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A Single Phase High Power Factor AC-DC converter with Soft Switching Characteristics

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ABSTRACT: This paper proposes an integrated high power factor ac-dc converter with soft switching characteristics. The circuit consists of a buck converter and a boost converter that integrates to form the proposed circuit topology. The boost converter operates in discontinuous-conduction mode (DCM) to perform the function of high power factor correction (PFC). The buck converter regulates the output voltage of the boost converter to supply stable dc voltage to the load. Both converters operate at high switching frequency. The active switches of the proposed converter operates at DCM for achieving zero-voltage switch-on(ZVS).The low-pass filter is used to remove the high frequency ripples of current. Circuit configuration and the circuit operation for eight modes explained. The simulink model of the proposed circuit provided.

KEYWORDS: Boost converter, Buck converter, Discontinuous-conduction mode (DCS), Zero-voltage switch-on, Power factor correction (PFC).

I.INTRODUCTION

Ac/dc converters have been widely used in many applications such as LED lighting systems, industrial drives, electric power distribution systems, telecommunication systems, energy conversion systems and other high power applications. The boost, buck-boost converters have been widely used as power factor correctors. The most popular topology in power factor correction application is the boost topology. A boost converter or step up converter is a power dc to dc converter with an output dc voltage which is greater than output dc voltage. The boost topology is simple, and it allows low distorted input currents and an almost unity power factor with different control techniques. At low line input, the switch conduction losses are high, because the input RMS current has the highest value and the highest step-up conversion is required. The inductor has to be over sized for large RMS currents at a low line input, and for the highest volt-seconds applied throughout the input-line range. As a result, a boost converter designed for universal-input PFC applications is heavily oversized, compared to a converter designed for a narrow range of input line voltages. Due to large energy storage filter capacitor at the output, the boost converter has inrush current problems that can be mitigated by using additional components. Here the boost converter performs the function of PFC to obtain high power factor and low current harmonics at the input line. The buck converter further regulates the dc-link voltage to provide a stable dc output voltage.

Hard switching operation of active switches causes many problems in the circuit. This generates high switching losses and introduces high voltage and current stresses on circuit components. The circuit efficiency and stability decreases.
In the proposed circuit both active switches are turned on at ZVS. It assures high circuit efficiency and stability.
PI control method is used in the proposed circuit.

II.CIRCUIT MODEL

The circuit topology is derived by integrating a boost converter and buck converter. The proposed circuit consists of a low-pass filter circuit, a diode-bridge rectifier, a boost converter, a buck converter. The buck converter is composed of L_b, D_5, D_{S2}, S_1 and C_0. The boost converter is composed of L_p, D_{S1}, S_2 and C_{dc}. Both converters operate at a high-switching frequency. The boost converter performs the function of power factor correction (PFC) to obtain high power factor at input line. When the boost converter operates at discontinuous-conduction mode (DCM), the average value of its inductor current in every high-switching cycle is approximately a sinusoidal function. The low-pass filter is used to

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remove the high frequency current of the inductor current. The input line current becomes sinusoidal and in phase with the input line voltage. So that high power factor can be achieved. The buck converter regulates the output voltage of boost converter to supply stable dc voltage to the load. In order to prevent both the active switches conducting at same time, there is a short non-overlap time defined as “dead time”.

Fig. 1 Proposed ac/dc converter circuit topology

The proposed circuit shown in figure 1 consists of a low-pass filter circuit, a diode-bridge rectifier, a boost converter, a buck converter.

