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AC-DC Converter Using Bridgeless SEPIC

Kakkeri, Shilpa[1], Patil, Nagabhushan[2]

[1, 2] Department of Electrical and Electronics Engineering, P.D.A.C.E, Gulbarga, Karnataka, India

Abstract: ***This paper presents a new bridgeless single phase AC-DC converter based on Single Ended Primary Inductance Converter (SEPIC). The proposed rectifier utilizes a bidirectional switch (MOSFET) and two fast diodes. The absence of an input diode bridge and the presence of only one diode in the flowing current path during each switching cycle result in less conduction loss compared to existing PFC rectifiers. In the proposed scheme, DSPIC30F2010 controller is used to produce signals. Experimental circuit of this converter is developed with universal input voltage capability for 20-30V DC output voltage connected to resistive load (incandescent lamp with different watts). Textronics TDS2024B storage oscilloscope is used to store the gate pulses and waveforms.***

Keywords: Bridgeless rectifier, MOSFETs, AC-DC Converter, Voltage level sensor, Zero cross detector

1. Introduction

The active power factor correction (PFC) circuits are widely used to effectively draw the energy from the mains via an AC to DC converter. These PFC circuits are normally consists of full bridge diode rectifier and DC-DC converter. If only one DC-DC converter is used, then it will be classified as a single-stage converter while two-stage converter utilizes two-DC-DC converter. On the other hand, some PFC circuits are realized without the full-bridge rectifier circuit, which is known as the bridgeless PFC topology. Actually, these bridgeless PFC circuit combines the operation of bridge rectifier and DC-DC converter into a single circuit.

The bridgeless PFC topology has less number of components conduct at each switching cycle compared to the conventional Boost PFC circuit. Numerous works on bridgeless PFC which focus on several key issues such as higher power factor and higher efficiency capability compared to the conventional PFC converters. A new bridgeless PFC circuit based on single ended primary inductance converter (SEPIC) offer several advantages as a PFC circuit such as lower input current, simple control circuitry, and reduced switch voltage stress easily implemented as isolated converter and less electromagnetic inference (EMI). The demand for improving power quality of the ac system has become a great concern due to the rapidly increased number of electronic equipment. To reduce harmonic contamination in power lines and improve the transmission efficiency. In recent years, the demand for improving power quality of the ac system has become a great concern due to the rapidly increased number of electronic equipment. To reduce harmonic distortion in power lines and improve the transmission efficiency, power factor correction became an active topic in power electronics.

2. Block Diagram and its Explanation

2.1 System overview

The block diagram of the proposed AC-DC converter using bridgeless SEPIC is shown in fig 1. It has gate drive unit, control unit. Each MOSFET acts as a switch without any switching losses and facilitates the operation of the converter. The primary function of the gate drive circuit is to convert logic level control signals into the appropriate voltage and current for efficient, reliable, switching of the MOSFET module. In this work an optocoupler TLP50 is used to isolate the gate drive circuit and the MOSFET based circuit. The optocoupler consists of an infrared light-emitting diode and a silicon phototransistor. The input signal is applied to the IRLED and the output is taken from the phototransistor. A controller (DSPIC30F2010) is used to implement the core of the control function, which simplifies the hardware setup.

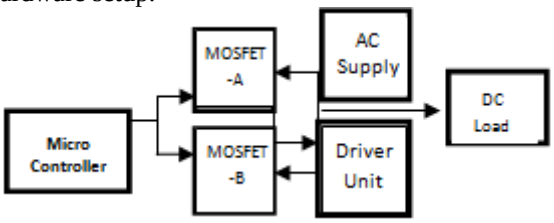
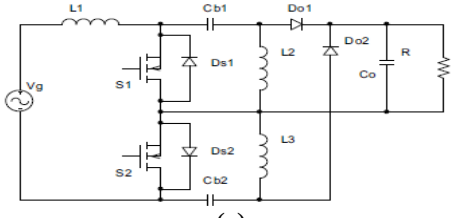


Figure 1: Block diagram of the proposed system

2.2 Control circuit

The control circuit of the proposed scheme consists of a Digital signal controller DSPIC30F2010.The microcontroller is operated at 10MHz crystal frequency. A control unit (CU) is, in general, a central (or sometimes distributed but clearly distinguishable) part of the machinery that controls its operation, provided that a piece of machinery is complex and organized enough to contain any such unit. The controller decides the instant timing of the gate signal to be given to the MOSFETs in order to avoid overlapping in conduction of incoming and outgoing MOSFETs.

