ZCS BRIDGELESS BOOST PFC RECTIFIER

Anna Joy[1], Neena Mani[2], Acy M Kottalil[3]
[1] PG student, annajoykandathil@gmail.com ,8111948255

Abstract— A new bridgeless single-phase ac–dc converter with a natural power factor correction (PFC) is proposed. Compared with existing single-phase bridgeless topologies, the proposed topology has the merits of less component counts. The absence of an input diode bridge and less conduction losses; hence, improved thermal management compared to existing PFC rectifiers is obtained. The proposed topology is designed to work in resonant mode to achieve an automatic PFC close to unity in a simple and effective manner. The resonant mode operation gives additional advantages such as zero-current turn-on in the active power switches.

Keywords— Bridgeless AC-DC Converters, Power-factor correction, Resonant power conversion , Zero Current Switching, Total harmonic distortion , Pseudo boost converters, Voltage gain

INTRODUCTION

Power factor correction (PFC) techniques are becoming necessary for many types of electronic equipment especially in the telecommunication and computer industries to meet harmonic regulations. Also, higher power density and lower system cost are always very desirable features, especially for low power supplies. Most of the PFC rectifiers utilize a boost or buck-boost topology converter at their front end due to its high power factor (PF) capability. However, a conventional PFC scheme has lower efficiency due to significant losses in the diode bridge. During each switching cycle interval, the current flows through three power semiconductor devices. The forward voltage-drop across the bridge diodes degrades the converter efficiency, especially at low-line input voltage [1].Pseudo boost converters are thus named because the voltage transfer ratio of pseudo boost converter is similar to that of conventional boost converter, with no relation to the resonant parameters and switching frequency. A bridgeless PFC circuit allows the current to flow through a minimum number of switching devices compared to the conventional PFC circuit. Accordingly, the converters conduction losses can be significantly reduced, and higher efficiency and lower cost can be obtained. However, most of the previous proposed bridgeless PFC converters have at least one of the following drawbacks:

1) high components count, 2) Components are not fully utilized over whole ac-line cycle, 3) complex control, 4) dc output voltage is always higher than the peak input voltage, 5) lack of galvanic isolation, and 6) due to the floating ground, some topologies require additional diodes and/or capacitors to minimize EMI. In order to overcome most of these problems, an interesting topology has been introduced with reduced component count. However, the proposed topology in still suffers from having at least two semiconductors in the current conduction path during each switching cycle. In [4], a zero current switch topology is presented. This topology has reduced-component count; however, the load is floating with respect to the input. A novel low count topology has been introduced in [5]. The proposed topology has low-component count with an input stage similar to a boost converter. Here a new bridgeless PFC circuit based on the modified boost converter is introduced and presented Compared with existing single phase bridgeless topologies. The proposed topology has low component count, a single control signal, and non-isolating output. Since the topology operates in discontinuous conduction mode, the proposed converter is intended for low power applications. The converter components are fully utilized during the positive and negative ac-line cycle [9].

Pseudo naming comes because this converters have voltage transformation ratio same as that of conventional boost converter, but it is independent of resonant parameters and duty ratio. Voltage conversion ratio can be further increased by quasi resonant technique [10].

BRIDGELESS RESONANT PSEUDO-BOOST PFC RECTIFIER

Introduction

The Bridgeless Resonant Pseudo boost PFC Converter circuitry consists of two MOSFET switches, two power diodes, resonant inductor and capacitor. At input side, LC filter is provided. The Bridgeless Resonant Pseudo boost PFC Rectifiers are designed to operate in discontinuous-conduction mode (DCM) during the switch turn-on interval and in resonant mode during the switch turn off intervals. As a result, the switch current stress is similar to the conventional DCM PFC converter, while the switch voltage stress is higher [1]. Moreover, the two power switches Q1 and Q2 can be driven by the same control signal, which significantly simplifies the control circuitry. Basic circuit of Bridgeless Resonant Pseudo boost PFC Rectifier is shown in Fig 3.1. Referring to Figure 2.1, the switching conduction sequences are as follows:

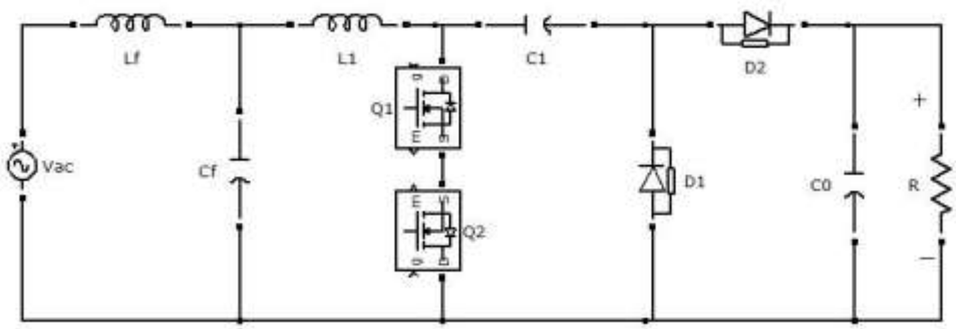

Figure 2.1: The Bridgeless Resonant Pseudo boost PFC Rectifier

During positive ac-line cycle, Q_1, D_{Q2}, D_2, D_1 ,X (all switches are off); and 2) during negative ac-line cycle, Q_2,D_{Q1},D_1,D_2,X. On the other hand, the switching conduction sequences for the converter are as follows: 1) during positive ac-line cycle, Q_1, D_{Q2} D_1, D_2, X and 2) during negative ac-line cycle, Q_2, D_{Q1}, D_2, D_1,X. Thus, during each switching period T_S, the current path goes through only two or one semiconductor devices instead of three. As a result, the total conduction losses of the semiconductor devices will be considerably lower compared to the conventional bridgeless PFC converters. In addition, the following assumptions are made: input voltage is pure sinusoidal, ideal lossless components, the switching frequency (fs) is much higher than the ac line frequency (f_L), and the output capacitor C_0 is large enough such that the output voltage can be considered constant over the whole line period. Based on these assumptions, the circuit operations in one switching period Ts in a positive ac-line cycle can be divided into four distinct topological stages.

From simulation results, for an input voltage 110 V, fs (switching frequency) = 50 kHz, simulation is performed in MATLAB Ra2010. The parameters used includes L_f = 1mH and C_f = 1 µF, L_1 = 100 µH, C_1 = 65nF and R_L = 500. Output voltage is obtained as 242V and output current as 0.4A. Output voltage step up. Switching frequency used is 50 kHz. Power factor is obtained near unity, 0.92 and Total Harmonic Distortion is only 2%.Output power is nearer to 100 W, so it is used only for low power application.

Working Principle

Resonant Pseudo boost PFC Rectifiers are designed to operate in discontinuous- conduction mode (DCM) during the switch turn-on interval and in resonant mode during the switch turn off intervals. As a result, the switch current stress is similar to the conventional DCM PFC converter, while the switch voltage stress is higher. Moreover, the two power switches Q_1 and Q_2 can be driven by the same control signal, which significantly simplifies the control circuitry. However, an isolated gate drive is required for the power switch Q_1.

Table I: Tabulation of simulated results

Input Voltage	110 V
Input Current	1.5 A
Input Power Factor	0.92
THD	2%
Output Voltage	242 V
Output Current	0.4 A

ZCS BRIDGELESS BOOST PFC RECTIFIER

For further improving voltage conversion ratio of conventional boost converters a new converter can be designed. An alternative approach to soft switching in modified boost converters is to use quasi-resonant (QR) techniques that can be cheaply implemented by using only a few passive components. This converter can operate with soft-switching and PFC in low line applications. It is economical because it requires only two active switches and two diodes for the main power circuit and a few passive components for soft switching. ZCS bridgelss boost PFC rectifiers are shown in fig 3.1.