III.CIRCUIT OPERATION

The circuit operation of the proposed circuit can be described in eight operation modes.

a) Mode 1

Prior to mode 1, S_1 is at “ON” state. Boost inductor current I_p is zero. The dc-link capacitor supplies the buck inductor current I_b which flows through S_1, D_5, L_b, and C_0. This mode starts when S_1 is turned off by the gate voltage V_{GS1}. At the beginning of this mode, I_b is diverted from S_1 to flow through the output capacitors C_{DS1} and C_{DS2}. C_{DS1} charged and C_{DS2} discharged. As the voltage across C_{DS2}, that is V_{DS2} decreases to be lower than the rectified input voltage V_{rec}, then the boost inductor current I_P starts to increase. WhenV_{DS2} equals to -0.7V, D_{S2} turns on and mode 1 ends.

b) Mode 2

At the beginning of mode 2, V_{DS2} maintained at about “-0.7V” by antiparallel diode D_{S2}. After short dead time, S_2 is turned on by the gate voltage V_{GS2}.The on resistance of S_2 is small enough, most of I_b will flow through S_2 from source to drain. In this mode I_b is greater than I_p. I_b keep decreases and I_p increases from zero, since boost converter designed to operate in DCM. I_b has two loops. A part of I_b flows through S_2, rest are equal to I_p that flows through the line voltage source, diode rectifier and L_p. This mode ends when I_p is greater than I_b.

c) Mode 3

In this mode I_p is greater than I_b. I_p has two loops. A part of I_p flows through S_2 so the direction of current flow naturally changes. Current flows from drain to source. The rest flows through buck converter, equals to I_b. In this mode I_b keep decreases and I_p increases. This mode ends when I_b equals to zero, since buck converter designed to operate at DCM.

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d) Mode 4

In this mode S_2 remains on to carry I_p. Because of I_b is zero, the buck converter is at off state. Here I_p increases. The output capacitor C_0 supplies current to load. This mode ends when S_2 is turned off by V_{GS2}.

e) Mode 5

At the beginning of this mode I_b equals to zero. Current I_p reaches maximum when S_2 turned off. I_p will be diverted from S_2 to flow through C_{DS1} and C_{DS2}. C_{DS1} discharged and C_{DS2} charged. As the voltage across C_{DS1} decreases to be lower than V_{dc}-V_0 then I_b start to increase so that voltage across L_b becomes positive. When V_{DS1} equals to -0.7V, D_{S1} turns on and this mode ends.

f) Mode 6

At the beginning of this mode, V_{DS1} maintained to about -0.7V by antiparallel diode D_{S1}. After short dead time, S_1 is turned on by V_{GS1}. On resistance of S_1 is small enough, so that rest of I_p will flows through S_1 in the direction from source to drain. In this mode I_p is greater than I_b. There are two loops for I_p. A part of I_p flows through S_1 to charge dc link capacitor. The rest are equals to I_b, flows into buck converter. This mode ends when I_b is greater than I_p.

g) Mode 7

In this mode I_b is greater than I_p. Current I_p keep decreases and current I_b keep increases. I_b has two loops. A part of I_b flows through S_1, the direction naturally changed so that from drain to source. The rest flows through boost converter. This mode ends when current I_p becomes zero.

h) Mode 8

In this mode S_1 remains on and I_b keeps increasing. This mode ends at the time when V_{GS1} becomes a low level to turn off S_1. The circuit operation returns to mode1.

IV.SIMULATION

The simulink model of the proposed circuit for an open loop control is as shown in the figure 2. The output voltage waveform obtained is shown in the figure 3.

