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A Novel Boost Converter for Power Factor Correction in Dual Mode

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ABSTRACT: A dc to dc converter is a circuit which converts a fixed dc input voltage to a controllable dc output voltage. The conventional methods for this conversion employed an inverter followed by a step up transformer and a rectifier (for low power applications) or an electric motor to drive a generator of desired voltage range (for higher power applications).As such methods have proved to posses low efficiency and high cost, we go for dc to dc converters. Here we are dealing with a dual mode boost converter with input power factor correction which is designed to work in two modes namely continuous conduction mode (CCM) and critical conduction mode (CrCM), based on the load requirement. An inductor is the key element of the boost converter, and the current through it determines the mode of operation. The dual mode operation is obtained using modern PID controller depending on the inductor current. These converters offer a method to increase the voltage level thereby saving space instead of using multiple batteries for the same purpose.The proposed converter can work under both light load and heavy load conditions.Other advantages of the converter scheme used include, simple construction, low cost, high efficiency and higher regulated output voltage when compared to traditional one. The model is simulated using MATLAB Simulink software.

KEYWORDS: Continuous conduction mode (CCM), Critical conduction mode (CrCM), Proportional integral derivative controller (PID),Power factor correction (PFC)

I.INTRODUCTION

With the increasing demand for devices such as MP3 players and cellular phones, the demand for power generation circuits has increased. These circuits produce constant DC output voltage with high efficiency and low power consumption from the system even if the inputs arechanging.In many devices, load conditions change drastically, such as when the device is operated from standby mode to operational mode [9]. Improving the light-load (stand-by mode) efficiency of these power circuits is important for extending battery life, since these devices operate in this mode for most of the time. A high efficiency DC-DC converter with a wide operating current range becomes crucial for these devices. The boost is a popular non-isolated power stage topology, sometimes called a step-up power stage [7]. Power supply designers choose the boost power stage because the required output voltage is always higher than the input voltage and is of the same polarity.The output current for a boost power stage is discontinuous, or pulsating, because the output diode conducts only during a portion of the switching cycle. The output capacitor supplies the entire load current for the rest of the switching cycle. The input current for a boost power stage is continuous, or non-pulsating.The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field.

A schematic of a boost power stage is shown in figure1(a) given below:

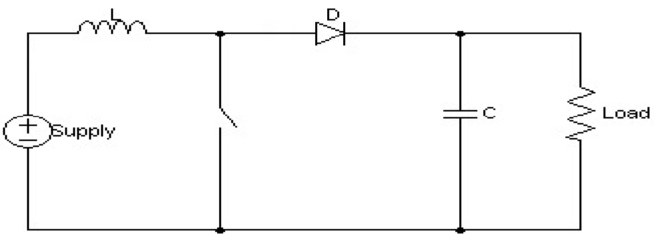

Figure 1(a)Basic Boost converter

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The basic principle of a Boost converter consists of 2 distinct states.

(a) During the On-state as in figure 1(b), the switch S is closed, so current flows through the inductor and the short circuit path. The rest of the circuit is inactive. This results in an increase in the inductor current and inductor stores some energy by generating a magnetic field.

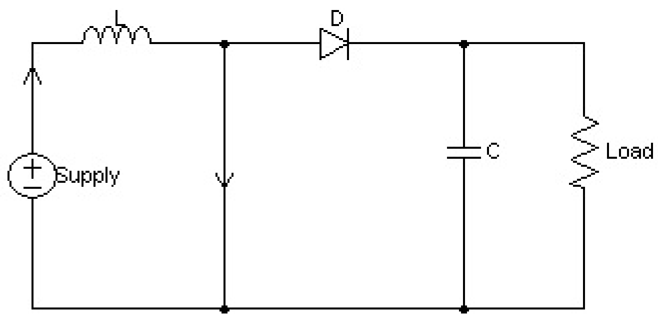

Figure1 (b)Switch closed

(b) During the Off state which is shown in figure 1(c), the switch is opened and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This result in transferring the energy accumulated in the inductor into the capacitor during the On state. Now the output voltage will be the sum of the supply voltage and the voltage across the inductor.