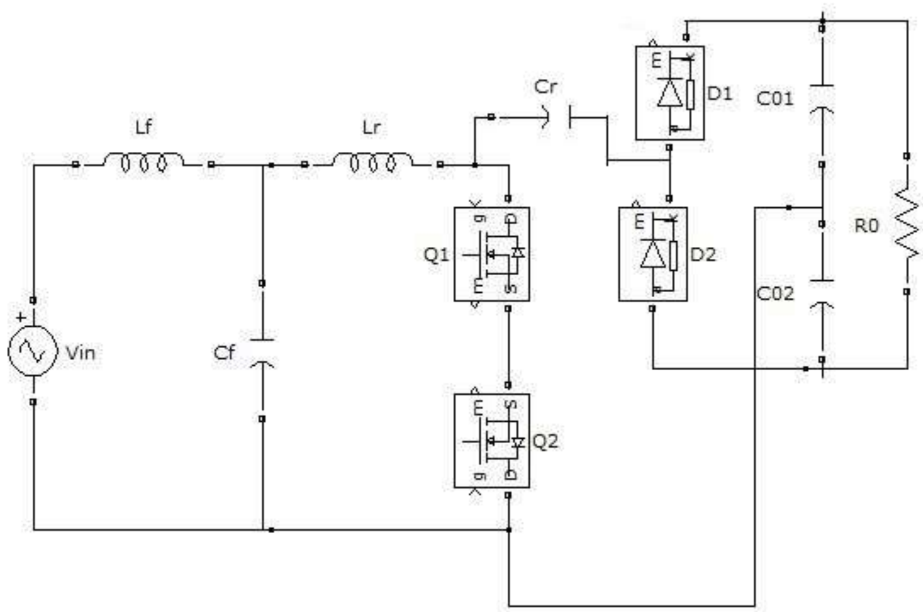

Figure 3.1: ZCS Bridgeless boost PFC Rectifier

Operational modes:

Stage 1: This stage starts when the switch Q_1 is turned-on. The body Diode of Q_2 is forward biased by the inductor current I_{L1}. Diodes are reverse biased by the voltage across C . In this stage, the current through inductor L_1 increases linearly with the input voltage, while the voltage across capacitor C_1 remains constant at voltage V_X.

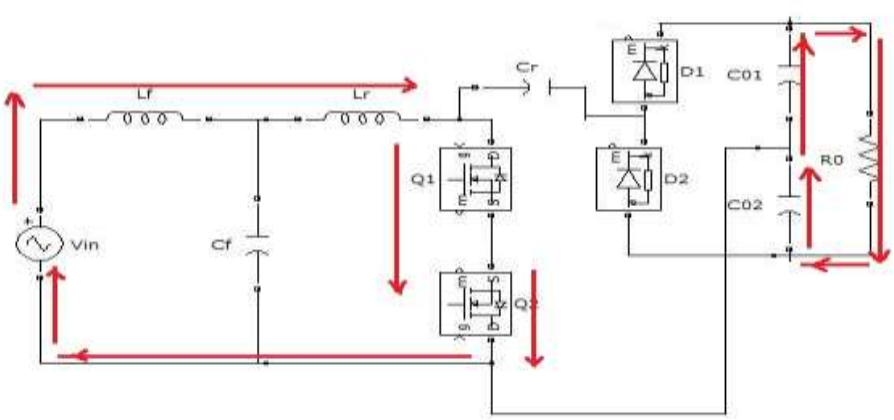

Figure 2.1: Mode 1 of ZCS Bridgeless boost PFC Rectifier

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Stage 2: This stage starts when switch Q_1 is turned OFF and diode D_1 is turned ON simultaneously providing a path for the inductor currents I_{L1} .As a result, diode D_2 remains reverse biased during this interval. The series tank consisting of L_1 and C_1 are excited by the input voltage V_{AC}. The stage ends when the resonant current I_{L1} reaches zero. During this stage, capacitor C is charged until it reaches a peak value as shown in Figure 2.2