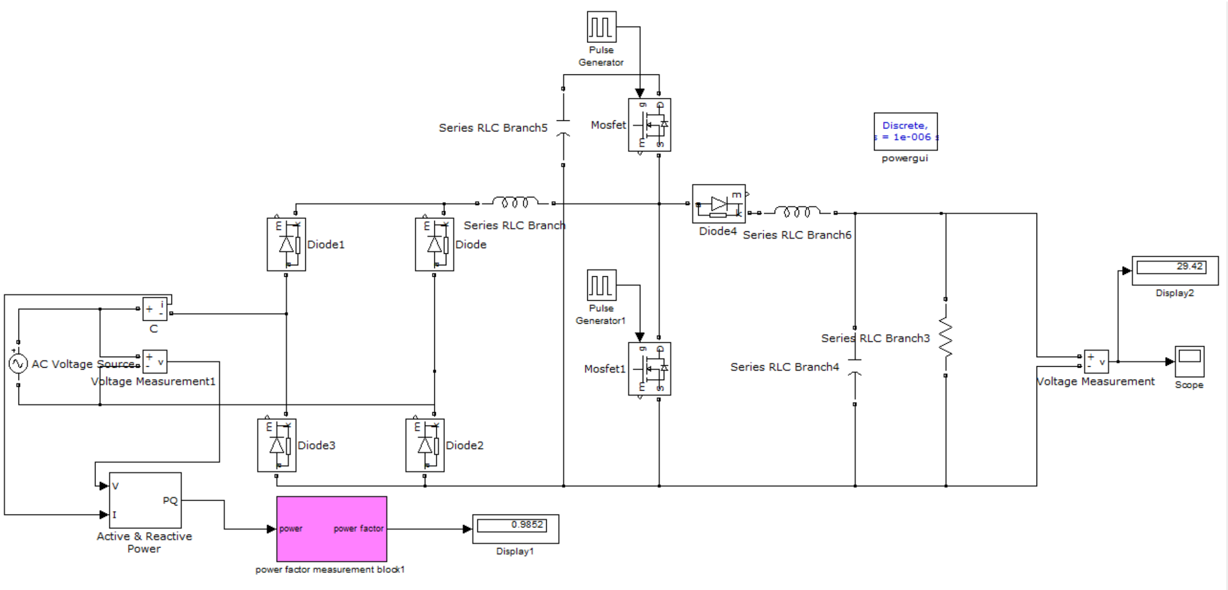

Fig. 2 Open loop control for proposed circuit

The boost converter is designed for an input ac voltage of 14V and an output voltage of 30V. Power output is considered to be 9W. Switching frequency taken as 20 KHz. For the buck converter the input voltage considered as

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30V and it designed for 0.20 duty ratio. The open loop control of proposed circuit as shown in the figure 2 gives a PF of 0.9852

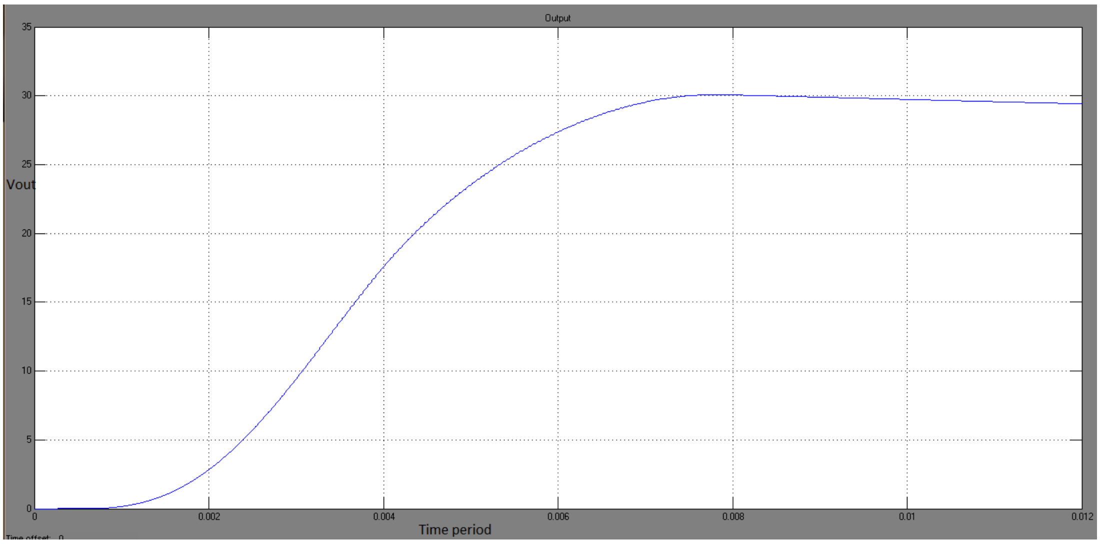

Fig. 3 Output voltage for open loop control circuit

The output voltage waveform obtained is shown in the figure 3. By using open loop control method the output obtained is 29.42V.