3. Converter System Description



(a)

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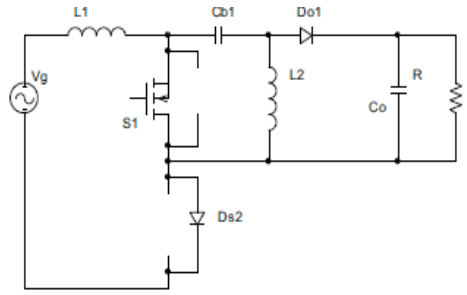
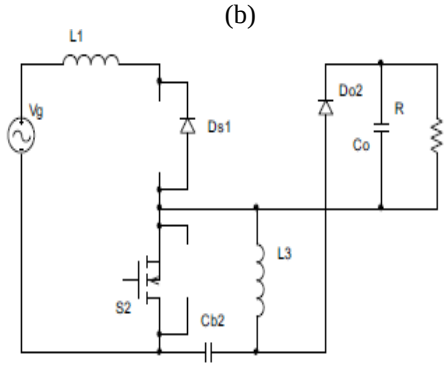


(b)



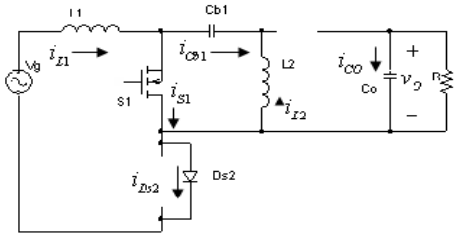
(c)

Figure 2: (a) The proposed bridgeless SEPIC operated during (b) positive and (c) negative half line cycle

The proposed circuit is much simpler in several aspects namely: (1) less number of components operated at each input-voltage cycle, (2) the minimum number of output capacitor (Co) required is one, (3) driving the MOSFETs gate terminal is simpler due to both 'source' terminals of the MOSFETs are connected to a common node and (4) no gate-driver circuit with isolation is required. In the operation of the converter the three conductors are working in DCM. Operating the SEPIC in DCM offers advantages over continuous-current-mode (CCM) operation, such as a near-unity power factor can be achieved naturally and without sensing the input line current. In DCM, both S1 and S2 are turned on at zero current, while diodes Do1 and Do2 are turned off at zero current. Thus, the loss due to the switching losses and the reverse recovery of the rectifier are considerably reduced. As the analysis goes deeper, it is found that the circuit analysis can be divided into two main parts which are the operation during positive half-line cycle and negative half-line cycle as shown in Fig 3(b) and (c). During positive half-line cycle, all components will conduct except Ds1, S2, C2, L3 and Do2. During negative cycle, the components that will not conduct are Ds2, S1, C1, L2 and Do1.

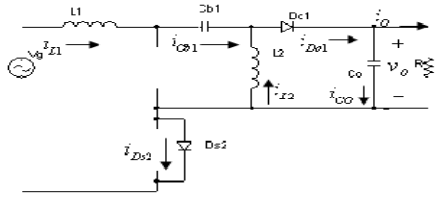
4. Circuit Operation

The proposed converter will operate in Discontinuous Conduction Modes (DCM) since this type of mode offers several advantages namely capability to operate as PFC is inherent, suitable for low power applications and lower component stress. As depicted in Figure 3, the circuit operation of the proposed converter within each switching period, TS, can be divided into three subinterval modes, namely MODE 1 (d1TS), MODE 2 (d2TS) and MODE 3 (d3TS).

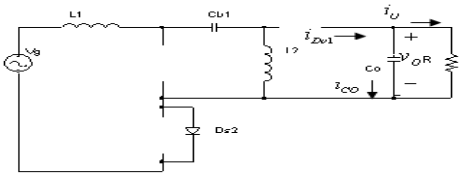


(a)

In MODE1, equivalent circuit is shown in Figure 3(a). As can be seen, when the upper MOSFET, S1, is turned on, the current from the source, Vg, will flow through the input inductor and continue to S1and Ds2 before completing the current path through Vg.



(b)



(c)

Figure 3: Equivalent circuit during (a) MODE 1(d1Ts),(b) MODE 2(d2Ts) and MODE 3(d3Ts).

Figure 3(b) shows the circuit in MODE 2. Obviously at this mode, S1 is turned off such that no current will flow through it, but now Do1 is forward-biased. At this point, L1 falls linearly due to the process of discharging its current to the load through iCb1 and iDo1 and create the return path through Ds2. At the same time, L2 will also discharge its current linearly to the load through iDo1.

Finally, in MODE 3, both S1 and Do1 are turned off resulting only two closed current path which is at the input and the output side. L1 and L2 are equal while Vg is equal to VCb1. As a result, the input current is approximately equal to zero. However, an almost DC current exist at this mode and the amount of current at L1 and L2 are equal but on the opposite direction.