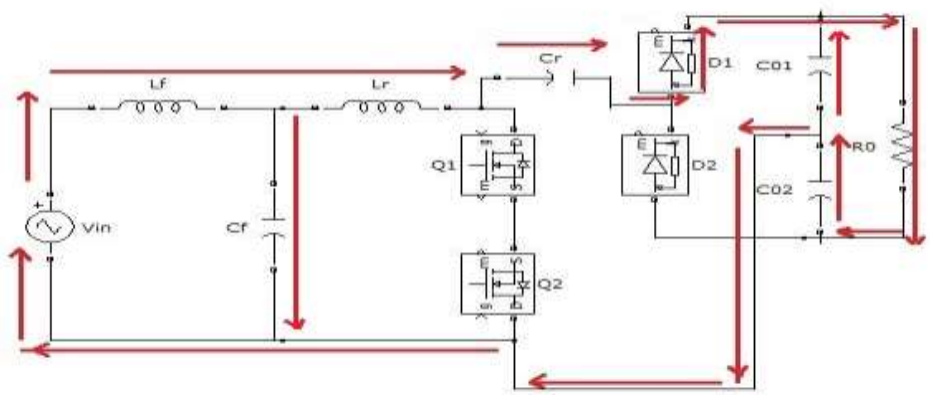


Figure 2.2: Mode 2 of ZCS Bridgeless boost PFC Rectifier

Stage 3: During this stage diode D_1 is forward biased to provide a path during the negative cycle of the resonating inductor current I_{L1}. This stage ends when the inductor current reaches zero. Thus, during this stage diode D_2 is switched ON under zero current conditions. Assuming the constant input voltage over a switching period, the capacitor is discharged until it reaches a voltage V_X.

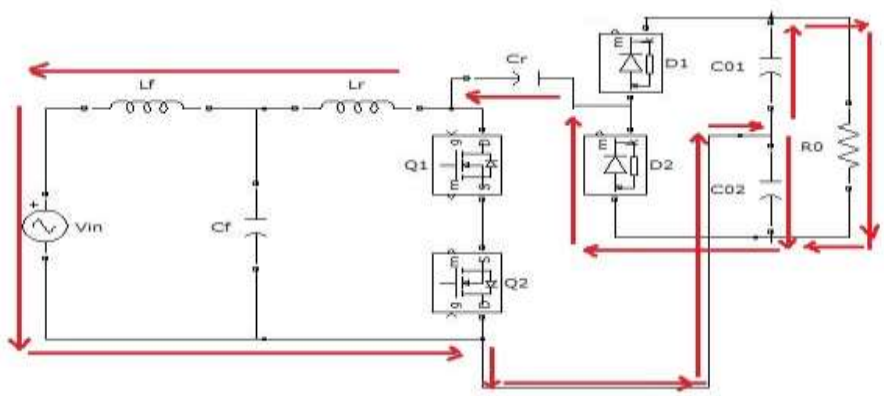


Figure 2.3: Mode 3 of ZCS Bridgeless boost PFC Rectifier

Stage 4: During this stage all switches are in their off-state. The inductor current is zero, while the capacitor voltage remains constant (V_X). It shall be noted that for this converter to operate as specified, the length of this stage must be greater than or equal to zero.