The simulink model of the proposed circuit for PI control is as shown in the figure 4. The output voltage waveform obtained is shown in the figure 5. The gate pulse waveform of switches is given in figure 6.

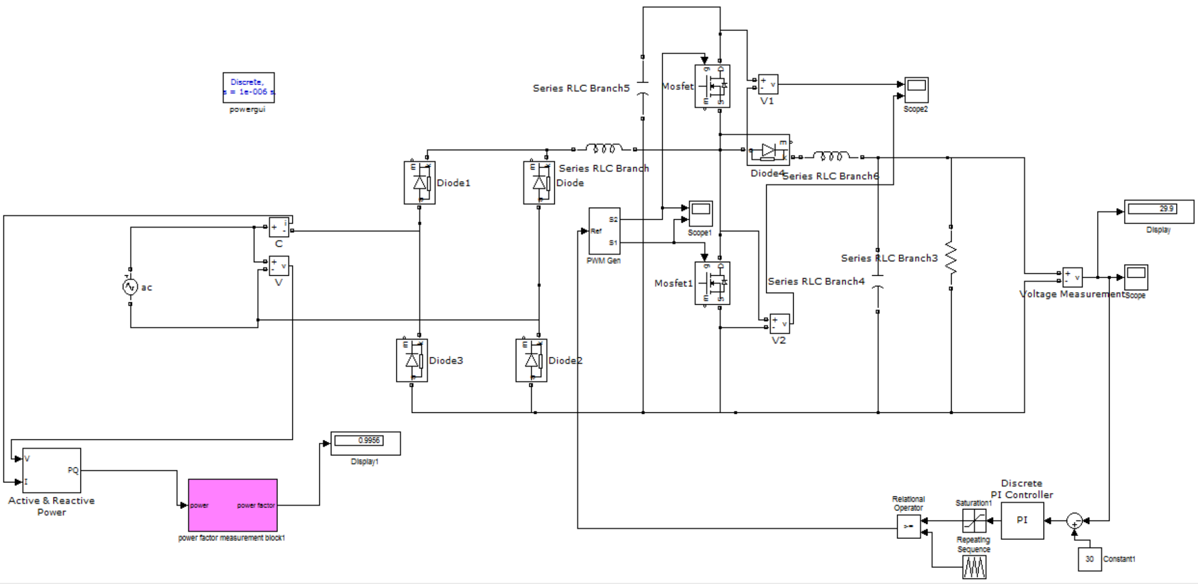

Fig. 4 PI control for proposed circuit

The simulink model of the proposed circuit for PI control is as shown in the figure 4. The boost converter is designed for an input ac voltage of 14V and an output voltage of 30V. Power output is considered to be 9W. Switching frequency taken as 20 KHz. For the buck converter the input voltage considered as 30V and it designed for 0.20 duty ratio.

