L to obtain oscillating component $\tilde{p}_L$ which is used for harmonic compensation.

The reference currents for three phase can be generated by the following expressions.,

$$i^*_{refa} = \sqrt{\frac{2}{3}}\left(\frac{1}{e_{\alpha^2} + e_{\beta^2}}\right)((p^* + p_{av})e_\alpha) \quad (10)$$

$$i^*_{refb} = \sqrt{\frac{2}{3}}\left(\frac{1}{e_{\alpha^2} + e_{\beta^2}}\right)\left(\left(\frac{\sqrt{3}e_\beta - e_\alpha}{2}\right)(p^* + p_{av})\right) \quad (11)$$

$$i_{refc}^* = \sqrt{\frac{2}{3}}\left(\frac{1}{e_{\alpha^2} + e_{\beta^2}}\right)\left(-\left(\frac{\sqrt{3}e_\beta + e_\alpha}{2}\right)(p^* + p_{av})\right) \quad (12)$$

where p_{av} is the instantaneous real power

B. Capacitor Calculation

The value of capacitor depends upon variation of oscillating real power $\tilde{p}_L$ which indirectly influences the capacitor value chosen for voltage source converter. It can be derived from the equation,

$$\varepsilon = (v_{cd\,\max} - v_{cd\,\min}) / 2V_{cd} \quad (13)$$

where ε is the voltage regulation, v_{cd} is the average voltage across the dc capacitor and V_{cd} is the average value of v_{cd}. Consider $\tilde{p}_L$ is sinusoidal, i.e.,

$$\tilde{p}_L = P_m.\sin\omega t \quad (14)$$

The voltage regulation derived as follows:

$$\varepsilon = P_m / \omega.C_d.V^2{}_{cd} \quad (15)$$

C. d-q Transformation

Control method requires reference current generation which uses direct and quadrature components. These components can be derived from α-β quantities using the transformation matrix, shown in equation (16)

$$B_2 = \begin{bmatrix} \cos\theta_h & \sin\theta_h \\ -\sin\theta_h & \cos\theta_h \end{bmatrix} \quad (16)$$

Synchronously rotating reference frame travels at a speed of ω_h. Therefore θ_h in B_2 is determined by assuming that t=0. This yields

$$\theta_h = \omega_h t \quad (17)$$

$$\omega_h = 2\pi h f_1 \text{ elec. rad/s} \quad (18)$$

where ω_h is the angular frequency at the selected harmonics, h is the harmonic order and f_1 is the fundamental frequency.

III. SELECTIVE HARMONIC ELIMINATION

Considering six pulse rectifier as a non-linear load. The dominant harmonics are 5th and 7th harmonics. Hence the active power filter is designed for selective harmonic elimination of 5^{th} and 7^{th} harmonics. The method can also be extended for other harmonics occurring, based on power quality requirements.

A. Reference Current Generation

The reference currents for selective harmonic elimination is obtained using the block diagram as shown in Fig. 2.

