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A Boost Converter for Low Voltage Applications through Bridgeless Circuit

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ABSTRACT - A single-stage ac–dc power electronic converter is proposed to efficiently manage the energy harvested from electromagnetic generators.The conventional ac-dc converters for energy harvesting system with diode rectifiers suffers considerable voltage drop results increase in power loss of circuitry and complexity. The proposed topology combines a boost converter and a buck-boost converter to condition the positive and negative half portions of the input ac voltage, respectively. The proposed converter avoids the use of bridge rectifiers, and converts the ac input to the required dc output. Only one inductor and capacitor are used in both circuitries to reduce the size of the converter. In this paper electrical and physical characteristics of the power conditioning interfaces determine the functionality, efficiency, and size of the integrated systems. The simulation is done with the help of MATLAB software using Simulink.

KEYWORDS - Bridgeless, Low voltage rectification**,** Boost, AC/DC Conversion.

I.INTRODUCTION

Power electronic circuits form key interfaces in energy harvesting systems. Kinetic energy harvesters convert mechanical energy present in the environment into electrical energy. Typically, kinetic energy is converted into electrical energy using electromagnetic, piezoelectric, or electrostatic transduction mechanisms [1]. The electromagnetic generators normally consist of permanent magnets and coils. Due to practical size limitations, the output voltages of the electromagnetic generators are very low [18]. The electromagnetic generators are typically spring mass-damper based system, in which the mechanical energy is converted to electrical energy by electromagnetic damping. The output of electromagnetic generator is an ac quantity. Hence the generator output has to be processed by a power converter to produce a suitable dc output voltage [19].

Energy harvesting systems aim to reduce or eliminate the need to replace batteries, by converting ambient energy into electrical energy and charging a battery over time. Energy harvesting devices generally produce relatively low output power. In energy harvesting systems, power electronic circuit forms the key interface between transducer and electronic load, which might include a battery. Energy can be stored in a capacitor or super capacitor. Capacitors are used when the application needs to provide huge energy spikes. The power electronic circuits are employed to 1) regulate the power delivered to the load, and 2) actively manage the electrical damping of the transducers so that maximum power could be transferred to the load [1]. The output voltage level of the micro scale and meso scale energy harvesting devices is usually in the order of a few hundred millivolts depending on the topology of device.

Bridgeless boost rectifier which omits rectifier-bridge there are only two semiconductors in any given conduction path. In each circuit, the boost converter is implemented by replacing a pair of bridge rectifier with switches and employing an ac side boost inductor. The bridgeless boost topologies are most suitable for medium -to-high power applications [20]. Bridgeless topology reduces conduction losses. The bridgeless topology not only reduces conduction loss, but also reduces total components. With a simple circuit analysis, it can be identified that the bridgeless topology namely the Boost bridgeless has less number of components conduct at each switching cycle compared to the conventional boost circuit[8].

Conventional ac–dc converters for energy harvesting and conditioning usually consists of two stages. A diode bridge rectifier typically forms the first stage, while the second stage is a dc–dc converter to regulate the rectified ac voltage to a dc voltage. However, the diode bridge would incur considerable voltage drop, making the low-voltage rectification infeasible. This arrangement of two stage power conversion has several disadvantages: 1) Diode voltages in a bridge rectifier are difficult to overcome for low input voltage. 2) Diode losses are increased, as input current is much higher than output current. 3) A rectifier offers a nonlinear load, which makes the converter unsuitable for energy harvesting.[]The main aim of this project is to combine a boost converter and a buck-boost converter to condition the positive and negative half portions of the input ac voltage. To regulate the power delivered to the load, and actively manage the electrical damping of the transducers so that maximum power could be transferred to the load. In these converter bridge rectification is avoided and the generator power is processed only in single stage boost and buck boost type power converter.

II. PRINCIPLE OF OPERATION

A bridgeless boost rectifier is a unique integration of boost and buck boost converter. The proposed converter consists of a boost converter (S1, L and D1) in parallel with a buck boost converter (S2, L and D2).The output dc bus is realized by using a single capacitor. The output capacitor is charged by the boost converter in positive half cycle and by the buck boost converter in the negative half cycle. Therefore it resolves the problems present in a dual polarity boost converter.

