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# Study of Shunt Active Power Filter for Harmonic Reduction Using Different Methods

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*Abstract*—**The nonlinear loads generate harmonic currents which distorts the power quality in the distribution network, so it can be considered as a pollutant which pollutes the entire power system. To overcome problems due to harmonics, Shunt Active Power Filters are used as a solution. This paper represents various methods to eliminate current harmonics caused by the non-linear loads and compensate reactive power has been presented in this work. Modularity and simple maintenance make the proposed SAPF an attractive solution compared to some conventional configurations.**

*Keywords*—**ABB, APF, SAPF, UPQC.**

## I. INTRODUCTION

Distribution power systems are suffering hard impact on their power quality. This is due to the intensive use of nonlinear loads added with the growth of renewable energy sources. Such aspects have been leading electrical systems to poor power quality levels. Most common disturbances include: i) harmonic voltages/currents, ii) voltages imbalances, iii) voltage sags/swells, iv) flickers, v) transients and vi) interruptions. Non-linear loads and unbalanced loads are the main reasons of the injected current harmonics and reactive power components at the grid, leading to a low system efficiency with a poor power factor. Extensive surveys have been carried out to quantify these problems, as discussed in [1]. In this way, some custom power devices have been introduced and investigated in the literature. Initially, the harmonic current and reactive power compensations have been treated with passive L-C filters and capacitors. However, this solution has disadvantages associated with fixed compensation and resonance effect on the power system. Then, power companies/industries (e.g., ABB, Siemens, Fuji, Westinghouse, etc.) started the development of active power filters (APFs) [1], [2]. There are three types of APFs most applied in the customized power quality market: i) series APF [3]; ii) shunt APF [4]–[6] and iii) universal APF or unified power quality conditioner (UPQC) [7], [8]. This paper considers the shunt APF (SAPF) technology for applications on three-phase three-wire systems.

## II. SHUNT ACTIVE POWER FILTER CONFIGURATION

Shunt active power filters compensate current harmonics by injecting equal-but-opposite harmonic compensating current. The shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by $180^0$. The components of harmonic currents contained in the load current are cancelled by the effect of the active filter, and the source current remains sinusoidal and in phase with the respective phase to neutral voltage. With an appropriate control scheme, the active power filter can also compensate the load power factor [5].

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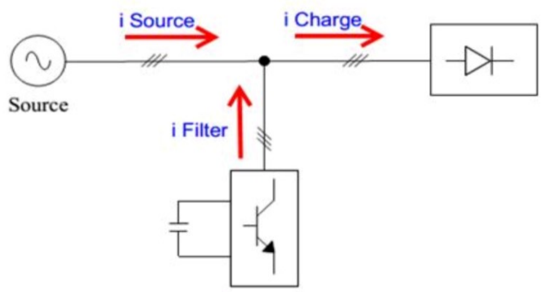


Fig. 1. Basic configuration of shunt APF

## Types of Shunt Active Power Filter

***Single Phase Shunt Active Power Filter Configuration***

The fundamental structure of the single phase shunt APF connected to a single phase AC system feeding non linear loads are shown in Fig.1.

Where, Vs = Supply voltage Is = Source current

Ls = Source impedance IL = Load current

The single phase shunt APF is built by an H-Bridge VSI, a DC link capacitor (Cdc) and an interfacing filter inductance (Lf).Its current controller must determine the compensation reference current, which is composed by the load current component and an instantaneous compensation current component corresponds to the reference current [6].

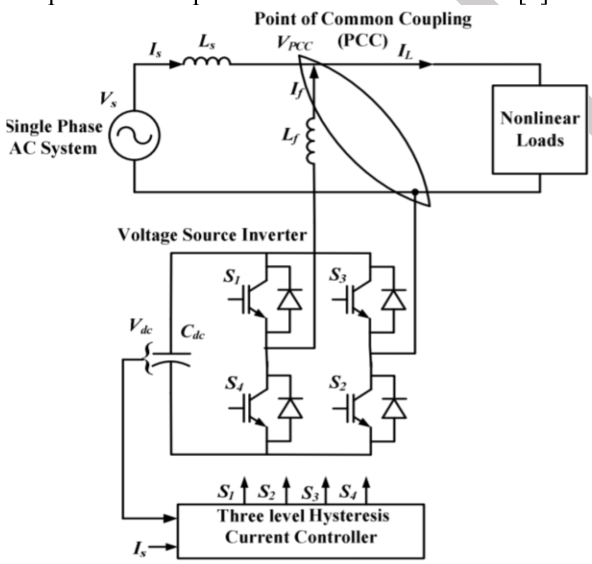


Fig. 2. Three level HCC based single phase shunt APF configuration

The APF behaves as a variable current source. It is used to compensate the current harmonics and to exchange the essential reactive power required by the nonlinear load. A single-phase welding machine load is considered as a nonlinear load, the current harmonics wave form of the welding machine load is measured using FULKE 435 II power quality analyzer, in the simulation studies the current harmonic waveform of the welding machine is obtained by considering a diode rectifier along with RL elements.