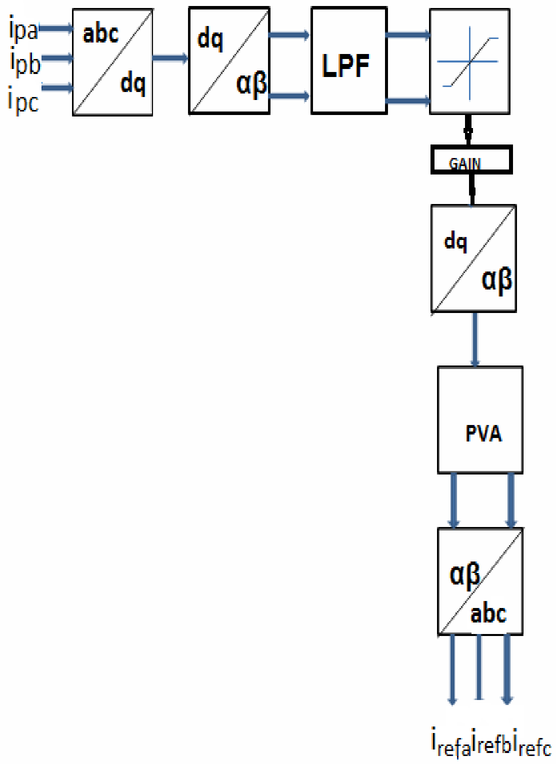

Fig. 2. Reference current generation for selective harmonic elimination

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where i_{pa}, i_{pb}, i_{pc} are the pulse converter currents for phase a, phase b and phase c respectively. It is transformed into α-β components using eqn (2), referred in section II. For extraction the α-β components are again transformed to d-q axis using equation (15) and low-pass filter pertaining to specific harmonics. After extraction of specific harmonics their respective α-β components are obtained using reverse transformation ,i.e., d-q to α-β transformation.

$$B_2^{-1}=B_2^{T} \qquad (19)$$

The α-β components thus obtained are provided with respective gain adjustments and phase shift caused by coupling transformer [1]. Further another reverse transformation of α-β to abc coordinates are applied in order to derive respective reference currents.

IV. EXPERIMENTAL RESULTS

A. Implementation of Selective Harmonic Elimination Using Matlab

The matlab simulation is done using the circuit shown in the Fig. 3.

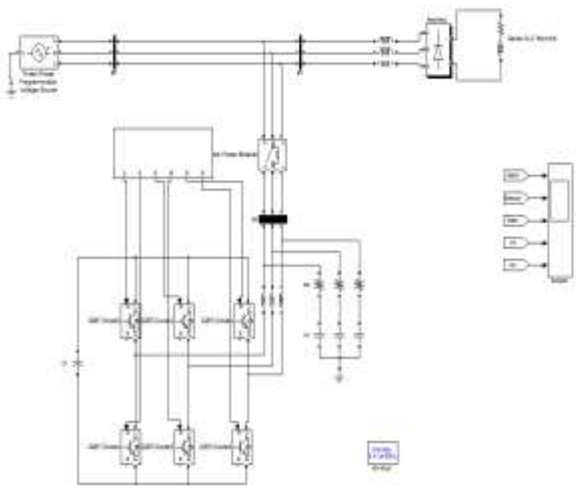
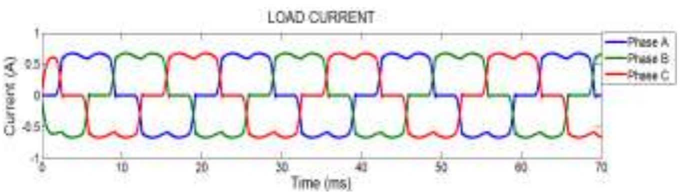


Fig. 5. Simulation Circuit for Selective Harmonic Elimination

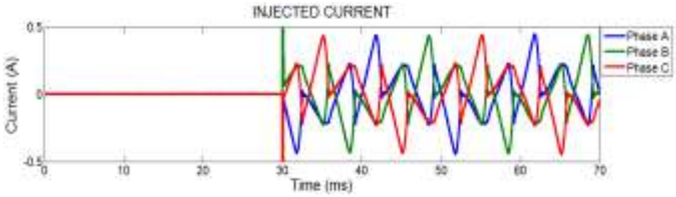
The load current considering six pulse converter as load is shown in the Fig. 6(a)

The extraction of d-q equivalent of particular harmonic and reference current generation are done by utilizing the concept stated in section II and III. As a result, current of opposite phase to the harmonics are generated as shown in the Fig. 6(b).