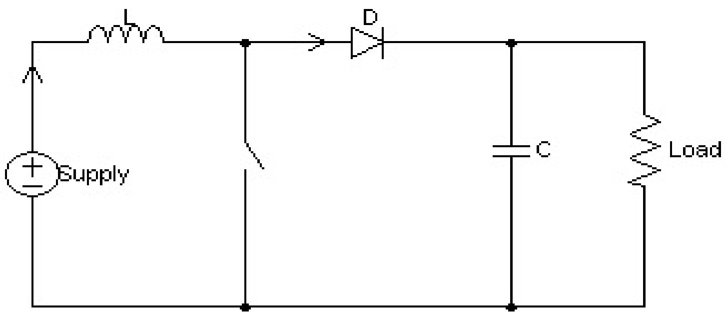

Figure 1(c)Switch open

c) The input current is the same as the inductor current. It can be continuous or discontinuous depending on the value of the inductor,L . The requirements on the input filter are relaxed compared to a buck converter.

The input and output voltage relationship depends upon the duty cycle, D.

For the boost converter

Duty cycle, D= $\frac{T_{ON}}{T_{ON}+T_{OFF}}$ (Eq.1)

Also D= $1-\frac{Vin}{V_{out}}$ (Eq.2)

An ideal boost converter is lossless in terms of energy, so the input and output power are equal. In practice, there will be losses in the switch and passive elements, but efficiencies better than 90 % are still possible through careful selection of system components and operating parameters such as the switch frequency. The internal operations of a

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boost converter can be thought of as a charge storage and transfer mechanism.To be in synchronization with the mains voltage, power factor correction (PFC) shapes the input current of the power supply, which in turn maximizesthe real power drawn from the mains [7]. The input current follows the input voltage in a perfect PFC circuit, as would an equivalent resistor, with no added input current harmonics.

II.MODES OF OPERATION OF BOOST CONVERTER

The boost converter can operate in three modes: continuous conduction mode (CCM), discontinuous conduction mode (DCM), and critical conduction mode (CrCM).In continuous conduction mode (CCM), current in the inductor never drops to zero between the switching cycles. In CrCM inductor current starts at zero, reaches a peak value, and returns to zero during each switching cycle[8], whereas current is zero for a part of switching cycle in discontinuous conduction mode (DCM) [5].

Value of inductance is different for the two modes.

The value of CCM inductance is given by the equation (3):

$$L_{CCM} = \frac{D(1-D)R}{2f} \quad \text{(Eq.3)}$$

Where, R is the load resistance and f is the frequency.

DCM inductance can be written as shown in equation (4):

$$L_{DCM} = \frac{1}{4} L_{CCM} \quad \text{(Eq.4)}$$

The average inductance for the proposed converter is given by the equation (5):

$$L_{Avg} = \frac{L_{CCM} + L_{DCM}}{2} \quad \text{(Eq.5)}$$

DCM mode of operation seems much simpler than CrCM, but, it may operate at constant frequency. So, DCM possesses highest peak current compared to other modes but with no performance advantage. The paper focuses on continuous and critical conduction modes. In CrCM, the operation is made to stay at the boundary between CCM and DCM which considers CrCM as a special case of CCM.CrCM usually uses constant on-time control,in which case,the line voltage is changing across the 60Hz line cycle, the reset time for the boost inductor varies, and the operating frequency will change as well,while maintaining boundary mode operation[1]-[4].Dedicated controllers in CrCM sense the inductor current zero crossing so as to trigger the start of the next switching cycle. The current ripple peak in CrCM is twice the average value, which greatly increases the RMS currents and turn off current. Turn on loss is usually eliminated since every switching cycle starts at zero current. Also, since the boost rectifier diode turns off at zero current, reverse recovery losses and noise from switching in the boost diode are eliminated which is a major advantage of CrCM mode. The power stage equations and transfer functions for CrCM are the same as that of CCM. The main differences relate to the current ripple profile and switching frequency, which affects RMS and switching power losses. Highpower PFC designs give the lowest peak to average currentratio for the converter and it operates at a fixed switching frequency [6].Therefore, continuous conduction mode is most applicable in heavy loads. Thelowpeakto average current ratio minimizes the power mosfet peakcurrent and output capacitor ripple currentrequirements.

III. PROPOSED SCHEME

Figure 2 shows the proposed converter and it consists ofa diode rectifiercircuit,and a basic boost converter together with its control circuit. Here diodes D1-D4 makes a rectifier circuit and D5 is used in the boost circuit for preventing

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current flow in reverse direction.The bridge rectifier converts the input ac voltage to a dc voltage. This output voltage is filtered by a capacitor. The dc output of the rectifier is made to a higher level by a boost circuit which consist of an inductor, a mosfet (used as a switch), a diode, and a load.The converter operates based on the property of the inductor to resist changes in current.The inductor current decides whether the converter works in continuous conduction mode or critical conduction mode.During heavy load condition the current through the inductor will be high and the boost converter will operate in continuous conduction mode. Similarly, during light load condition, the converter will operate in critical conduction mode. Based on that load, the inductor current will change. However the output voltage remains constant.

