IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
PP 15-19

Suppressing DC-capacitor voltage ripples by inducing negative sequence fundamental current with APF

(R.Vishnupriya, R.Thamizharasi, K.Shobana)
(Assistant professor, Electrical and Electronic Engineering, IFET College of Engineering, Anna university, India)
(student, Electrical and Electronic Engineering, IFET College of Engineering, Anna university,India)
(student, Electrical and Electronic Engineering, IFET College of Engineering, Anna university, India)

Abstract: *This project is mainly used to reduce the voltage ripple and improve the power quality of the DC system. The proposed method superimposes a negative sequence fundamental current on the compensating current to cancel out the active power ripple caused by harmonic. We have proposed a control method for active power filter using k-step compensator capable of a great reduction in the dc capacitor voltage fluctuation when a sudden load change occurs. The proposed method has also confirmed to fulfil the reduction in the capacitance value of the dc capacitor to 1/7 by theoretically analysis and experimental verification. As a result, the proposed method has the capability to eliminate the source frequency*.
Keywords-*Active power filter, dc capacitor, k-step compensator, voltage ripple, negative – sequence fundamental current.*

I. Introduction

Currently many control methods for various power converters have been developed to employ a film capacitor as the dc capacitor [1]-[5]. Although, the electrolytic capacitor having some problems in the maintenance its is widely used as the dc capacitor because of its merit in the cost and the size [6]-[8]. The power converter would be expected to extend the operation lifetime and to puts down the power loss and volume. An active power filter is generally connected with a large electrolytic capacitor for the practical application because it requires an energy storage element [9]-[11]. The active power filter reduces the source current harmonic by using the harmonic current which is antiphase from the load side harmonic current. The small film capacitor is used as the dc capacitor when the APF is operated only under balanced steady-state condition. If the APF is operated under the unbalanced or transient condition it requires large energy storage element to reduce the voltage fluctuation across the dc capacitor.

In the proposed control method for APF using the k-step compensator which has the capability to reduce the dc capacitor voltage fluctuation during the sudden load change occurs. From the theoretical analysis and the experimental verification, the proposed method reduces the capacitor value of the dc capacitor in to 1/7 [4]. In addition, a dc capacitor voltage control fitting for the APF equipped with a small dc capacitor has been proposed in [12]. The three-phase diode rectifier produces the negative sequence fundamental current when the source voltage and impedance are unbalanced. The APF is not compensate for the negative sequence fundamental current because it's not a harmonic current, but should be required to compensate for the third-order harmonic current.

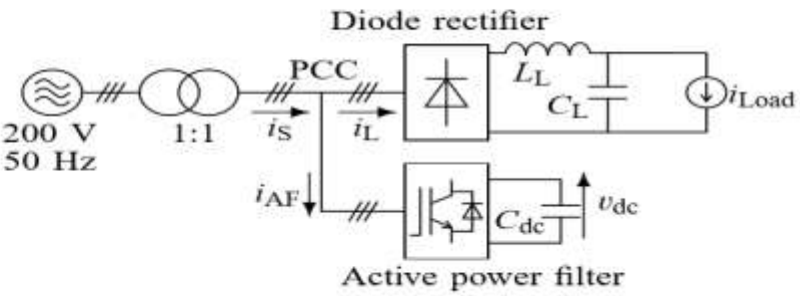

Fig. 1. Experiment system configuration.

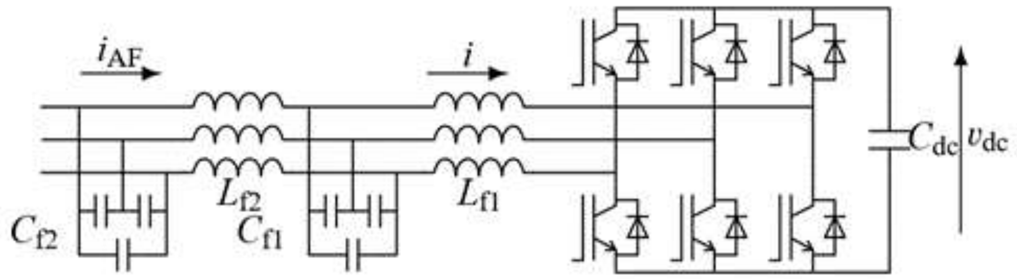

Fig. 2. Main circuit of the experimental three-phase active power filter.

