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Bridgeless Cuk Power Factor Corrector with Regulated Output Voltage

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Abstract: **A single-phase, bridgeless Cuk AC/DC power factor correction (PFC) rectifier with regulated positive output voltage is proposed in this work. For low output voltage product applications, the rectifier is designed to convert high input voltage to low output voltage. This work presents bridgeless single-phase AC-DC power factor correction (PFC) rectifier based on Cuk topology. The topology does not possess input diode bridge and have only single semiconductor switches in the current owing path during each interval of the switching cycle, which resulting in less conduction losses and better thermal management. This topology is designed to work in discontinuous conduction mode (DCM). The advantages of Cuk converter are also available when bridgeless circuit topology is introduced. The operation is symmetrical in two half-line cycles of input voltage. In conventional, output voltage varies according to input voltage. A closed loop control technique is designed to regulate the output voltage in the desired level. Performance and applicability of this converter is presented on the basis of simulation in MATLAB/SIMULINK.**

Keywords: **Power Factor Corrector (PFC), Discontinuous Conduction Mode (DCM), Pulse Width Modulation (PWM), Total Harmonic Distortion.**

I. INTRODUCTION

An AC-DC converter plays an important role in alternative and renewable energy conversion, portable devices, and many industrial processes. It is essentially used to achieve a regulated DC voltage from an unregulated DC source which may be the output of a rectifier or a battery or a solar cell etc. Nevertheless, the variation in the source is significant, mainly because of the variation in the line voltage, running out of a battery etc., but within a specified limit. Taking all these into account, the objective is to regulate the voltage at desired value while delivering to a widely varying load [1]. The output voltage of an AC-DC converter is controlled by operating it in the closed loop, and altering its MOSFET (switch) gate signal accordingly. It is basically governed by a switching logic, thus constituting a set of subsystems depending upon the status (ON-OFF) of the switch. In the well known pulse width modulation (PWM) technique, the control is accomplished by varying the duty ratio of an external fixed frequency clock through one or more feedback loops, whenever any parameter varies. PI controllers are the most widely used type of controller for industrial applications. They are structurally simple and exhibit robust performance over a wide range of operating conditions [2]. In the absence of the complete knowledge of the process these types of controllers are the most efficient of choices.

In recent years, switched-mode power supply technologies have developed rapidly. Most switched-mode power supplies for electronic products are used to convert AC to DC sources in different applications. The use of a transformer, a bridge rectifier, and capacitors can achieve a DC-output voltage easily, but the input current may be seriously distorted. Therefore, the PFC converters are critically required for AC-DC conversion. A variety of circuit topologies have been developed for the PFC applications [3]. The conventional PFC converter is a full-bridge rectifier followed by a boost converter. The converter is widely used, because of its simplicity. However, due to boosting behaviour of the converter, the output voltage is always greater than the input voltage. In many applications, such as low-voltage and low-power

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supplies, it is desired to have the output voltage lower than the peak of input voltage. A buck-type converter is thus required. The buck converter is seldom used in the PFC application, since as the input current of the buck converter is discontinuous, it would lose control when the input line voltage is lower than the output voltage. Also, to filter the input current, additional passive filter Bridgeless Cuk Power Factor Corrector with Regulated Positive Output Voltage must be used at the buck converter input. A buck PFC rectifier is recently proposed for voltage step-down applications. However, the input line current cannot follow the input voltage around the zero crossing of the input line voltage. Besides, the buck PFC converter may lead to increased total harmonic distortion (THD) and reduced power factor. Therefore, in such applications, converters like buck-boost, single-ended primary-inductor converter (SEPIC) or Cuk converter are often used next to a full bridge rectifier, to have a PFC converter with low output voltage. The Cuk converter offers several advantages in PFC applications, such as easy implementation of transformer isolation, natural protection against inrush current occurring at start-up or overload current, lower input current ripple, and less electromagnetic interference (EMI) associated with the DCM topologies.

