Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 14 (14): 1648-1652, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.1648.1652

Active Power Factor Correction Using Hysteresis Current Control of Boost Converter

[2]N. Subashini, [1]V. Dharmalingam and [2]M. Vetriselvan
[1]MAM School of Engineering, Trichy, India
[2]School of Electrical and Electronics Engineering, SASTRA University, India

Abstract: This study covers hysteresis current control operation of boost converter which serves two purposes (i) Power factor improvement (ii) Controlled output voltage. The power factor is improved with the help of feed forward or inner current loop that changes the shape of non sinusoidal supply current to sinusoidal and also in phase with the supply voltage. The outer voltage loop maintains the boost converter output voltage as constant irrespective of supply voltage variation and load variation. This technique is simulated using MATLAB SIMULINK. The simulation result shows constant output voltage, low THD of input current and high pf.

Key words: Hysteresis control, feed-forward , feedback loop, THD

INTRODUCTION

In most power electronic equipment like SMPS, UPS, AC to DC converters are used as the interface with the utility voltage source. These equipments use diode rectifiers to convert the input AC into DC. Capacitive and inductive filters are used in the DC side to keep the output voltage ripple free. The uncontrolled rectifier with capacitive filter draws very large current near the peak of AC line voltage. The current does not flow continuously and it becomes zero for finite durations. Hence, these rectifiers draw distorted current from the AC line (Mohan *et al*., 1995).

In the recent years, massive use of power electronic equipments has increased the problem of power quality in electrical systems, the problem of line current harmonics also grows in its significance (Erickson and Maksimovic, 2001). The non-sinusoidal current which contains harmonics lead to distortion of the line voltage waveform, increased RMS current, electromagnetic interference etc. Several international standards are now available which limit the harmonic content due to line currents of equipment connected to electric utility. Passive filters are used to meet the standards such as IEC 61000, IEEE. But these filters increase the cost and occupies more space due to it's size and weight. As a result, there is the need for a reduction in line current harmonics, or Active power Factor Correction (Rashid, 2007).

Many power electronic converters are used to shape the input current to nearly sinusoidal and also follow the supply voltage waveform closely (Singh *et al*., 2003). Among various power electronic converters boost converter is well suited for input current shaping and to obtain a controllable output voltage (Bashi *et al*., 2005; Lin and Tzou, 2009). The boost configuration reduces the noise at the input capacitor and the inductor present in the boost converter minimizes line current ripple and results in continuous current. There are two operating modes in boost converter based on current ripple. Discontinuous conduction mode results large current ripple and causes more stress on the switches. Therefore, it is preferred for low power applications. Continuous conduction mode operation reduces the current ripple and losses and it is the obvious choice for High power loads (Karaarslan, 2008).

The PFC of boost converter with CCM condition is possible with certain control strategy (Moon *et al*., 2011; Roggia *et al*., 2012). Among the various control methods, Hysteresis Current Control (HCC) is extensively used technique owing to its noncomplex implementation, enhanced system stability, fast response and less distortion in input current waveform (Zhou *et al*., 1990). In this study, HCC technique is used for wave shaping and regulating the output voltage. It also includes the design of boost converter and modelling of the converter using state space averaging. Finally, by using the MATLAB/SIMULINK model the simulation results are obtained.

BOOST CONVERTER OPERATION

The simplified configuration of boost converter with PFC controller is shown in Fig. 1. The boost converter has two distinct operating modes.

Mode 1: When the switch is in closed position (Fig. 2) the current is passing through the inductor L and

Corresponding Author: N. Subashini, School of Electrical and Electronics Engineering, SASTRA University, India

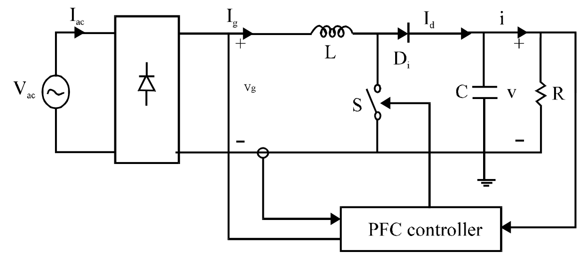

Fig. 1: Boost converter with PFC controller

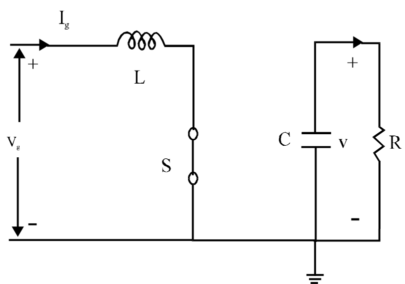

Fig. 2: Switch is closed (TON)