II. Circuit Configuration

Fig. 1 shows the experimental system configuration used in the following experiments, and Fig. 2 shows the circuit configuration of the three-phase active power filter (APF). The circuit parameters are listed in Table I. The main purpose of the APF in this paper is to compensate the harmonics produced by a motor drive system in air conditioners and so on. The diode rectifiers used in such the system essentially have a balanced three-phase current with a unity displacement power factor. The main circuit of the APF is a conventional three-phase bridge PWM converter using an intelligent power module (IPM: PS21869, 600 V, 50 A, Mitsubishi), which is rated at 5 kVA. The converter is equipped with a cascaded ripple filter consisting of ac inductors Lf1 and Lf2 and filter capacitors Cf1 and Cf2 on its ac side. The switching frequency is set to be fsw = 20 kHz. A three-phase diode rectifier rated at 10 kVA is employed as a harmonic producing load in the following experiments.

$\boldsymbol{C_1}$ is represented by

$$\boldsymbol{C_1} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\omega t) & \cos\left(\omega t - \frac{2}{3}\pi\right) & \cos\left(\omega t + \frac{2}{3}\pi\right) \\ -\sin(\omega t) & -\sin\left(\omega t - \frac{2}{3}\pi\right) & -\sin\left(\omega t + \frac{2}{3}\pi\right) \end{bmatrix}. \quad (1)$$

In thistransformation, the positive-sequence fundamental component in the load current is transformed into dc components in i(1) Ld and i(1) Lq, and the other components are transformed into ac components. Moving average filters extract the dc components and the inverse transformation matrix CT 1 calculates the fundamental currents. The load current harmonics iLh are extracted by subtracting the fundamental current from the load current iL. Note that the inverse transformation matrix CT 1 is not the inverse matrix, but the transpose of C1 in (1).

In this analysis, the source is assumed to be a three-phase balanced sinusoidal voltage without any harmonic component as given by

$$\begin{bmatrix} v_{Su} \\ v_{Sv} \\ v_{Sw} \end{bmatrix} = \sqrt{\frac{2}{3}} V_S \begin{bmatrix} \cos(\omega t) \\ \cos\left(\omega t - \frac{2}{3}\pi\right) \\ \cos\left(\omega t + \frac{2}{3}\pi\right) \end{bmatrix}, \quad (2)$$

where VS is the source rms voltage. The compensating current i can be defined as the sum of the fundamental and harmonic components as follows:

$$\begin{bmatrix} i_u \\ i_v \\ i_w \end{bmatrix} = \sum_{n=-\infty}^{\infty} \sqrt{2} I_{(n)} \begin{bmatrix} \cos\left(n\omega t + \phi_{(n)}\right) \\ \cos\left(n\omega t + \phi_{(n)} - \frac{2}{3}\pi\right) \\ \cos\left(n\omega t + \phi_{(n)} + \frac{2}{3}\pi\right) \end{bmatrix}, \quad (3)$$

where I(n) is the rms current of the component at the angular frequency of nω, ϕ(n) is the corresponding phase angle. Here, I(1) and I(−1) represent the positive- and negative-sequence fundamental currents, respectively. As the same manner, both positive and negative numbers should be considered in the integer n for each harmonic order |n|. For example, a three phase diode rectifier produces a fifth-order harmonic current which includes the dominant component of n = −5. On the other hand, a single-phase diode rectifier produces an unbalanced harmonic current which is represented by using both n = −5 and n = 5 components. It is assumed that the switching ripple current and the leading current through the filter capacitors Cf1 and Cf2 are negligible, and thus, iAF ≈ i. This approximation yields the instantaneous active power flowing into the APF, as given by

$$p = i_u v_{Su} + i_v v_{Sv} + i_w v_{Sw} = \sqrt{3} V_S \sum_{n=-\infty}^{\infty} I_{(n)} \cos\{(n-1)\omega t + \phi_{(n)}\}. \quad (4)$$