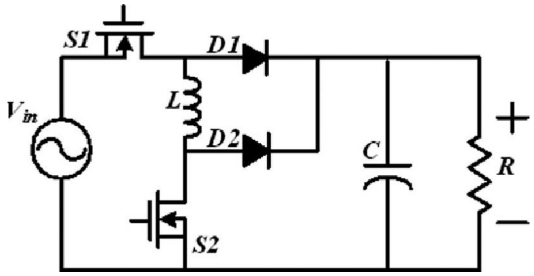

Fig.1. Proposed bridgeless boost converter

The boost converter is the common power conditioning interface due to its simple structure, voltage step-up capability, and high efficiency. The buck-boost converter has ability to step up the input voltage with a reverse polarity; hence, it is an appropriate candidate to condition the negative voltage cycle. Besides, the boost and buck-boost topologies could share the same inductor and capacitor to meet the miniature size and weight requirements.

When the input voltage is positive, *S*1 is turned ON and *D*1 is reverse biased, the circuitry operates in the boost mode. As soon as the input voltage becomes negative, the buck-boost mode starts with turning ON *S*2 and reverse biasing D2. MOSFETs with bidirectional conduction capability work as two-quadrant switches to ensure the circuitry functionality in both positive and negative voltage cycles.

A. *Modes of Operation:*

The converter has six operation modes. Modes I-III for positive input voltage where S1 is turned ON while D1 is reverse biased. Modes IV-VI for negative input voltage where S2 is turned ON while D2 is reverse biased.

MODE I:

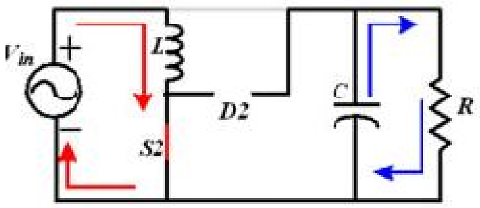

Fig.2.Operating mode 1of proposed converter

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During this mode switch S2 is turned ON under ZCS condition to reduce the switching losses. The inductor current is zero. Inductor L is energized by the input voltage as both S1 and S2 are conducting. Energy is stored in output filter capacitor ‘C’.

MODE II:

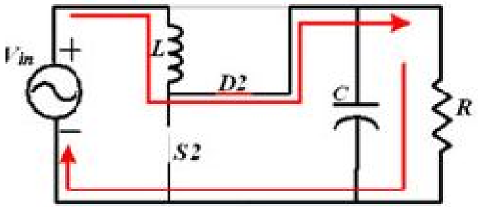


Fig.3.Operating mode 2 of proposed converter

During this mode S2 is turned OFF. The energy stored in the inductor during mode I is transferred to the load. During this mode diode D2 is turned ON so switching loss occurs.

MODE III:

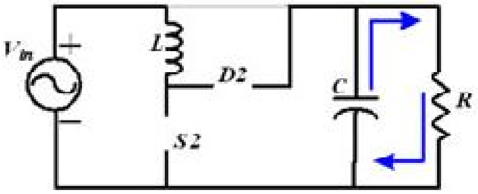


Fig.4.Operating mode 3 of proposed converter

During this mode D2 is automatically turned OFF as soon as inductor current becomes zero. The load is again powered by energy stored in capacitor.

MODE IV:

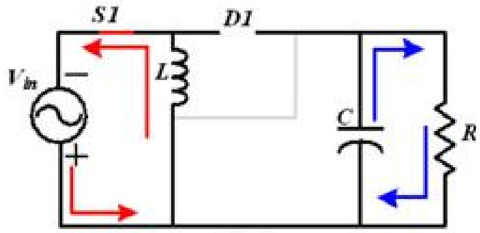


Fig.5.Operating mode 4 of proposed converter

During negative input cycle, S1 is turned ON under ZCS conditions. The energy is transferred to inductor ‘L’ again, while the output filter capacitor ‘C’ feeds the load.

MODE V:

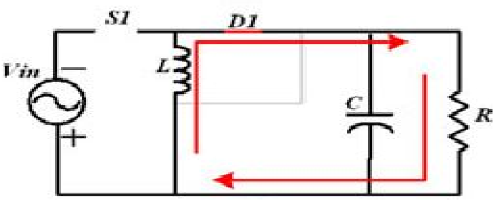


Fig.6.Operating mode 5 of proposed converter

During this mode S1 is turned OFF. The energy stored in inductor ‘L’ during mode IV is transferred to the load. Inductor current decreases linearly. Diode D1 is turned ON.

