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Single Phase Buck Boost AC-AC Regulator

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Abstract: AC voltage converters are widely used as one of the power electronics systems to control an output ac voltage, where a variable ac voltage is obtained from a fixed ac voltage, for power ranges from few watts up to fraction of megawatts. Phase angle control line commutated voltage controllers and integral cycle control of thyristors have been extensively employed in this type of regulators for many applications. However, they suffer from inherent disadvantages such as retardation of the firing angle, lagging power factor at the input side especially at large firing angles and high low order harmonic content on both load and supply sides. Moreover a discontinuity of power flow appears at both input and output sides. Solid-state switch based AC-AC PWM regulator similar to the DC-DC converters have been designed to alleviate the problems. In this project a single phase Buck-Boost AC-AC converter has been proposed where a single bi-directional switch has been used. The conversion is achieved by Buck-Boost conversion of each half cycle. Hence the AC-AC switch mode conversion proposed in this project provides step up/down output voltage. Also, such conversion is achieved with low input current THD, high input power factor, small input filter and high conversion efficiency.

Keywords: CUK, Buck Boost, AC-AC converters, THD, DC-DC Converters

I. INTRODUCTION

AC to AC voltage converters operate on the AC mains to regulate the output voltage. Part of the supply appears at the load while the semiconductor switches block the remaining portions. AC-AC phase-angle controlled or integral cycle controlled single and three phase voltage-controllers are widely used in low, medium and high-power applications for controlling voltage across loads. Conventional techniques have many drawbacks like the retardation of the firing angle causing lagging power factor at the input side, substantial low order harmonics in the supply voltages/currents and discontinuity of power flow to the load etc.

Solid-state switch-based AC-AC PWM regulator similar to the DC-DC converters have been reported to alleviate the problems. They require a bi-directional freewheeling path across the load. As a result, only controlled freewheeling device could be used on the reported circuits. Also, switches in the circuits require synchronized (current-sensed) switching to attain in phase input current to improve power factor. The buck, boost, buck-boost and Ćuk topologies of single - phase ac-ac converters, where, the switches used are bidirectional. Four switch pwm single-phase ac-ac converters are also reported in literature. Two Switch AC-AC Switch Mode Converter Topologies In this project implementation of a buck-boost single-phase ac-ac converter is investigated. In the differential connection average dc of the individual outputs are cancelled out and the load voltage lower than the expected peak to peak is available. In the differential mode of connection two quadrant operation of single switch converter in each positive and negative cycle of the supply voltage is necessary because path for current flow from load to source is necessary when the switch is OFF. Two schemes of buck-boost single-phase single-switch ac-ac converter is presented illustrating the mentioned concepts. Reducing the number of control switch will make the design simple, cost effective and reliable. Input current distortion to the circuit is in acceptable range and the circuits exhibit good performance in respect to input power factor, input current THD and efficiency in a given range of duty cycle.

II. CUK Topology

The Ćuk converter (pronounced chook; sometimes incorrectly spelled Cuk, Čuk or Cúk) is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

Similar to the buck–boost converter with inverting topology, the output voltage of non-isolated Ćuk is typically also inverting, and can be lower or higher than the input. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use an inductor. It is named after Slobodan Ćuk of the California Institute of Technology, who first presented the design.

A. Principle of Operation

CUK converter is modified form of buck – boost converter. CUK converter provides an output voltage that is less than or greater than the input voltage whereas output voltage polarity is opposite to that of the input voltage. The CUK converter is based on capacitive energy transfer as the capacitor C_1 is the medium for transferring energy from the source to the load. The proposed AC CUK voltage regulator is shown in figure 6.1 (without controlled circuit)

B. Positive Cycle

The circuit operation can be explained in positive and negative half- cycle of input voltage. The circuit operation during the positive half - cycle of AC input voltage can be explained. During the positive half - cycle of input voltage when IGBT-1(Z_1) is ON (by gate signal) and IGBT-2 (Z_2) is OFF, the current passes through inductor L_1 (rises-energy stored), diode $D_{1,}$ IGBT-1(Z_1) and diode $D_{3,}$ and at the same time previously charged capacitor C_1 discharges (transfers) its energy to the circuit formed by $C_{1,}$ diode D1, IGBT-1(Z1), diode D3, the load and L2 (energy stored).