5. Experimental Setup and Results

Table 1: Experimental results for Resistive load and incandescent lamp

Vin	*Vout(Observed value of output voltage for set Vout=23V)*		
	Resistive load	*60w*	*100w*
70	23.2	22.5	20.8
80	23.2	22.3	20.7
90	23.6	23.4	20.9
100	23.8	23.6	21.5
110	23.9	23.2	21.6
120	23.9	23.8	21.8

Table 2: Experimental results for Resistive load and incandescent lamp

Vin	*V out(Observed value of output Voltage for set Vout=30V)*		
	Resistive load	*60w*	*100w*
70	23.2	22.5	20.8
80	23.2	22.3	20.7
90	23.6	23.4	20.9
100	23.8	23.6	21.5
110	23.9	23.2	21.6
120	23.9	23.8	21.8

The new AC-DC converter using bridgeless SEPIC developed hardware is tested with load. The proposed control system is implemented by a DSPIC30F2010. C language is used to develop the program. The device is programmed using MPLAB Integrated Development Environment (IDE) tool. For execution of C-code, MPLAB compiler is used. In this work, I have used resistive load, 60W & 100W incandescent lamp.

The hardware set is developed and tested in power electronics laboratory and the photograph of complete setup is shown in fig 4. The test is carried out on resistive load and bulb. DC voltages and DC output voltages for different loads are tabulated.

In the complete experiment the oscilloscope used is Tektronix TDS2024B Digital Storage Oscilloscope (DSO) to store gate pulses and voltage waveforms. Tables 1and 2 shows, the output voltages for resistive load and for incandescent lamps of different voltages. Fig 5. a-d & 6.a-d. shows the corresponding waveforms taken from the Digital Storage Oscilloscope.

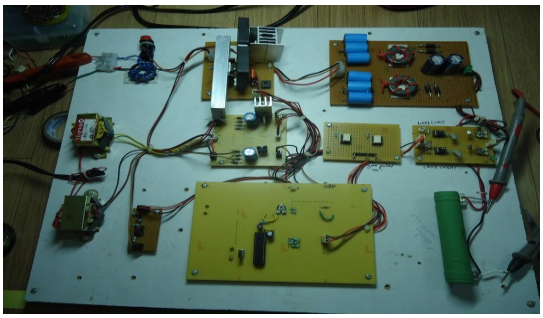


Figure 4: Photograph of the complete designed system

Waveforms for resistive load and incandescent lamps of different wattages for set Vout =23v

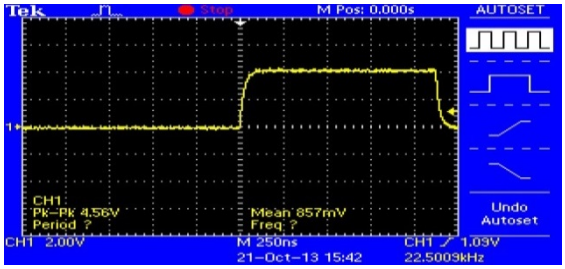


Figure 5(a): Gate pulse waveform

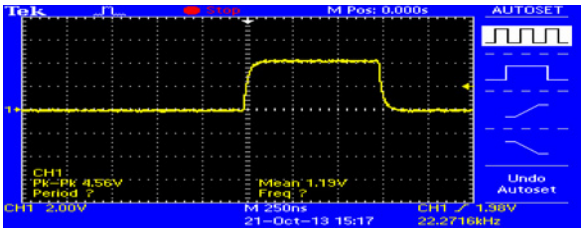


Figure 5(b): Gate pulse waveform

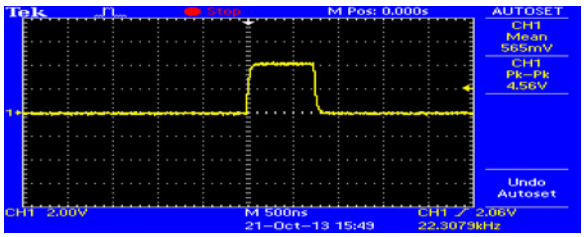


Figure 5(c): Gate pulse waveform

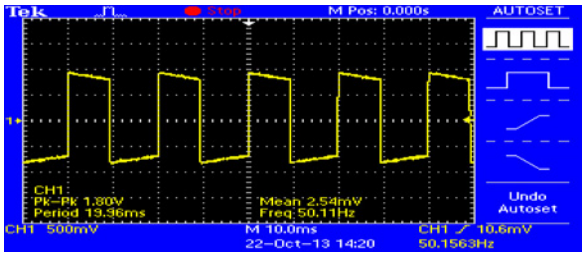


Figure 5(d): Gate pulse waveform with respect to zero cross detector

Waveforms for resistive load and incandescent lamps of different wattages for set Vout =30v

