A Comparative Analysis on Hysteresis Current Control Strategy

Ambuj Kumar Anu[1], Prof. E. Vijay Kumar[3]

[1]*Mtech. Research Scholar*, [2]*Research Guide*

Department of Electrical Engineering, RKDFIST, Bhopal

Abstract - Power quality has become a major research topic in power distribution systems due to a significant increase of harmonic pollution caused by proliferation of nonlinear loads such as diode rectifiers, switching power supplied and other types of line connected power converters etc. The shunt APF is recognized as a cost effective solution for harmonic compensation in low and medium power systems. Electrical energy should be transferred from the source to the load with the sinusoidal voltage and current in fixed-frequency. But in practice, existence of nonlinear elements, especially power electronic devices, in the different parts of the system render this impossible, because they always produce harmonic distortion in the system. Filtering is the major criteria to maintain power quality improvement in the three phase three wire system. To overcome power quality problem shunt APF is recognized as cost effective solution for compensating harmonics in low and medium power applications. In this study a brief review of literature on various hysteresis current control strategy has presented.

Indexed Terms- Hysteresis current, Active Power Filter (APF), Power Quality, PI Controller, Quality Control.

I. INTRODUCTION

As an instance, in an industrial application we may need to convert the DC voltage to AC voltage. It means that the usage of inverter is inevitable, but inverters and any other equipment such as converters, rectifiers etc. which consist of power electronic devices, inject harmonics into the system.

According to the nature of power electronic devices, which is often nonlinear and based on switching operation, lead to the generation of harmonics distortion. So, it causes to have poor power quality. Hence the requirement to have systems with minimum harmonic distortion (minimum THD) compelled scientists and engineers to introduce passive and active power filters (APFs) as a solution of this problem and they are still optimizing both passive and active power filters (APFs) as much as possible.

In general, PI controllers are played major role for controlling shunt APF. For three phase Systems synchronous frame PI controllers can be used but it requires computational burden in case of multiple frame transformations. To overcome the above problem Proportional resonant controller is used. The frequency response characteristic of a PR controller is similar to that of a PI controller. PR controllers are used for reference tracking in the stationary reference frame. The basic functionality of a PR controller is to introduce infinite gain at a selected resonant frequency for eliminating steady state error at that frequency.

Under unbalanced load the fundamental negative sequence component appears in load current. It can result in the fundamental negative sequence component in the APF AC currents and APF AC voltages. The interaction of negative and positive sequence component of switching functions and ac currents of the APF produces a 2nd order harmonic ripple on the DC link of the

APF, which will generate the 3rd order harmonic distortion in AC currents of the APF and line currents [2]. In addition, under a nonlinear load ac current of the APF contains high harmonics due to load current harmonics. The interaction of fundamental negative and positive sequence component of switching functions and high harmonics AC currents of APF produces high order even harmonics on the DC link voltage of the APF, which create high order odd harmonics in the

APF AC currents. Such harmonics flow into the line, thereby lead to worsen the performance of the system. Moreover, the high harmonic voltage across capacitors in dc side results in high temperature due to their ESR. This leads to reduce their life-cycle of the capacitors.

Power quality problems are common in most of commercial, industrial and utility networks. Natural phenomena, such as lightning are the most frequent cause of power quality problems. Switching phenomena resulting in oscillatory transients in the electrical supply.

For all these reasons, from the consumer point of view, power quality issues will become an increasingly important factor to consider in order to satisfy good productivity. To address the needs of energy consumers trying to improve productivity through the reduction of power quality related process stoppages and energy suppliers trying to maximize operating profits while keeping customers satisfied with supply quality, innovative technology provides the key to cost-effective power quality enhancements solutions. However, with the various power quality solutions available, the obvious question for a consumer or utility facing a particular power quality problem is which equipment provides the better solution.