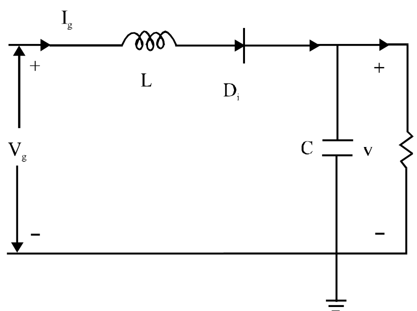

Fig. 3: Switch is open (TOFF)

the switch. During this time interval (TON), the current increases and inductor stores energy. At the same time the capacitor starts discharging through the load R.

Mode 2: When the switch is in open position as in Fig. 3, the current is flowing through the inductor L, diode D, the load R and the capacitor C. During this interval (TOFF), the current decreases and the energy that has been accumulated in the inductor get transferred to the capacitor. The mathematical equations are derived from the equivalent circuits of both the operating modes (Ramanarayanan, 2008). Then the state space averaging is used to obtain various matrices from which transfer function can be determined.

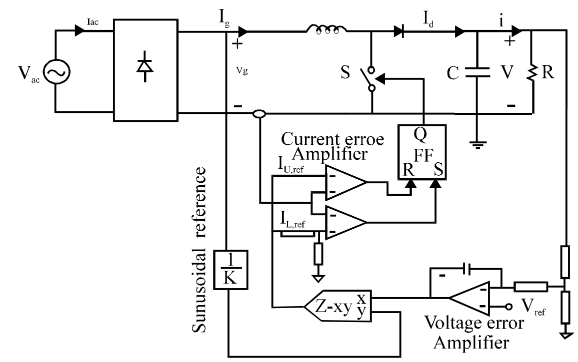

Fig. 4: Closed loop boost converter using hysteresis control for PFC

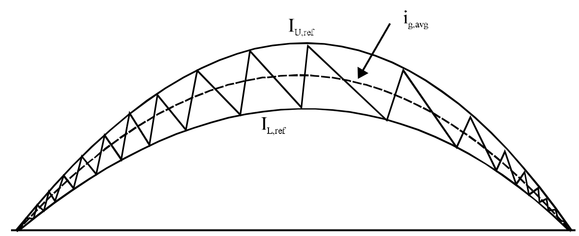

Fig. 5: Hysteresis band

During first sub interval ($0<t<DT_S$)

$$di_L/dt = V_g/L$$

$$dv_c/dt = -v/RC$$

$$di_L/dt = V_g/L - (v/L)$$

During second sub interval ($DT_S<t<T_S$)

$$dv_c/dt = I_L/C - (v/RC)$$

Where, D = Dutycycle = T_{ON}/T_S, $T_S = T_{ON}+T_{OFF}$, D' = 1-D

CURRENT MODE CONTROL FOR PFC

Different current control techniques are usually used for controlling the PFC converters (Fig. 4). For implementing the closed loop control, the supply voltage and the output voltage, input current of the boost converter are sensed. In outer voltage control loop, the boost converter output voltage is scaled down and compared with the reference value. The difference is given to the PI controller. The sine template obtained from the supply voltage is multiplied with the output of PI controller and the resulting signal sets the reference current. In Hysteresis current control, depending upon