MODE VI:

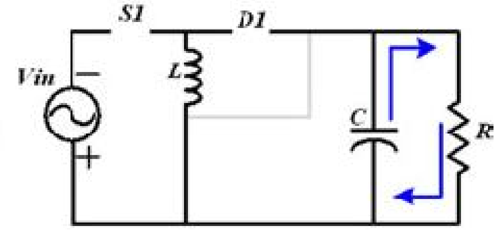


Fig.7.Operating mode 6 of proposed converter

During this mode diode D1 is turned OFF when inductor current decreases to zero. The load is continuously powered by energy stored in the output capacitor ‘C’.

III CONTROL STRATEGY

When the input voltage is positive, *S*1 is turned ON and *D*1 is reverse biased, the circuitry operates in the boost mode. As soon as the input voltage becomes negative, the buck-boost mode starts with turning ON *S*2 and reverse biasing D2. MOSFETs with bidirectional conduction capability work as two-quadrant switches to ensure the circuitry functionality in both positive and negative voltage cycles. The switching signals of *S*1 and *S*2 are dependent on the polarity of the input voltage. During the positive input cycle, *S*1 is turned ON, while *S*2 is driven by the boost control scheme. When the circuit operates in the negative input cycle, S2 is turned ON, while S1 is controlled under the buck-boost conditioning strategy. The output voltage is filtered by a passive low pass filter (LPF) and then fed to ADC of the controller. The difference between ADC output and the desired voltage is calculated and compensated through the PID algorithm to generate an adjustable duty cycle signal. The switching signals of *S*1and *S*2 are dependent on the polarity of the input voltage.

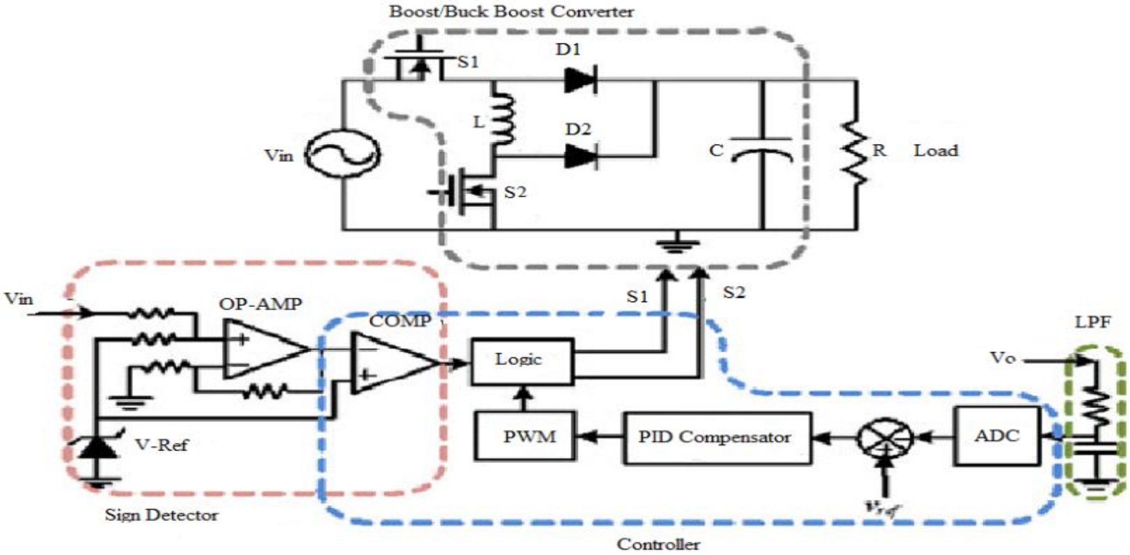


Fig.8.Control circuit for proposed converter

The proposed converter is operated under DCM. This reduces switch turn ON and turns OFF losses. The DCM operation also reduces the diode reverse recovery losses of the boost and buck boost converter diodes. A sign detector is used to determine the input voltage polarity. The sign detector is composed of a voltage reference, an op-amp, and the on-chip analog comparator. The op-amp operates as an analog adder, where a dc bias (voltage reference) is added to the input voltage. The signal summation is compared with the voltage reference to detect the polarity.

