ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Simulation of Active Power Filter for DC Capacitor Voltage Fluctuations and Harmonics Reduction

Kolli Sandhya
PG Scholar,
Department of Electrical and Electronics Engineering,
Swamy Vivekananda Engineering College,
Kalavarai, Vizianagaram, India.

R. Shiv Kumar
Assistant Professor,
Department of Electrical and Electronics Engineering,
Swamy Vivekananda Engineering College,
Kalavarai, Vizianagaram, India.

Abstract:

This paper proposes a new control method of three phase active power filters for reducing the dc capacitor voltage fluctuations in transient load change. The proposed control method introduces a new k-step compensator, which maintains the mean active power flowing into the dc capacitor at zero every 1/(k − 1) ac line period. Therefore, the compensator can suppress the transient voltage fluctuations across the dc capacitor even when a quick load change occurs. This paper theoretically reveals the relationship between the step number k and the reduction effect of the dc voltage fluctuations. The experimental setup introducing the proposed seven-step compensator exhibits a good suppression effect of the dc voltage fluctuations and makes it possible to reduce the required capacitance value of the dc capacitor by a factor of seven.

Index Terms:

Nonlinear loads, Active Power Filter (APF), Hysteresis Control, DC Capacitor.

INTRODUCTION:

Active Power Filters (APFs) have been developed and put into practical use for suppressing the harmonic current produced by harmonic-producing loads in power systems [1], [2]. An APF suppresses the source harmonic current by absorbing harmonic current which is anti-phase from the harmonic currents drawn by the harmonic-producing load. The APF requests a high-accuracy and a small-phase delay in the harmonic-detection and the current-control circuit and/or method to improve the compensation performance [3], [4]. Various control methods have been proposed mainly to improve harmonic compensation characteristics [5]–[12]. Nakata etal[6] have proposed the application of moving average filters to a comprehensive harmonic detection method for suppressing the steady-state error. The current control performance of the APF is also an important factor for the improvement of harmonic compensation characteristics. A deadbeat control method [7] and a quadruple sampling technique for single-phase APFs[11] have been reported to expand the current control bandwidth. Any control method causes an amount of instantaneous active power flowing into/out of APFs, which is formed by the source voltage and the compensating current.

Thus, a small energy storage element is required on the dc side of the APF. Usually, an electrolytic capacitor has been widely used as the energy storage element because of its high energy density. However, it should have large capacitance enough to meet the required ripple current because it has a large equivalent series resistance (ESR) value. On the other hand, film capacitors, which have a low energy density but a small ESR value, are expected to miniaturize its volume and to extend its operating lifetime because of its large ripple current rating [13]. Since the APF absorbs only the power ripples caused by harmonic currents in steady states, the required energy storage or capacitance is relatively small [14],[15]. However, a sudden load change may cause a serious voltage fluctuation and/or an overvoltage across the dc capacitor in the transient state, when a small dc capacitor is installed on the dc side.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

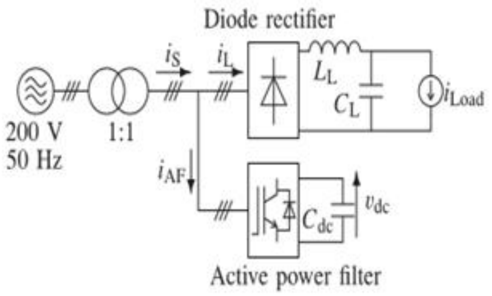


Fig.1 Block diagram of proposed active power filter

To overcome the disadvantages due to Passive Filters, Active Power Filters (APFs) have been presented as a current-harmonic compensator for reducing the total harmonic distortion of the current and correcting the power factor of the input source. The Active Power Filter is connected in parallel with a nonlinear load. The approach is based on the principle of injecting harmonic current into the ac system, of the same amplitude and reverse phase to that of the load current harmonics.. This will thus result in sinusoidal line currents and unity power factor in the input power system. In this case, only a small portion of the energy is processed, which may result in overall higher energy efficiency and higher power processing capability. These kinds of approaches are applicable for low-power (less than 5kVA) to high-power applications (around 100kVA). A three-phase shunt APF is typically composed of a three-phase bridge converter and control circuitry. Most of the previous control approaches need to sense the load current and calculate its harmonics and reactive components in order to generate the reference for controlling the current of a bridge converter. Those control methods require fast and real-time calculation; therefore, a high-speed digital microprocessor and high-performance A/D converters are necessary, which yields high cost, complexity, and low stability.

