Comparision of Three And Two Level Hysteresis Current Controller Based on Active Power Filter For Harmonic Compensation

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Abstract*- This paper depicts the performance of a three-level hysteresis current-control (HCC) scheme for three-phase four-switch shunt active power filters. This four-switch topology develops four power semiconductor switches along with two series connected capacitors which decrease the cost, switching losses and improve the consistency of system. In this topology, the control of phases current A and B is achieved successfully, the control of phase current C is connected to the center of the series connected capacitors is accomplished spontaneously. By using a three-level HCC strategy the current control is achieved. Operation of the control scheme is that it enables access to the zero level of the input voltage of active filter so that a switching device is only switched on when the current error is negative, while it remains off when the current error is positive. Morever, the imbalance in the capacitor voltages is removed by summing a feedback term (the difference in the capacitor voltages multiplied by a suitable gain) to the current control. This paper gives an review of harmonic currents in power electronics devices generated by nonlinear loads.. Shunt active power filters (APF) play an important role to reduce current harmonics produced by nonlinear loads. An important consequence of shunt active power filter (APF) for compensating the harmonics current has been examined and reviewed by using Hysteresis current control technique.The proposed control scheme gives a reduced switching frequency, losses and cost. The developed algorithm is verified by simulations tests using MATLAB simulink.*

Keywords- Active Power filters (APF), PIController, 3-level Hysteresis Current Controller (HCC), Harmonics, Power quality)

I. INTRODUCTION

Power electronic devices are widely used in advance electrical system leading to increase of harmonic distortion and reactive power problem in ac supply. This harmonic distortion is due to increase of nonlinear loads such as power converters, SMPS, photo copiers, printer, UPS, speed drives, electric arc welders, and switching power supplies which are creating problems in the power distribution lines. And these harmonic currents causes voltage distortion, low power factor,increasing power losses harmful disturbance to near by loads heat dissipation on transformers, leads to operational failure of electronic equipments. Initially these problems are solved by passive L-C filters. But these have a drawback such as a resonant problem, fixed compensation stability aging problems, large in size.

As to remove these drawbacks shunt active power filters (SAPF) are being examined and developed as a efficient solution for solving power quality problems [1]. Active filters are broadly classified into two types 1]series active filter 2] shunt active filter Series active filter is used for voltage compensation and shunt active filter is used for current compensation. The active power filter network can be connected either in series or shunt and combinations of both (unified power quality conditioners). So Shunt active filter is more standard than series filter, because in most of all the industries and commercial applications current harmonics compensation is required rather than voltage harmonics compensation.

The shunt active power converter can be injected with current source inverter (CSI) or voltage source inverter (VSI) [6]. The voltage source inverter consists of three coupling inductors in series at the ac-side and an energy storage capacitor at the dc side.Similarly, the current source inverter consists of three coupling capacitors in parallel at the ac-side and an energy storage inductor in series at the dc-side [7]. In general the voltage source inverter type is selected for shunt active power filter due to low losses in the dc-side and for high power level applications multilevel inverter topologies ar developed.

The current control scheme plays a significant role in fast response current controlled inverters mainly shunt active power filters. Several kinds of current controllers technique are known. Independent and dependent hysteresis controllers, ramp comparison controllers and predictive controllers. But this method previews good current response, accuracy is better and uncertain stability to the system.

The current control strategy of the voltage source inverters can be mainly classified into linear controller and nonlinear controller [4-7]. The linear current controllers produce required variable voltage which is then provided into sine-triangle pulse width modulation (PWM) to produce the gate drives switching pulses for the VSI. The non-linear current controllers is subjected to hysteresis bands, in which actual currents are compared to reference currents instantly [8-9]. When the current error is greater than maximum limit or minimum limit of the hysteresis band; based on band limit, the upper or lower switch becomes either ON nor OFF.