II. ACTIVE HARMONIC FILTERING

Active Filters are commonly used for providing harmonic compensation to a system by controlling current harmonics in supply networks at the low to medium voltage distribution level or for reactive power or voltage control at high voltage distribution level. These functions may be combined in a single circuit to achieve the various functions mentioned above or in separate active filters which can attack each aspect individually. The block diagram presented in figure 2.1 shows the basic sequence of operation for the active filter. This diagram shows various sections of the filter each responding to its own classification.

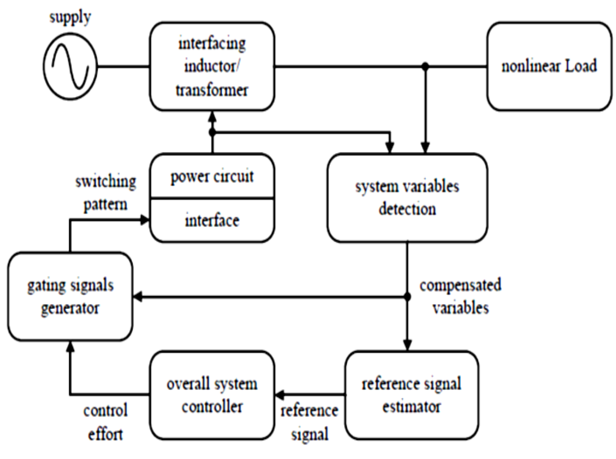

figure 2.1 Generalized block diagram for APF.

The reference signal estimator monitors the harmonic current from the nonlinear load along with information about other system variables. The reference signal from the current estimator, as well as other signals, drives the overall system controller. This in turn provides the control for the PWM switching pattern generator. The output of the PWM pattern generator controls the power circuit through a suitable interface. The power circuit in the generalized block diagram can be connected in parallel, series or parallel/series configurations, depending on the transformer used.

There is a lot of research and developments are required to make this technology well improved. The main disadvantage of APF is, it requires the fast switching of high currents in the power circuit of the APF. Which results in a high frequency noise that may cause an electromagnetic interference (EMI) in the power distribution systems. APF used in several power circuit configurations as illustrated in the block diagram shown in Figure 2.2. In general, they are mainly divided into three categories, namely shunt APF, series APF and hybrid APF.

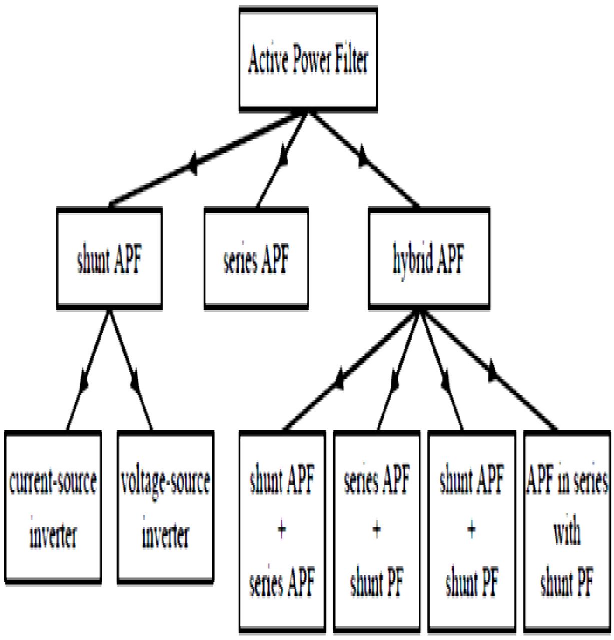

Figure 2.2 Subdivision of APF According to Power circuit Configuration and Connection.

III. LITERATURE REVIEW

SR. No.	Title	Author	Year	Approach
1	Three-level hysteresis current control strategy for three-phase four-switch shunt active filters	S. Biricik and H. Komurcugil	2016	A three-level hysteresis current-control (HCC) strategy is proposed for three-phase four-switch shunt active power filters.
2	Asymmetric overlap and hysteresis current control of zero-current switched alternate arm converter	H. R. Wickramasinghe, G. Konstantinou, J. Pou and V. G. Agelidis,	2016	Develops a double-band hysteresis-based circulating current control strategy by introducing an asymmetric overlap period control of the director switches (DSs).

