International Conference on Machine Learning and Computational Intelligence-2017
International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2017 IJSRCSEIT | Volume 2 | Issue 7 | ISSN : 2456-3307

Design of Single-Phase Active Filter Using Multi-level Inverter

Thripthika M P
Department of Electrical and Electronics Engineering, Government Polytechnic, Siddapur, Uttara Kannada, Karnataka, India

ABSTRACT

This paper deals with the design of Three-level inverter which is used as active power filter to reduce distorted current flowing in to the power system and hence to draw nearly sinusoidal line current with unity power factor. Proposed inverter is cascade connection of two full bridge inverters. Proposed control scheme is based on uncomplicated reference source current generation and PI controller based dc bus voltage regulation methods. Thus, complex computations are not needed. MATLAB/simulink is used to study and analyze the results.

Keywords : MATLAB/Simulink, P-I Controller, Multi Level Inerter, Harmonics and Reactive Power.

I. INTRODUCTION

In recent years with the development of power semiconductor technology, power electronics based devices such as static var compensators (SVCs), adjustable speed drives (ASDs) and uninterruptible power supplies (UPSs) are widely employed in various applications. Because of their nonlinear V-I characteristics these devices draw current with harmonic content and reactive power from ac mains. Current harmonics drawn by nonlinear loads disturb the waveform of the voltage at the point of common coupling (PCC) and lead to the voltage harmonics that the other linear loads and sensitive electronic equipments have to deal with [1].

These non-linear loads also draw reactive power and harmonic currents along with active power from ac mains. The reactive power and harmonic components of load current cause poor power factor, poor utilization of distribution system, overheating which deteriorate life expectancy of other equipments and cause low efficiency, disturbance to other consumers and interference to communication network.

Conventionally, passive L-C filters were employed to reduce harmonics and capacitors were used to compensate the lagging power-factor of the linear and non-linear loads. But they have many demerits like fixed compensation, large size and weight, resonance, noise, and increased losses. These problems of reactive power and harmonic pollution are well recognized and concept of active power filter was introduced a couple of decade ago by Gyugli and Strycula to provide an effective solution for elimination of harmonics. A large number of attempts were made in the last two decades but most of them were on 3-phase active filters. However, there are many applications of single-phase non-unity power-factor linear and non-linear loads which draw reactive power and harmonic currents from ac mains[8].

Recently some attempts have been made on single-phase active filters. Most of them are either two level inverters as APF and/or use of complex control schemes. This paper is aimed to design a three level inverter as single-phase shunt active filter with a simple control scheme for reactive power and harmonic compensation of linear and non-linear loads. Multilevel scheme provides a number of advantages over the conventional technology especially for high power or medium voltage applications [6-8].

In this paper a simple P-I (proportional-integral) controller is employed to regulate an averaged dc bus voltage to derive the reference supply current peak value in phase with supply voltage. The triangular carrier PWM current control over the supply current is used to generate the gating signals for the devices of the APF. An uncontrolled rectifier with non-linear loads is considered for reactive power and harmonics by the proposed APF. The steady state and transient performance along with harmonic analysis of the APF is given and described in brief.

These non-linear loads also draw reactive power and harmonic currents along with active power from ac mains. The reactive power and harmonic components of load current cause poor power factor, poor utilization of distribution system, overheating which deteriorate life expectancy of other equipments and cause low efficiency, disturbance to other consumers and interference to communication network.

Conventionally, passive L-C filters were employed to reduce harmonics and capacitors were used to compensate the lagging power-factor of the linear and non-linear loads. But they have many demerits like fixed compensation, large size and weight,

resonance, noise, and increased losses. These problems of reactive power and harmonic pollution are well recognized and concept of active power filter was introduced a couple of decade ago by Gyugli and Strycula to provide an effective solution for elimination of harmonics. A large number of attempts were made in the last two decades but most of them were on 3-phase active filters. However, there are many applications of single-phase non-unity power-factor linear and non-linear loads which draw reactive power and harmonic currents from ac mains[8].

Recently some attempts have been made on single-phase active filters. Most of them are either two level inverters as APF and/or use of complex control schemes. This paper is aimed to design a three level inverter as single-phase shunt active filter with a simple control scheme for reactive power and harmonic compensation of linear and non-linear loads. Multilevel scheme provides a number of advantages over the conventional technology especially for high power or medium voltage applications [6-8].