The range of the current error instantly controls the voltage source inverter switching transistor (MOSFET or IGBT switches) [10]. The linear current controllers are represented by constant switching frequency where as the non-linear current controllers are represented by variable switching frequencies [9]. It produces quick response to dynamic conditions and therefore non-linear hysteresis current control is the most important method of current control. The advantages of non linear hysteresis current control are in automatic peak current limitation, simple hardware performance, load parameter independence and uncertain stability. Generally two level hysteresis current controllers are used, because the circuit is very easy [11]; it will not use zero voltage from the inverter dc-side; only positive and negative dc supply voltages are used [12- 13].

This paper describes three-phase four-switch shunt active power filters for current harmonic compensation under non-linear load conditions. The three phase active power filter is employed with current controlled voltage source inverter (VSI). The VSI switching signals are obtained from 3-level hysteresis current controller; the results will be improved version of 3-level HCC compared to 2-level HCC. The shunt active power filter system is examined under unbalanced non-linear load conditions.

Basically two types of filters are used in improvement of Power Quality mainly they are Active Power filter and Passive Power filters.

II. ACTIVE POWER FILTER

An active filter is a analog electronic filter that uses dynamic components operating as an amplifier. Amplifiers consists of filter design can be used to develop the performance of a filter. An amplifier inhibts the impedance of load affecting the characteristics of the filter. An active filter consists of complex poles and zeros without using a large or valuable inductor. Active elements consists of some limitations. In designing filter equations they neglect the finite bandwidth of amplifiers. Some of the active devices have limited bandwidth, at high frequencies. Amplifiers consume power and inject noise into a system. Active filters uses power electronic converters to compensate current harmonics and voltage harmonics caused by non-linear loads, And the harmonic voltages are avoided when it is connected to sensitive loads. Active filters are classified into two types of : the shunt active filter and the series active filter [4].

SHUNT ACTIVE POWER FILTER

The main function of Shunt active power filter is to compensate current harmonics by injecting equal-but-opposite harmonic compensating current. This shunt active power filter perform as a current source injecting the harmonic components produced by the load but phase shifted by 180^0. This can be applicable to any type of load such as harmonic source. In this control scheme, the active power filter can also compensate the load power factor. Similarly, the power distribution system views the non linear load and the active power filter as an ideal resistor [5]. The current compensation characteristic of the shunt active power filter is shown in Figure load conditions.

It shows the circuit diagram of three phase four switch shunt active power filter. Shunt active power filter is connected to power grid and makes shunt with a main supply and nonlinear load.The main principle of shunt active power filter is to the power supply network as the same current harmonics generated by nonlinear load in reverse direction This shunt active filter consists of voltage source inverter which contains four switching devices with power transistor and free wheeling diodes and two energy storage capacitor at DC side. Phase A and Phase B is connected to switching devices and Phase C is connected at center of DC link capacitor.As current will be flowing through phase A and phase B spontaneously the current will be flowing through phase C. Let (i_s $i_f i_l$) be the three phase currents flowing through shunt active power filter from mainsupply undistorted source currents at unity power factor and is disturbed by nonlinear loads current

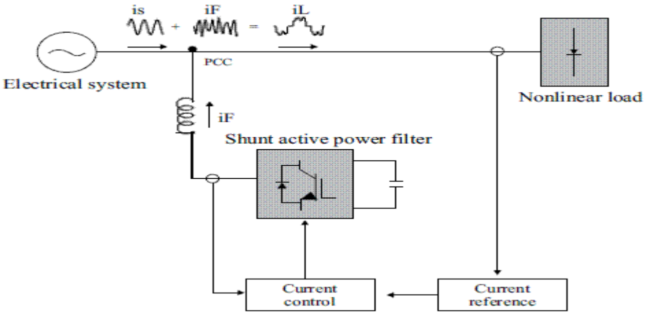

Fig 1 reviews Block diagram of three phase shunt active filters

Also, it is assumed that the series connected capacitors are identical (C1 = C2). However, in practice, the values of these capacitors may not be equal which cause imbalance between two capacitors. v_{c1} v_{c2}

III. HYSTERESIS CURRENT CONTROLLER

The hysteresis current control is component of the PWM technique which is used to generate the pulse for switching the power of inverter. There are different current control scheme proposed for active power filter but the hysteresis current control method has the superior rate among all other current control method because of quick Current controllability, easy operation and unconditioned stability[10-11]. The hysteresis band current control is powerful, provides superior dynamics and fastest control with minimal hardware. This paper presents two-level and three-level hysteresis current controller for designed active power filter systems.

