IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 2, Issue 10, May 2014)

Simulation of a Novel Shunt Active Filter to Reduce the Harmonics Due to Non Linear Loads in Distribution System

Anand Kumar Rathore
M. Tech. Scholar,
Dr. C. V. Raman Institute of Science and technology, Chhattisgarh (India)
anand.rathore.1989@gmail.com

Dharmendra Kumar Singh
HOD. (Electrical Department)
Dr. C. V. Raman Institute of Science and Technology, Chhattisgarh (India)
dmsingh2001@rediffmail.com

Abstract: **The active power filter has been proved to be an effective method to mitigate harmonic currents generated by nonlinear loads and to compensate reactive power present in the system. However the Active Power Filters for harmonic current compensation do not show significant moderations for harmonic voltage problems and filters for harmonic voltage compensation do not provide reliable solution for harmonic current problems. Also the Active Power Filters performance for low frequency problems is very poor. The methods of harmonic current detection play a crucial part in the performance of active power filter (APF). This paper presents a new control strategy in which shunt active power filter configuration is developed using adaptive fuzzy control in order to define simple control algorithm which requires minimum number of current measurements. The effectiveness of the proposed control strategies are demonstrated through results. The proposed systems are implemented with MATLAB/SIMULINK.**

Keywords: **Active Power Filter, Harmonic voltage, Shunt Active Power Filter, Fuzzy Control.**

I. INTRODUCTION

The irregularity in the resistance is primary source of non-linear loads. Also the fluctuations during each sine wave of applied voltage waveform results in an array of positive and negative pulses. With non-linear loads, the third harmonic on all three phases is exactly in phase and adds, rather than cancels, thus creating current and heat on the neutral conductor. Left un-treated, harmonic loads can reduce the distribution capacity and degrade the quality of the power of public utility power systems, increase power and AC costs, and result in equipment malfunctions such as communication errors and data loss. The effect on the public power system has led regulatory agencies to set lower harmonic levels and power utilities to charge more for wasted energy. Various topologies of active power filters have been developed so far [1-12]. The shunt active power filter based on current controlled voltage source type PWM converter has been proved to be effective even when the load is highly non-linear [1][4][11]. Most of the active filters developed are based on sensing harmonics [7] [10] [11] and reactive volt-ampere requirements of the non-linear load [1][3][12][17] and require complex control. A new scheme has been proposed in [10], in which the required compensating current is determined by sensing load current which is further modified by sensing line currents only [8][13]. An instantaneous reactive volt-ampere compensator and harmonic suppressor system is proposed [13] without the use of voltage sensors but require complex hardware for current reference generator.

Three-phase systems are commonly used in generation, propagation and distribution of electric current (power). The power in a three-phase system is linear rather than pulsating and three-phase motors start and run much better than single-phase motors. The three-phase system has a generator-load pair which employs the generator to produce three sinusoidal voltages of equal amplitude and frequency but differing in phase by 120° from each other.

The phase voltages $v_a(t), v_b(t)$ *and* $v_c(t)$ are as follows:

$$V_a = V_m cos\omega t$$

$$V_b = V_m \cos(\omega t - 120^o)$$

$$V_c = V_m \cos(\omega t - 240^o) \quad (1)$$

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 2, Issue 10, May 2014)

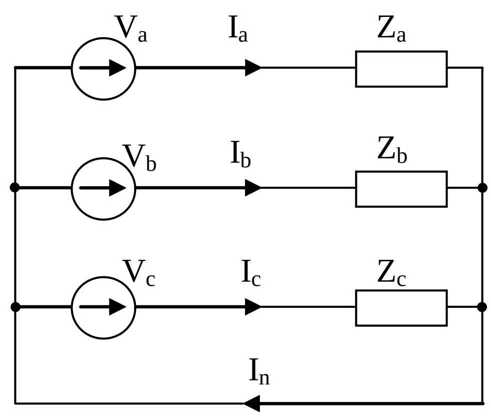

Figure 1: Three Phase System Block Representation

Using KCL, we have

$$I_n = I_a + I_b + I_c = \frac{1}{Z}(V_a + V_b + V_c) \qquad (2)$$

Since the current flowing through the fourth wire is zero, the wire can be removed (see Fig. 2).