ACTIVE POWER FILTERS

Introduction:

Active power filter has been proposed since 1970s. The advantages of the active filtering process over the passive one caused much research to be performed on active power filters for power conditioning and their practical applications. By implementing the active power filters for power conditioning; it provides functions such as reactive power compensations, harmonic compensations, harmonic isolation, harmonic damping, harmonic termination, negative-sequence current or voltage compensation and voltage regulation. The main purpose of the active power filter installation by individual consumers is to compensate current harmonics or current imbalance of their own harmonic-producing loads. Besides that, the purpose of the active power filter installation by the utilities is to compensate for voltage harmonics, voltage imbalance or provide harmonic damping factor to the power distribution systems.

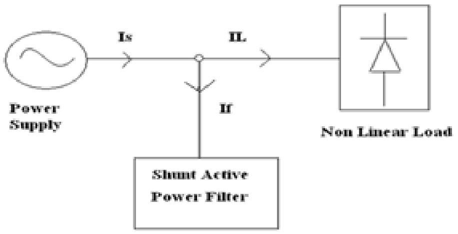


Fig.2 Basic principle of harmonic currents compensations

Classification of Active Power Filters:

The configurations of the active filters are the shunt, series power filter. The shunt active filter shown in Figure 2.2 is the most fundamental system configurations. The shunt active power filter is controlled to draw and inject compensating current, I_f to the power system and cancel the harmonic currents on the AC side of a general purpose rectifier. The shunt active power filter is normally used for the thyristor or diode rectifier with a DC link inductor. Besides that, it has the capability of damping harmonic resonance between an existing passive filter and the supply impedance.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

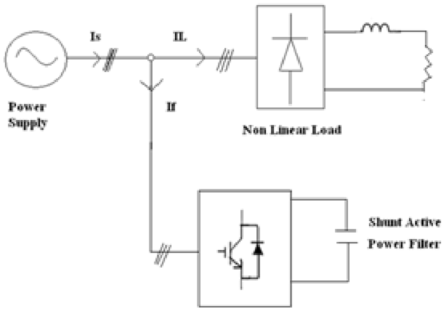


Fig.3 Shunt active power filter

PWM CONTROL OF ACTIVE POWER FILTER:

The main aim of an active power filter (APF) is to generate compensating currents into the power system for canceling the current harmonics contained in the nonlinear load current. This will thus result in sinusoidal line currents and unity power factor in the input power system.

Principles of Operation of PWM Control:

Fig. 3.1 shows the configuration of a three-phase active power filter. The active power filter is connected in parallel with a nonlinear load. It consists of a power converter, a DC-link capacitor (C_2) and a filter inductor (L_2). To eliminate current harmonic Components generated by nonlinear loads, the active power filter produces equal but opposite harmonic currents to the point of connection with the nonlinear load. This results in a reduction of the original distortion and correction of the power factor. The inductor L_2 is used to perform the voltage boost operation in combination with the DC-link capacitor C_2 and functions as a low pass filter for the line current of an active power filter

The exclusive features of this proposed PWM controlled APF are summarized as follows:

(a) The reference frame transformation and a digital low pass filter are used to compute the harmonics of the nonlinear load current.

(b) The voltage decouplers and pole-zero cancellation method are used in the current controllers of the active power filter to provide fast current harmonic compensation and simplify the control scheme.

(c) The delay times of both current response of an active power filter and DC-link voltage feedback are considered. This results in decreasing the settling time of the DC-link voltage and reducing the high frequency current harmonic components of the power system.

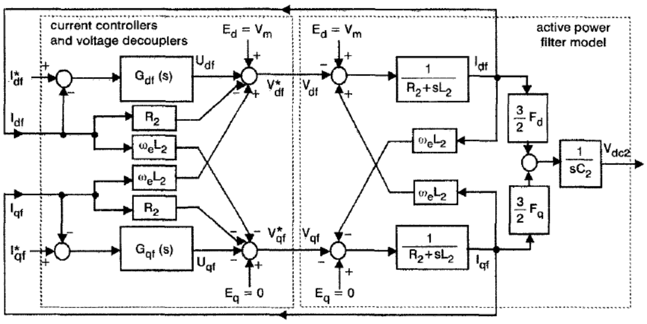


Fig. 4 Control block diagram of d- and q- axis current controllers of active power filter.