## A Proposed Three level Hysteresis control

HCC is a widely used current control technique in majority of the current controlled VSI applications, because of its simple configuration and fast dynamic response with peak current-limiting capability [4]-[5]. The conventional two-level HCC is also a better solution for most of the current control applications. However, the two level HCC technique has a limitation of wide deviation in switching frequency, which can be prohibitively high and it leads to higher switching losses of the inverter because of increased number of switching per cycle. A suitable selection of the HB width is necessary to limit the maximum switching frequency. A narrow HB reduces the current tracking error which leads to increased switching frequency whereas a wider HB increases the current tracking error with a reduced switching frequency.

*A. Two level hysteresis current control*

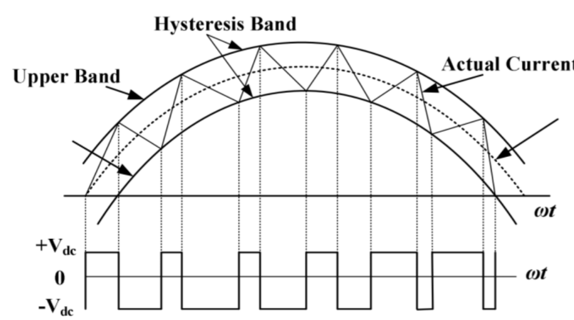


Fig. 3. Conventional two level hysteresis modulation

Traditionally, two level HCC technique is used for single phase system because of its simplicity. The two level HCC is operated by comparing a current error (i.e. the difference between the reference and the actual current aligned with fixed HBs.) Fig.3. illustrates the conventional two level hysteresis modulation. When the current tracking error crosses the upper HB, the VSI output is switched low, and when the current error crosses the lower HB, the inverter output switches high. Therefore each inverter phase leg output is the replica of the other. This approach does not employ the inverter zero state

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condition.

### *B. Improved three level hysteresis current control*

The proposed control technique for single phase shunt APF is shown in Fig. 4.

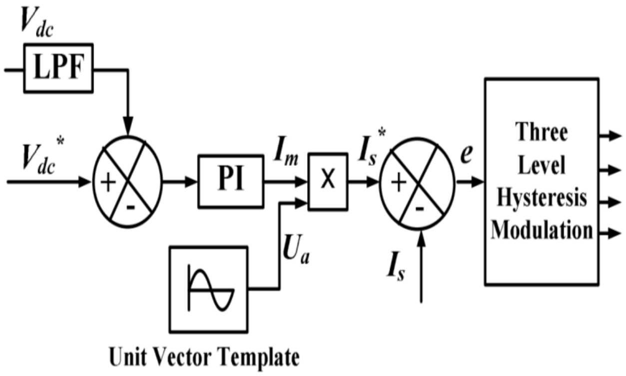


Fig. 4. Proposed three level hysteresis current control

The DC bus voltage *($V_{dc}$)* is fed through a low pass filter (LPF) in order to reduce the switching ripples in the measured voltage and compared with its reference voltage value *($V_{dc}$*)*. The error voltage is passed through the PI controller, which restrict the output to an allowable maximum current value. This PI controller output is considered as a source current peak value *($I_m$ )*. In this control technique unit vector template of the supply voltage has been generated [7]. The source current peak magnitude is multiplied by $U_a$ to generate sinusoidal reference source current which is in phase with source voltage. This reference source current *($I_s$)* is compared with instantaneous source current *($I_s$*)* to extract the current tracking error *(e)*. The current tracking error is fed to the HB comparator to generate the switching signals to the inverter.
The instantaneous source current *($I_s$*)* is written as

$$I_s^* = I_m \times U_a \qquad (1)$$

The current tracking error is written as

$$e = I_s^* - I_s \qquad (2)$$

In [8] the basic three level HCC for a single phase VSI is presented. Here the maximum switching frequency has been reduced to 1/4th that of conventional two level HCC for a motor load application. In this paper an enhanced three level
HCC for active filtering application is developed.