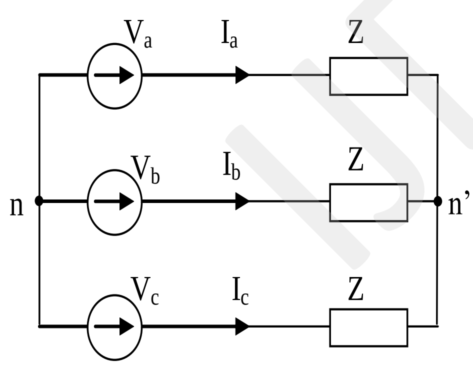

Figure 2: Three Phase Power Y-System (star system) with $I_n = 0$

Power in three-phase circuits

In the balanced systems, the average power consumed by each load branch is the same and given by

$$\tilde{P}_{av} = V_{eff} I_{eff} cos\emptyset \qquad (3)$$

Where, V_{eff} is the effective value of the phase voltage, I_{eff} is the effective value of the phase current and ϕ is the angle of the impedance. The total average power summoned by the load is the sum of those consumed by each branch; hence, this can be written as:

$$P_{av} = 3\tilde{P}_{av} = V_{eff} I_{eff} cos\emptyset \qquad (4)$$

In this paper, shunt active power filter is compensated for the prolonged implementation in three phase systems based on linear power circulation. The properties of this filter are cascaded with fuzzy control as it is the conventional tool to modify the new outputs based on current trend estimation. The second segment discusses the problem domain of the research subject followed by the literature of keen study from works of different authors. Further sections discuss the detailed proposed structure and results to verify the proposed subject. A conclusion is present to conclude the topic.

II. RESEARCH WORKS AND MOTIVATION

The non-linear load creates the harmonic current and harmonic voltage in the three phase power system. The active power filters are conventionally used to balance the harmonic current by injecting the sinusoidal grid current. The scheme is effective to simulate the harmonic current but renders un-useful for harmonic voltage problems. A voltage sourcing series active power filter is suitable for controlling harmonic voltage sources, but it cannot properly compensate for harmonic current sources [14].

This paper presents a new control algorithm for an active power filter (APF) to compensate harmonic and reactive power of a 3-phase thyristor bridge rectifier under non-ideal mains voltage scenarios. Sensing load current, dc bus voltage and source voltages compute reference currents of the APF. APF driving signals are produced with these signals via a hysteresis band current controller. MATLAB/SIMULINK power system toolbox is used to simulate the proposed system. The proposed method's performance is compared with conventional instantaneous power (p–q) theory. The simulation results are presented and discussed showing the effectiveness of the control algorithm. The proposed algorithm is found quite satisfactory to compensate the reactive power and harmonics under non-ideal mains voltage conditions. The increased performance of the active power filter under different non-

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 2, Issue 10, May 2014)

sinusoidal mains voltage and dynamic load conditions are extensively demonstrated [17].

Murat Kale architected the control algorithm for APF to manipulate the effects of harmonic and reactive power. In comparison with P-Q theory, shunt active filter in environment of non-ideal mains voltage conditions performed better in constrained of high performance parameters. The main purpose of the active filter based on voltage detection is not to compensate for current harmonics but to damp out harmonic propagation caused by line inductors and shunt capacitors for power factor correction. However, time and phase delays inherent in digital controllers might lead to unsatisfactory harmonic-damping performance although digital controllers are preferable to analog controllers. Dealing with design and implementation of a digital controller for a shunt active filter is based on voltage detection. Experimental results obtained from a laboratory system developed paper of Pichai Jintakosonwit [16] verify the viability and effectiveness of the fully-digital-controlled active filter [19].

Shunt active power filters have been proved as useful elements to correct distorted currents caused by nonlinear loads in power distribution systems. We can present an all-digital approach based on a particular repetitive control technique for their control. Specifically, a digital repetitive plug-in controller for odd-harmonic discrete-time periodic references and disturbances is used for the current control loops of the active filter. An approach by Robert Grino [18] does not introduce a high gain at those frequencies for which it is not needed and, thus, improves robustness of the controlled system. The active power balance of the whole system is assured by an outer control loop, which is designed from an energy-balancing perspective. The design is performed for a three-phase four-wire shunt active filter with a full-bridge boost topology. [18].

III. PROPOSED METHODOLOGY

The shunt-connected active power filter, along with a self-controlled dc bus, has a topology which is similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems. Shunt active power filters reimburse load current harmonics by injecting equal-but opposite harmonic compensating current. In such a case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase-shifted by 180°.

