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Comparison between the fixed_band HCC and adaptive HCC used for APF control

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Abstract: *Among the various Pulse Width Modulation techniques(PWM),Hysteresis Current Control (HCC)is widely used due to its simplicity in implementation ,excellent dynamic response and low cost. But ,the variable switching frequency of this technique leads to switching losses and switching noise .To overcome this problem,Adaptive Hysteresis Current Control(AHCC) can be implemented which builds a variable hysteresis band width which is calculated instantaneously. Hence, the switching frequency will become fixed and switching speed becomes smooth.In this paper the Instantaneous Reactive- PowerTheorem (IRPT)(P-Qtheory)is used to estimate the compensation reference current .After that ,the fixed band hysteresis current control is discussed.Due to the variable frequency disadvantageof the fixed band, the adaptive hysteresis current control is applied and discussed which achieves a constant switching frequency and less switching losses. The simulation of the system performed using Matlab-Simulink.*
Keywords:*HCC, FBHCC,AHCC, (P-Q)theorem*

I. Introduction

Applying the Shunt Active Power Filter (SAPF) is the most successful way to remove the harmonic current components caused by the nonlinear loads. SAPF is a device that connected in parallel with the load as shown in fig(1),cancelling the harmonic component of the current by injection the same current as harmonic current with same amplitude and opposite in sign .

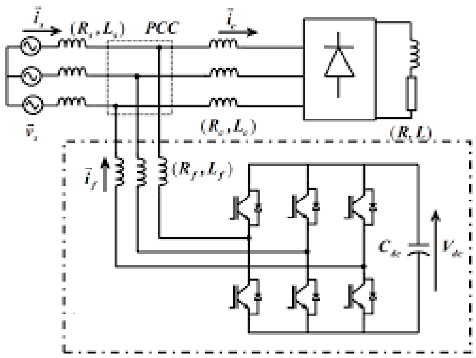

Fig (1) block diagram of SAPF

Hysteresis Current Control (HCC) is one of the various current control methods which proposed for SAPF configuration. Conventional fixed band HCC techniqueis characterized by fast response, unconditional stability,and goodaccuracy, but the drawbacks of variable switching frequency affected the performance of the controller as it leads to switching losses and audible noise.

Adaptive Hysteresis Current Controller (AHCC) technique has been proposed to overcome the drawbacks of the fixed band hysteresis current controller .AHCC changes the hysteresis band according to the variation of (d_{ic}/d_t) and V_{dc}, resulting in a nearly constant switching frequency of the inverter and smooth switching speed.

In the next section, theinstantaneous reactive- powertheoremis used to estimatethe compensation reference current.After that the fixed band HCC and AHCC are explained .Finally, somesimulations are done with Matlab-Simulink which illustrating the switching frequency diagram ofboth FBHCC and AHCC.

II. Instantaneous Reactive Power Theorem (IRPT)

One of the most popular compensation reference current estimation methods is theInstantaneous Reactive Power Theorem (IRPT*)*.The instantaneous reactive power theorm (IRPT) or (p-q) theory was formulated by Akagi, Kanazawa and Nabae[1,2] for the active filter control. (p-q) theory is based on

Clarketransformation _shown in fig (2)_ of three phase source voltages (V_{sa},V_{sb} ,V_{sc}) and load currents(I_{la} ,I_{lb},I_{lc}) in the (a-b-c) coordinates to the(α-β) coordinates.The control algorithm block diagramforAPF based on (p-q) theory is shown in fig (3).

