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Performance Analysis of Power Factor Correction for Converters using Hysteresis Current Mode Control

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Abstract: This paper presents ac-dc converter utilising current control mode to obtain unity p.f. Many applications demanding ac-dc converter require stable dc voltage at the terminals with better steady state and transient performance, which is accomplished by boost converters. These converter produce higher, regulated dc output voltage and simultaneously improving the p.f. Utilising control techniques of current, it is observed that input current can be made to follow input sinusoidal voltage wave thus shaping the input current and reducing harmonics distortion and bringing p.f. to almost unity. Amongst various current control strategies hysteresis current mode in CCM mode control is preferred. Simulation is done in PSIM software.

Keywords: Power Factor Correction, Harmonics, Boost Converter, Control strategy, Hysteresis Current Mode Control.

I.INTRODUCTION

Most of electronic equipments have a rectifier circuit tending to draw pulsating current from the utility grid resulting in current and voltage distortions, giving poor power quality and high harmonic distortion .These have drawn attention of regulatory bodies around the world for setting standards to limit harmonic content [1].

The need to limit the harmonic content of line currents drawn by electronic devices connected to electricity distribution networks resulted in need for Power Factor Correction [PFC].PFC techniques broadly classified as passive and active, active dominated passive due to improved voltage regulation, ability to reduce harmonic content and thereby bringing p.f. to almost unity. Additional advantage being filters used are compact in size. Hence, single phase boost PFC is preferred [2].

Boost canoperate in different modes referring to the nature of inductor current within the switching cycle. Modes being critical conduction mode [CCM], discontinuous conduction mode [DCM] and critical conduction mode[CRM].DCM and CRM modes though easier to control but has higher peak to peak current ripple almost twice that of CCM mode resulting in increased losses and large filtering requirements[4].

PFC control strategies have two modes of control, voltage mode control and other being current mode control. Voltage mode control regulates the output voltage and is fed back, compares control voltage to a sawtooth waveform for signals, while current mode control replaces sawtooth waveform by current signal making response faster[8].

Several strategies discuss the implementation of current mode control depending on the current command given to the comparator.

In Section II of this paper basic principle of operation of boost converter for ac-dc converters is presented. Section III details control strategy of hysteresis current mode control scheme presenting its advantages and drawbacks. In Section IV, results of simulation are given. Section V gives the conclusion.

II BOOST CONVERTER CONFIGURATION

PFC converter uses different topologies, topology used here is single phase ac-dc boost converter. Most of electronic

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equipments undergo powerprocessing demanding dc output voltage at their terminals. In the simplest form, this is done by using bridge rectifier followed by bulk capacitor. Capacitor filters out rectified voltage and provides energy storage. As a result line current has increased harmonic content giving poor power quality and power factor. One of the topologies used to handle this problem is called single phase boost power factor correction. Simplified boost PFC circuit is shown in fig.1.

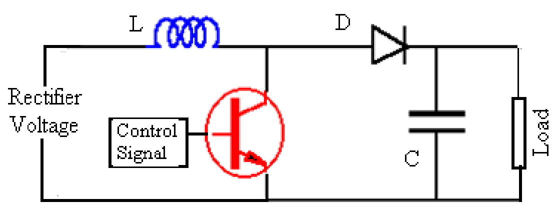

Figure 1 Boost Converter

Main principle of boost converter indicates tendency of inductor to resist changes in current. When inductor is charged it acts as load and absorbs energy, when it is discharged it acts as energy source. Basic principle is divided into 2 strategies and their equivalent circuits based on ON state and OFF state are shown in fig.2a and fig.2b.

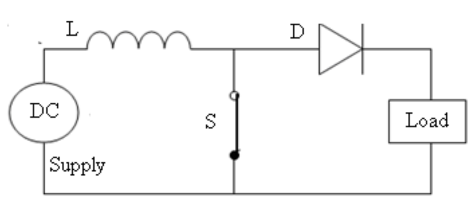

Figure2aOnstate

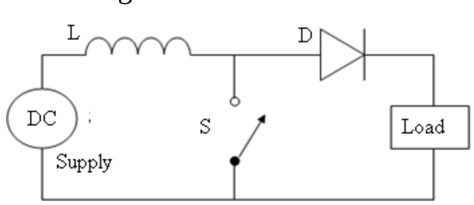

Figure 2b Off state

Boost converter also called as step up converter has output voltage always greater than input voltage. There are two modes of operation continuous conduction mode (CCM) and discontinuous conduction mode(DCM).In CCM input inductor current varies between I_{min} and I_{max}.