HYSTERESIS CONTROL:

The hysteresis current control (HCC) is the easiest control method to implement; it was developed by Brod and Novotny in 1985. The shunt APF is implemented with three phase current controlled VSI and is connected to the ac mains for compensating the current harmonics. The VSI gate control signals are brought out from hysteresis band current controller.

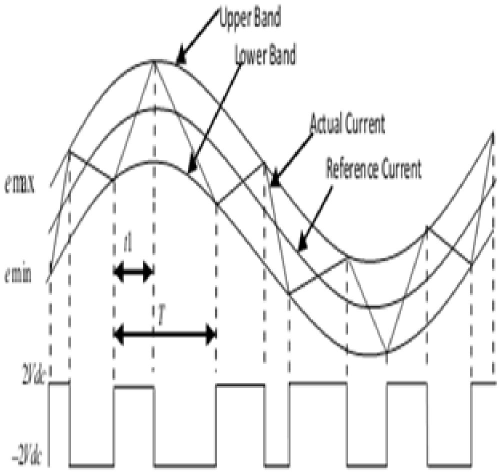


Fig:5 Waveform of Hysteresis current controller

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A hysteresis current controller is implemented with a closed loop control system and waveforms are shown in Fig 4.4. An error signal exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned off and the lower switch is turned on. As a result, the current starts decaying. If the error crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned off and the upper switch is turned on. As a result, the current gets back into the hysteresis band. The minimum and maximum values of the error signal are e_{min} and e_{max} respectively. The range of the error signal $e_{max} - e_{min}$ directly controls the amount of ripple in the output current from the VSI.

A. Simulink Model of Hysteresis Current Control

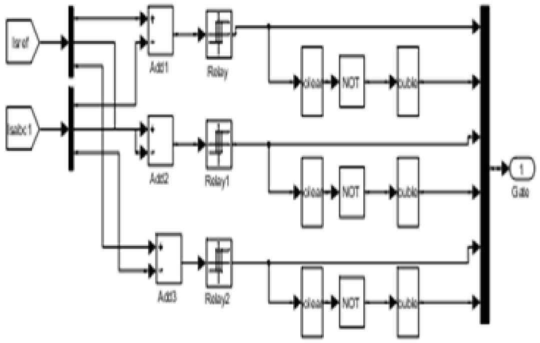


Fig. 6: Simulink Model of Hysteresis Current Control

SIMULINK MODELS OF PWM CONTROLLED APF

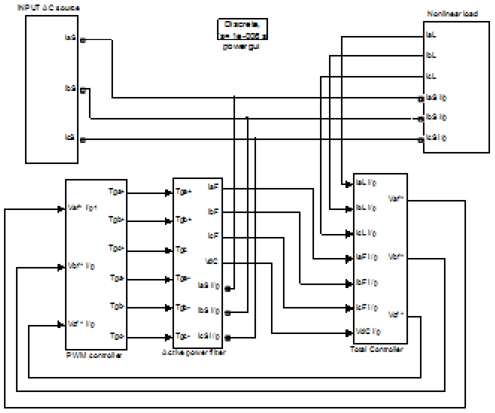


Fig.7 Simulink Model of PWM Controlled APF for the Three-Phase Power System

Here in Fig.5.17 total system is shown as five sub systems, those are Three phase ac source, which is supplying for Nonlinear load. Active Power Filter (APF) ,that is connected parallel to the load and also PWM controller subsystem which is giving pulses to the APF such that it will inject compensation currents into the power line which are opposite in phase to the harmonic currents introduced by the nonlinear loads. Total controller subsystem will provide reference voltages to the PWM controller subsystem.

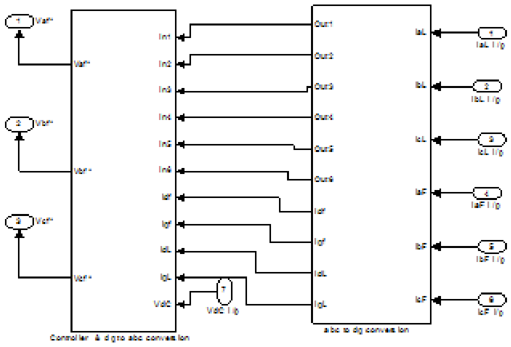


Fig .8 Simulink Model for conversions and for producing reference waves Vaf ,Vbf , Vcf .