IV.RESULT AND DISCUSSION

The input is considered to be a sinusoidal input voltage with a frequency of 50 Hz. The simulation results are presented to demonstrate the capability of the converter to maintain a nominal DC voltage of 3.3V. The MOSFETs selected for the converters are IRF840.The rectifying diodes D1 and D2 are schottky diodes. The design of the inductor value is 4.7µH. The output capacitor has a value of 100 µF.

INPUT VOLTAGE

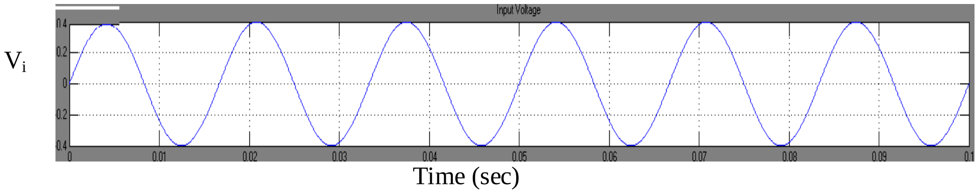
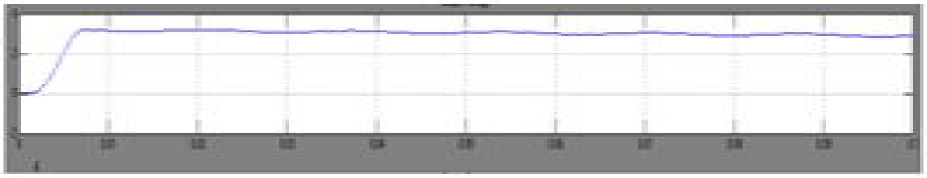


Fig.9. Input Voltage

In the fig 9, it shows the graph of time V_S input voltage.

OUTPUT VOLTAGE

Vo



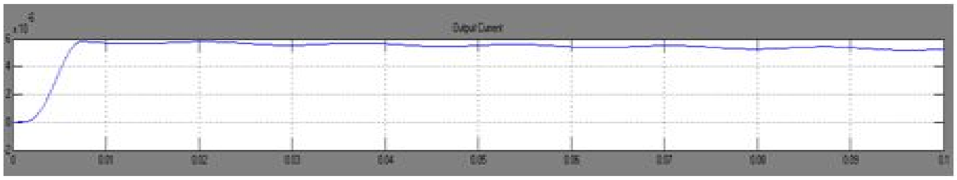
Time (sec)

Fig.10. Output Voltage

In the fig 10, it shows the graph of time V_S output voltage.

OUTPUT CURRENT

I_O



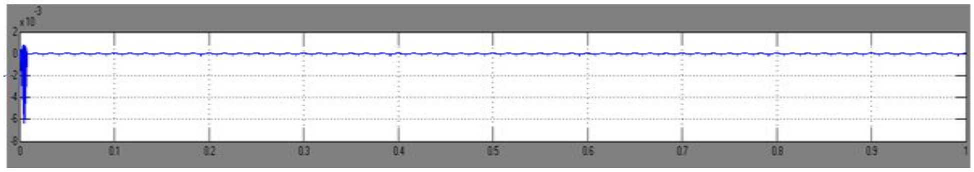
Time (sec)

Fig.11. Output Current

In the fig 11, it shows the graph of time V_S output current.

INDUCTOR CURRENT

I_L



Time(sec)

Fig.12. Inductor Current

In the fig 12, it shows the graph of time V_S inductor current.

V. CONCLUSION

A single stage ac–dc topology for low-voltage low-power energy harvesting application is proposed in this project. The ac to dc low voltage energy harvesting converter avoids the conventional bridge rectification. The proposed converter uniquely combines a boost converter and a buck-boost converter to control the positive input cycles and negative input cycles, respectively. Only one inductor and one filter capacitor are required in this topology. The converters are operated in DCM to reduce the switching losses and for simple control. The low-voltage bridgeless rectifiers, this employs the minimum number of passive energy storage components, and achieves the maximum conversion efficiency. The converter is operated to step up the low ac voltage to a high dc voltage.

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