Neglecting the power loss in the APF, all the active power is stored into the dc capacitor. Note that the positive-sequence fundamental current I(1) is essentially zero in case of APF applications. The component I(1) causes an amount of active power flowing into the APF continuously, as given by

$$p_{(0)} = \sqrt{3} V_S I_{(1)} \cos \phi_{(1)}. \quad (5)$$

The component I(1) is widely used to regulate the dc capacitor voltage. Thus, the active power makes it possible to compensate for the power loss in the APF. On the other hand, the other components form ripples in the active power p. The active power ripple having an angular frequency of mω is represented by

$$p_{(m\omega)} = \sqrt{3} V_S \{ I_{(m+1)} \cos(m\omega t + \phi_{(m+1)}) + I_{(-m+1)} \cos(m\omega t - \phi_{(-m+1)}) \}. \quad (6)$$

Therefore, the active power ripple having an angular frequency of mω consists of two different components in the compensating current, which are corresponding to n = m + 1 and n = −m+1. Assuming that the voltage ripple in the dc capacitor is much smaller than its mean voltage, the small signal analysis yields the dc-capacitor voltage ripple at an angular frequency of mω, as follows

$$v_{dc(m\omega)} \approx \frac{\sqrt{3} V_S}{m\omega C_{dc} V_{dc}} \{ I_{(m+1)} \sin(m\omega t + \phi_{(m+1)}) + I_{(-m+1)} \sin(m\omega t - \phi_{(-m+1)}) \}. \quad (7)$$

As (7), the lower angular-frequency current component exists, the more remarkable ripple in the dc capacitor voltage is induced, because the amplitude of the voltage ripple is in inverse proportion to its angular-frequency mω.On the other hand, the APF requires to compensate for the third-order harmonic current (n = 3) and controls the corresponding component in the compensating current. The component theoretically forms the active power ripple at 2ω. Moreover, it is possible to eliminate the 2ω active power ripple by addition of a negative-sequence fundamental current (n = −1) to the compensating current. To eliminate 2ω active power ripple the following requirement should be satisfied:

$$p_{(2\omega)} = \sqrt{3} V_S \{ I_{(3)} \cos(2\omega t + \phi_{(3)}) + I_{(-1)} \cos(2\omega t - \phi_{(-1)}) \} = 0, \quad (8)$$

where I(−1) and ϕ(−1) are rms value and phase angle of the superimposed negative-sequence fundamental current. The superimposed component would flow out and cause an unbalance in the source current, but it has no effect on the harmonic compensating performance. From (8), the rms value and phase angle of the superimposed component should be controlled as follows:

$$\begin{cases} I_{f(-1)} = I_{(3)} \\ \phi_{f(-1)} = \pi - \phi_{(3)} \end{cases} . \quad (9)$$

Under the condition in (9), the 2ω ripple is not included in the dc-capacitor voltage even when the APF compensates for the harmonic component at n = 3 in the load current. Here, the load current is defined as

$$\begin{bmatrix} i_{\mathrm{Lu}} \\ i_{\mathrm{Lv}} \\ i_{\mathrm{Lw}} \end{bmatrix} = \sum_{n=-\infty}^{\infty} \sqrt{2} I_{\mathrm{L}(n)} \begin{bmatrix} \cos\left(n\omega t + \phi_{\mathrm{L}(n)}\right) \\ \cos\left(n\omega t + \phi_{\mathrm{L}(n)} - \frac{2}{3}\pi\right) \\ \cos\left(n\omega t + \phi_{\mathrm{L}(n)} + \frac{2}{3}\pi\right) \end{bmatrix}, \qquad (10)$$