II. BRIDGELESS CUK POWER FACTOR CORRECTOR WITH REGULATED POSITIVE OUTPUT VOLTAGE

The circuit configuration of Cuk converter is in some ways like a combination of the buck and boost converters, although like the buck-boost circuit. Cuk converter produces an output voltage that is less than or greater than the input voltage, but the output voltage polarity is opposite to that of the input voltage. It is named after its inventor. In a conventional PFC Cuk , when switch Q is ON current flows through three power semiconductor devices. That is two bridge diodes and one switch. This will result in conduction losses and poor efficiency. The Bridgeless Cuk PFC with Positive Output voltage converter is the combination of a CUK converter and a bridgeless rectifier. This combination operates like the conventional CUK PFC converter. The operation is symmetrical in two half-line cycles of input voltage. Therefore the converter operation is explained during one switching period in the positive half-line cycle of the input voltage. It is assumed that the converter operates in DCM. This means that the output diode turns off before the main switches turn on. The objective is to regulate the voltage at a desired value. The output voltage of an AC-DC converter is controlled by operating it in the closed loop, and altering its MOSFET (switch) gate signal accordingly.

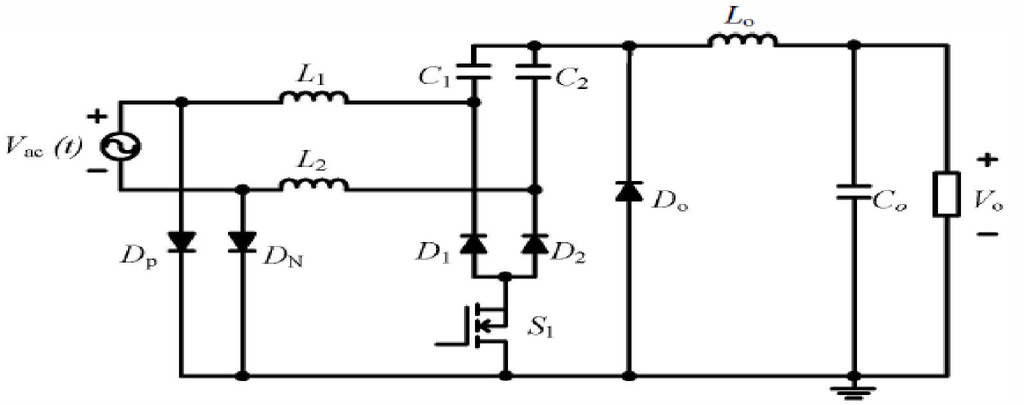

Fig:1 Circuit Diagram of Bridgeless Converter

III. CONTROL STRATEGY

Modelling the power stage presents one of the main challenges to the power supply designer. A popular technique involves modelling only the switching elements of the power stage. An equivalent circuit for these elements is derived and is called the PWM Switch Model where PWM is the abbreviation for the Pulse Width Modulated. PWM technique is used for controlling the output power. PWM is a digital periodic signal. It is like a square wave, but the duty cycle is variable. The duty cycle is the ratio between the high level period duration and the low level period duration, often expressed in percentage. In this circuit, PI control method is applied to control the duty ratio of switches. For control over steady state and transient errors all the three control strategies discussed so far should be combined to get proportional-

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integral (PI) control. Hence the control signal is a linear combination of the error, the integral of the error, and the time rate of change of the error. All three gain constants are adjustable.

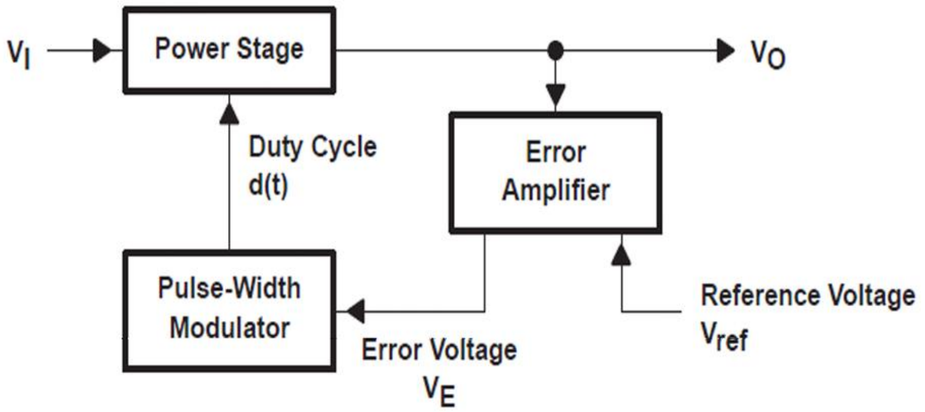

Fig. 2: Block Diagram of Control Circuit

The PI controller contains all the control components (proportional and integral).In order to get acceptable performance the constants K_p and K_i can be adjusted. This adjustment process is called tuning the controller. Increasing K_p and K_i tend to reduce errors but may not be capable of producing adequate stability. The PI controller provides both an acceptable degree of error reduction and an acceptable stability and damping