C. Negative cycle

The circuit operation during the negative half - cycle of AC input voltage can be explained with the help of figure 4.3 (a) and (b). The operation of the negative half -cycle for AC input voltage is the same as the positive half - cycle, but direction is opposite. During the negative half - cycle of input voltage when IGBT-1(Z_1) is ON (by gate signal) and IGBT-2 (Z_2) is OFF, the current passes through diode $D_{7,}$ IGBT-1(Z_1), diode D_8 and inductor L_1 (rises-energy stored). At the same time the previously charged capacitor C_1 discharges (transfers) its energy to the circuit formed by L2 (energy stored), load, diode D7, IGBT-1, diode D8 and $C_{1.}$ Moreover, when IGBT-1(Z_1) is OFF and IGBT-2 (Z_2) is ON (by gate signal), the stored energy of the inductor L_1 is transferred to the capacitor C_1 (charging) by forming circuit D5, IGBT-2, D6, C1 and L1. ; at the same time previously stored energy of L_2 is transferred to the load by formed circuit L_2, load, D5, IGBT-2, D6. So in both cycles we get the output voltage across the load.

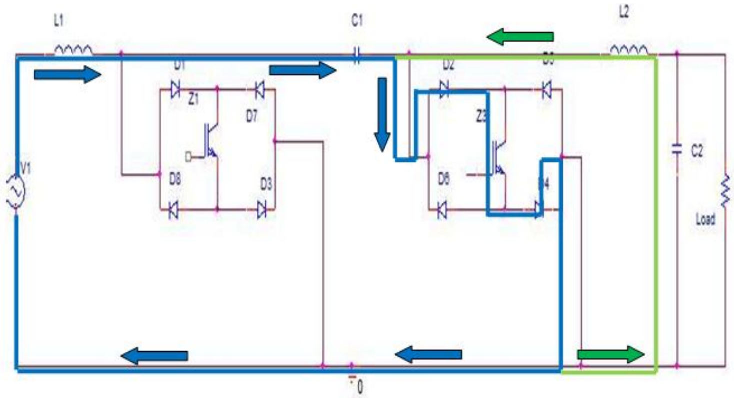


Figure 1: Positive cycle

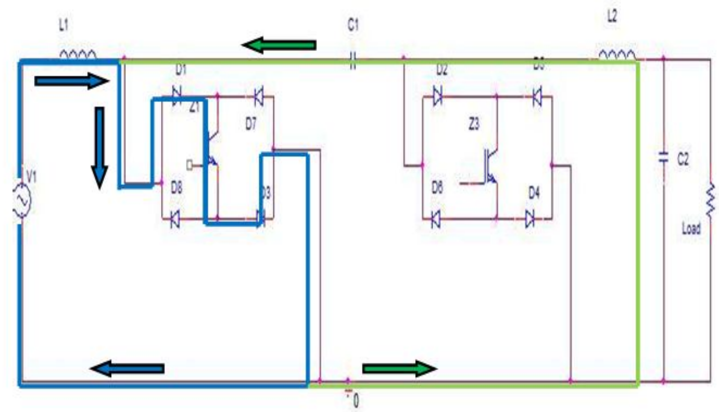
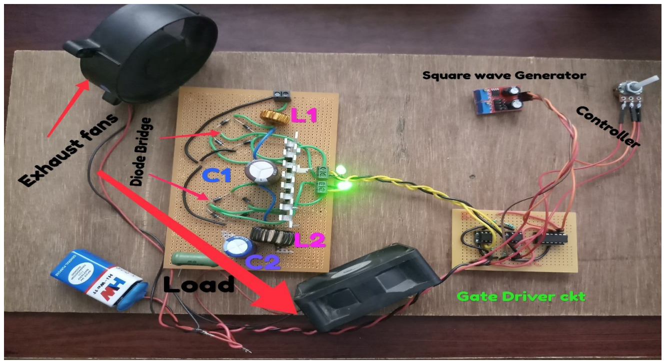