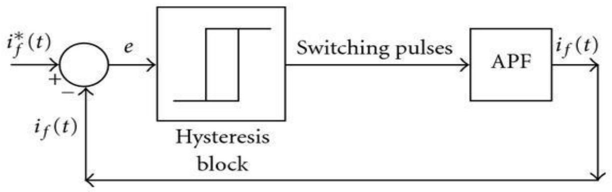

Fig 2 Shows Block Diagram of Hysteresis current controller

A. Two-level hysteresis current controller:

Generally hysteresis current control operates the PWM Potential source inverter by comparing the current error e (t) against fixed hysteresis bands. By seeing the difference between the reference current $i_{ref}(t)$ and the actual current the current error is obtained.

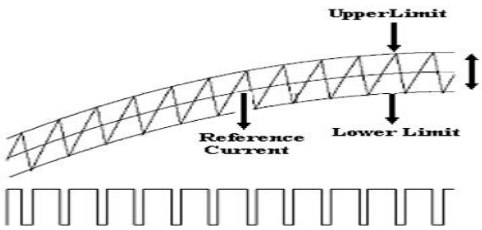

Figure 3 Shows two level Hysteresis current controller

If the current error crosses the maximum limit of the hysteresis band, the upper switch of the inverter leg is turned OFF and the lower switch of the inverter leg is turned ON. If the current error crosses the lower limit of the hysteresis band, the lower switch of the inverter leg is turned OFF and the upper switch is turned ON. In the two level HCC will not use the inverter zero output condition, but the 3-level HCC uses inverter zero output condition [9]. The deviation in the switching frequency gives the operation of the current controller both in case of harmonics as well as maximum switching frequency.

B. Three-level hysteresis current controller:

Three-level hysteresis current controller: The performance of three level hysteresis controller are set as maximum limit and minimum limit and displacement is given by a small dc offset current. Whenever the current error ( ) e t exceeds an outer hysteresis band,at that time the output of inverter is set to an active positive or negative output and to force a reversal of the current error. Correspondingly whenever the current error reaches an upper hysteresis band, at that time the output of inverter is set to a zero condition and the current error will be forced to opposite direction without reaching the near outer band. In this section if zero output does not reverse the t error current, it will continue to the inner hysteresis band rather than next outer hysteresis band, at which point an reverse polarity inverter output will be controlled and the current will move in opposed anyway. In this switching process there will be a positive or negative dc offset error into the average output current and is dependant on the active output voltage. And, this error can be compensated by adding a compensation factor of hysteresis band offset magnitude to the reference current; it will be a positive when a positive inverter output is in used and negative when a negative inverter output is in used.

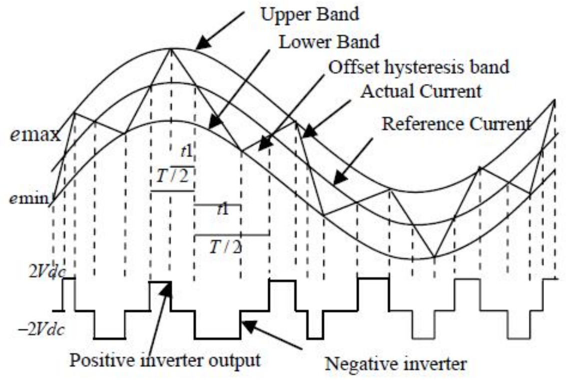

Fig 4 shows three-level hysteresis current control scheme

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IV. ANALYSIS OF PI CONTROLLER