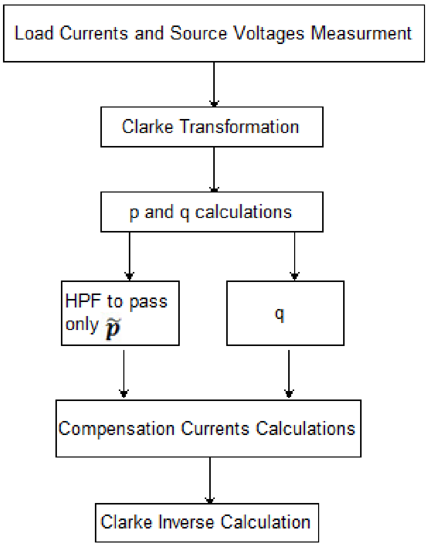

Fig (2) the Clarke transformation block diagram

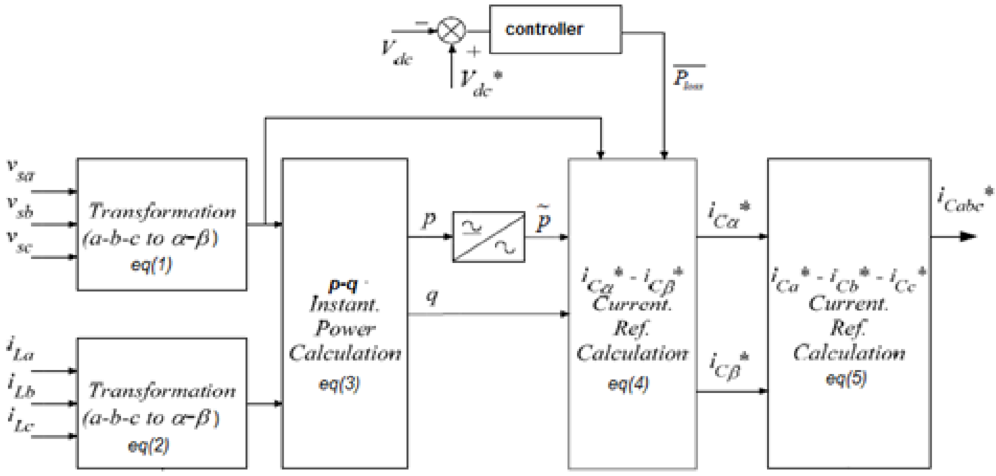

Fig (3)the control algorithm block diagramforAPF based on (p-q) theory

Based on Clarke transformation the p-q theory first transformed three phase voltage and current waveforms from the a-b-c coordinates to α-β-coordinates and then defines instantaneous active and reactive power on these coordinates through the following two matrices:

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \qquad (2)$$

From (1) & (2), we can calculate the instantaneous active and reactive powers p & q

$$\begin{bmatrix} p = \bar{p} + \tilde{p} \\ q = \bar{q} + \tilde{q} \end{bmatrix} = \begin{bmatrix} v\alpha & v\beta \\ -v_\beta & v\alpha \end{bmatrix} \begin{bmatrix} i\alpha \\ i_\beta \end{bmatrix} \quad (3)$$

The compensating reference currents are calculated by taking the inverse of Eq. (3) after the process of filtering the instantaneous active power (p) by H.P.F to pass only the AC components.

$$\begin{bmatrix} i^* c\alpha \\ i^* c\beta \end{bmatrix} = \frac{1}{v^2{}_\alpha + v^2{}_\beta} \begin{bmatrix} v\alpha & -v\beta \\ v_\beta & v\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} + p_{loss} \\ q \end{bmatrix} \quad (4)$$

In order to obtain the reference compensation currents in a-b-c coordinates, the inverse of the transformation given in Eq 2 is applied:

$$\begin{bmatrix} i^* ca \\ i^* cb \\ i^* cc \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i^* c\alpha \\ i^* c\beta \end{bmatrix} \quad (5)$$

The eq (5)gives the reference compensation current to be injectedto the system.

III. Hysteresis Current Control (HCC)

TheHysteresis current control(HCC)is one of the various (PWM) techniques which used popularly due to it's simplicity in implementation and it is characterized by unconditioned stability, very fast response and good accuracy [3, 4].

HCC is a method to derive the switching signals (pulses) of the Voltage Source Inverter (VSI) power switches in (APF) [5]. HCC is implemented with a closed loop control system (shown in fig (4)). An error signal (e (t)) is used to control the switches in the inverter. This error is the difference between the desired (reference) current ic*, and the current being injected by the inverter i_C .When the error reaches an upper limit, the transistors are switched to force the current down. When the error reaches a lower limit the current is forced to increase .In another words, the switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference. The current ramping up and down between two limits (Hysteresis Band (HB)).