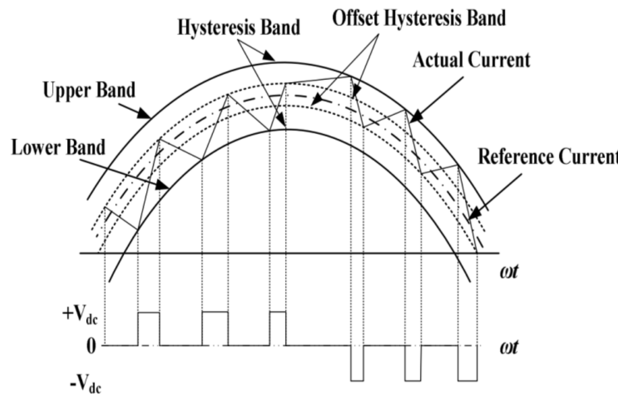


Fig. 5. Improved three level hysteresis modulation

## III. Shunt Active Power Filter Using Slide Mode Control

Shunt active filter is a voltage source full bridge inverter whose input is connected to large capacitor and output connected to source with filter inductor. Role of the inverter is to actively shape the source current by p pro0viding harmonics and reactive current required by the non linear load. Since the harmonic currents are comp compensated by the shunt APF source current are in phase with voltage by supplying only fundamental component of the load current.

### *A. Operating Principle*

Fig.6 shows the configuration for the single phase shunt active filter connected in parallel with source and nonlinear load. As shown in Fig.6 source current inductor current, capacitor current and load current are represented by , , and respectively. , and are source voltage, inverter output voltage and capacitor voltage respectively. Filter inductor is represented by

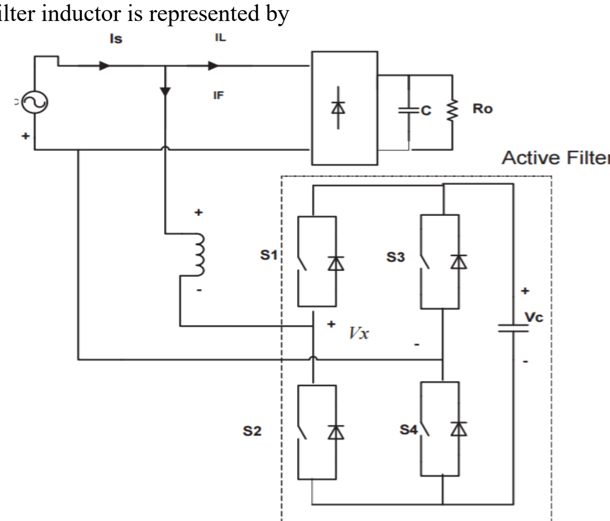


Fig. 6. Shunt active filter with non-linear load

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In the voltage source inverter switches supports unipolar voltage and bipolar current and controls the current flowing through inductor. Current through inductor forces source current to follow the shape of source voltage. Capacitor voltage should be greater than the source voltage in order to shape the source current [6].

Switches and of inverter defines the voltage at each half cycle of, while switches and defines magnitude of the current [6]. Switches of APF are controlled in such a manner that during positive half cycle of switch is ON and during negative half cycle of switch is ON. Considering these switch position single phase shunt APF has four modes of operation. Let the modes be 1 and 2 during positive half cycle of and 3 and 4 during negative half cycle of Equivalent circuit for mode 1, with switches and are ON is shown in Fig.7.

Similar analysis can be done for mode 3 and 4 with □□ and either S1 or S2 is ON. Result of the analysis at these four modes of operation is summarized in Table 1.

TABLE1

Operating Modes

| | | | | | |
|---|---|---|---|---|---|
| Mode 1 | $V_S$>0 $S_4$=1 | $S_1$=1 | $I_F$ ↓ | $V_x = V_C$ | $I_C = I_F$ |
| Mode 2 | | $S_2$=1 | $I_F$ ↑ | $V_x = 0$ | $I_C = 0$ |
| Mode 3 | $V_S$<0 $S_3$=1 | $S_2$=1 | $I_F$ ↑ | $V_x = -V_C$ | $I_C = -I_F$ |
| Mode 4 | | $S_1$=1 | $I_F$ ↓ | $V_x = 0$ | $I_C = 0$ |