IV. SIMULINK MODEL AND SIMULATION RESULTS

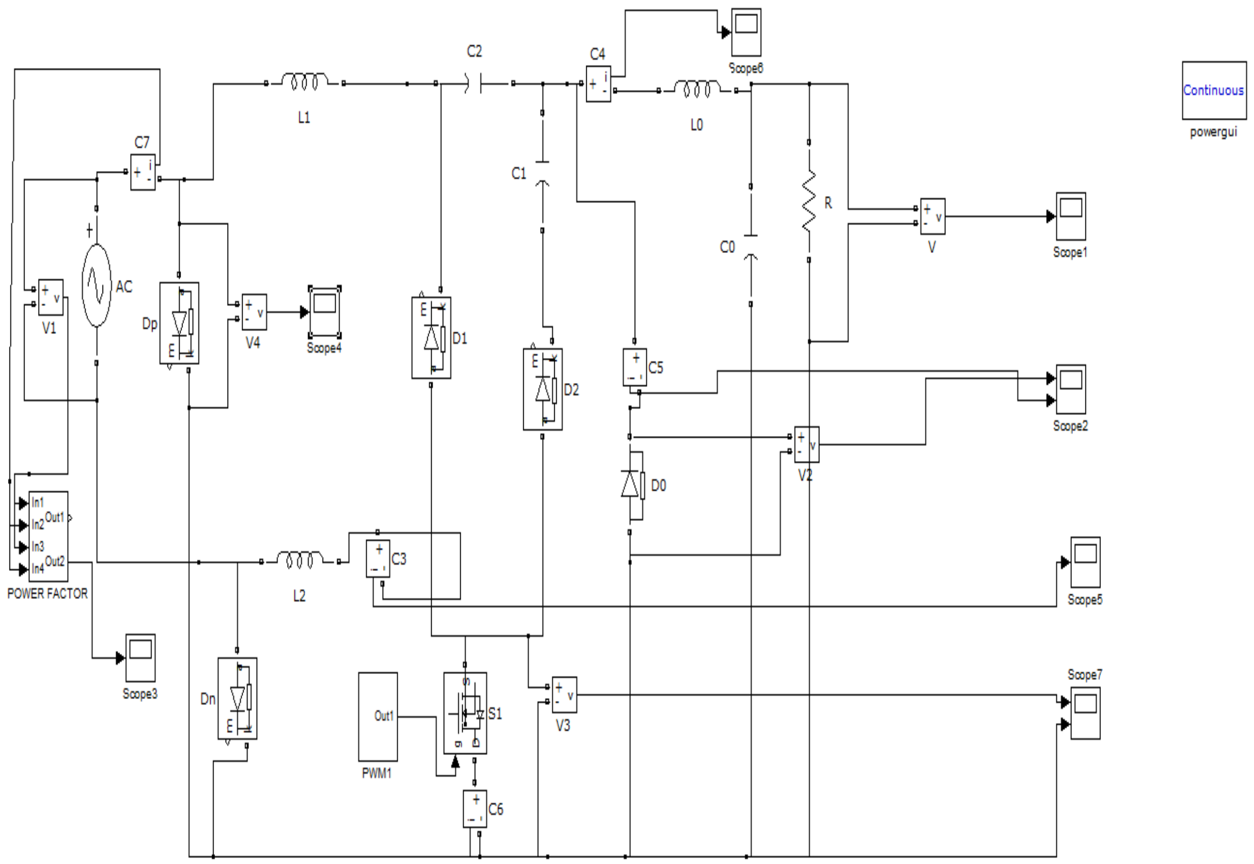

Fig.3: Simulink Model of Bridgeless Cuk Power Factor Corrector with Regulated Positive Output Voltage