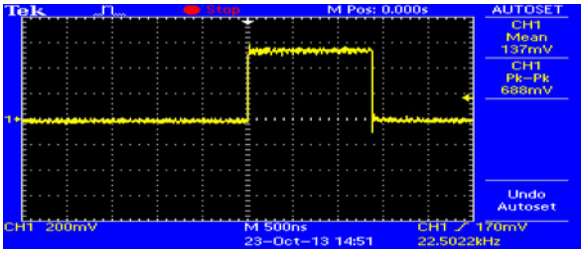


Figure 6(a): Gate pulse waveform

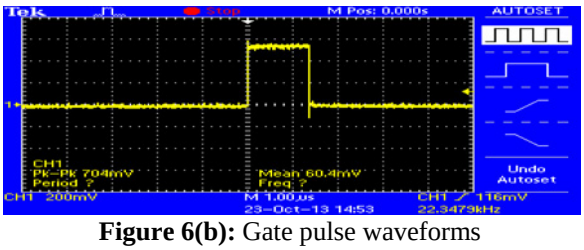


Figure 6(b): Gate pulse waveforms

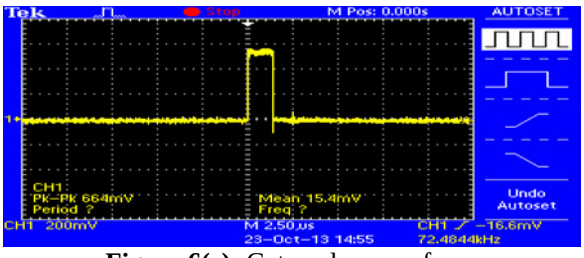


Figure 6(c): Gate pulse waveform

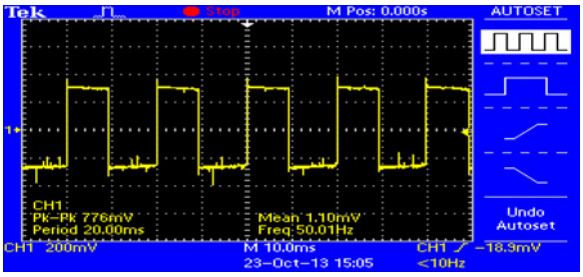


Figure 6(d): Gate pulse waveform with respect to zero cross detector

6. Conclusion

A new AC-DC converter using bridgeless SEPIC has been proposed and verified by experimental works.It is showed that the proposed circuit is capable to achieve high power factor under universal input voltage condition. The capability to reshape the input current is inherent when the circuit is operated in DCM. The main features of the proposed converters include high efficiency, low voltage stress on the semiconductor devices & simplicity of design. This circuit would be most suitable to be used as a switch mode power supply application for low power equipments especially those requiring high quality input power.

In the proposed scheme, DSPIC30F2010 controller is used to produce signals. Experimental circuit of this converter is developed with universal input voltage capability for 20-30V DC output voltage and the developed hardware setup is tested on a resistive load and incandescent lamp (60w,100w)in power electronics laboratory. From the experimental setup and results chapter it is clear that the developed hardware satisfactory converts AC-DC, & can be used in switch mode power supply, equipments which require high quality input power, LED lightning DC motor etc.

7. Future Scope

This paper has explored some good ideas and suitable solutions, but further investigation is necessary either for telecom and computer server applications or in related field of power management, which are suggested as follows:

1. Dynamic response in low power applications,
2. Design of PFC converter at very high switching frequency,
3. Unbalanced input voltage in modular approach.

8. Appendix

The following defines the nomenclature and system parameters used in this paper :
Loads: 60W, 100W incandescent lamps
Inverter parameters
Vin :lnput voltage 230V
Cb1, Cb2, Co capacitors
S1, S2MOSFETs

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Author Profile

Shilpa Kakkeri received the B.E degree in Bio-Medical engineering from Khaja Banda Nawaz College of engineering (VTU) Gulbarga 2010, Pursuing M. Tech in Power electronics from Poojya Doddappa Appa College of Engineering (Autonomous) Gulbarga 2013.

Nagabhushan Patil graduated from Gulbarga University, Gulbarga in 1985 and post graduated from IIT Madras, Chennai in the year 1992 with specialization in Energy Systems. Presently he is pursuing Ph. D from JNTU Hyderabad. Research area includes High Voltage Engineering and Power Systems. Presently working as Selection Grade lecturer in government aided P. D. A. College of Engineering, Gulbarga.