where IL(n) is the rms value of the load current component having an angular frequency of nω and ϕL(n) is its phase angle. When the APF compensates for the harmonic component at n = 3, the rms value and phase angle of the component at n = 3 in the compensating current are controlled as

$$\begin{cases} I_{(3)} = I_{\mathrm{L}(3)} \\ \phi_{(3)} = \pi + \phi_{\mathrm{L}(3)} \end{cases} . \qquad (11)$$

Therefore, the rms value and the phase angle of the superimposed negative-sequence fundamental current on the compensating current are given by

$$\begin{cases} I_{\mathrm{f}(-1)} = I_{\mathrm{L}(3)} \\ \phi_{\mathrm{f}(-1)} = -\phi_{\mathrm{L}(3)} \end{cases} . \qquad (12)$$

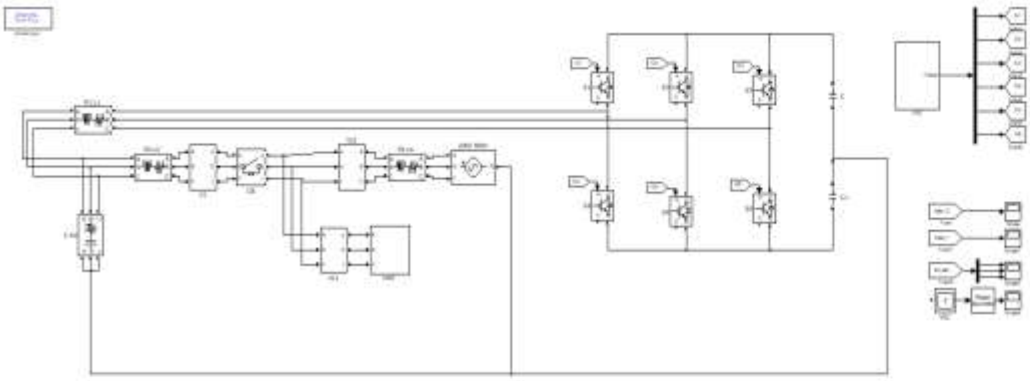

Fig.3. MATLAB circuit of the experimental three phase active filter.

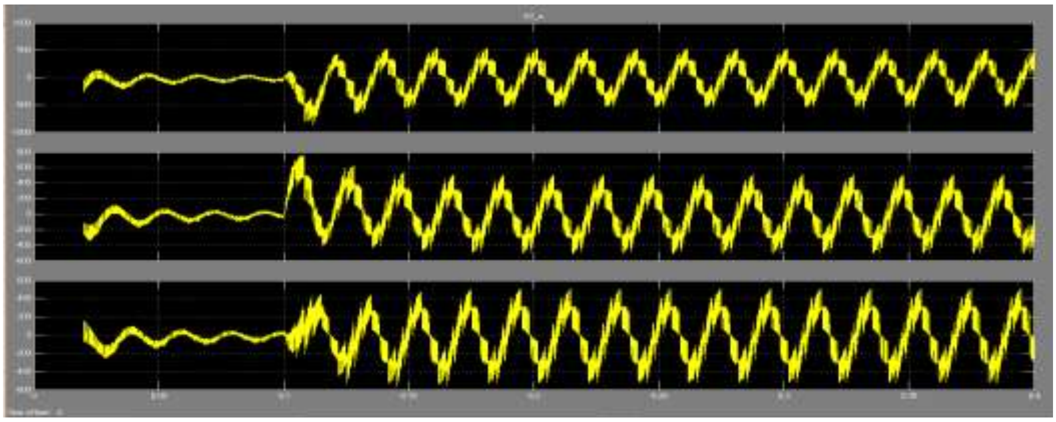

Fig. 4. Output wave form of the Simulink model of the three phase active power filter.