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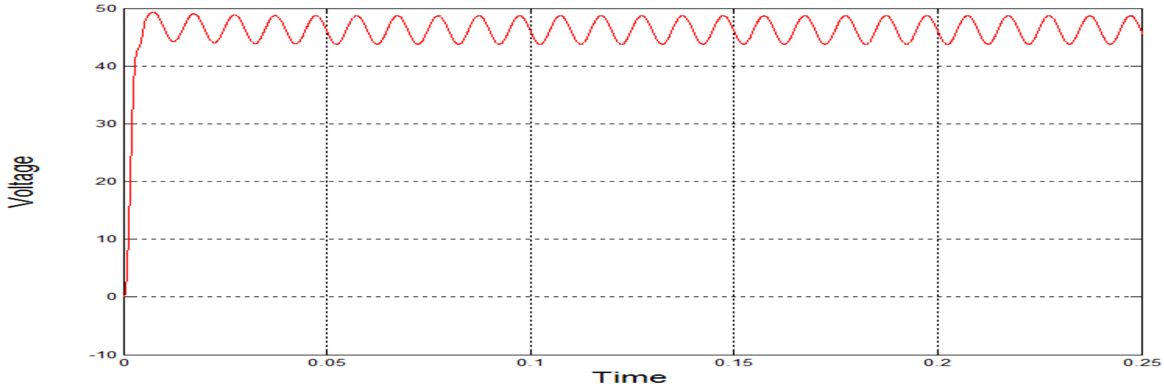

Fig.4: Output Voltage

Output Voltage is obtained as 48V DC. Ripple is reduced to 0.4V.

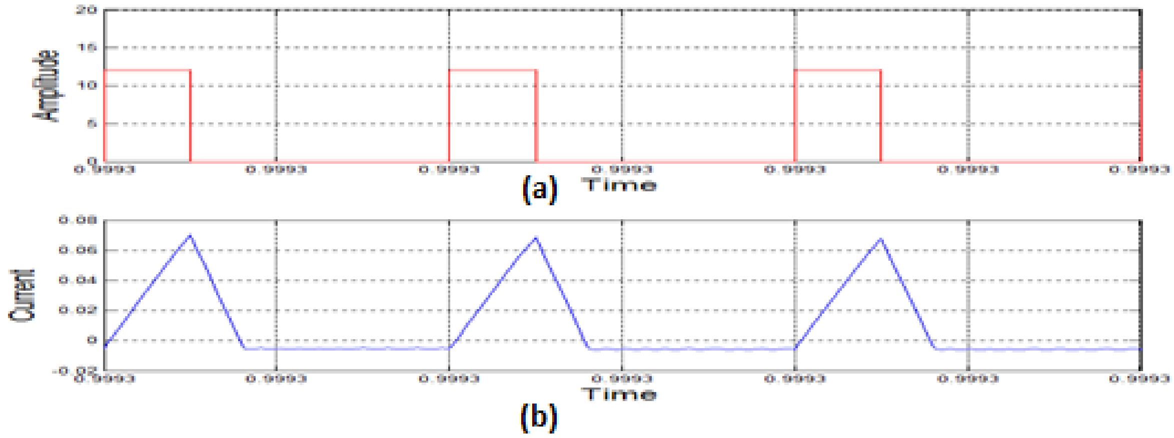

Fig.5: a) Switching Pulse b) Inductor Current

Fig.5 shows that the current flowing through inductor. From the figure it can be inferred that the proposed converter work in discontinuous conduction mode. So we can implement Zero current switching for the switch.