Fig.8 is a simulink model consists of two subsystems one is abc to dq transformation Subsystem another one is dq to abc transformation and also having current controllers. Here transformation is doing for sake of simplicity and easy of calculations for designing the controller to the analytical model of Active Power Filter.

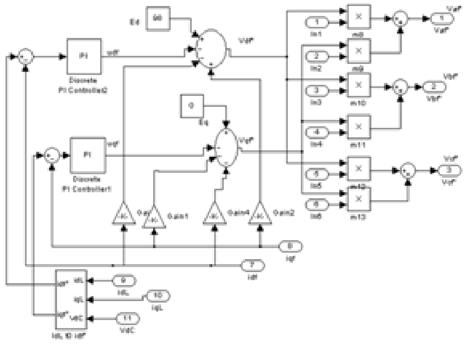


Fig .9 Simulink Model for d and q axis current controllers of APF and dq to abc conversion of reference voltages

Fig 10 shows the simulink diagram for dc-link voltage regulator, reference current calculation. Here dc-link voltage is taken as feedback, to maintain constant dc-link voltage. Maintaining constant dc-link voltage is necessary to avoid real power processing between the converter and main power system. This feedback voltage is compared with the reference voltage and error voltage is considered in the development of d-axis reference current. Here reference currents are nothing but harmonics due to the nonlinear load in the d-,q-axis load currents. In Fig 10 the reference currents are compared with the actual filter currents and error is passes through the current controllers, after that from the given model resultant reference voltages will come. Fig.11 is the simulink model for PWM controller. Here the reference voltages are compared with the triangular wave which is having frequency of 10KHZ and produced the switching gate pulses for the power converter.

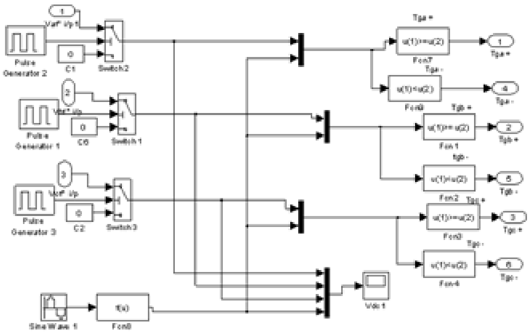


Fig .10 Simulink Model for PWM control of APF for Gating pulses

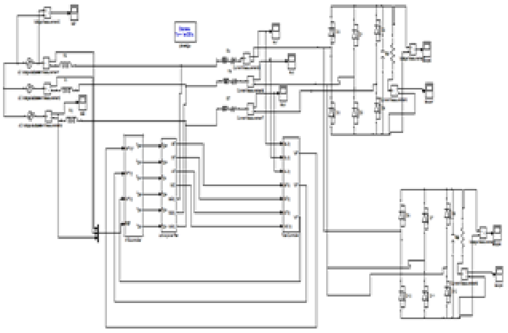


Fig .11 Simulink Model of Hysteresis Controlled APF for the Three-Phase Power System