In this paper a simple P-I (proportional-integral) controller is employed to regulate an averaged dc bus voltage to derive the reference supply current peak value in phase with supply voltage. The triangular carrier PWM current control over the supply current is used to generate the gating signals for the devices of the APF. An uncontrolled rectifier with non-linear loads is considered for reactive power and harmonics by the proposed APF. The steady state and transient performance along with harmonic analysis of the APF is given and described in brief.

II. SYSTEM DISCRIPTION

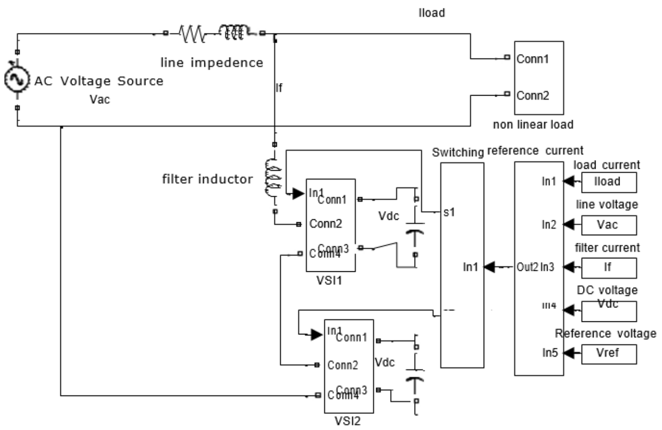

Fig. I. Basic Circuit of the Active Power Filter

Block diagram of the proposed shunt APF is shown in Fig. 1. It comprises of a two voltage source single phase cascaded IGBT based full bridge converter with an energy storage capacitor at the dc side and connected in parallel with the linear or non-linear load through a filter inductor at the ac side. To represent reactive power compensation capability, leading and lagging power factor linear loads and to represent both reactive power and current harmonics compensation capability uncontrolled rectifier and thyristor based ac regulator non-linear loads are connected to the system.

Active filter provides reactive power and harmonic components of load current hence filter and load together behaves like a resistive load and only fundamental component of load current in phase with voltage is drawn from ac mains. The advantages of multilevel inverters over the two-level inverters are improved voltage waveform on the ac side, smaller filter size, lower switching losses, lower electromagnetic interference and lower acoustic noise.

III. CONTROL STRATEGY

A. Reference Source Current Generation

In order to determine harmonic and reactive component of load current, reference source current generation is needed. Thus, reference filter current can be obtained when it is subtracted from total load current. For better filter performance, generation of reference source current should be done properly. In this paper multiplication with sine function method is used for extraction of reference source current. In this method it is assumed that after compensation the source current will become sinusoidal in phase with voltage. Then, instantaneous power drawn by load is calculated as in (1)

$$v_{ac}(t) = V_m \sin(\omega t). \quad (1)$$

$$i_{ac}(t) = I_m \sin(\omega t). \quad (2)$$

$$P_L(t) = v_{ac}(t) * i_{ac}(t) = V_m I_m \sin^2(\omega t). \quad (3)$$

From (3) active power drawn by the load in one cycle is given by (4) and (5)

$$P_L = \frac{1}{2\pi} \int_0^{2\pi} V_m I_m \sin^2(\omega t) d\omega t \quad (4)$$

$$P_L = \frac{V_m I_m}{2} \quad (5)$$

Therefore, if active power of load before and after compensation is equalized, peak value of reference source current can be calculated;

$$I_m^* = \frac{2P_L}{V_m} \quad (6)$$

After multiplication of peak value of reference source current and unity sine function, reference source current can be found; And finally reference filter current is calculated by subtracting load current from reference source current as in (8);

$$i_{ac}^*(t) = I_m^* \sin(\omega t) = \frac{2P_L}{V_m} \sin(\omega t) \quad (7)$$

$$i_{fl}^* = i_{ac}^*(t) - i_{ld}(t) \quad (8)$$

B. PI controller as DC Bus Voltage Controller

A P-I (proportional-integral) controller is used to regulate the dc bus capacitor voltage of the APF. The dc bus capacitor voltage Vdc is sensed using a voltage sensor and compared with set reference voltage (Vref). The resulting voltage error Ve(n) at nth sample instant is expressed as :