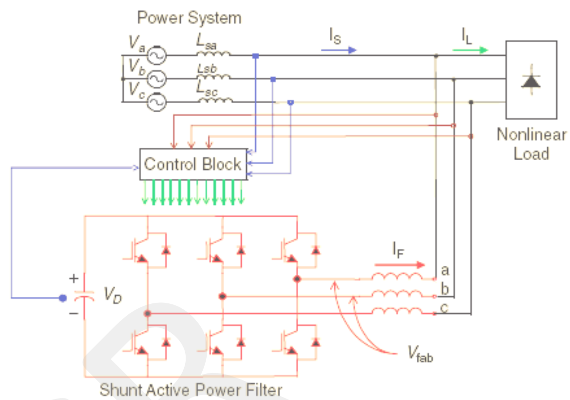

Figure 3: Shunt Active Filter

$$i_s(t) = i_l(t) - i_c(t) \quad (5)$$

Source voltage is given by

$$v_s(t) = v_m sin\omega t \quad (6)$$

If a non-linear load is applied, then the load current can be represented as a fundamental component and harmonic components which can be represented as

$$i_L(t) = \sum_{n=1}^{\infty} \sin(n\omega t + \phi_n)$$

$$I_1 \sin(n\omega t + \phi_n) + \sum_{n=2}^{\infty} \sin(n\omega t + \phi_n) \quad (7)$$

The instantaneous load power can be written as

$$P(t) = v_s(t) * i_l(t)$$

$$= V_m I_1 sin^2 \omega t * V_m I_1 sin\omega t * cos\omega t * sin\phi_1 + V_m sin\omega t * \sum_{n=2}^{\infty} I_n \sin(n\omega t + \phi_n)$$

(8)

$$= P_f(t) + P_r(t) + P_h(t) \quad (9)$$

The design of the DC side capacitor is based on the principle of instantaneous power flow. The selection of C_{dc} can be governed by reducing the voltage ripple [15]. As per the specification of the peak to peak voltage ripple $(V_{dc\,p-p(\max)})$ and rated filter

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 2, Issue 10, May 2014)

current ($I_{c1,rated}$), the DC side capacitor C_{dc} can be found from equation

$$C_{dc} = (\pi * I_{c1,rated})/(\sqrt{3}\omega V_{dc\,p-p(\max)}) \quad (10)$$

Fuzzy Control

Fig. 4 shows the block diagram of the implemented fuzzy logic control scheme of a shunt active power filter. Fig. 5 shows the schematic diagram of the control algorithm. In order to implement the control algorithm of a shunt active power filter in closed loop, thee DC side capacitor voltage is sensed and then compared with a reference value. The obtained error *e* (=$V_{dc,ref}$-$V_{dc,act}$) and the change of error signal *ce(n)*=e(n)-e(n-1) at the nth sampling instant as inputs for the fuzzy processing. The output of the fuzzy controller after a limit is considered *as* the amplitude of the reference current I_{max} takes care of the active power demand of load and the losss in the system.

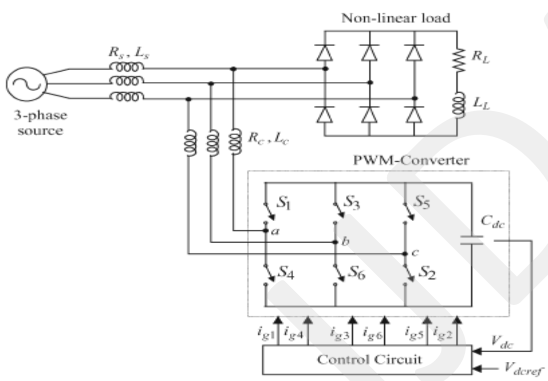

Figure 4: Schematic diagram of closed loop fuzzy logic controlled shunt active power filter.

The switching signals for the PWM converter are obtained by comparing the actual source currents (i_{sa}, i_{sb}, and i_{sc}) with the reference current templates (i_{sa}^*, i_{sb}^*, and i_{sc}^*) in the hysteresis current controller. Switching signals so obtained, after proper amplification and isolation, are given to switching devices of the PWM converter [6].

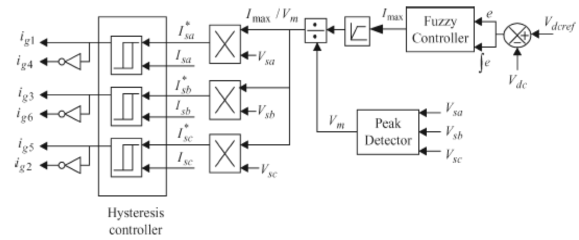

Figure 5: Fuzzy Control scheme.