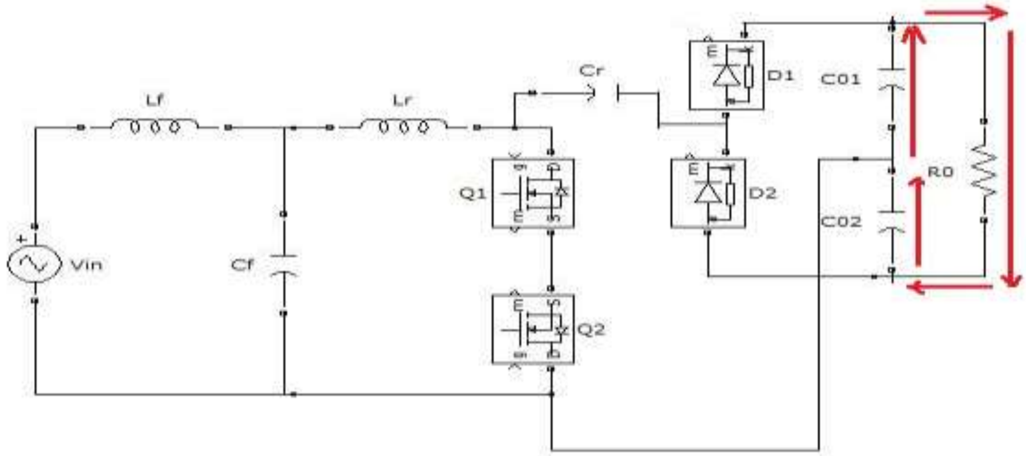


Figure 2.4: Mode 4 of ZCS Bridgeless boost PFC Rectifier

DESIGN OF COMPONENTS

Design procedure of this converter is explained with the following specifications.

Input Voltage, Vin =110 V

Output Voltage ,Vo =275 V

Duty Ratio, D = 40 %

Power Factor, pf =0.98

Switching Frequency f_s=50 kHz

In order to perform the analysis and derive equations independent of any particular parameter, all equations derived in this paper are normalized using the following base quantities:

Base voltage = Output voltage, V_0

Base Impedance = Z_0 = $\sqrt{(\frac{L_1}{C_1})}$

Base Current = $\frac{V_0}{Z_0}$

Base Frequency = $\frac{\omega_r}{2\pi}$

To ensure DCM operation, normalised switching frequency, F= $\frac{f_s}{f_r}$

The values of circuit components are calculated as follows:

1. Voltage Conversion Ratio, M = $\frac{V_0}{V_m}$ = 2.4

2. Critical Inductance, $L_1 \leq \frac{R_L T_S}{4}\ x \left(\frac{F}{\pi}\right)^2 = 163\ \mu H$

3. Resonant Capacitance,$C_1 = \frac{1}{L_1 2\pi (f_r)^2}$ = 65nF

SIMULATION MODEL AND RESULTS

For an input voltage 110 V, fs (switching frequency) = 50 kHz, simulation is performed in MATLAB Ra2010. The parameters used includes L_f = 1mH and C_f = 1 μF, L_1 = 100 μH, C_1 = 65nF and R_L = 500. Fig 4.1 shows the Simulink model of a ZCS Bridgeless boost PFC Rectifier.