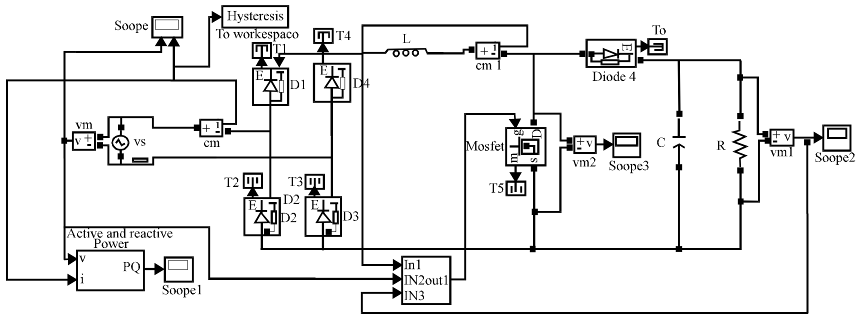

Fig. 6: Hysteresis current control for PFC

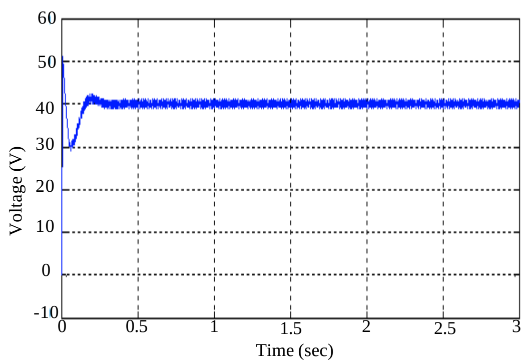

Fig. 7: Output voltage of hysteresis current control boost converter for Vin = 35 V and R = 45 Ω

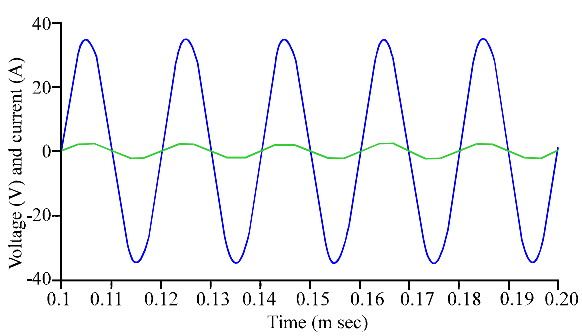

Fig. 8: Supply voltage waveform and current waveform of hysteresis current control boost converter for Vin = 35 V and R = 45 Ω

Table 1: Simulation parameters

Parameters	Ratings
Input voltage (V)	30 (peak)
Output voltage (V)	40
Capacitance (μF)	1500
Inductance (μH)	570
Switching frequency (kHz)	15
Load (Ω)	45

the maximum and minimum boundary limits of current, two sinusoidal current references are generated. When the inductor current becomes less than the lower reference (IL, ref) the switch is turned ON and if it exceeds the upper reference (IU, ref) the switch is turned OFF. This results in variable frequency operation. A small Hysteresis band is selected in order to reduce the ripple in the boost inductor current (Fig. 5).

SIMULATION RESULTS

The boost converter with Hysteresis current control is implemented using MATLAB/SIMULINK program to improve the power factor. The values of various parameters used in the simulation circuit is given in Table 1.

Figure 6 shows the schematic diagram of Hysteresis current control for PFC in MATLAB/SIMULINK. The Fig. 7, 8 and 9 shows the waveforms for boost converter output voltage, supply voltage, source current and THD of source current.

The input voltage is varied from nominal value of 30 V (peak) to 40 V (peak) and the Load is varied from 35 45 Ω. The performance of the PFC converter is Analyzed with the help of THD, power factor for input voltage variation and load variation which is shown in Table 2 and Fig. 10.

CONCLUSION

This study concerns with modeling and simulation of boost converter with hysteresis current mode control. The duty ratio of the boost converter is varied by the control signal from the PFC controller. Hence, the output voltage regulation is good and the input current shape is nearly sinusoidal. Simulation studies were carried out for supply voltage variation as well as for load variation. The result of simulation shows that the THD of input current is less and there is no significant change in the power-factor corresponding to input voltages variation and load variation.

