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Modified Active Power Filter for Harmonics Mitigation and Comparison with Standard APF Analysis

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***Abstract* - This paper presents a comparative study of two controlling techniques using a direct control algorithm for a single phase shunt active power filter. This technique proposes a Modified active power filter control for compensation of current harmonics and the reactive power introduced into the grid by the nonlinear loads. The proposed Modified APF consists of a single-phase voltage source inverter with an energy storage capacitor at dc bus and is connected in shunt mode with load through a filtering inductor. A simple P-I controller is used to regulate an averaged dc bus voltage to derive the reference supply current peak value in phase with supply voltage. The simulation and experimental results have been presented with a comparison to determine which of the two techniques either Standard APF and a Modified APF performs well in terms of source current THD and reactive power compensation.**

Keywords *- Active power filters (APFs), Total Harmonic Distortion (THD), and Pulse Width Modulation (PWM).*

I. INTRODUCTION

All nonlinear loads such as temperature controllers, electric furnaces, light controllers, ac voltage regulators, UPS, electrical drives and many more devices need solid state power convertors to control and convert ac power. These non-linear loads generally draw reactive power and harmonic currents in addition to active power from ac mains. Reactive power and harmonic components of nonlinear load current results in poor power factor, partial utilization of distribution system, deteriorated life expectancy of other equipments and interference to communication network.

Harmonics in power systems causes a serious drawback towards the wide use of power electronics devices. Conventionally, a passive power filter and capacitor were main tools to reduce the harmonics and increase the input power factor. But they have many drawbacks, such as their large size and fixed compensation characteristic etc. To solve the problem of harmonics several methods based on the technique of power electronics have been proposed. One of them is the active power filter. The configurations of active power filter developed include three-phase and single-phase systems. The three-phase system implemented by a three phase bridge inverter is suitable for severe unbalanced loads and require compensation for each phase separately. Considerable research has been made in the field of active power filters as well as new control techniques to overcome harmonics problem [1-14].

Different control strategies may be used to regulate the current produced by the inverter having hysteresis along with sliding-mode controls, allowing direct current control at the cost of a time varying switching frequency, thus making the design of the output filter and the reduced noise level to be controlled much difficult. PWM control allows avoiding such problems on cost of limit in the time response of the current feedback loop and thus reducing the ability of the filter to compensate for fast current transitions. A comparative study of Standard APF and a Modified APF control

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algorithm is proposed in this paper to improve compensation accuracy for distorted mains voltage. This paper investigates the performance of Standard APF and a Modified APF in terms of source current THD and reactive power compensation on a single-phase shunt active power filter.

II. ACTIVE POWER FILTER

Fig. 1 Shows the operation and working principle of Active Power Filter. Fig. 1 shows the fundamental block diagram of the proposed Modified Active Power Filter comprising of a standard single phase voltage source MOSFET based bridge inverter with dc bus capacitor and boost voltage for an effective current control. A PWM current control technique implementing hysteresis rule used here provides fast dynamic response. Linear loads of lagging and leading power-factors are considered for demonstrating reactive power compensation capability of the APF in response to step change.

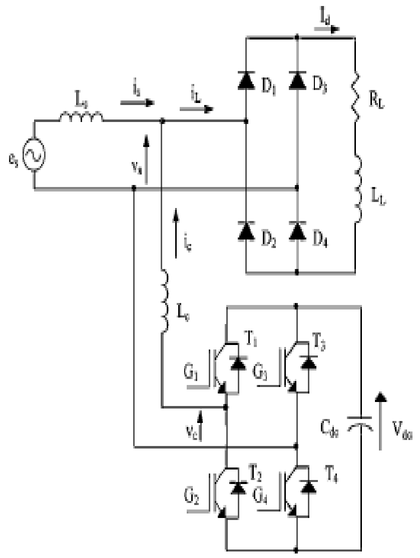

Fig: 1 Basic circuit of Active Power Filter.

Fig. 2 shows Non-linear loads comprising diode rectifier with capacitive loading and inductive load in solid state ac regulator, are implied with APF system to illustrate its capability for harmonic and reactive power compensation in loads. The main application of the proposed Modified APF is in elimination of harmonics and to facilitate reactive power requirement of the load locally so that ac source feeds only fundamental sinusoidal active component of unity power factor current. As the Modified APF in the system is in shunt with load, which results in improved system efficiency which is because the active power delivered to the load is not processed.