The control strategy of the shunt active power filter employes a regulation of voltage circuit on the DC capacitor. The block diagram gives control strategy is shown in Fig.2The control variables uses PI control algorithm for DC bus voltage, supply current and supply voltage. The DC capacitor voltage consists of second harmonic ripple and is used a part from filtering, it will develop in the compensated current supply. A low pass filter has to be used to eliminate the ripple on the DC bus causes delay in the compensation operation. It is analysed that the capacitor voltage remains constant at all zero crossings. This circuit implies sample and hold . The 3-phase source voltages are transformed into 3-phase load current(s) at that instant load current and phase angles are given as

$$i_a = \sin \omega t,$$
$$i_b = \sin(\omega t - 120^0)$$
$$i_c = \sin(\omega t + 120^0)$$
..(7)

These load currents are multiplied with maximum reference current for generating the reference currents. The proposed PI-control strategy analysed the peak reference current of an APF system. The two storage DC-side capacitor voltage is sensed and compares with a reference voltage and the supply current of amplitude is given by the PI controller are thus it is seen that at zero crossing point the supply current is remains constant for the full period of one cycle. The ripples present in the capacitor can be eliminated with PI controller. PI technique [6] operates this system and is controlled with a weighted addition of the error and the integral of that value . It is simple arithmetic and more consistency in steady state . It does not need any transformation.

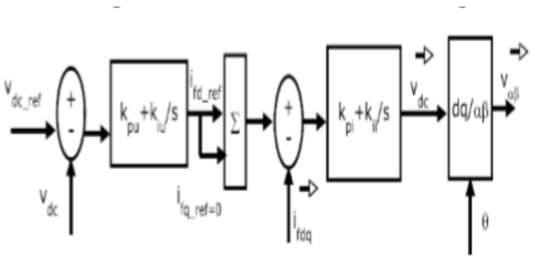


Fig 5 shows Block diagram of PI controller

where, *KP* [*KP* =0.3] is determines the transient response of the DC-side voltage and *KI* [*KI* =15] is determines the settling time. The PI- technique controls the capacitor voltage across DC side and calculates the magnitude of maximum reference current. The peak current must be multiplied with output of load current vector for defines the reference current.

V. SIMULATION RESULT AND ANALYSIS

The execution of the three-stage four-wire shunt APF network is designed through Matlab simulink under uneven non-direct load conditions. The network parameters qualities are; Line to line source voltage is 440 V; System recurrence (f) is 50 Hz; DClink capacitor C1=1100 μF and C2=1100 μF ; Reference dc voltage 600 V; Interface inductor is 2 mH and 1 Ω 168 + j 16 Ω.

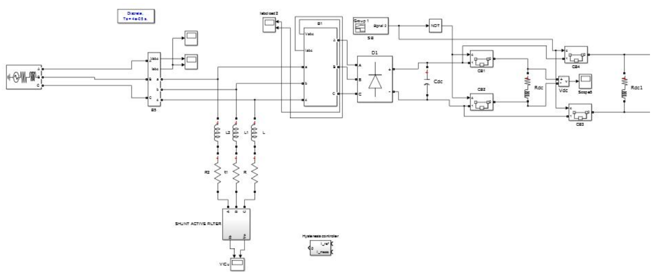


Fig 6 Simulation circuit of three phase four switch shunt active filter

The generally power circuit of the active filter is based on voltage source inverter connected at the point of common coupling, as shown in Fig 4. The voltage source inverter consists of four power transistors with freewheeling diodes and two energy storages capacitor at DC-side

The three-phase four-wire AC power supply when it is connected to the unbalanced non-linear load as shown in Fig 7. The main supply voltage is balanced and is represented by as v(t)= V = .