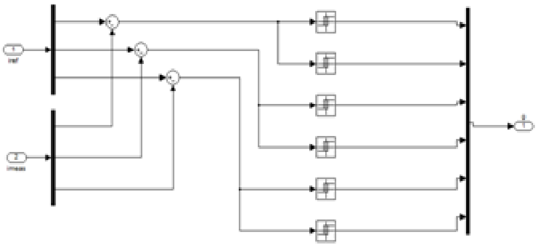


Fig .12 Hysteresis controller desing

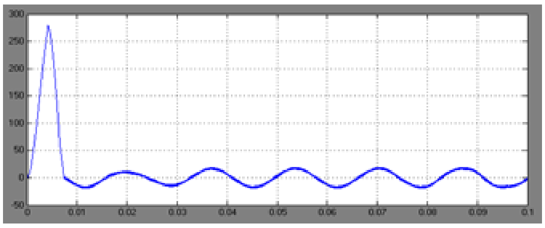


Fig .13 Source current with PWM technique

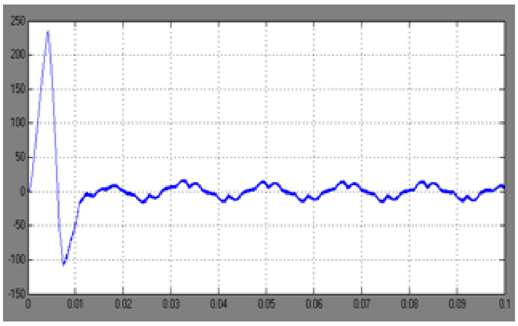
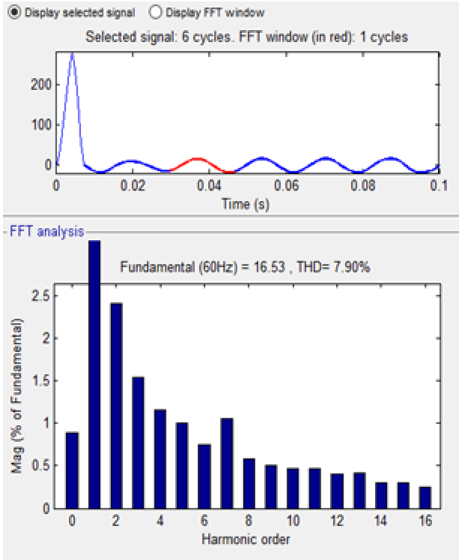


Fig .14 Injected current to the line with PWM



Selected signal: 6 cycles. FFT window (in red): 1 cycles

Fundamental (60Hz) = 16.53 , THD= 7.90%

Fig .15 THD using PWM technique

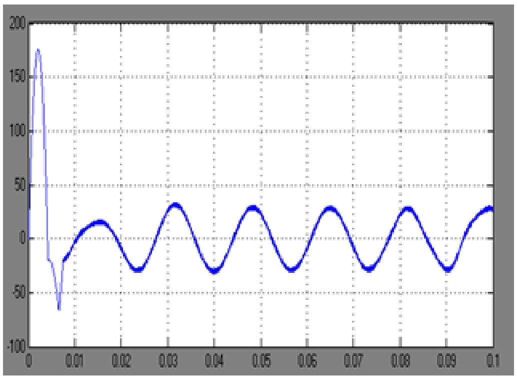


Fig .16 Source current with Hysteresis technique

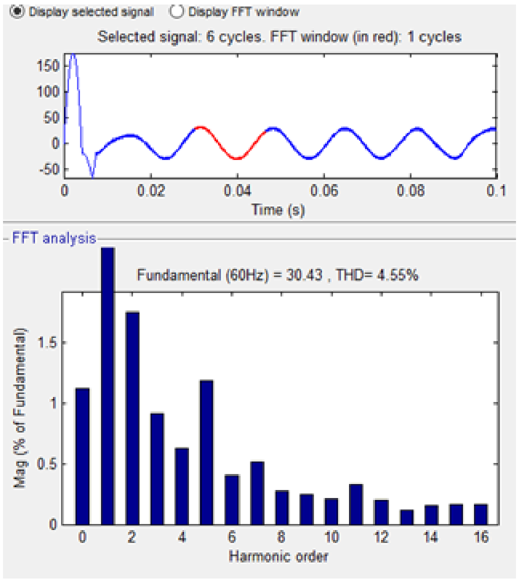


Fig .17 THD using Hysteresis technique

VI CONCLUSION:

This paper has proposed a new harmonic current detection method which can suppress the voltage fluctuation caused by sudden load changes. The experiment confirms the suitability of the proposed method. As a result, the proposed method makes it possible to compensate harmonic currents as well as a conventional one and to reduce the voltage fluctuation applied across the dc capacitance in transient states. Therefore, the proposed method can reduce the capacitance of the dc capacitor to 1/7.

REFERENCES:

[1] S. Bhattacharya, T.M. Frank, D. M. Divan, and B. Banerjee, “Active filtersystem implementation,” IEEE Ind. Appl. Mag., vol. 4, no. 5, pp. 47–63,Sep./Oct. 1998.

[2] B. Singh, K. Al-Haddad, and A. Chandra, “A review of active filters forpower quality improvement,” IEEE Trans. Ind. Electron., vol. 46, no. 5,pp. 960–971, Oct. 1999.

[3] L. Asiminoael, F. Blaabjerg, and S. Hansen, “Detection is key—Harmonicdetection methods for active power filter applications,” IEEE Ind. Appl.Mag., vol. 13, no. 4, pp. 22–33, Jul./Aug. 2007.