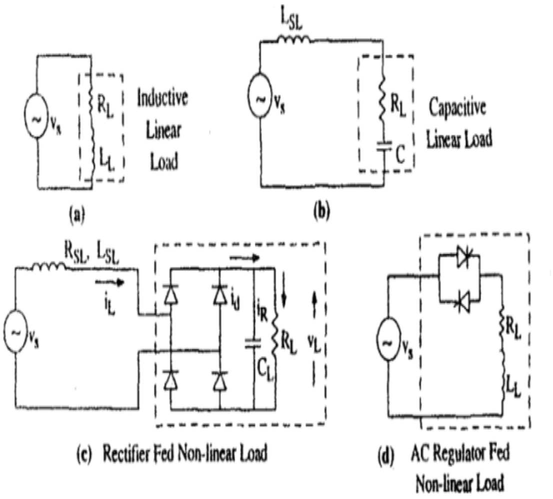

Fig: 2 Different types of loads.

III. CONTROL SCHEME FOR STANDARD APF

The generation of the Standard APF control pattern is illustrated in Fig. 4. It is based on two comparisons:

(1) A comparison between a control signal ² and a triangular high-frequency carrier and

(2) A comparison between the opposite of the control signal (-²) and the same carrier.

Such signal, which varies slowly over time in each half-period interval, is generally delivered by a closed-loop PI controller that continuously adjusts the current i_C at the input of the active filter to track a current reference i_s^* such that:

$$i_L - i_C = i_S = \hat{i}_S \sin \omega_S t$$

Where ω_S denotes the angular frequency of the mains.

Principle of PWM: The reference current i_s^* obtained from the control algorithm is compared with sensed current i_s. From fig.3, the error signal is fed a controller having a limiter at its output. Consequently the controlling signals **v** and its opposite -v are compared with a triangular carrier

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resulting in the switching signals to the gates (fig. 3).

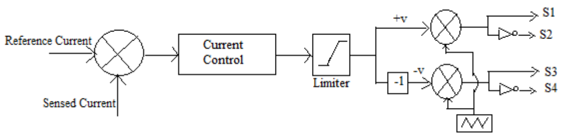

Fig. 3 PWM principle of gating signal generation

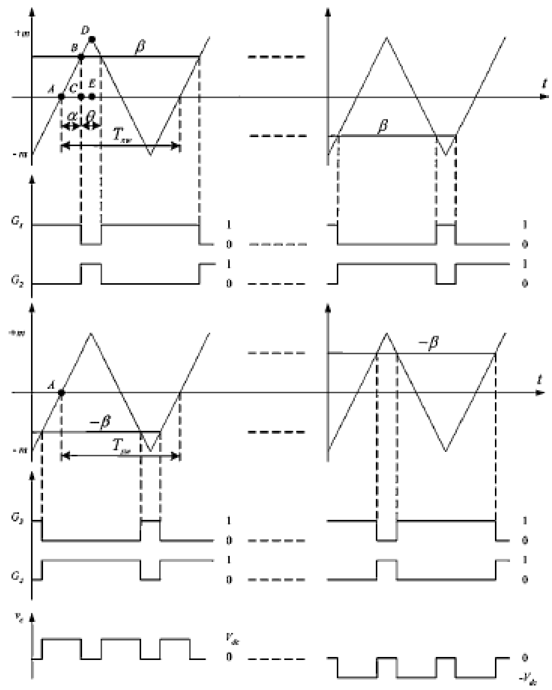

Fig: 4 PWM gating signal generation using the SAPF control technique.

IV. CONTROL SCHEME FOR MODIFIED APF

Fig. 5 shows the block diagram of a control scheme for the modified APF system. DC bus voltage and supply voltage and current are sensed from the system to control the APF. AC source supplies fundamental active power component of load current and a fundamental component of a current to maintain average dc bus voltage to a constant value. The later component of source current is to supply losses in VSI such as capacitor leakage current, switching loss etc. in steady state and to recover stored energy on the dc bus capacitor during dynamic conditions such as addition or removal of the loads. The sensed dc bus voltage of the APF along with its reference value are given to the P-I controller. The output of the P-I controller is taken as peak of source current. A unit vector in phase with the source voltage is generated using its sensed value. The peak source current is multiplied with the unit vector to generate a reference sinusoidal unity power factor source current. The reference source current and sensed source current are processed in hysteresis carrier less PWM current controller to derive gating signals for the MOSFETs of the APF. In response to these gating signals, the APF impresses a PWM voltage to flow a current through filter inductor to meet the harmonic and reactive components of the load current. Since all the quantities such as dc bus voltage etc. are symmetric and periodic corresponding to the half cycle of the ac source. A corrective action is taken in each half cycle of the ac source resulting in fast dynamic response of the APF.