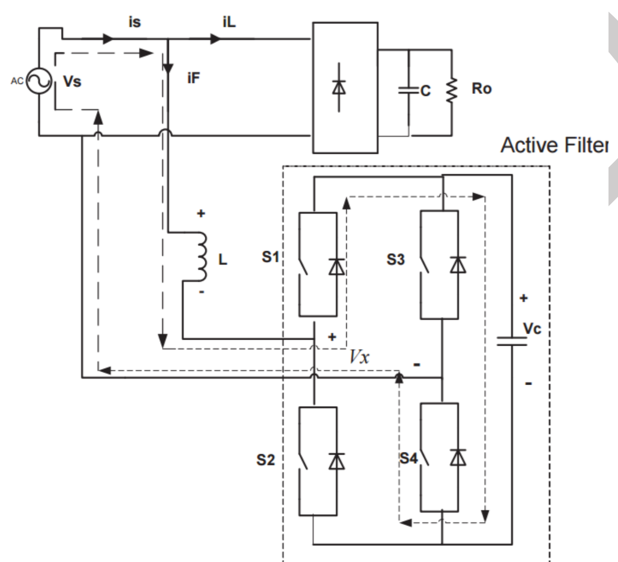


Fig. 7. Equivalent circuit when and ON

*B. Sliding mode controller*

Sliding mode controller is a nonlinear controller which uses variable structure control method to change the dynamics of a nonlinear system. Since the structure of APF also changes by the action of switches, SMC method is one of the best method to generate switching pulses for power converter.

In the sliding mode control, trajectories are forced to reach sliding surface in finite time and stay on the surface for all future time. When the system is on the sliding surface, its dynamic is independent of the circuit parameters. It depends only on the selected sliding surface of SMC basically involves two stages, design of the suitable sliding surface and a control law to force the system trajectories to reach and stay on the sliding surface

## IV. A REPETITIVE BASED CONTROL FOR SHUNT ACTIVE POWER FILTER

Shunt active filters are mainly used to eliminate the harmonic distortion in electric powered transmission and distribution systems. A voltage source inverter is used to inject harmonic currents into the ac system in order to compensate the current harmonics produced by the distortion load. Shunt active filters are widely available in markets for their continuous requirements.

Facts about the Shunt Active Filters while compensating the harmonic voltage at the point of coupling in the transmission/distribution feeder is explained as follows. In 1983 Kawa hira, et al. [1], different harmonic methods are explained in detailed. In the Voltage detection Method, the compensating current in the time domain for an AF is given as follows:

$$i_{AF} \quad k_v * v_n$$
$$V_{AF} \quad k * v_n$$

Where $k_{..}$is the real number values, $v_{..}$ is the harmonic voltage. From above equation it is clear that active filter acts a current source and behaves as a pure resistance. In 1997 Akagi [2] proposed a strategy to control shunt AF which behaves as resistor, in time domain the voltage detection is the most suitable among the harmonic detection methods. The conclusion is that Voltage detection installed at the end of the feeder line is more prone to harmonic propagation. In 2014, Menniti. et al. [9] .effectively used some methods to damp the harmonic resonance along a power distribution line by avoiding the line characteristics impedance.

$$V_{AF} \quad k * v_n$$

In Fig.8. the basic block diagram of SAPF is shown above. From ref [6-9] the focus is mainly on the Shunt AFs based on the detection of the voltage at PCC, from equation above, it is clear that the compensation of the harmonic voltages is obtained from the detected voltage.in this paper a repetitive based control for the shunt Active Filter is done, the same control regulates the power at the fundamental frequency in order to maintain the voltage across capacitance placed at the dc side, simulation results are shown in order to prove the efficiency and feasibility.

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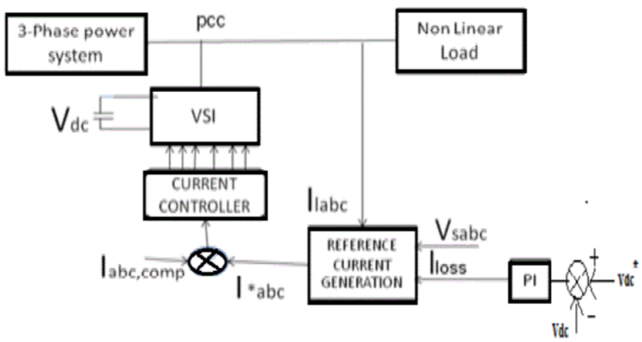


Fig. 8. Basic block diagram of SAPF

**Proposed Method**

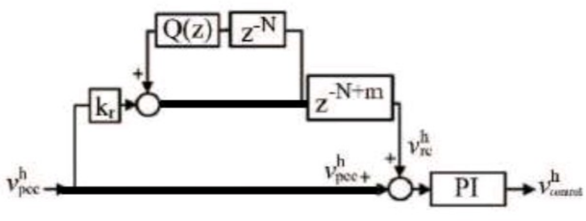


Fig. 9. P-I repetitive controller block

Compensation of the harmonic voltages in the electrical power distribution system is done by the proposed method i.e. the repetitive control method which is given in Fig 9. The control signal is the sum of two output signals $V_{1\_swtc}$ and $V_{h\_swtc}$ where the first block is power regulation at the fundamental frequency represented as *fund_ctrl*, second block is the power regulation at the non-fundamental frequencies represented as *harm_ctrl.* It is designed in a way such that when the power source is absent the control is activated by the self-charging functionality. In this the fundamental power is equal to the sum of non-fundamental power in order to compensate the harmonic distortion. In order to operate without the presence of power source, it should be placed parallel to the capacitance C.