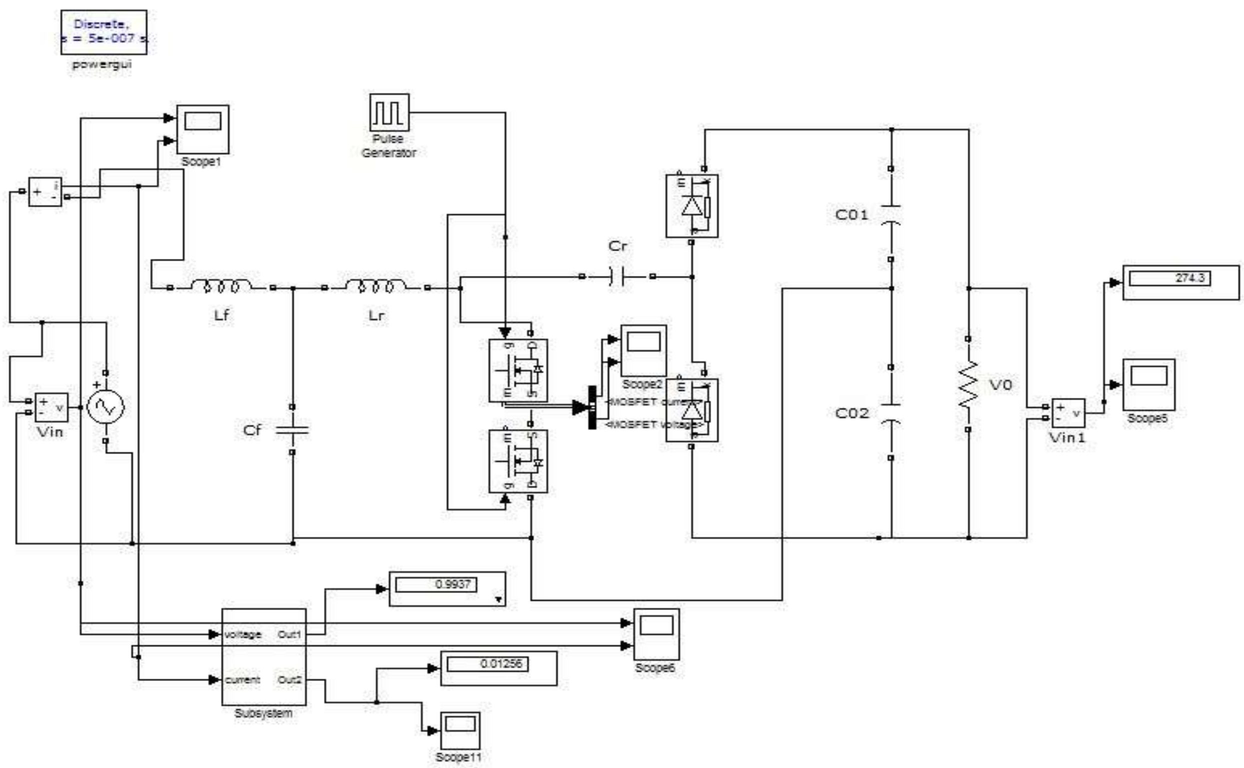
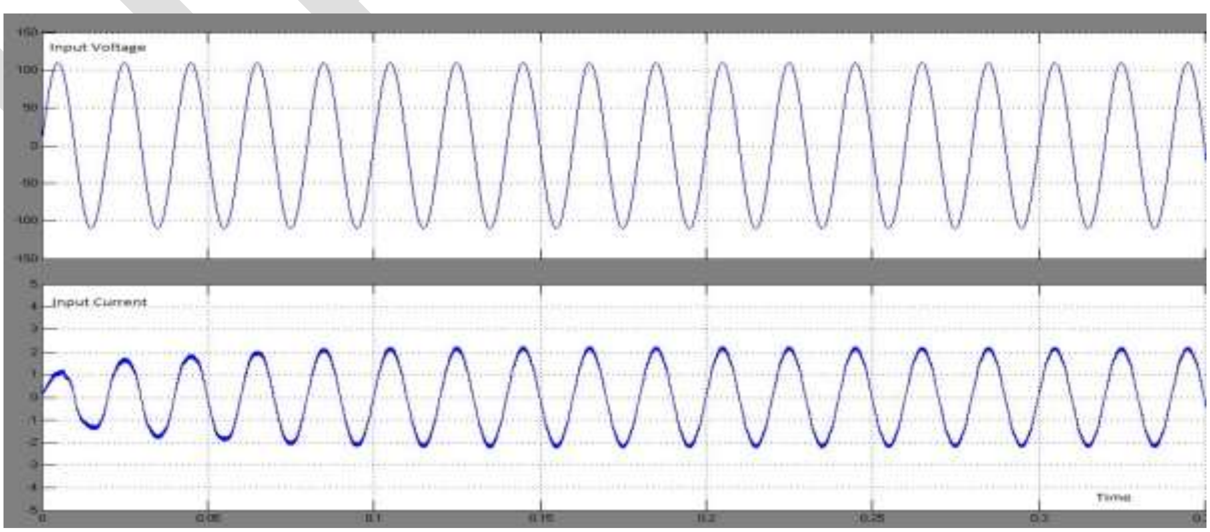


Figure 4.1: Simulink Model of ZCS bridgeless boost PFC Rectifier

For input voltage 110 V and input current 1.5A, output voltage is obtained as 274 V. Switching frequency used is 50 kHz. Power factor is obtained near unity, 0.99 and Total Harmonic Distortion is only 1%.Output power is nearer to 100 W, so it is used only for low power application.