The gating pulses for the switch is produced using the control circuit depending on the load. If converter is feeding a heavy load, it has to operate in continuous mode. The gating pulse for this mode is produced based on the reference voltage. If the converter is operating with light load, i.e. in critical mode operation, the gating pulse produced depends on both reference voltage and inductor current. Since the system works in a closed loop manner, the most appropriate controller is a modern PID controller. The resistive load has been used whose design is based on the load requirement.The modulating signals can be generated by the PWM generator itself, or they can be a vector of external signals connected at the input of the block. The amplitude (modulation), phase, and frequency of the reference signals are set to control the output voltage (on the AC terminals) of the bridge connected to the PWM Generator block.

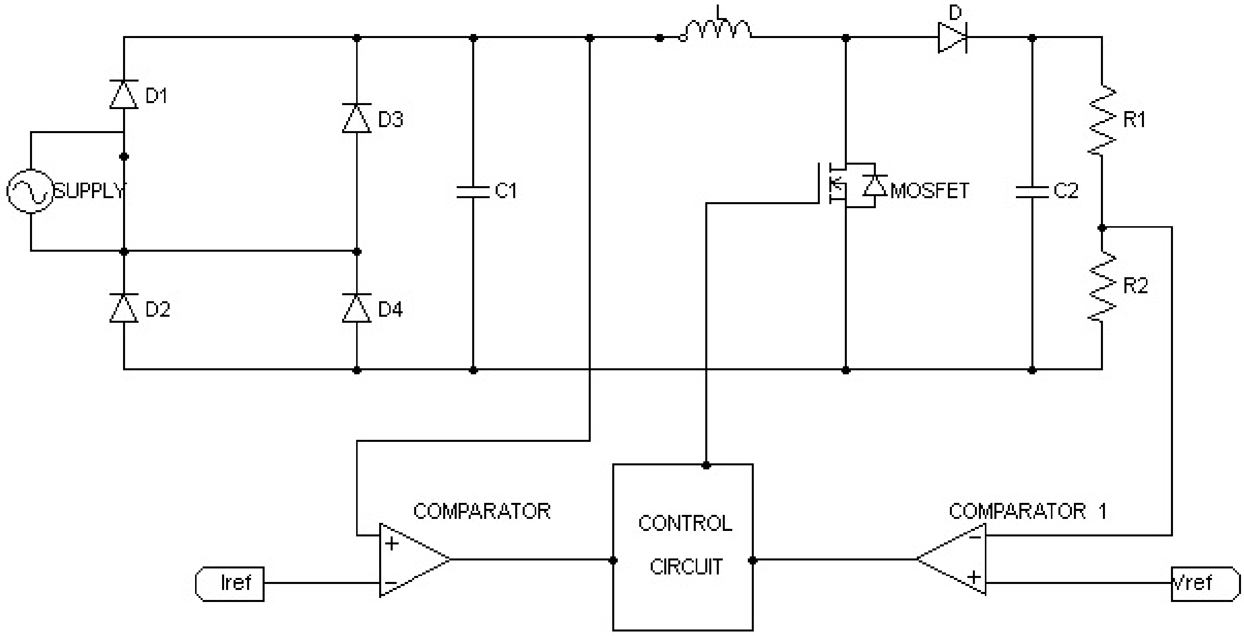

Figure2.Proposed Control Circuit

IV.SIMULATION RESULTS

The experiment is performed with the following parameters: input voltage V_{ac} = 110V_{rms}, output voltage V_O= 400V_{dc}, output power P_O = 30−300 W, fixed switching frequency = 60 kHz, variable switching frequency = 60−265 kHz, average inductance L = 500µH, and output capacitor C_o = 220 µF.Output power ranges from (30-300) W. Figure 3 (a) shows waveforms for dual mode in which the proposed system works in CCM mode for a time and in CrCM mode for the remaining time. The load voltage is 400V. Figure3(b) shows output voltage and current waveforms for light load condition where the system works in continuous conduction mode at a load voltage of 400V.The inductor current is 220 A during that period of operation.Voltage and current waveforms in critical conduction mode is shown in the figure3(c).Working in critical conduction mode occurs for light load condition. The current becomes zero at an instant in this mode. Load voltage remains constant and is at 400V.The inductor current is 140A.