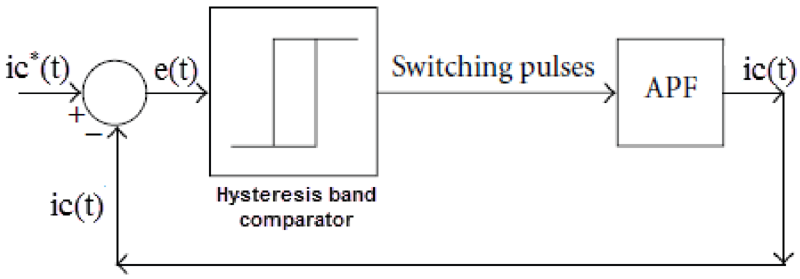

Fig (4) Hysteresis Current Control (HCC)

The turn-on and turn-off conditions for the inverter switches is

- Upper switch off: (ic – ic*) > HB.
- Lower switch off: (ic – ic*)< -HB.

When the current through the inductor exceeds the upper hysteresis limit, a negative voltage is applied by the inverter to the inductor. This causes the current through the inductor to decrease. Once the current reaches the lower hysteresis limit, a positive voltage is applied by the inverter through the inductor and this causes the current to increase and the cycle repeats (As shown in fig 5).

A-Fixed-Band Hysteresis Current Control

In fixed-bandHCC, the Hysteresis Bandwidth (HB) has been taken asa small portion related to system current, the width of the hysteresis band determines the switching frequency of the inverter. As the bandwidth narrows - the switching frequency increases. A suitable bandwidth should be selected in accordance with theswitching capability of the inverter [5].Although, the fixed hysteresis band is very simple and easy to implement,and however, this control scheme exhibits several unsatisfactory features. The main drawback is producingfluctuate switching frequency that causes acoustic noise and difficulty in designing input filters [6].

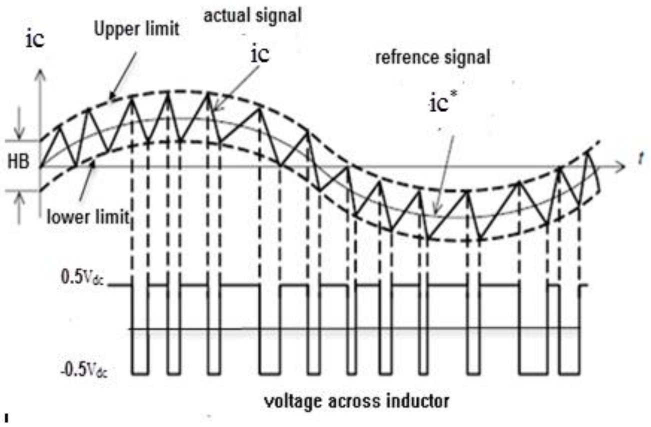

Fig (5) Fixed band hysteresis current control

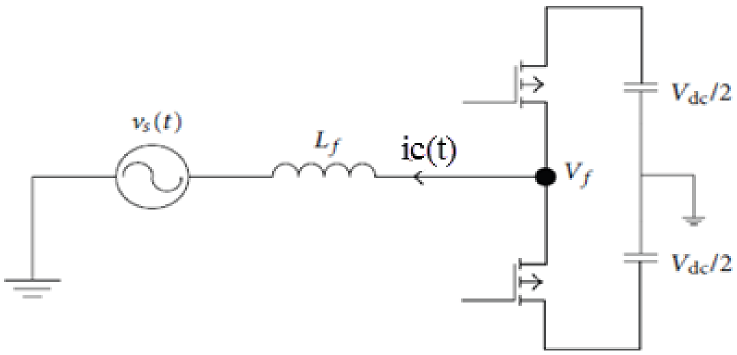

Fig (6) Single-phase diagram of a power system with APF

b- Adaptive Hysteresis Current Controller (AHCC)

Due to the drawbacks of the fixed-band HCC mentionedabove, (AHCC) has been recommended, itbuilds the hysteresis bandwidth which is calculated instantaneously according to the instantaneous compensation current variation (d_{ic}/d_t) and V_{dc} voltage, hence the switching speed becomes smooth and the frequency switching will be fixed considerably.