$$V_e(n) = V_{ref}(n) - V_{dc}(n) \quad (9)$$

The output of the P-I voltage controller $V_0(n)$ at the n^{th} sampling interval is expressed as

$$V_0(n)=V_0(n-1)+K_p[V_e(n)-V_e(n-1)]+K_i V_e(n) \quad (10)$$

If (7) is recomposed, new reference source current is computed as below

$$i_{ac}^*(t) = (I_m^* + I_{ad})\sin(\omega t) = \frac{2P_L}{V_m} \sin(\omega t). \quad (11)$$

Where *Kp* and *Ki* are proportional and integral gain constants of the voltage regulator. *V0(n-1)* and *Ve(n-*

1) are the output of controller and voltage error at (n-I)th sampling instant. This output *Vo(n)* of the voltage controller is limited to safe permissible value and resulting limited output is taken as peak value of supply current I_{im}

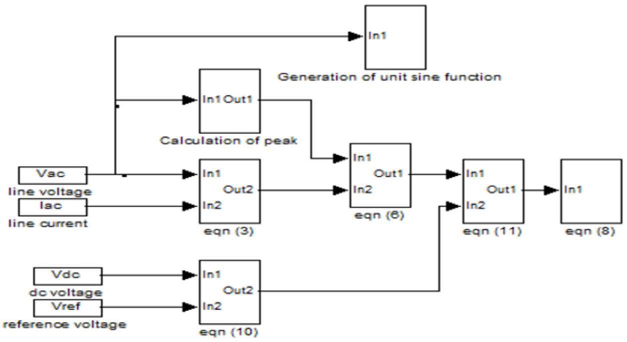

Fig.2. Block diagram of reference current generation

C .Triangular carrier Current controller

The triangular carrier current controller is one of the familiar methods for active power filter applications to generate gate control switching pulses of the voltage source inverter. To determine the switching transitions by means the error current [desired reference current *(ir*)* compared with the actual source current *(iac)*] is multiplied with proportional gain *(Kp)*. The output signal of the proportional gain is compared with triangular carrier signal.

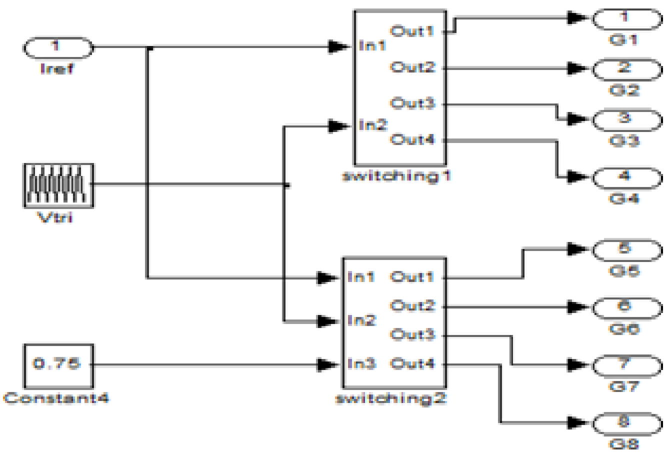

Fig.3. Triangular-carrier current controller

For the bridge inverter switches two sets of square pulses are generated. The first set is generated by comparing the modulating signal with a small DC voltage while the second set is generated by comparing the inverted modulating signal with the same DC voltage. This provides necessary dead time compensation between two conducting switches of each leg.

IV. SIMULATION RESULTS

To verify the working of the proposed inverter with control circuitry, the inverter is simulated using MATLAB/ SIMULINK with the Vdc is equal to 550 Volts, frequency of modulating signal is equal to 50Hz, Carrier signal frequency is equal to 300Hz, modulation index is equal to 0.8,non linear load of 30kw and 20kvr,supply voltage(peak) of 311V. Designed active filter is applied to the network at 0.1seconds. Wave forms at different stage are as shown in figures from Fig.3 to Fig.10.FFT analysis is done to line current. It shows that THD is reduced after using proposed Active filter. Before filtering THD is 11.16% and after filtering THD is 5.69%.