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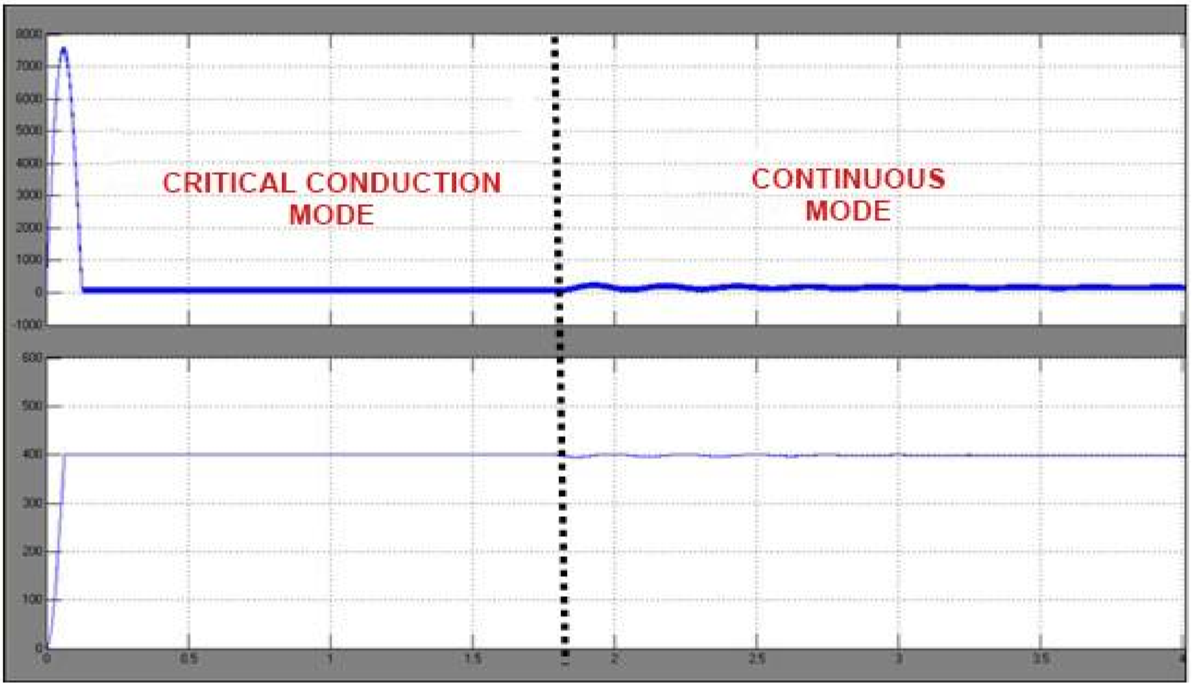