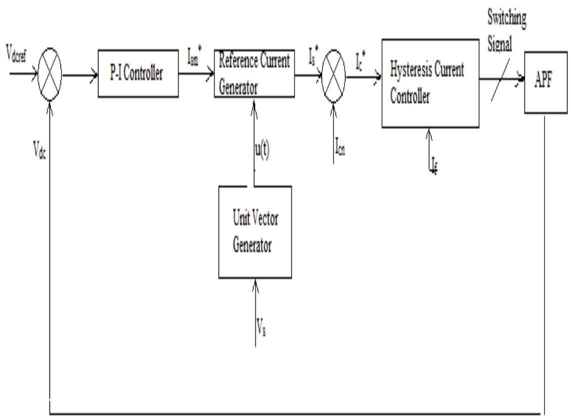

Fig: 5 Basic circuit of active power filter

V. HARMONIC ANALYSIS AND MODEL EQUATIONS

The proposed Modified APF system is comprised of a voltage controller, a current controller, a voltage source inverter bridge with dc bus, a non-linear load with input impedance and a filter inductance at the input of the APF. All parts are modelled separately and then joined together in order to simulate the APF system.

(i) Voltage and P-I controller:

The resultant voltage error

$$e(t) = V_{dcref} - V_{dc} \quad (1)$$

$$I_{sm}^{*} = e(t) \,.\, K_P + K_i/T_i \,.\, \int e(t)\, dt \quad (2)$$

where, K_p and K_i are the proportionality and integral gain constants of the P-I controller.

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***(ii)* Reference current generation:**

$$I_s^* = u(t)\ .\ I_{sm}^* \qquad (3)$$

Where, u(t) is the unit vector for input voltage V_{in}.

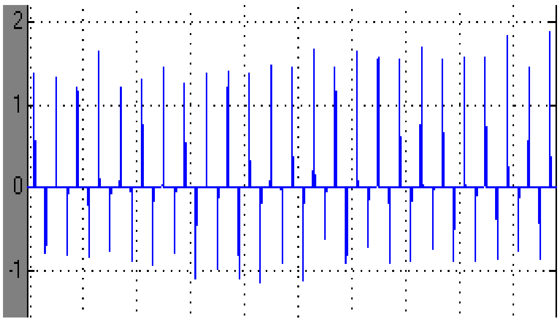
(iii) Current Controller:

If ($I_c > I_c^* + h_b$) S_1 and S_2 on, S_3 and S_4 off.
If ($I_c > I_c^* - h_b$) S_1 and S_2 off, S_3 and S_4 on.
S_1, S_2, S_3, S_4 are the switching devices of the APF and h_b is the hysteresis bandwidth in ampere.

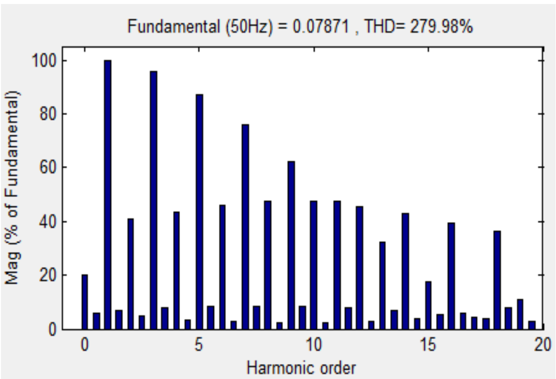
V_s (rms) = 325V, f = 50Hz, R_c = 0.01 ohm, L_c= 10.12 mH, C_c = 8000 µF, K_p = 1, K_i = 1.

VI. RESULTS

Results from the Modified APF system are demonstrated through Fig 6 – Fig 8.
Fig. 6(a) shows the waveforms of input current (i_s) without active power filter for an AC to DC rectifier load. Fig. 6(b) Supply current is 10A with a huge THD with different frequency spectrums specially having 3rd, 5th… odd harmonics.



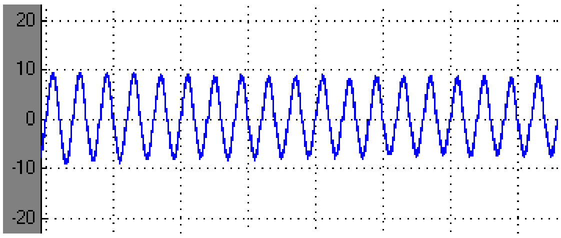
(a)



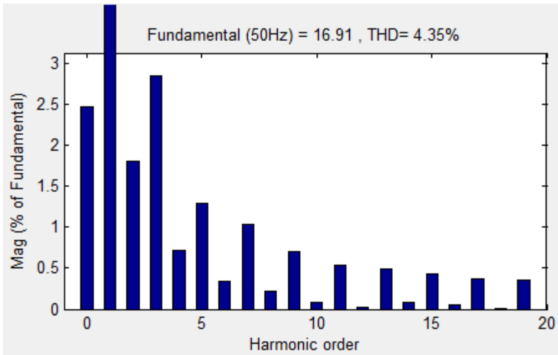
(b)

Fig: 6 Without APF (a) Input current (b) THD analysis

From fig. 7(a) and Fig. 7(b) it may observed that harmonics are eliminated from the supply current. Therefore, APF is quite effective to reduce the THD of supply current well below the permitted value of 5 % by IEEE-519 standard.