Output voltage is given by equation:

$$\frac{V}{V} = \frac{\quad}{D} \qquad (1)$$

Where V_i =input voltage

V_0=output voltage

D=Duty cycle

$$D = \frac{T}{T} \qquad (2)$$

From equation 1output voltage is higher than input voltage and approaches infinity.

In discontinuous conduction mode inductor current reduces to zero i.e. $I_{min.}$=0

$$\frac{V}{V} = 1 + \frac{V_i D \;\; T}{LI} \qquad (3)$$

Since V_0 voltage not only depends on duty cycle, input voltage and inductor therefore CCM is preferred.

III CURRENT MODE CONTROL

Out of several current control techniques used. In this section hysteresis current mode control is discussed. Main objective is to synchronise input current with input voltage and simultaneously regulate output voltage. It has two control loops .Outer voltage loop regulates output voltage to a predetermined value and inner current loop synchronises input current with input voltage.

Output voltage is scaled and compared to given reference. Error obtained is given to PI controller. Output of this controller is deciding factor to obtain reference current. I_{ref} is obtained by multiplying rectified input voltage with voltage controller output. Error is processed and given as gating signal to switch.

Hysteresis Current Mode Control

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Unlike either constant on time or constant off time control, HCMC has both constant on time and constant off time control in which one current command is used to limit minimum and maximum current[].

The circuit of HCMC is given in figure 4.

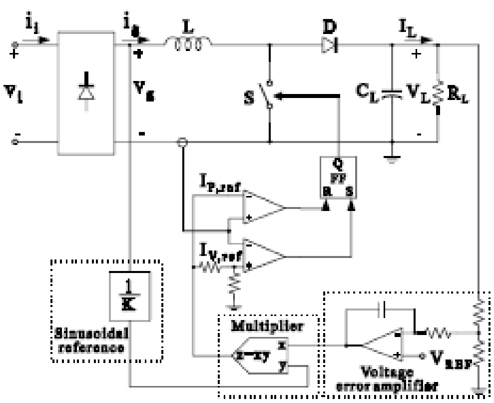

Figure 4 HCMC circuit

In HCMC, reference current if falls below valley current then switch turns on and if exceeds peak value then turned off. Hysteresis comparators impose hysteresis band around reference current .To achieve smaller ripple, a narrow hysteresis band is desired. However, narrower switching band higher switching frequency. Performance of hysteresis mode control improves in constant frequency operation, but increases complexity. Also with this control technique converter works in CCM mode. Advantages and Disadvantages of control strategy are as follows:

Advantages

- No Compensation ramp required.
- Input waveform is less distorted.

Disadvantages

- Switching frequency is large.
- Inductor current must be sensed.
- Sensitive to noise.

Line current waveforms is shown in figure.5

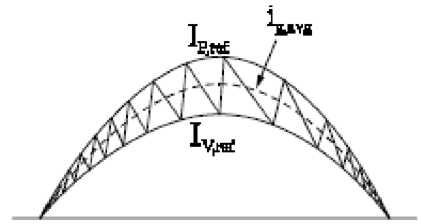

Figure 5 line current waveform

IV SIMULATION RESULTS

Many software programs can be used in simulation of power electronic circuits. Few to mention here are Matlab, Orcad, Pspice and PSIM, simulation can be carried out. In this study, PSIM is used for simulation. PSIM is a simulation software provides an intuitive user interface for schematics [].

Single phase boost PFC converter topology for HCMC is simulated in PSIM program. CCM is preferred due to its improved current control with more power handling capability.

Fig.6 shows input voltage and input current respectively.

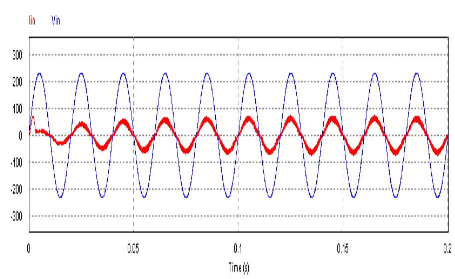

Figure6 Input Voltage and Input Current

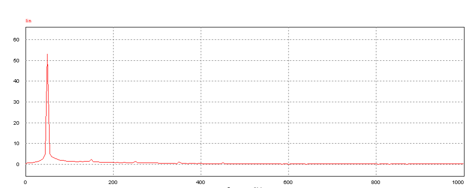

Figure 7 FFT analysis

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Fig. 7 THD analysis of input current using FFT analysis. Analysis shows that THD value is 0.15 and p.f. is 0.96 Using HCMC technique THD of input current is very low and p.f. is improved.

V CONCLUSION

In this study, current control technique of single phase boost PFC converter is simulated and obtained results. Results are comparatively better to conventional methods of PFC. Control techniques used here is HCMC. Simulation is carried out using PSIM program control strategy.THD values, p.f, advantages and disadvantages are highlighted

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