[4] A. Bhattacharya, C. Chakraborty, and S. Bhattacharya, “Shunt compensation,”IEEE Ind. Electron. Mag., vol. 3, no. 3, pp. 38–49, Sep. 2009.

[5] T. Ohnishi and H. Yamauchi, “Active filter by instantaneous ripple linepower reduction,” IEEJ Trans. Ind. Appl., vol. 111, no. 11, pp. 921–929,1991.

[6] A. Nakata, A. Ueda, and A. Torii, “A method of current detection for anactive power filter applying moving average to pq-theory,” in Proc. 29thAnnu. IEEE Power Electron. Specialists Conf., 1998, vol. 1, pp. 242–247.

[7] P. Jintakosonwit, H. Fujita, and H. Akagi, “Control and performance of a fully-digital-controlled shunt active filter for installation on a powerdistribution system,” IEEE Trans. Power Electron., vol. 17, no. 1,pp. 132–140, Jan. 2002.

[8] W. Merk, H. Stemmler, and J. Allmeling, “Stationary-frame generalizedintegrators for current control of active power filters with zero steady-state error for current harmonics of concern under unbalanced and distorted operating conditions,” IEEE Trans. Ind. Appl., vol. 38, no. 2, pp. 523–532, Mar./Apr. 2002.

[9] P. Jintakosonwit, H. Akagi, H. Fujita, and S. Ogasawara, “Implementation and performance of automatic gain adjustment in a shunt-active filter for harmonic damping throughout a power distribution system,” IEEE Trans. Power Electron., vol. 17, no. 3, pp. 438–447, May 2002.

[10] M. E. Ortuzar, R. E. Carmi, J. W. Dixon, and L. Moran, “Voltage-source active power filter based on multilevel converter and ultracapacitor DC link,” IEEE Trans. Ind. Electron., vol. 53, no. 2, pp. 477–485, Apr. 2006.

[11] H. Fujita, “A single-phase active filter using an H-bridge PWM converter with a sampling frequency quadruple of the switching frequency,” IEEE Trans. Power Electron., vol. 24, no. 4, pp. 934–941, Apr. 2009.

[12] H. Yi, Y. Zhang,W. Chen, F. Zhuo, and J. Liu, “A source current detected APF control scheme based on novel resonant regulator,” Proc. IEEE Energy Convers. Congr. Expo., 2012, pp. 1004–1010.

[13] A. Lahyani, P. Venet, G. Grellet, and P.-J. Viverge, “Failure prediction of electrolytic capacitors during operation of a switchmode power supply,” IEEE Trans. Power Electron., vol. 13, no. 6, pp. 1199–1207, Nov. 1998.

[14] G. Joos, “Direct power control of three phase active filter with minimum energy storage components,” in Proc. 16th Annu. IEEE Appl. Power Electron. Conf. Expo., 2001, vol. 1, pp. 570–576.

[15] C. Jin, Y. Tang, P. Wang, X. Liu, D. Zhu, and F. Blaabjerg, “Reduction of dc-link capacitance for three-phase three-wire shunt active power filters,”in Proc. 39th Annu. Conf. IEEE Ind. Electron. Soc., 2013, pp. 1203– 1208.

[16] N. Bruyant, M. Machmoum, and P. Chevrel, “Control of a three-phase active power filter with optimized design of the energy storage capacitor,” in Proc. 29th Annu. IEEE Power Electron. Specialists Conf., 1998, vol. 1, pp. 878–883.

[17] H. Akagi, Y. Kanazawa, and A. Nabae, “Instantaneous reactive power compensators comprising switching devices without energy storage components,” IEEE Trans. Ind. Appl., vol. IA-20, no. 3, pp. 625–630, May 1984.

[18] H. Komurcugil and O. Kukrer, “A new control strategy for single-phase shunt active power filters using a Lyapunov function,” IEEE Trans. Ind. Electron., vol. 53, no. 1, pp. 305–312, Feb. 2006.

[19] H. Fujita, “A reduction method of a DC capacitor in a single-phase active power filter,” in Proc. Int. Conf. IEEE Power Electron. Drive Syst., 2009, pp. 517–522.

[20] F. Z. Peng, “Application issues of active power filters,” IEEE Ind. Appl.Mag., vol. 4, no. 5, pp. 21–30, Sep./Oct. 1998.