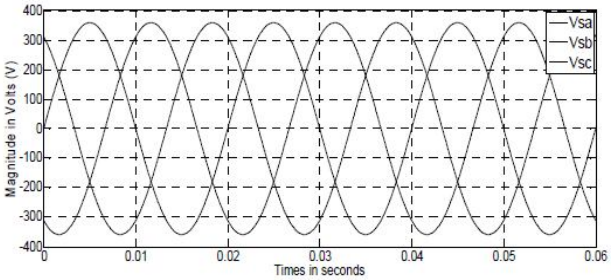


Fig 7 shows Supply voltages for 3phase four switch shunt active filter under balanced condition

The source draws non-sinusoidal current due to presence of non-linear load. This fundamental signals and harmonic current components are presented in nonlinear load current

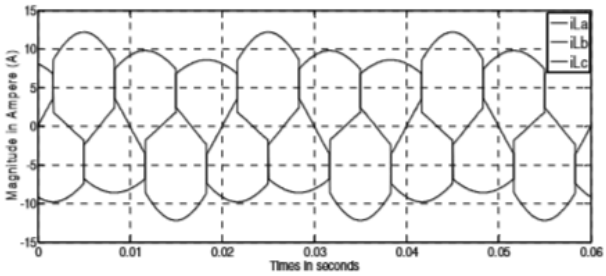
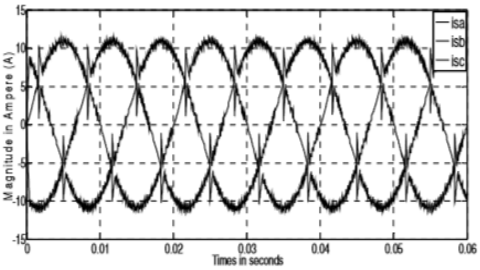


Fig 8 shows the unbalanced non-linear load condition

The active filter offers the current harmonic filter or compensated current. The harmonic current are compensated by inserting equal but opposite current distortion components are connected at the PCC, there by erasing the original harmonic and improving the power quality. The simulation conducts that source current after compensation is presented in Fig 10 that implies that current is sinusoidal.



The two DC-link capacitors voltage which are connected at DC side is controlled by proportional integral (PI) controller. The PI-controller supports the capacitors voltage with small ripple in steady and dynamic state, shown in Fig 11. It gives as an energy storage element to supply a real power to operate three-phase voltage source inverter.

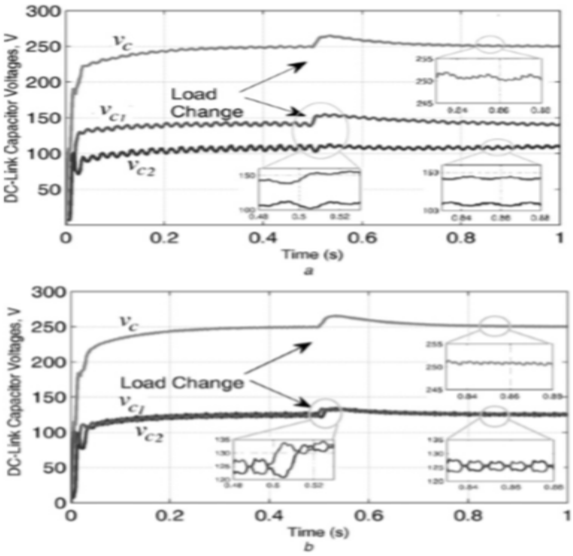


Fig 9 shows voltage across DC capacitor voltage with load and without load

The Fast Fourier Transform (FFT) is used to asses the order of harmonics with the fundamental frequency 50 Hz at the source current. These harmonics are plotted against source current before active filter compensation that is shown in Fig 12 (a). The Total harmonic Distortion (THD) of the harmonics current without APF is 25.41%.. The Total harmonic Distortion (THD) of distorted are also plotted against source current after active filter compensation that is shown in Fig 12 (b) Total harmonic Distortion THD current with APF is 3.74 %.