Power factor correction is observed from the input voltage and current waveforms, these are in phase. PF is measured as 0.92. Switching frequency is taken as 50 kHz and duty ratio 50%. Discontinuous conduction mode is operated.

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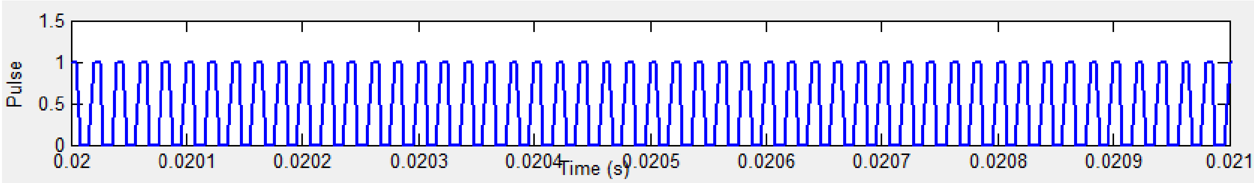
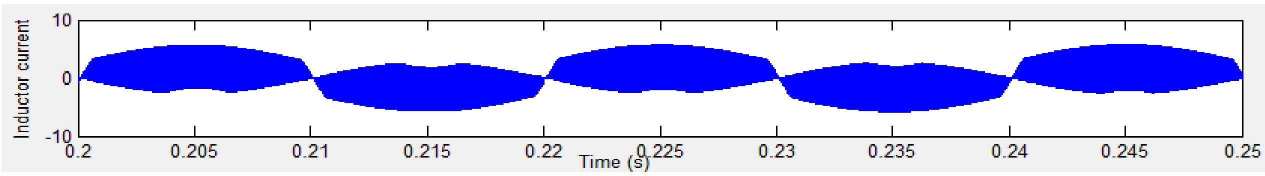
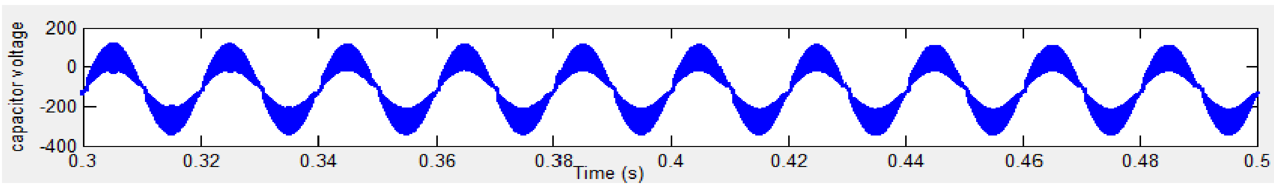


Fig 4.3: Switching Pulses



(a)



(b)