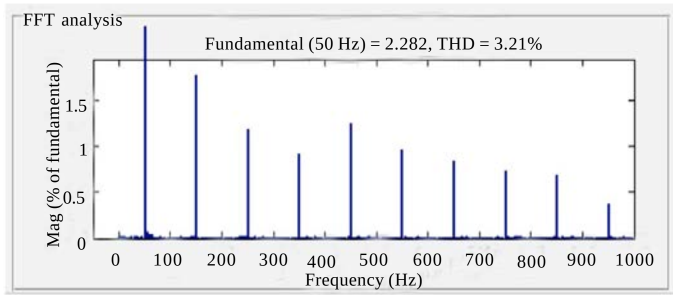

Fig. 9: FFT analysis of hysteresis current control boost converter for Vin = 35 V and R = 45 Ω

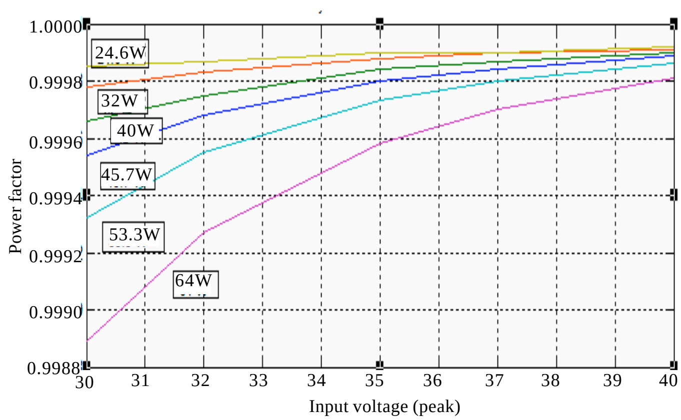

Fig. 10: Variation of Power factor for various input voltages and loads

Table 2: Vout (avg), THD and power factor for supply voltage variation and load variation

Input voltage variation					Load variation				
Vin (volts)	Load (ohms)	Vout (avg) (volts)	THD (%)	Power factor	Vin (volts)	Load (ohms)	Vout (avg) (volts)	THD (%)	Power factor
30	45	40	4.35	0.99969	35	35	40	3.64	0.99980
32	45	40	3.98	0.99977	35	40	40	3.35	0.99984
35	45	40	3.55	0.99985	35	45	40	3.55	0.99985
37	45	40	2.87	0.99989	35	50	40	3.04	0.99988
40	45	40	2.55	0.99991	35	55	40	2.98	0.99989

REFERENCES

Bashi, S.M., N. Mariun, S.B. Noor and H.S. Athab, 2005. Three-phase single switch power factor correction circuit with harmonic reduction. J. Applied Sci., 5: 80-84.

Erickson, R.W. and D. Maksimovic, 2001. Fundamentals of Power Electronics. 2nd Edn., Springer, USA., ISBN-10: 0792372700, pp: 912-941.

Karaarslan, A., 2008. Hysterisis control of power factor correction with a new approach of sampling technique. Proceedings of the IEEE 25th Convention of Electrical and Electronics Engineers in Israel, December 3-5, 2008, Eilat, Israel, pp: 765-769.

Lin, Y.T. and Y.Y. Tzou, 2009. Digital control of boost PFC AC/DC converters with low THD and fast dynamic response. Proceedings of the IEEE 6th International Power Electronics and Motion Control Conference, May 17-20, 2009, Wuhan, China, pp: 1672-1677.

Mohan, N., W.P. Robbin and T. Undeland, 1995. Power Electronics: Converters, Applications and Design. 2nd Edn., Wiley, New York.

Moon, S., L. Corradini and D. Maksimovic, 2011. Autotuning of digitally controlled boost power factor correction rectifiers. IEEE Trans. Power Electron., 26: 3006-3018.

Ramanarayanan, V., 2008. Course material on switched mode power conversion. Department of Electrical Engineering Indian Institute of Science, January 15, 2008, Bangalore, India.

Rashid, M.H., 2007. Power Electronics Handbook: Devices, Circuits and Applications. 2nd Edn., Elsevier, UK, pp: 1172.

Roggia, L., F. Beltrame, J.E. Baggio and J.R. Pinheiro, 2012. Digital current controllers applied to the boost power factor correction converter with load variation. IET Power Electron., 5: 532-541.

Zhou, C., R.B. Ridley and F.C. Lee, 1990. Design and analysis of a hysteretic boost power factor correction circuit. Proceedings of the 21st Annual IEEE Power Electronics Specialists Conference, (PESC'90), San Antonio, TX., USA., pp: 800-807.

Singh, B., B.N. Singh, A. Chandra, K. Al-Haddad, A. Pandey and D.P. Kothari, 2003. A review of single-phase improved power quality AC-DC converters. IEEE Trans. Ind. Electron., 50: 962-981.