Figure 2: Negative cycle

D.Hardware



E. Hardware Results

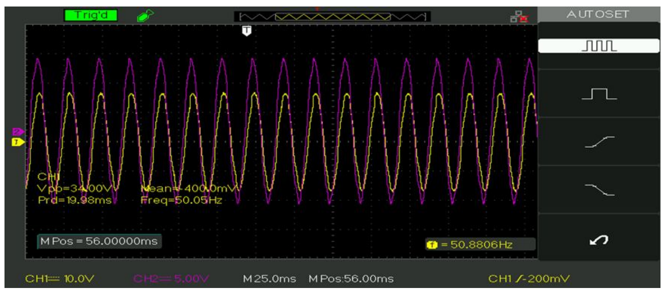


Fig Input output voltage waveform for Boost operation

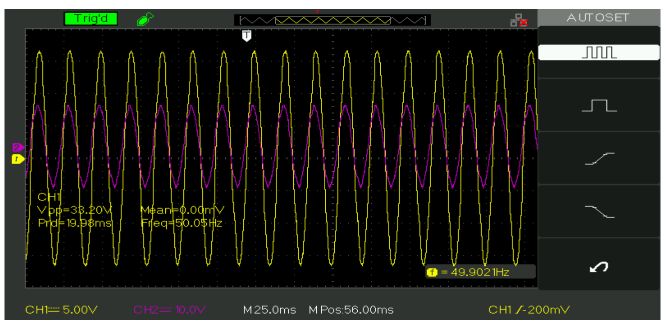


Fig Input output voltage waveform for Buck operation

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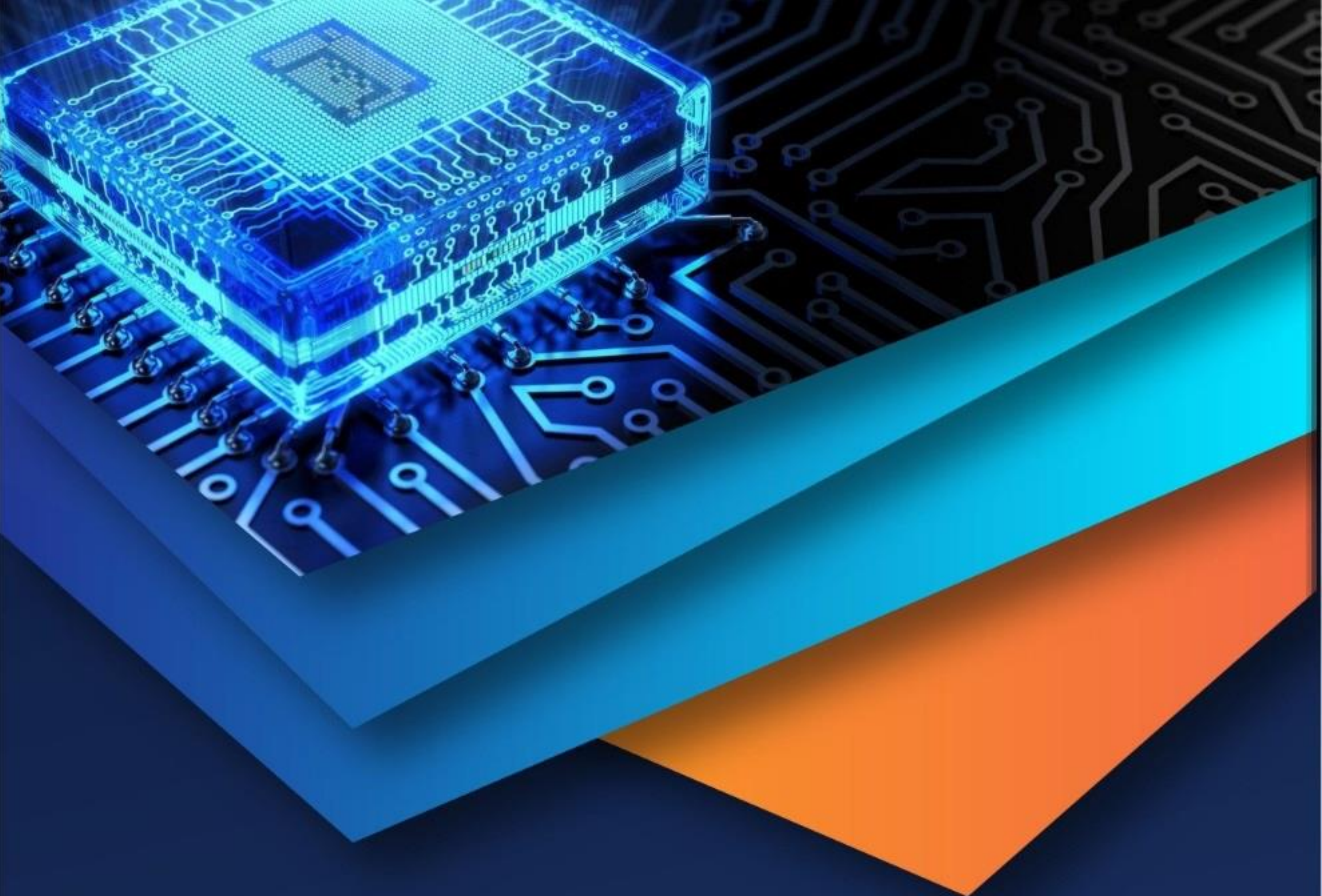

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