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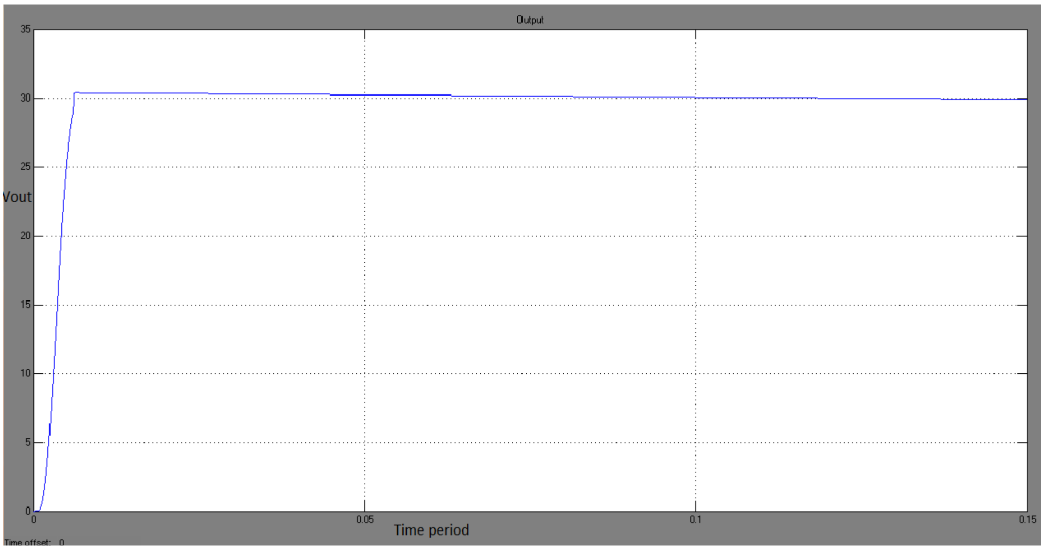

Fig. 5 Output for the PI control circuit

The output voltage obtained for the PI control method is as shown in the figure 5. PI control circuit gives an output voltage of 29.9V.

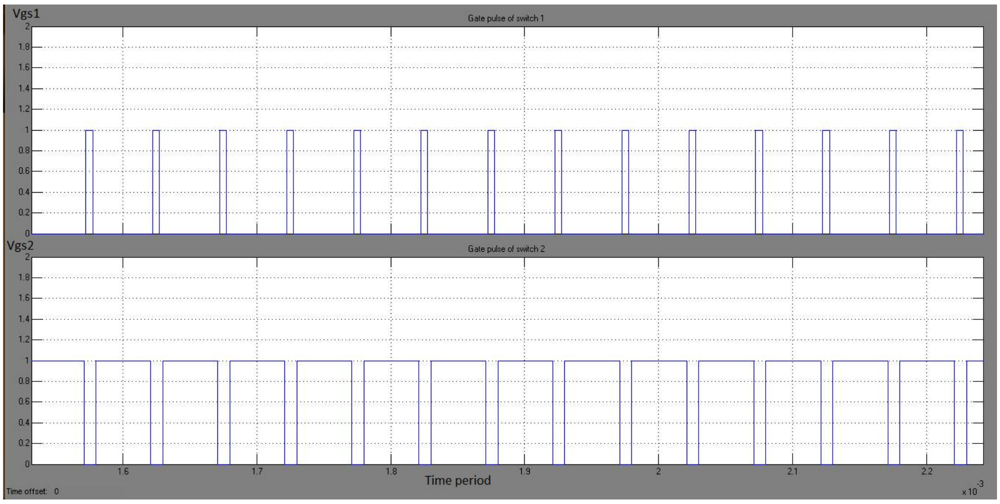

Fig. 6 Gate pulse generated for active switches

The gate pulses generated for the on/off operation of active switches is as shown in the figure 6. There is a short non-overlap time defined as "dead time".

V.HARDWARE IMPLEMENTATION

The hardware implementation of the proposed circuit is as shown in the figure 7 The circuit is implemented by using dsPIC30F2010 . LM7805 voltage regulator IC used to regulate the output voltage at 5V. An input from 7.2 to 35 provides a steady value of 5V.