In case if the power source is present, depends upon the amount of power value, the fundamental power is regulated by the control methodology for the compensation of harmonics. The fundamental power is the pure active power because the fundamental current of the active filter is in phase with fundamental voltage at the PCC, In Fig.1. Repetitive control method for Shunt active filters is designed in a way such that the two blocks *fund_ctrl* and *harm_ctrl* are involved in the harmonic voltage compensation is also used in control of a conventional or small photovoltaic inverter [7, 15]. A microcontroller implementation of those blocks with proper difference is developed for the proposed control to employ in already existing distributed generation solutions.

## *A) FUNDAMENTAL FREQUENCY CONTROL*

The fundamental frequency control block *fund_ctrl* regulates the fundamental power, the power is calculated in order to maintain the voltage $V_{dc}$ across the capacitance which is close to the $V_{dc\ ref}$ it is close to the DC side of the VSI. Hence the $V_{dc}$ across the capacitance should be less than the $V_{dc\ ref}$. The input of the $G_c$ block is given as follows

$$G_c(s)=K1K2/2$$

The above equation returns the amplitude of the filter current at the fundamental frequency and this value is multiplied by sine term in order to obtain a reference current value in phase with respect to the voltage at the PCC and also at the fundamental frequency

## *B) NON-FUNDAMENTAL FREQUENCY CONTROL*

The non-fundamental frequency power is regulated by the *harm_ctrl* block, this block also eliminates the non-fundamental voltage at the PCC. The non-fundamental voltage is given as:

$$v^h{}_{pcc} = v^1{}_{pcc\_ref} - v_{pcc}$$

## V. SHUNT ACTIVE POWER FILTER USING HYSTERESIS CONTROL TECHNIQUE

Fig. 10 shows principle configuration of a VSI based shunt APF. It consists of a DC-bus capacitor (Cf), interfacing inductor (Lf) and power electronic switches. The current injected by the filter compensates the harmonies due to non-linear loads. The shape of compensation current (if) is obtained by subtracting load current (is) from source current. This process is graphically shown in Fig. 3.

Non-linear load

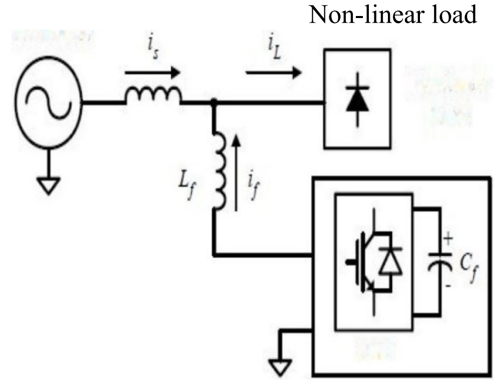


Fig. 10. Block diagram of APF

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Load current (h) consists of two components which are fundamental component (IL[) and harmonic (hh)·The compensating current(Ic) injected by APF is taken equal to harmonic component of load (ILh). The harmonic component of load current is supplied by APF and therefore, source current (ls) only has to supply the fundamental current of the load.

$$I_s = I_L - I_c = I_{Lf} \quad (3)$$

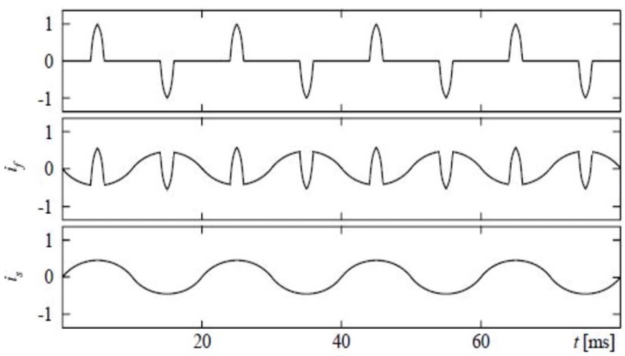


Fig. 11. Effect of compensating current injected by APF

## A. REFERENCE SIGNAL ESTIMATION TECHNIQUE

The DC capacitor which is connected to DC side of VSC acts as reactive energy storage element and carries input harmonic current of converter. The AC terminals of the converter are connected to PCC through a filter inductance in case of active shunt filter and through leakage inductance of transformer in case of active series filter.