III. Conclusion

This paper proposed a new control method for suppressing the dc capacitor voltage ripple caused by the third-order harmonic current compensation in three-phase active power filters. The proposed method superimposes a negative-sequencefundamental current on the compensating current to suppress the active power flowing into the dc capacitor having double the source frequency. As a result, the voltage ripple fluctuating at double the source frequency can be reduced without any effect on the harmonic compensating performance. The validity of the proposed method has also be confirmed in the experimental verification using a three-phase diode rectifier load under an unbalanced source voltage condition. In the experiments, it had been clarified that the proposed method can reduce the dc capacitor voltage ripple compared with the conventional control method. It has also confirmed that the voltage ripples were almost equal under both balanced and unbalanced conditions.

From these experimental results, it is expected to reduce the capacitance of the dc capacitor by using the proposed method.

Reference

[1]. H. Fujita "A reduction method of a DC capacitor in a single-phase active power filter" Proc. IEEE Power Electronics and Drive Systems pp. 517-522 2009.

[2]. H. Fujita R. Suzuki "A three-phase solar power conditioner using a single-phase PWM control method" IEEJ Trans. IA vol. 130 no. 2 pp. 173-180 2010.

[3]. C. Jin Y. Tang P. Wang X. Liu D. Zhu F. Blaabjerg "Reduction of DC-link capacitance for three-phase three-wire shunt active power filters" IEEE IECON 2013 pp. 1203-1208 2013.

[4]. T. Mannen H. Fujita "Dynamic control and analysis of DC-capacitor voltage fluctuations in three-phase active power filters" IEEE Trans. Power Electron. vol. 31 no. 9 pp. 6710-6718 2016.

[5]. Y. Tang W. Yao P. Loh F. Blaabjerg "Highly reliable transformer less photovoltaic inverters with leakage current and pulsating power elimination" IEEE Trans. Ind. Electron. vol. 63 no. 2 pp. 1016-1026 2016.

[6]. A. Lahyani P. Venet G. Grellet P. J. Viverge "Failure prediction of electrolytic capacitors during operation of a switch mode power supply" IEEE Trans. Power Electron. vol. 13 no. 6 pp. 1199-1207 1998.

[7]. B. Kirisken H. F. Ugurdag "Cost-benefit approach to degradation of electrolytic capacitors" IEEE Reliability and Maintainability Symposium pp. 1-6 2014.

[8]. H. Wang F. Blaabjerg "Reliability of capacitors for DC-link applications in power electronic converters-An overview" IEEE Trans. Ind. Appl. vol. 50 no. 5 pp. 3569-3578 2014.

[9]. H. Akagi "New trends in active filters for power conditioning" IEEE Trans. Ind. Appl. vol. 32 no. 6 pp. 1312-1322 1996.

[10]. S. Bhattacharya T. M. Frank D. M. Divan B. Banerjee "Active filter system implementation" IEEE Ind. Appl. Mag. vol. 4 no. 5 pp. 47-63 1998.

[11]. B. Singh K. Al-Haddad A. Chandra "A review of active filters for power quality improvement" IEEE Trans. Ind. Electron. vol. 46 no. 5 pp. 960-971 1999.

[12]. J. Allmeling "A control structure for fast harmonics compensation in active filters" IEEE Trans. Power Electron. vol. 19 no. 2 pp. 508-514 2004.

[13]. A. Chandra B. Singh B. N. Singh K. Al-Haddad "An improved control algorithm of shunt active filter for voltage regulation harmonic elimination power-factor correction and balancing of nonlinear loads" IEEE Trans. Power Electron. vol. 15 no. 3 pp. 495-507 2000.

[14]. S. J. Chiang W. J. Ai F. J. Lin "Parallel operation of capacity-limited three-phase four-wire active power filters" IEE Proc. Electric Power Appl. vol. 149 no. 5 pp. 329-336 2002.