3	Modified hysteresis current-controlled PWM strategy for Single phase grid connected inverters,	S. Jena, P. R. Behera and C. K. Panigrahi,	2015	a relative analysis between Conventional Hysteresis Current Controller (CHCC) and Modified Hysteresis Current Controller (MHCC) for 1-Φ grid integrated inverter system.
4	Grid voltage stability analysis of Wind Energy Conversion System based PMSG by using Matlab/Simulink	G. A. Kumar, P. A. Jeyanthy and D. Devaraj,	2015	Wind Energy Conversion System based PMSG
5	A novel variable-frequency hysteresis and space-vector current control strategy for three-phase PWM rectifier	H. Wang, Q. Cheng, M. Li, G. Chen and L. Deng,	2014	Compared with traditional current hysteresis control and space-vector control methods,
6	Comparative study of SVM and hysteresis control strategies for grid side converter of PMSG	R. K. Soni, A. K. Chauhan, R. R. Kumar and S. K. Singh,	2014	A directly driven Permanent Magnet Synchronous Generator (PMSG) with a full scale converter interfaced to the grid.
7	Hysteresis current-control strategy for single-phase half-bridge shunt active power filters,	H. Komurcugil	2013	A hysteresis current-control (HCC) strategy for a single-phase half-bridge shunt active power filter.

S. Biricik and H. Komurcugil,[1] In this study, a three-level hysteresis current-control (HCC) strategy is proposed for three-phase four-switch shunt active power filters. The four-switch topology which utilises four switching devices together with two series connected capacitors is able to reduce the cost, switching losses and improve the reliability of system. In this topology, when the current control of phases A and B is achieved successfully, the current control of phase C which is connected to the midpoint of the series connected capacitors is achieved automatically. The current control is achieved by using a three-level HCC strategy. An important consequence of using this control strategy is that it enables access to the zero level of the input voltage of active filter so that a switching device is only switched when the current error is negative, while it remains off when the current error is positive. Furthermore, the imbalance in the capacitor voltages is eliminated by adding a feedback term (the difference in the capacitor voltages multiplied by a suitable gain) to the current control. The proposed control strategy offers a reduced switching frequency, losses and cost. The steady-state and dynamic performance of the proposed control strategy is verified through simulations and experimental studies.

H. R. Wickramasinghe, G. Konstantinou, J. Pou and V. G. Agelidis, [2] The alternate arm converter (AAC) is a multilevel converter of the same family as the modular multilevel converter (MMC). Contrary to the MMC, the AAC offers dc-fault tolerant capabilities but requires complex submodule (SM) capacitor voltage/energy regulation and circulating current control. Such control is also limited due to the small overlap period where both arms conduct and energy between the arms can be exchanged. This research work develops a double-band hysteresis-based circulating current control strategy by introducing an asymmetric overlap period control of the director switches (DSs). The proposed controller ensures zero-current switching operation of the DSs, and increases the flexibility of SM capacitor voltage regulation owing to the asymmetric overlap period. It improves the performance of current control and energy regulation for the AAC at both near sweet-spot and non sweet-spot operation without disturbing the output voltages and currents. The performance and effectiveness of the proposed controller are illustrated through simulations on MATLAB-Simulink and PLECS.

S. Jena, P. R. Behera and C. K. Panigrahi,[3] As the power demand increases rapidly in the electricity market the use of renewable energy sources also increasing. Renewable sources are significantly different from the traditional power sources due to their stochastic nature. Therefore it is a tough task to integrate renewable energy sources with the existing utility grid. In order to ensure the grid reliability, current controlled Pulse Width Modulated VSI is used to interface renewable energy sources with utility grid. This research work presents a relative analysis between Conventional Hysteresis Current Controller (CHCC) and Modified Hysteresis Current Controller (MHCC) for 1-Φ grid integrated inverter system. The benefit MHCC is, it avoids short circuiting of the DC link voltage. Further MHCC gives more sinusoidal current and lesser THD than that of CHCC. The MATLAB Simulink environment is used to model, study and stimulate the system.