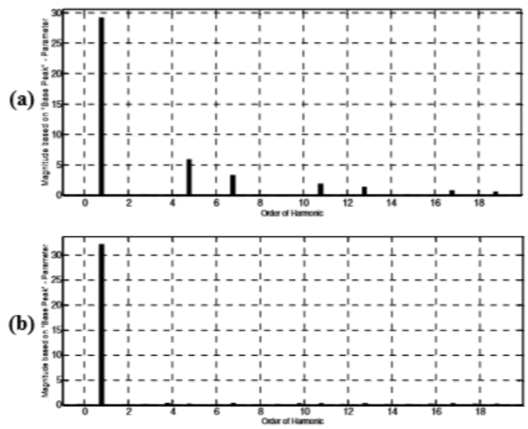


Fig 10 shows THD of three phase four switch shunt active filter with load and without load.

IV. CONCLUSIONS

This paper presents design and implementation of a three level hysteresis current control scheme for three-phase fourwire active power line conditioners. The three-level hysteresis controller reduces the variation of the switching frequency and it indicates improved performance compared to 2-level HCC. This active power filter system is tested and verified using MATLAB program. These results demonstrate that the active filter is effective in compensating current harmonics that facilitates improves power quality in the distribution network.

REFERENCES

[1] Fermin Barrero, Salvador Martinez, Fernando Yeves and Pedro M.Martinez "Active Power Filters for Line Conditioning: A Critical Evaluation" IEEE Trans on Power Delivery, Vol.15, No.1, pp.319-325, 2000.

[2] Christopher K. Duffey and Ray.P. Stratford "Update of Harmonic Standard IEEE-519: IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems"IEEE Trans on Industry Appl, Vol.25, No.6, pp.1025-1034, 1989.

[3] Joseph S. Subjak, JR and John S. Mcquilkin "Harmonics-Causes,Effects, Measurements, and Analysis: An Update" IEEE Trans on Industry Appl,Vol.26, No.6,pp.1034-1042, 1990.

[4] Bhim Singh, Kamal Al-Haddad and Ambrish Chandrs "A Review of Active Filters foe Power Quality Improvements" IEEE Trans on Industrial Electronics, Vol.46, No.5, pp. 960-970, Oct-1999.

[5] Prasad N. Enjeti, Wajiha Shireen, Paul Packebush and Ira J. Pitel "Analysis and Design of a New Active Power Filter to Cancel Neutral Current Harmonics in Three-phase Four-Wire Electric Distribution Systems" IEEE Trans on Industry appl,Vol.30, No.6, Nov/Dec-1994

[6] W.M.Grady, M.J.Samotyj, A.H.Noyola "Survey of Active Power Line Conditioning Methodologies" IEEE Trans on Power Delivery, Vol.5, No.3, pp.1536-1542, 1990

[7] Maria Isabel Milanes Montero, Enrique Romero Cadaval, and Fermin Barrero Gonzalez "Comparison of Control Strategies for Shunt Active Power Filters in Three-Phase Four-Wire Systems" IEEE Trans on Power Elects, Vol. 22,No.1,2007.

[8] O.Vodyakho T.Kim "Shunt active filter based on three-level inverter for 3-phase four-wire systems" IET Power Electron,Vol.2,No.3, pp.216–226, 2006

[9] G.H. Bode and D.G. Holmes "Implementation of Three Level Hysteresis Current Control for a Single Phase Voltage Source Inverter" IEEE-Conference, pp.7803-5692, 2000.

[10] Brod D.M, Novotny D.M "Current control of VSI-PWM Inverter"-IEEE Trans on Industry Appl, Vol.21, pp.562-570, 1985

[11] Jiang Zeng, Chang Yu, Qingru Qi, Zheng Yan, Yixin Ni, B.L. Zhang, Shousun Chen and Felix F. Wu (2004) "A novel hysteresis current control for active power filter with constant frequency" Electric Power Systems Research 68, pp.75-82

[12] Marian P. Kaunierkowski, Maciej A. Dzieniakowslu (1994) "Review of Current Regulation Techniques For Three-phase PWM Inverters" Conference on IECON'94, Vol.1, pp.567 – 575,1994

[13] N.Belhaouchet and L. Rahmani Development of Adaptive Hysteresisband Current Control of PWM Three-Phase AC Chopper with Constant Switching Frequency, Electric Power Components and Systems, Vol.33, No.10, pp.583-598, 2009