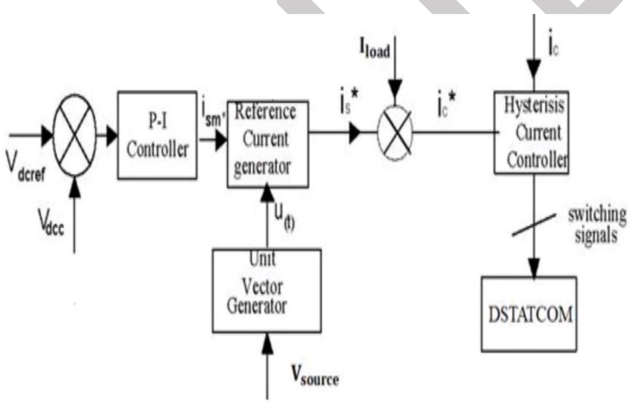


Fig. 12. Block diagram of gating generation scheme

The voltage at the DC terminals of VSC (V dee) is compared with predefined DC reference voltage (Vderef). The error signal obtained as result of this comparison is fed to a PI controller which is tuned to generate the magnitude of fundamental component of source current (lsm).Unit vector of fundamental component of source voltage (u(!») is obtained from sensed source voltage. Magnitude of fundamental component of source current is multiplied with unit vector of fundamental component of source voltage to obtain reference signal of fundamental source current (ls*). The generated reference signal is compared with sensed actual load current (lload) to obtain compensation current reference signal (le*). The advantage of this method resides in direct generation of peak value of supply reference current by proper tuning of PI controller parameters

## B.GATING SIGNAL GENERATION

Hysteresis band control technique is employed to generate gating signals of the VSc. It forces the compensation current from APF to follow the reference compensation current signal within a pre-specified tolerance limit. A typical control scheme waveform is shown in Fig. 13.

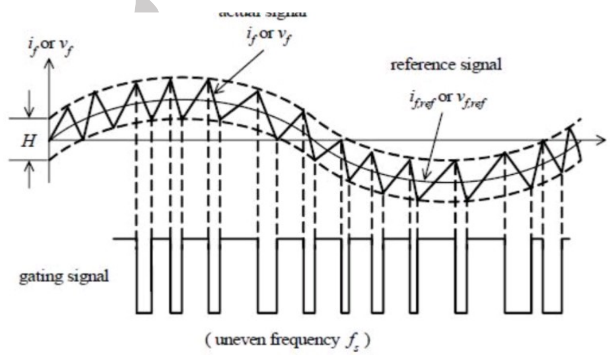


Fig. 13. A typical control scheme waveform

In this method, the tolerance limits are imposed on the compensation current signal (lc*) and is then compared to compensating current of APF. To minimize the ripple content of compensation current, the value of Hysteresis band Tolerance H can be decreased. However, this results in increase in switching frequency, which would lead to an increase in switching losses of switching devices. An optimized value of H is chosen considering the ripple content and switching losses of APF. There are certain advantages and disadvantages of Hysteresis Band control technique [1]. The merits of using hysteresis band technique are its appreciable dynamic performance and flexible control of peak-to-peak current ripple [5]. Also, the implementation of this control technique is less cumbersome compared to other control techniques; this is evident from the controller structure. However, this control scheme also has several demerits such as uneven switching frequency and generation of unwanted resonances

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in power distribution system. Even with the above mentioned demerits, fast and flexible current control and uncomplicated implementation makes hysteresis current control method far better compared to other control techniques.

## VI. A Wavelet Based Shunt Active Power Filter

High dependency on fossil fuels and consuming half of the world's total oil reserves results in a global preference towards the use of renewable green energy sources, such as photovoltaic systems. However, the power electronic inverters, used to integrate the photovoltaic systems to the grid lines, drastically raise many power quality issues through supply networks. This results in many technical problems such as: overheating of transformers, false operation of circuit breakers and relays, reduction in transmission system efficiency, and so forth.To address the issues, active power filters (APFs) are employed to power systems, and accordingly many compensation algorithms have been proposed to direct the control of the APFs. In [1], a compensation algorithm based on the A–GTIP is suggested to control the SAPF particularly in face of non–linear loads. Since APFS include the DC/AC power inverter with similar structure to that of used to integrate renewable sources to the grid; hence, employing of APFs can be multipurpose. This reduces the power system cost by decreasing the number of inverters. Nonetheless, available compensation algorithms used to direct the control of the APF work unsatisfactory. This is due to the dependency of these methods to the nonlinear mathematical equations and distorted variables such as load–current and voltage waveforms. This condition is worsened when the plant includes wind turbine which inherently produces the 3rd, 5th, 7th and 11th voltage harmonics. To improve the accuracy of the active power filters, the indirect compensation method was investigated in [2] where the THD of the source current is limited to 1.71%.In indirect methods, the error between the SAPF capacitor voltage and its reference value, applied to a PI controller, is multiplied by a unity sine wave which is in phase with the load voltage. The unity sine signal is obtained from the load voltage, while it is assumed that no harmonic is included in the load–terminal voltage. So, when the load voltage involves harmonics and distortions, this method is unable to compensate the load–terminal current.