A fuzzy inference system (or fuzzy system) basically consists of a formulation of the mapping from a given input set to an output set using fuzzy logic. This mapping process provides the basis from which the inference or conclusion can be made. A fuzzy inference process consists of the following steps:

• Step 1: Fuzzification of input variables

• Step 2: Application of fuzzy operator (AND, OR, NOT) in the IF (antecedent) part of the rule

• Step 3: Implication from the antecedent to the consequent (THEN part of the rules)

• Step 4: Aggregation of the consequents across the rules

• Step 5: De-fuzzification.

IV. SIMULATION & RESULTS

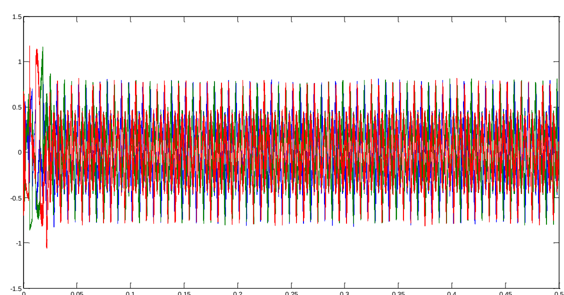

Figure 6: Inject current

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 2, Issue 10, May 2014)

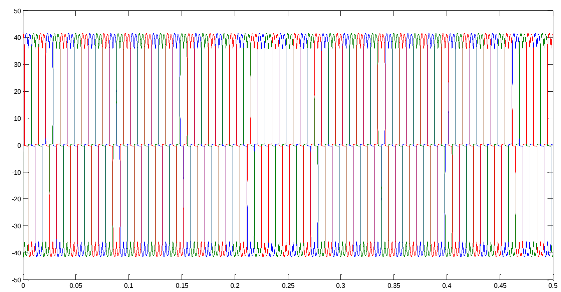

Figure 7: Source current without filter

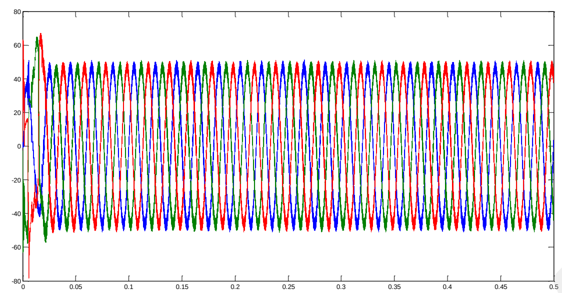

Figure 8: Source current with HCC Shunt Active Filter

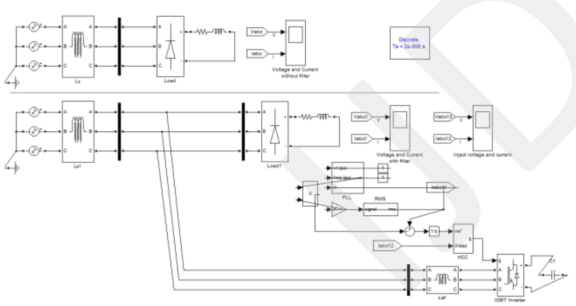

Figure 9: SIMULINK model for shunt active filter without fuzzy control

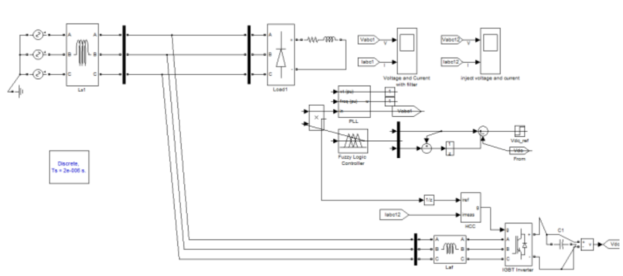

Figure 10: SIMULINK model for shunt active filter with fuzzy control

V. CONCLUSION

In this paper work fuzzy logic controlled three-phase shunt active power filter to compensate harmonics and reactive power by nonlinear load to improve power quality is implemented for three-phase three wire systems. The advantage of fuzzy control is that it is based on linguistic description and does not require a mathematical model of the system. The compensation process is based on sensing line currents only, an approach different from conventional methods, which require sensing of harmonics or reactive power components of the load. Simulation results are presented under steady state conditions and SIMULINK model of shunt active filter with and without fuzzy controller are shown. PWM pattern generation is based on carrier less hysteresis based current control to obtain the switching signals to the voltage sourced PWM converter.