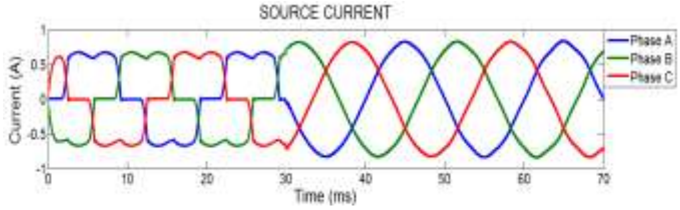
The resultant compensated current is shown in the Fig. 6(c).



(a) Load Current



(b) Injected Current



(c) Source Current

Fig. 6. Output Waveform for Selective Harmonic Elimination

In this paper elimination of 5^{th} and 7^{th} harmonic current alone is considered for filtering using selective harmonic elimination method. The magnitude of 5^{th} and 7^{th} harmonics along with 11^{th} and 13^{th} harmonics are shown in table I.

TABLE I
MAGNITUDE OF CURRENT HARMONICS

Current Harmonics On AC Side	Magnitude of Current Harmonics (mA)
5^{th}	154
7^{th}	69
11^{th}	49
13^{th}	37

The THD level of load currents before and after filtering at various levels of harmonics are shown in table II.

TABLE II
THD COMPARISION

THD	Percentage
Before Removal of Harmonics	25.54%
After Removal of 5^{th} and 7^{th} Harmonics	3.5%
After Removal of 5^{th}, 7^{th}, 11^{th} and 13^{th} Harmonics	0.94%

B. Inference and Justification

As per IEEE-519 standard, the THD tolerance is given as 5%. Since the removal of 5^{th} and 7^{th} harmonic is within the standard limit(i.e., 3.5%). Further elimination is not considered but may be taken for further analysis and improvement.

V. CONCLUSION

Active power filters are efficient enough to remove harmonic content of non-linear loads, it was proven beyond doubt by many researches in their footsteps, further extension of filtering process is done using new topology of selective harmonic elimination. The results obtained are appreciable and can be extended for the various power quality requirements.

REFERENCES

[1] Alper Terciyanli, Muammer Ermis, Isik Cadirci "A selective harmonic amplification method for reduction of kVA rating of current source converters in shunt active power filters" IEEE transactions on power delivery, vol. 26, No. 1, January 2011.

[2] Arindam Ghosh, Gerard Ledwich,*Power Quality Enhancement Using Custom Power Devices*,August 2002, ISBN 1-4020-7180-9, Book published by Kluwer Academic Press. Ch-3, pp. 67-70 and 255.

[3] Vijay K. Sood, *HVDC and facts controllers applications of static converters in power systems*, Kluwer Power Electronics and Power Systems Series, @ 2004. pp. 15-38.

[4] Hirofumi Akagi, Fellow,. "New trends in active filter for power conditioning", IEEE Transaction on Industry Applications, Vol 32, no6. November/December 1996.

[5] Chan-ki-kim, Vijay K. Sood, *HVDC Transmission power conversion application in power systems*, John Wiley & Sons(Asia) Pte Ltd, copyright 2009, pp. 88-92.

[6] Hirofumi Akagi, Akira Nabae, Satoshi Atoh "Control strategy of active power filters using multiple voltage-source PWM converters" IEEE transaction on industry applications, vol. 1A-22, No.3, May/June 1986.

[7] Antonio Moreno- Munoz, *Power quality mitigation technologies in a distributed environment,* Springer- Verilog London Limited 2007.pp. 231-238.

[8] Balasubramaniam. P.M, Gurusamy. G, "Three phase active conditioner for harmonics mitigation*",* Bonfring International Journal of Power Systems and Integrated Circuits, Vol. 2, No. 3, September 2012.

[9] Abdelmadjid Chaoui, Jean Paul Gaubert, Fateh Krim, Gerard Champenois,"PI Controlled Three-phase Shunt Active Power Filter for Power Quality Improvement" Electric Power Components and Systems, 35, , 2007, pp.1331–1344.

[10] Bimal K. Bose, *Modern Power Electronics and AC Drives*, First Edition, Prentice Hall, 2002. pp. 255-259.