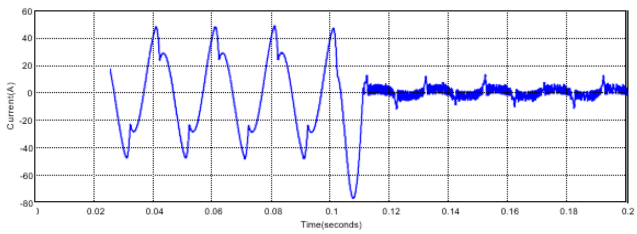

Fig.4. Reference current

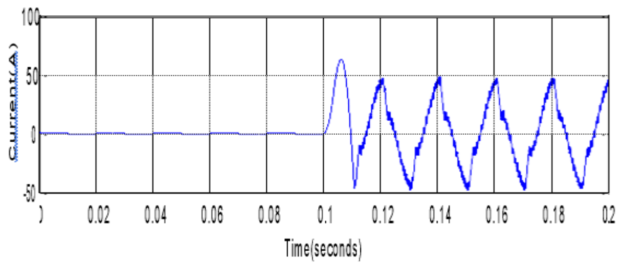

Fig.5. Filter current

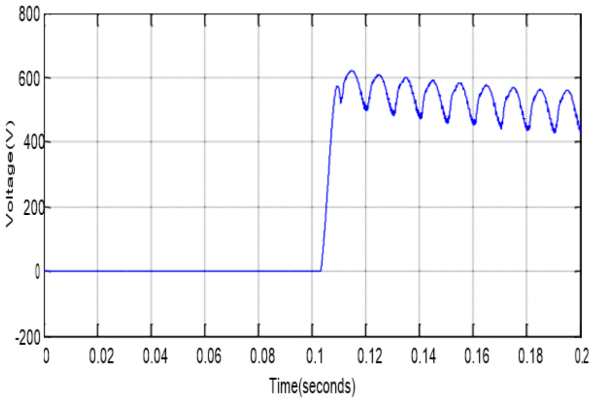

Fig.6. DC bus voltage

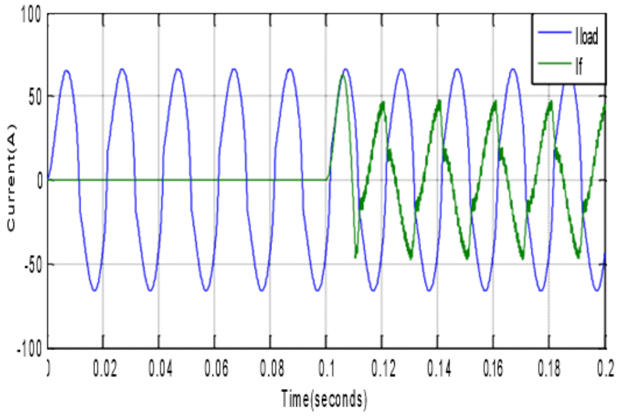

Fig.7. Load current and filter current

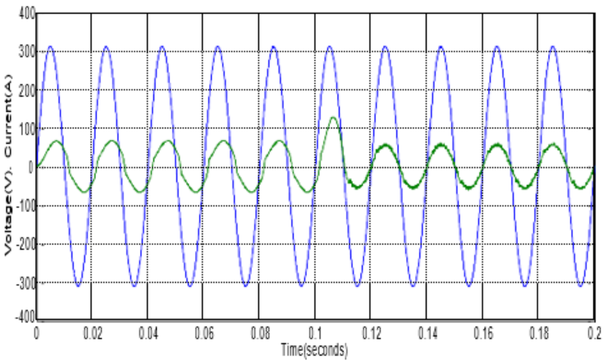

Fig.8. Line voltage and line current

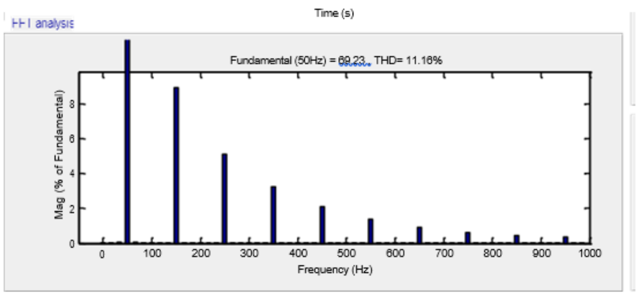

Fig.9. FFT analysis of line current without

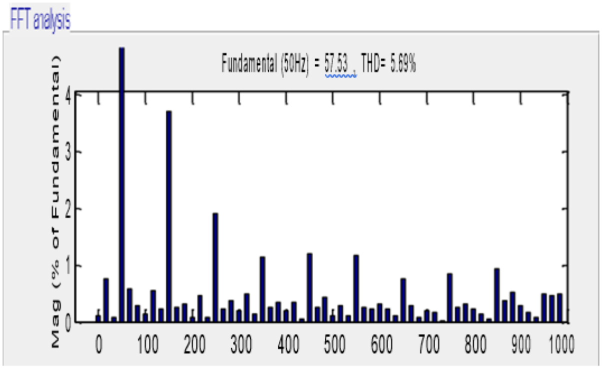

Fig.10.FFT analysis of line current with filter

V. CONCLUSION

In this paper, a simple control scheme for a single phase shunt active power filter using three-level inverter is implemented to compensate current harmonics and reactive power of linear and non-linear loads. Advantage of the proposed control scheme is that it comprises an uncomplicated reference source current generator and a simple PI controller based dc bus voltage controller. As for obtaining gating signals of the power switches a PWM technology is employed. Different types of linear and non-linear loads for reactive power and current harmonics compensation are connected to the APF to indicate steady-state and transient performance. Validity of the proposed control technique is verified by the presented simulation results.

VI. REFERENCES

[1]. H. Doðan, R. Akkaya "A Simple Control Scheme for Single-Phase Shunt Active Power Filter with Fuzzy Logic Based DC Bus Voltage Controller", March 18 - 20, 2009, Hong Kong

[2]. B. Singh, K. Al-Haddad, A. Chandra, "A Universal Active Power Filter for Single-Phase Reactive Power and Harmonic Compensation", Power Quality'98, Hyderabad, India, 1998, pp. 81-87

[3]. C. Y. Hsu, H. Y. Wu, "A New Single Phase Active Power Filter with Reduced Energy