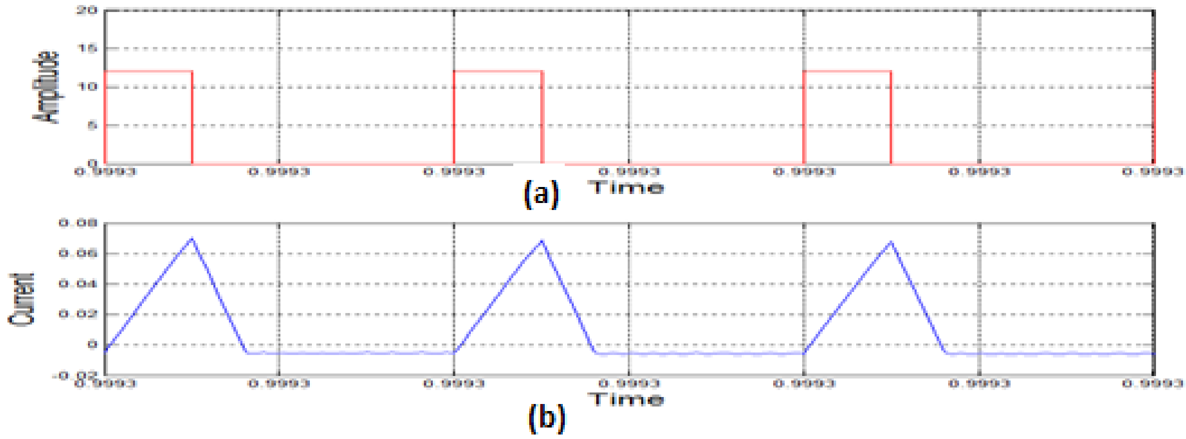

Fig.6: a) Switching Pulse b) Diode current

Fig.6 shows that the Current flowing through diode. So we can achieve Zero current turn off for the diode. Hence problems related to reverse recovery of diode is reduced.

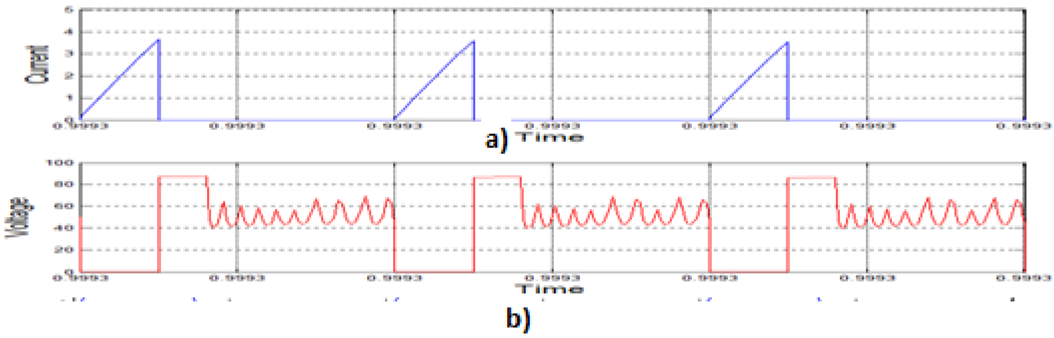

Fig.7: a) Input Current b) Voltage across MOSFET

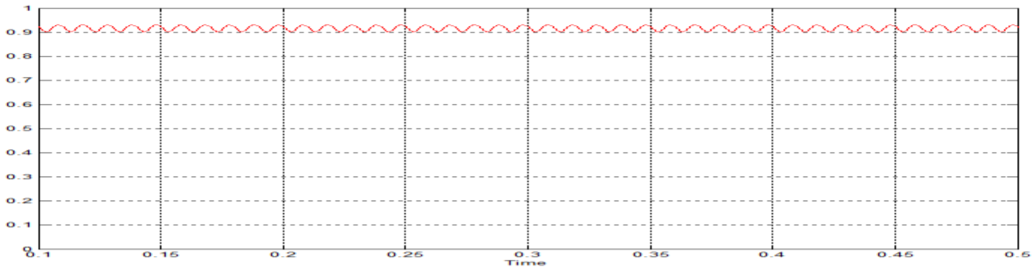

Fig.8: Power factor

The simulation results show that S_1 turns on under ZCS condition and Do turns off under ZCS condition. Therefore, reverse recovery problem of the main diode is resolved by employing the proposed Cuk rectifier in DCM. The waveforms of input voltage and current are almost in phase. The measured PF at full load is about 0.99 and THD is about 0.14. Thus the measured PF and harmonics satisfy the IEC standards. Output peak to peak voltage ripple is 0.6 V for 12V DC output voltage.

V. CONCLUSION

A new topology based on Cuk converter is designed and simulated. Apart from conventional systems, bridgeless topologies yield more efficiency and energy savings. This converter topology uses reduced number of power switches compared to conventional Cuk PFC converter and operates under DCM operation to produce less current ripple thereby improving the power factor. The simulation results have shown good agreements with the predicted waveforms analyzed in the work. The measured PF at full load is about 0.99 and THD is about 0.14. Thus the measured PF and harmonics satisfy the IEC standards. The closed-loop control is designed to improve the dynamic response of the presented converter and to provide the required output regulation. The design concepts are validated through simulation and results obtained show that a closed loop system using Cuk converter will be highly stable with high efficiency.

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