G. A. Kumar, P. A. Jeyanthy and D. Devaraj,[4] To diminish the environmental pollution and to meet the demand of power generation, the nations are concerned to generate the electrical power through the renewable energy resources. The wind energy is the massive energy resource compared to other mode of renewable energy resources. To integrate the wind energy into the grid often causes stability issues in the grid. The stability issues are normally called as voltage stability. In general the wind is alternatively changes the turbine speed, hence to maintain the voltage stability in the grid the DC link voltage in back to back converter should be same as the grid voltage. In order to achieve this, in this proposed work the gate signals passed to the rectifier side as well as inverter side is controlled through the Maximum Power Point Tracking (MPPT) control strategy and Hysteresis current control strategy. By using these control strategies voltage stability is maintained to the power grid.

H. Wang, Q. Cheng, M. Li, G. Chen and L. Deng,[5] A novel control scheme for three-phase PWM rectifier is proposed in the research work which improves variable-frequency hysteresis-current control and space vector control due to the fact that there are common shortcomings in the traditional hysteresis controlling method. Compared with traditional current hysteresis control and space-vector control methods, the improving variable-frequency hysteresis and SVPWM control can reduce the delay of control time significantly. The Matlab/Simulink simulation results verify the theoretical analysis and provide with super advantages such as reducing harmonic pollution, lowering switching frequency, accelerating dynamic response and so on. This makes it vital to build a highly effective control system and regulate widespread application for three-phase PWM rectifier which contributes to energy conversion and bidirectional flow of electricity.

R. K. Soni, A. K. Chauhan, R. R. Kumar and S. K. Singh,[6] This research work deals with dynamic simulation of a directly driven Permanent Magnet Synchronous Generator (PMSG) with a full scale converter interfaced to the grid. A comparative assessment of two control strategies is the main focus of this research work. The first is the SVM based voltage oriented control strategy and the second is the hysteresis current control strategy. Maximum power point tracking and pitch angle control is also modeled. The controller performance is analyzed through simulation results with various changes in wind velocity.

H. Komurcugil,[7] This research work presents a hysteresis current-control (HCC) strategy for a single-phase half-bridge shunt active power filter. The half-bridge topology employs two switching devices and two capacitors connected in series. It is shown that the imbalance existing in these capacitor voltages can be successfully eliminated. The HCC strategy is seen to be quite successful in eliminating the unwanted current harmonics. The steady-state and dynamic performance of the HCC strategy has been tested by computer simulations under a diode bridge rectifier load. Simulation results confirm the correct operation of the HCC strategy.

IV. PROBLEM STATEMENT

Hysteresis current controller derives the switching signals of the inverter power switches in a manner that reduces the current error. The switches are controlled asynchronously to ramp the current through the inductor up and down so that it follows the reference. 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. Harmonics are sinusoidal voltages and currents which have frequencies equal to integer multiples of fundamental frequency. Harmonics co-exist with the fundamental voltages or currents, and then they generate distortion in the system.

V. CONCLUSION

The active filters are used to cancel harmonic distortion in power system. The active filters use power electronic converters in order to inject harmonic components to the system that cancel out the harmonics in the supply current caused by non-linear loads. The shunt active filter is a pulse width modulated voltage source inverter that is connected in parallel with the load. The switches of the voltage source inverter in the active power filter are switched such that proper compensation is achieved. This work review various current control strategies proposed to control the inverter. Among the various current control techniques, hysteresis current control technique is the most commonly used approach due to its simplicity in implementation and fast response.

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