From fig.6 and fig.7, the following equations can be written for the switching intervals t_1 and t_2 respectively [7]:

$$\frac{di_c^+(t)}{dt} = \frac{1}{L}\,(0.5V_{dc} - V_s) \quad (6)$$

$$\frac{di_c^-(t)}{dt} = -\frac{1}{L}\,(0.5V_{dc} + V_s) \quad (7)$$

From the geometry of Fig.7, eq(6), (7) can be written as follow:

$$\frac{di_c^+(t)}{dt}t_1 - \frac{di_c^*(t)}{dt}t_1 = 2HB \quad (8)$$

$$\frac{di_c^-(t)}{dt}t_2 - \frac{di_c^*(t)}{dt}t_2 = -2HB \quad (9)$$

$$t_1 + t_2 = T_c = \frac{1}{f_c} \quad (10)$$

Where t_1 and t_2 are the respective switching intervals and f_C is the switching frequency.

By adding Eq. (8) and eq. (9) and substituting it into Eq. (10):

$$\frac{di_c^+(t)}{dt}t_1 + \frac{di_c^-(t)}{dt}t_2 - \frac{1}{\text{f}_c}\frac{di_c^*(t)}{dt} = 0 \quad (11)$$

Subtraction of eq. (9) from eq. (8), gives us:

$$4HB = \frac{di_c^+(t)}{dt}t_1 - \frac{di_c^-(t)}{dt}t_2 - (t_1 - t_2)\frac{di_c^*(t)}{dt} \qquad (12)$$

By substituting eq. (7) into eq. (12), the eq. (8) can be found as:

$$4HB = (t_1 + t_2)\frac{di_c^+(t)}{dt} - \ (t_1 - t_2)\frac{di_c^*(t)}{dt})(13)$$

By substituting eq. (7) to eq. (11) and simplifying it, the following equation can be written.

$$(t_1 - t_2) = \frac{di_c^*(t)}{dt} / \text{f}_c (\frac{di_c^+(t)}{dt}) \qquad (14)$$

Last step by substituting eq. (14) to eq. (13), the HB can be found as:

$$HB = \frac{V_{dc}}{8fL}\left[1 - \frac{4L^2}{{V_{dc}}^2}(\frac{V_s}{L} + \frac{di_c^*(t)}{dt})^2\right](15)$$

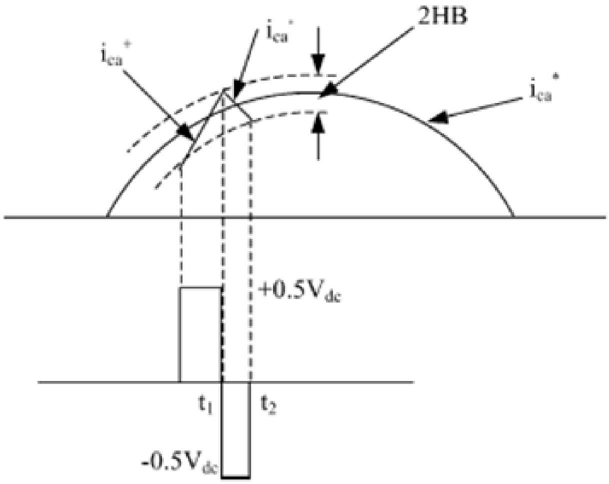

Fig.7 Current and voltage waves with Adaptive Hysteresis Band Current Control (AHCC) forAPF

IV. Simulation and Results

The simulation has been done using Matlab/ Simulink. The design specifications and the circuit parameters used in the simulation are indicated in TABLE I. The instantaneous switching frequency for conventional fixed hysteresis and adaptive hysteresis current controllers are shown in Fig.8, respectively. As shown in the figure,in adaptive hysteresis band current control method, the instantaneous switching frequency remains constant with littlevariation contrary to conventional fixed band hysteresis current control method.