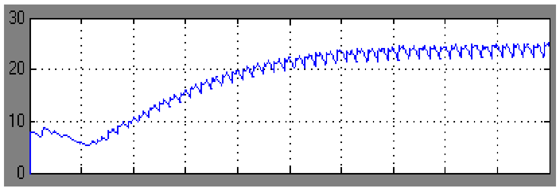


(a)

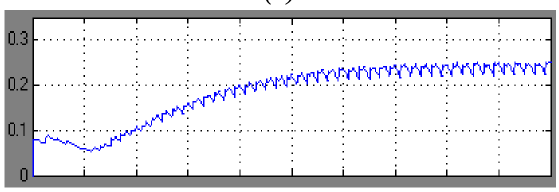


(b)

Fig: 7 With Modified APF (a) Input current (b) THD analysis



(a)



(b)

Fig: 8 With Series-Parallel resonant Converter (a) DC Load Voltage (b) DC Load Current

Fig 8 (a) and (b) shows the output DC voltage and current for load resistance 100 ohm. Fig 7 shows the performance of Series Parallel resonant converter. The THD of supply current is not much affected by dc bus capacitor values.

From these results it may be concluded that for the proper selection of ratings of dc bus capacitor, controller parameters and device specifications, the proposed modelling is essential at design stage of the Modified APF system.

VII.CONCLUSION

The proper selection of dc bus capacitor, controller parameters and device specifications, at design stage of the MAPF system can be used quite effectively to reduce the THD of supply current well below the permitted value of 5% (IEEE standard). And is much easier way to provide reactive power and harmonics compensation both for linear as well as non-linear single-phase loads in comparison to SPWM. The MAPF is easier and less complex than SAPF to control THD less than 5%. The MAPF eliminates frequency harmonic components effectively and is able to compensate the reactive power required by the ac-to-dc converter. Hysteresis current controller is used to obtain the gate signals for switching devices of APF.

VIII. REFERENCES

1) J. Holtz, "Pulsewidth Modulation-A Survey", IEEETrans. Ind. Electron, vol. 39, pp. 410–420, December 1992.
2) Janko Nastran, Rafael Cajhen, Matija Seliger, and Peter Jereb "Active power filter for nonlinear ac loads," IEEE Trans. PE, Vol. 9, No. 1, January 1994, pp 92.
3) V.B. Bhavaraju and Prasad N. Enjeti, "Analysis and design of an active power filter for balancing unbalanced loads," IEEE Trans. Power Electronics, Vol. 8, No. 4, pp 640, 1993.
4) J. Holtz, "Pulsewidth Modulation for Electronic Power Conversion", Proceedings of the IEEE, Vol. 82, No. 8 Aug. 1994, pp. 1194 – 1214.
5) D. A. Torrey and A. M. A. M. Al-Zamel, "A single-phase active power filter for multiple nonlinear loads," in Proceedings of the IEEE APEC'94, vol. 2, 1994, pp. 901–908.
6) Khambadkone and J. Holtz, "Low Switching Frequency High-Power Inverter Drive Based on Field-Oriented Pulsewidth Modulation", EPE Europ. Conf. Power Electronics and Appl., Florence/Italy, 1991, pp.4/672-677.
7) H. Akagi, "New trends in active filters for improving power quality," in Proc. IEEE PEDES'96, pp.417–425, 1996.
8) CHOE, G.H., and PARK, M.H.: 'Analysis and control of active power filter with optimized injection', IEEE Trans., PE-4, pp. 427-433, 1989.
9) C. Lott and H. Pouliquen, "High power voltage source PWM active filter," Proc. Conf. PQA'94, Part 2, Amsterdam, The Netherlands, October 24-27, 1994.
10) Mehdi Salehifar and Abbas Shoulaie,"Harmonic Elimination in Single Phase Systems by Means of a Hybrid Series Active Filter (HSAF)", 1st Power Electronic & Drive Systems & Technologies Conference pp.423-427, IEEE, 2010
11) L. R. Limongi, R. Bojoi, G. Griva and A. Tenconi, "New Control Scheme for Single-Phase Active Power Filters", pp. 2894-2900, IEEE, 2008
12) Hasan Komurcugil and Osman Kiikrer, "A Robust Current Control Strategy for Single-phase Shunt Active Power Filters", Proceedings of the IEEE. pp. 2277-2281, 2003
13) L. P. Kunjumuhammed, M. K. Mishra, "A Control Algorithm for Single-Phase Active Power Filter under Non-Stiff Voltage Source," IEEE Trans. Power Elec., vol. 21, pp. 822 - 825 No. 3, May 2006.
14) L. Zhou and Z. Li, "A novel active power filter based on the least compensation current control method," IEEE Trans. Power Elec., vol. 15, pp. 655–659, No. 4, Jul. 2000.

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