In [3], the online wavelet transform is applied to improve the accuracy of this method to direct the control of a single–phase active power filter. That method limits the THD of the compensated current to 1.01%. This paper improves the accuracy of the indirect compensation method in three–phase four–wire system using wavelet, such that the compensation of the load–terminal current is accomplished even at the presence of the load voltage harmonics and distortions. Meanwhile, the THD of the compensated current is limited to 1.21% by employing a second–order generalized integrator (SOGI). For this purpose as can be seen in Fig.14, a new method is proposed to extract the fundamental component of the load voltage, using the DWT accompanied by online inverse DWT (IDWT).

The rest of the paper is organized as follows: Section II presents practical issues and proposed solutions to improve the indirect compensation method. In section III, the wavelet transform and proposed solutions are clarified. Section IV outlines the photovoltaic system. Simulation results are considered in section V. Finally, the conclusions that have been drawn from the present work are summarized.

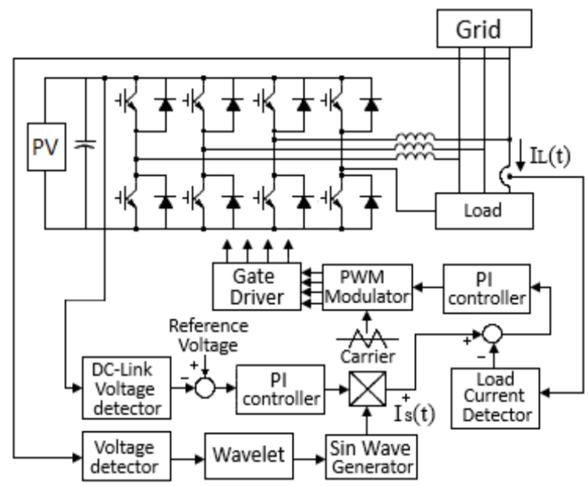


Fig. 14. Grid-connected PV system by the proposed wavelet based SAPF

### A. PRACTICAL ISSUES AND PROPOSED SOLUTION

The block diagram of indirect compensation method to direct the control of a three-phase active filter has been depicted in Fig.15. In this method, the amplitude of the source currents in fundamental sequence is firstly obtained using the difference between the capacitor voltage and its reference value which is applied to a PI controller [4]. Then, the fundamental component of source current is extracted by multiplying the obtained current magnitude and a unity sinusoidal waveform. Afterward, subtracting the fundamental component of source current from the load current yields the SAPF reference signal, required for compensating of load-terminal harmonics and distortions.

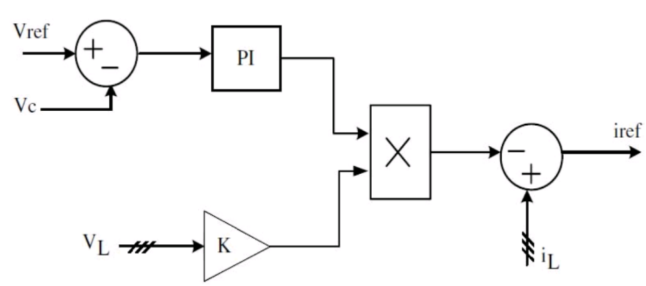


Fig. 15. Block diagram of indirect compensation method

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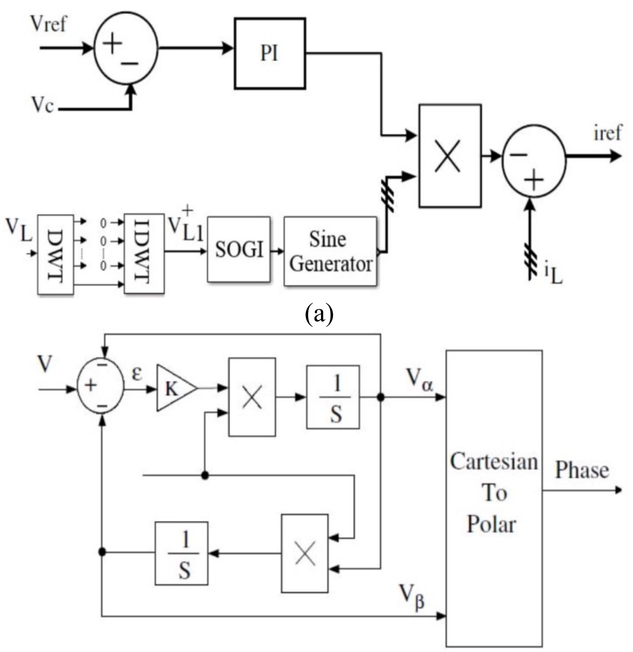
In this method, the unity sinusoidal waveform is produced by scaling of the load–terminal voltage as can be seen in Fig.15. Therefore, the amplitude of the scaled unity sinusoidal waveform depends on the amplitude of the load voltage. And so, under network voltage harmonics and distortions, the compensation of load current harmonics and distortions would not be done.