Storage Capacity", IEE Proc.-Electric Power Applications, vol. 143, Jan. 1996, pp. 25-30.

[4]. M. K. Mishra, P. K. Linash, "A Fast Transient Response Single Phase Active Power Filter", TENCON'05, Melbourne, Australia, 2005, pp. 1-6

[5]. P. K. Linash, M. K. Mishra, "Comparison of Single Phase Shunt Active Power Filter Algorithms", Power India Conference, Mumbai, India, 2006, pp. 8-15.

[6]. Salem Rahmani, Abdelhamid Hamadi and Kamal Al-Haddad, "A New Single Phase Hybrid Passive Filter to Dampen Resonances and Compensate Harmonics and Reactive Power under Distorted SourceConditions"

[7]. Krismadinata C., J. Selvaraj and N.A. Rahim "A Novel Topology and PWM Single-Phase Three-Level Rectifier ".

[8]. B.-R. LIN, and T.-L. HUNG "Analysis. and Implementation of a Single-phase Multilevel Inverter for Power Quality Improvement".

[9]. K M Soni, H.E. Akhter, V K Sharma "Neural Network based AC-DC Boost Converter with Improved Power Factor and Regulated Voltage"

[10]. Ahmad Faiz Minai and Abu Tariq "Analysis of Cascaded Multilevel Inverter".

[11]. F. Z. Peng. Application issues of active power filters. IEEE Industiy Applications magazine 4 (5) (1998) pp. 2 1-30.

[12]. C. Hochyaf, R. Lassetei-, D. Divan. and T. A. Lipo. Comparison of multilevel inverters for static var Compensation, IEEE IAS (1994) pp. 92 1- 928.

[13]. G. Sinha. and T. A. Lipo. A Four-level rectifier-inverter system for drive applications, IEEE Industry Applications magazine 4 (5) (I 998) pp.66- 74.

[14]. B. S. Suh. and D. S. Hyun. A new n-level high voltage inversion system, IEEETrans. lA44(1)(1097)pp. 107-115.

[15]. J . S. Lai, and F. Z. Peng. Multilevel converters - a new breed of power converters, IEEE 1-rans. IA 32 (5) (1996) pp. 509-55