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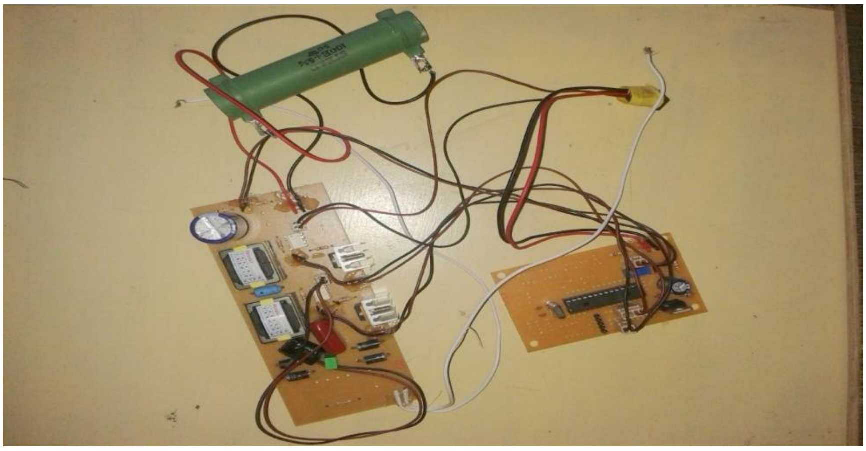

Fig. 7 Proposed circuit hardware

The output waveform obtained is given in figure 8.

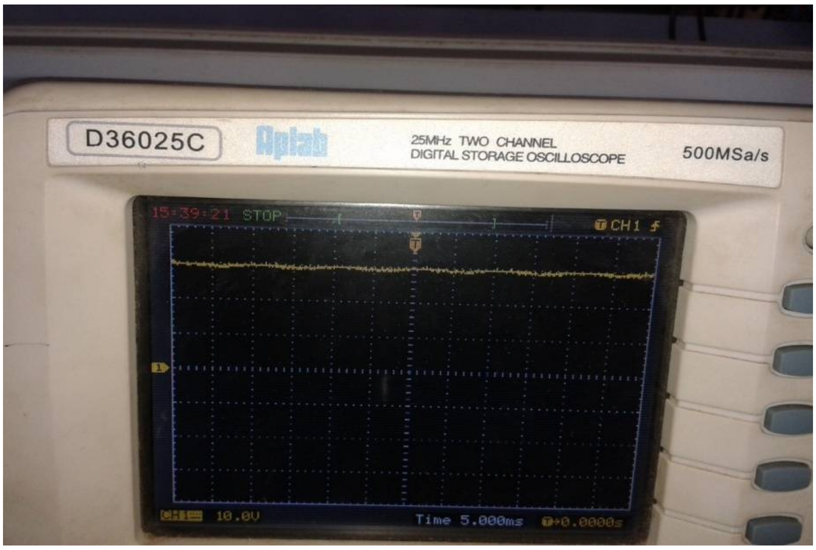

Fig. 8 Output waveform

Output voltage of the proposed circuit is 30V as per the design.

VI.RESULT

Proposed ac/dc converter is shown in the figure 1. By using open loop control circuit the ac/dc converter is as shown in figure 2, the power factor obtained is 0.9852. The circuit gives an output voltage of 29.42V. The output voltage waveform is given in figure 3. The proposed converter use PI control method as shown in figure 4. In the case of PI control the proposed circuit gives power factor of 0.9956 and the output voltage is 29.9V. The output voltage waveform is given in the figure 5. So PI closed loop control method is used in the ac/dc converter. The figure 6 shows gate pulses generated for the active switches that ensure dead time. The PI control assures high circuit efficiency and high power factor. The hardware implementation of the proposed circuit is given in figure 7. It provides an output voltage of 30V. The output voltage waveform is as shown in the figure8.

VII.CONCLUSION

The proposed circuit topology gives a high efficiency zero voltage switching ac/dc converter. It integrates a boost converter and a buck converter. Zero voltage switching achieved by freewheeling the inductor currents of converters

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through the intrinsic diodes of the MOSFETs. The boost converter performs the function of power factor correction. For the purpose boost converter is designed to operate at DCM. The buck converter in the circuit regulates the dc-link voltage to provide stable dc output voltage.. The proposed circuit is controlled by PI control method. It provides high power factor and assures circuit efficiency.

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