In this paper, the wavelet transform is firstly proposed to take one step forward to accurately extract the fundamental component of the distorted load–terminal voltage as can be seen in Fig.16 (a).




(b)

Fig. 16. (a) Block diagram of suggested controller of the three-phase shunt active filter; and (b) the proposed SOGI for decreasing the THD

Secondly, the second order generalized integrator (SOGI) is suggested to remove the dependency of the unity sine wave from the amplitude of the load–terminal voltage. For this purpose, the proposed SOGI just uses the phase of the network voltage to generate the unity sinusoidal waveform.

## REFERENCES

1. N. Mesbahi, A. Ouari, D. Ould Abdeslam, T. Djamah, A. Omeiri, "Direct power control of shunt active filter using high selectivity filter (HSF) under distorted or unbalanced conditions," Electric Power Systems Research, Vol. 108, March 2014, pp. 113-123.

2. M. Bouzidi, A. Benaissa, S. Barkat, "Hybrid direct power/current control using feedback linearization of three-level four-leg voltage source shunt active power filter," International Journal of Electrical Power & Energy Systems, Vol. 61, October 2014, pp. 629-646.

3. M. K. Mishra and K. Karthikeyan, "A Study on Design and Dynamics of Voltage Source Inverter in Current Control Mode to Compensate Unbalanced and Non-linear Loads," Power Electronics, Drives and Energy Systems, PEDES 06. International Conference on, New Delhi, 2006, pp. 1-8.

4.A. Cichowski, W. Sleszynski and J. Nieznanski, "Comprehensive compensation of grid current distortion by shunt active power filters," 2015 International School on Nonsinusoidal Currents and Compensation (ISNCC), Lagow, 2015, pp. 1-6.

5. B. Exposto, V. Monteiro, J. G. Pinto, D. Pedrosa, A. A. N. Meléndez and J. L. Afonso, "Three-phase current-source shunt active power filter with solar photovoltaic grid interface," Industrial Technology (ICIT), 2015 IEEE International C onference on, Seville, 2015, pp. 1211-1215.

6.Y. Bouzelata, E. Kurt, R. Chenni, N. Altın, "Design and simulation of a unified power quality conditioner fed by solar energy, " International Journal of Hydrogen Energy, Vol. 40, Issue. 44, 26 November 2015, pp. 15267-15277, in press.

7. R. Belaidi, M. Hatti, A. Haddouche and M. M. Larafi, "Shunt active power filter connected to a photovoltaic array for compensating harmonics and reactive power simultaneously," Power Engineering, Energy and Electrical Drives (POWERENG), 2013 Fourth International Conference on, Istanbul, 2013, pp. 1482-1486.

8. T. Noguchi, H. Tomiki, S. Kondo and I. Takahashi, "Direct power control of PWM converter without power-source voltage sensors," in IEEE Transactions on Industry Applications, vol. 34, no. 3, pp. 473-479, May/Jun 1998.

9. Zainal Salam, Tan Perng Cheng and Awang Jusoh. "Harmonics Mitigation Using Active Power Filter:A Technological Review" in Faculty of Electrical Engineering, Universiti Teknologi Malaysia.

10. H. Dogan, R. Akkaya "A Simple Control Scheme for Single-Phase Shunt Active Power Filter with Fuzzy Logic Based DC Bus Voltage Controller" in Proceedings of the International MultiConference of Engineers and Computer Scientists 2009, Hong Kong.

11. Shyamsundar Jena, Thesis on " MatIab simulation of single phase shunt active power filter and development of experimental set up" in National Institute of Technology, Rourkela.

12. Bhim Singh, Kamal A1-Haddad, Senior Member, IEEE, and

13 .Ambrish Chandra, Member, IEEE "A Review of Active Filters for Power Quality Improvement." in ieee transactions on industrial electronics, vol. 46, no. 5, October 1999.

14. Shi Zhang, Daheng Li, Xu Wang "Control Techniques for Active Power Filters" in 20I 0 International Conference on Electrical and Control Engineering.