Fig 4.4: (a) Inductor Current (b) Capacitor Voltage

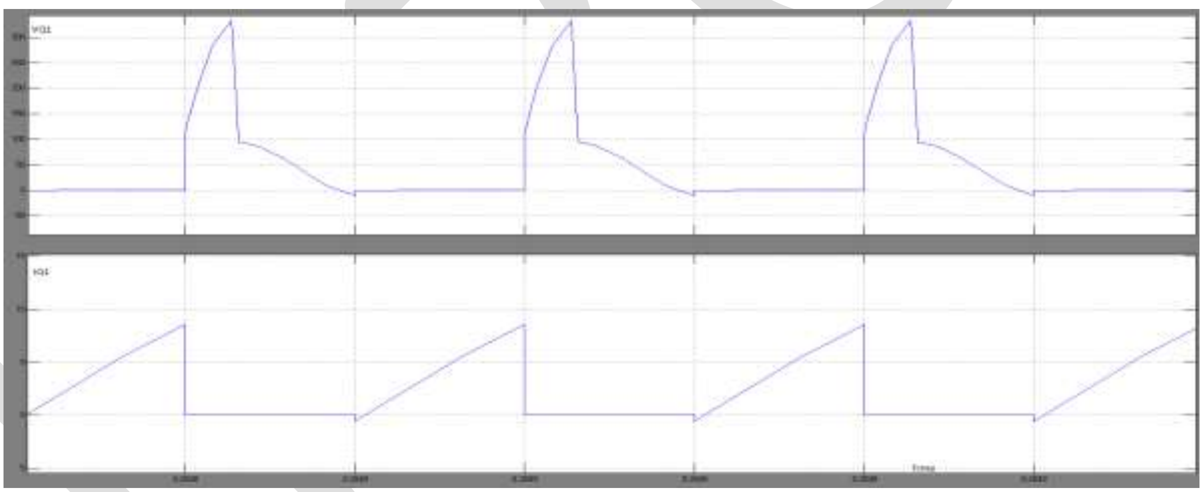


Fig 4.5: Voltage and Current across the switch

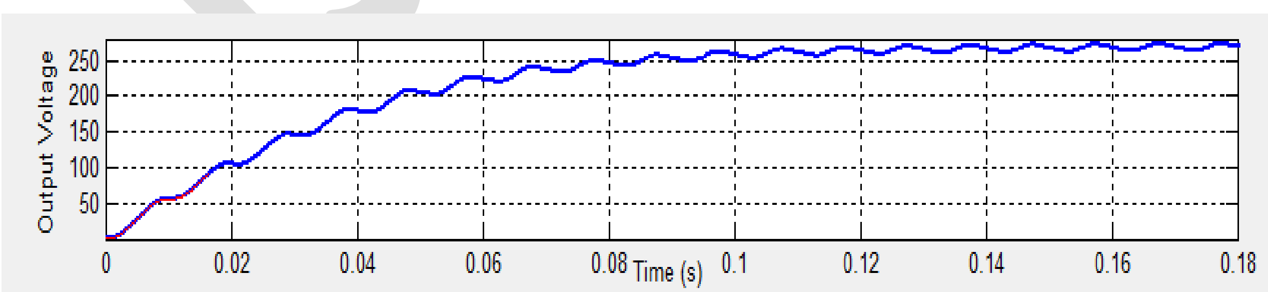


Fig 4.6: (a) Output Voltage of ZCS bridgeless boost PFC rectifier

For input voltage 110 V, output voltage boost upto 274 V. Voltage conversion ratio is increased to 2.4 where less than 2 for conventional type. Zero Current switching can be observed from the fig 4.5. ZCS Bridgeless boost PFC rectifier gives high step up conversion and high input power factor 0.99. Total harmonic distortion is only 1 to 2%.

Table II: Tabulation of simulated results

Input Voltage	**110 V**
Input Power factor	**0.99**
THD	**0.012**
Output Voltage	**274 V**
Voltage Gain	**2.4**

CONCLUSIONS

A new AC to DC converter with low component count and its topology derivation have been presented. The components of this topology are fully utilized over the whole line cycle. The two power switches in the proposed topology can be driven by the same control signal, which significantly simplifies the control circuitry. Voltage transfer ratios of ZCS bridgeless boost PFC rectifier is greater than conventional boost converters. Analysis, component stresses, design constraints, and simulation results of the converter have been presented. For an input voltage 110 V, switching frequency is 50 kHz. Output voltage is obtained as 274 V with high input power factor 0.99 and less THD(1-2%).Output Power is nearer to 100 W , so it is used only for low power applications. simulation is performed in MATLAB Ra2010

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