Table 1 Design Specifications And Circuit Parameters

Name	Quantity
Switching Frequency	12KH
Fundamental frequency	60HZ
Ac Supply Voltage	220V
Inverter dc Voltage	700V
Rectifier Load Resistance	20Ω
Rectifier Inductance	1mH
Inverter Side Inductance	2mH
DC link Capacitor (C_{dc})	1500 μf

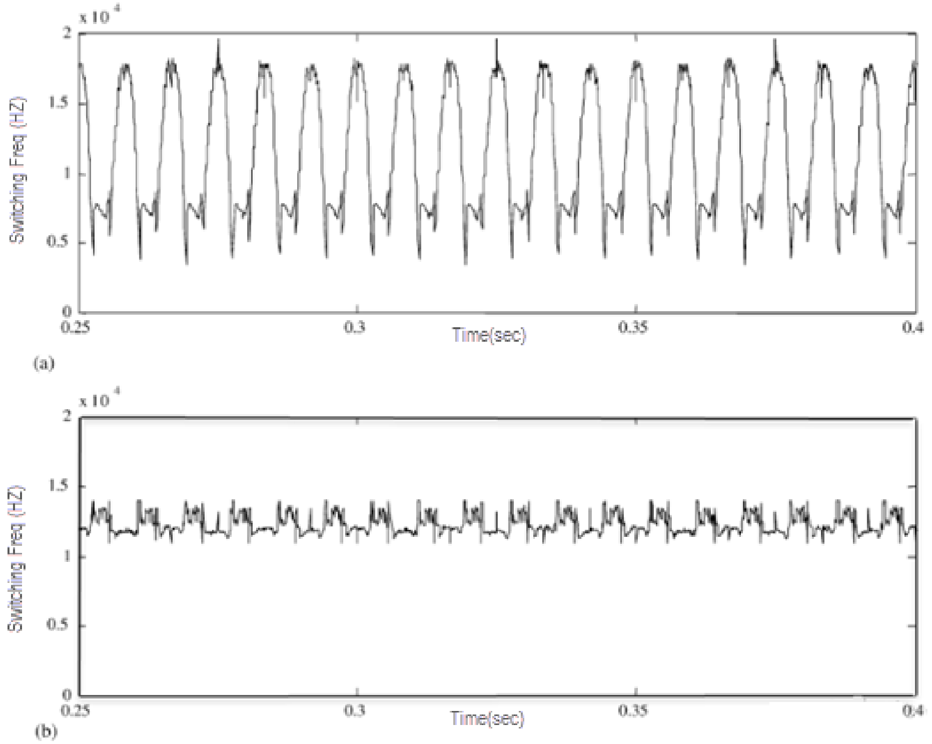

Fig (8) instantaneous switching frequency (a) fixed band hysteresis current control, (b) adaptive hysteresis band current control

V. Conclusion

This paper demonstrates the hysteresis current control has been clarified with two modes: fixed-band and Adaptive Hysteresis band Current Control.The simulation results proved that AHCC technique made the fixed switching frequency that results in reducing the high-frequency components of source current and switching losses.

References

[1]. W.M. Grady, M.J. Samotyj, A.H. Noyola, Survey Of Active Power Line Conditioning Methodologies, IEEE Trans. Power Delivery 5 (3) (1990) 1536–1542.
[2]. H. Akagi, New Trends In Active Filter For Improving Power Quality, In: Proceedings Of The 1996 International Conference On Power Electronics, Drives And Energy System For Industrial Growth.
[3]. J. Holtz, PulsewidthModulation For Electronic Power Conversion, Proc. IEEE 82 (8) (1994) 1194–1214.
[4]. Buso, S. Et. Al. "*A Dead-Beat Adaptive Hysteresis Current Control*, " IEEE Transaction On Industry Appliances, Vol. 36, Pp.1174-1180, July- Aug. 2000
[5]. Anita Choudhary1 .A Study Of Hysteresis Band Current Control Scheme For Shunt Active Power Filter Used For Harmonics Mitigation , (IJARCET), Volume 4 Issue 6, June 2015
[6]. S. Buso, S. Fasolo, L. Malesani, P. Mattavelli, A Dead Beat Adaptive Hysteresis Current Control, IEEE Trans. Ind. Appl. 36 (4) (2000) 1174–1180.
[7]. PG Scholar, C.V.R.U. Kota, Bilaspur, " A Novel Current Control Technique For Three Phase Shunt Active Power Filter " Ijesrt , Issn: 2277-9655 , [Soni, 4(7): July, 2015]