In future various other different techniques can be carried out for the power factor correction methodologies based on fuzzy control. Experimental investigations can be done on shunt active power filter by developing a prototype model in the laboratory to verify the simulation results for fuzzy controller. Modelling and further verification can lead to the generation of new approach a step further in this work.

REFERENCES

[1] W. M. Grady, M. J. Samotyj, and A. H. Noyola, "Survey of active power line conditioning methodologies," IEEE Transactions on Power Delivery, vol. 5, no. 3, Jul. 1990, pp. 1536–1542.

[2] H. Akagi, Y. Kanazawa, and A. Nabae, "Instantaneous reactive power compensators comprising switching devices without energy storage components," IEEE Transactions on Industry Applications, vol. IA-20, no. 3, May/Jun. 1984, pp. 625–630.

[3] S. Jain, P. Agarwal, and H. O. Gupta, "Design simulation and experimental investigations on a shunt active power filter for harmonics and reactive power compensation," Electrical Power Components and Systems, vol. 32, no. 7, Jul. 2003, pp. 671–692.

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary research
Website: www.ijdacr.com (Volume 2, Issue 10, May 2014)

[4] F. Z. Peng, H. Akagi, and A. Nabae, "Study of active power filters using quad series voltage source PWM converters for harmonic compensation," IEEE Transactions on Power Electronics, vol. 5, no. 1, Jan. 1990, pp. 9–15.

[5] H.Akagi, "Trends in active power line conditioners," IEEE Transactions on power Electronics, vol 9, no 3, 1994, pp 263-268.

[6] S. K. Jain, P. Agrawal, and H. O. Gupta, "Fuzzy logic controlled shunt active power filter for power quality improvement," Proceedings of Institute of Electrical Engineers, Electrical Power Applications, vol. 149, no. 5, 2002.

[7] L. A. Morgan, J. W. Dixon & R. R. Wallace, "A three phase active power filter operating with fixed switching frequency for reactive power and current harmonics compensation," IEEE Transactions on Industrial Electronics, vol.42, no.4, August 1995, pp 402-408.

[8] B. Singh, A. Chandra, and K. Al-Haddad, "Computer-aided modeling and simulation of active power filters," Electrical Machines and Power Systems, vol. 27, 1999, pp. 1227–1241.

[9] B. Singh, A. Chandra, and K. Al-Haddad, "A review of active filters for power quality improvement," IEEE Transactions on Industrial Electronics, vol.46, no 5, Oct 1999, pp1-12.

[10] R. M. Duke and S. D. Round, "The steady state performance of a controlled current active filter," IEEE Transactions on Power Electronics, vol. 8, Apr. 1993, pp. 140–146.

[11] J. W. Dixon, J. J. Garcia & L. Morgan, "Control system for three phase active power filter which simultaneously compensates power factor and unbalanced loads," IEEE Transactions on Industrial Electronics, vol.42, no.6, 1995, pp636-641.

[12] E. H. Watanbe, R. M. Stephan & M. Aredes, "New concepts of instantaneous active and reactive powers in electrical systems with generic loads," IEEE Transactions on Power Delivery, vol.8, no.2, April 1993, pp.697-703.

[13] K. Chatterjee, B. G. Fernandes, and G. K. Dubey, "An instantaneous reactive volt-ampere compensator and harmonic suppressor system," IEEE Transactions on Power Electronics, vol. 14, no. 2, Mar. 1999, pp. 381–392.

[14] Fang Zheng Peng, "Application issues of Active Power Filters," IEEE Industry Applications Magazine, pp. 21-30, Sept 1998

[15] Joao Afonso "Shunt Active Filter for Power Quality Improvement", International Conference UIE 2000 – "Electricity for a Sustainable Urban Development" Lisboa, Portugal, 1-4 Novembro 2000, pp. 683-691

[16] Pichai Jintakosonwit, "Control and Performance of a Fully-Digital-Controlled Shunt Active Filter for Installation on a Power Distribution System" IEEE Transactions On Power Electronics, Vol. 17, No. 1, January 2002

[17] Murat Kale, "Harmonic and reactive power compensation with shunt active power filter under non-ideal mains voltage" Electric Power Systems Research 74 (2005) 363–370, Elsevier

[18] Robert Grino, "Digital Repetitive Control of a Three-Phase Four-Wire Shunt Active Filter" Industrial Electronics, IEEE Transactions on Volume: 54, Issue: 3