Fig. 3(a) Waveforms of Inductor current and output voltage

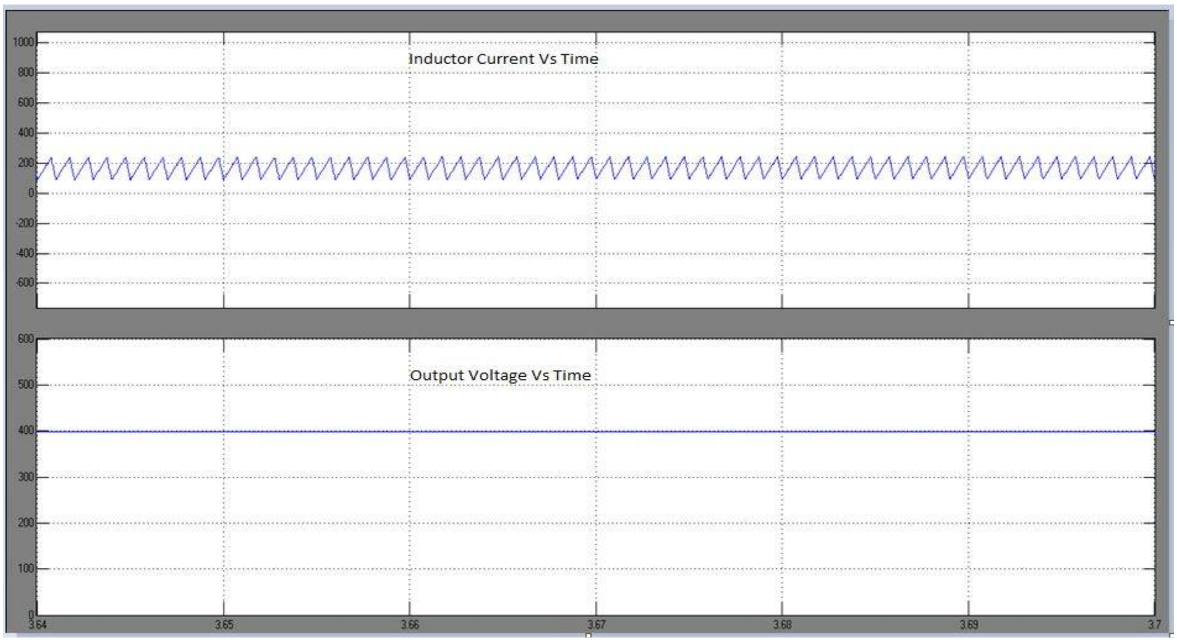

Fig. 3(b) Waveforms of Inductor current and output voltage in continuous mode

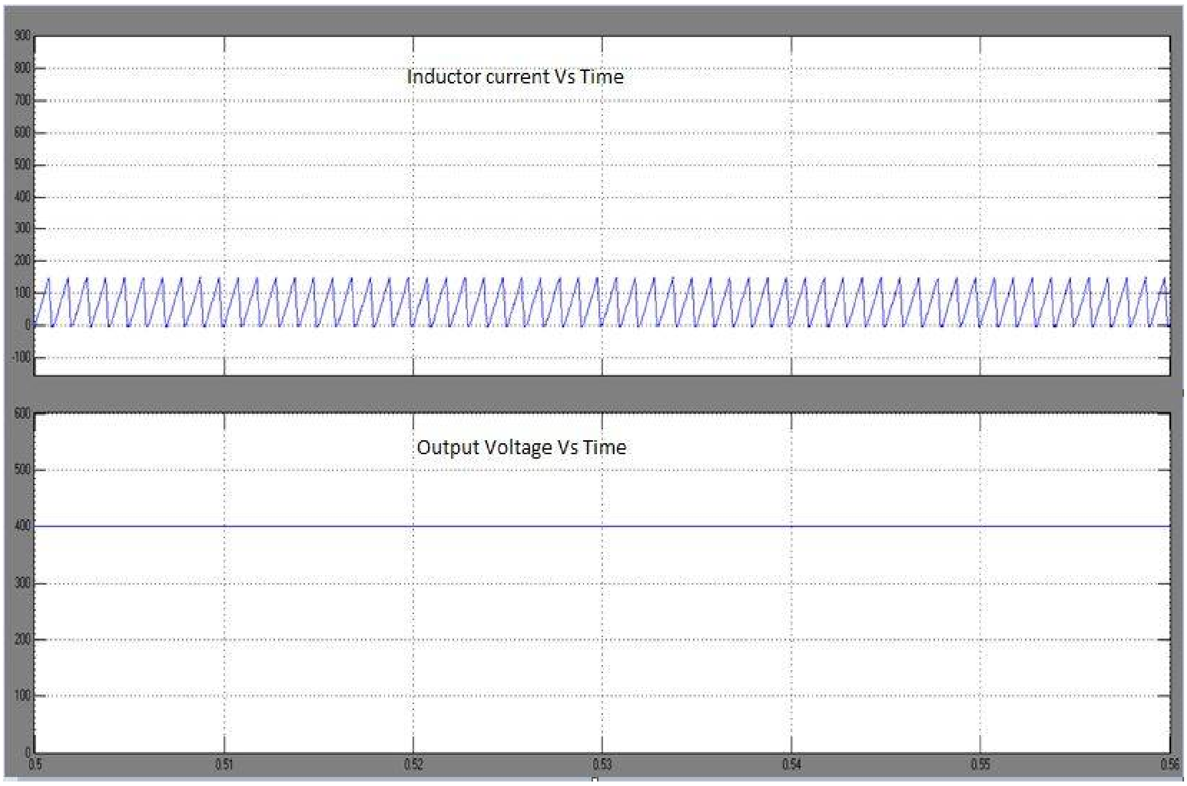

Fig. 3(c) Waveforms of Inductor current and output voltage in critical mode

V.CONCLUSION AND FUTURE SCOPE

A novel dual mode boost converter for input power factor correction has been presented here.Working of the boost converter in both light load and heavy load has increased the efficiency of the system.The proposed converter have a natural power factor correction in the circuit and so it exhibit better performance characteristics. A reduction in line current harmonics, increase in system efficiency and increase in capacity is obtained by this natural power factor correction circuit. Because of the simple circuit structure and good control effort, the system has a broad application background. It can be used in integrated chips which require high power and high efficiency in light load condition. In addition, the dual mode control circuit is simple and easy to be built into an integrated circuit without additional cost and space. When used for power factor correction the above scheme can be used in computerised power plants and personal computers to improve the efficiency of the system and to eliminate the effects of input current distortion.

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