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An Efficient AC-DC Step-Up Converter for Low-Voltage Piezoelectric Micro Power Genrator Energy Harvesting

K.S.S. Prasad

Electrical and Electronics Engineering,
Bharath University, India

Abstract: This project presents an efficient ac to-dc power converter that avoids the bridge rectification and directly converts the low ac input voltage to the required high dc output voltage at a higher efficiency. The proposed converter consists of a sepic converter and a cuk converter, which are operated in the positive half cycle and negative half cycle, respectively. Based on the control schemes are proposed to operate the converter. Simulation results are presented to validate the proposed converter topology and control schemes.

Key words: Project presents an efficient · Input voltage to the required · Half cycle and negative

INTRODUCTION

Many types of micro generators, used in the self-powered devices, are reported in the literature for harvesting different forms of ambient energies. The inertial micro generators, which harvest mechanical energy from the ambient vibrations, are currently the focus of many research groups. The power level of the inertial micro generators is normally very low, ranging from few microwatts to tens of mille watts. Based on the energy conversion principle, the inertial micro generators can be classified mainly into three types: electromagnetic, piezoelectric and electrostatic. Among them, the piezoelectric micro generators have the highest energy density [1]. The output voltage of a piezoelectric Micro generator is ac type, but the electronic loads require dc voltage for their operation. Therefore, the ac voltage of the piezoelectric micro generator output has to be processed by a suitable power converter to produce the required dc voltage for the load [2].

In these converters, bridge rectification is avoided and the micro generator power is processed only in a single-stage boost-type power converter. A dual-polarity boost converter topology for direct ac-to-dc power converter. In this converter, the output dc bus is split into two series connected capacitors and each of these capacitors is charged only for one half cycle of the micro generator output voltage [3].

Extremely large capacitors will be required to achieve acceptable voltage ripple at the output dc bus. This is not practical due to the size limitations of the micro generators [4].

A direct ac-to-dc converter is conventional converter, consists of a boost converter (inductor L_1, switch S_1 and diode, D_1) in parallel with a buck-boost converter (inductor L_2, switch S_2, and diode D_2). In this converter, the negative output to input voltage gain of a buck-boost converter is utilized to step-up the negative half input voltage of the micro generator to a positive high-dc output voltage. The output dc bus is realized by using a single capacitor. The output capacitor is charged by the boost converter in the 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 [5].

Piezo Electric Micro Power Generator: It is the inherent property of piezo electric material to produce an electrical potential, high voltage-low current, when put under strain, either deflection or compression. Used both micro-fibre composite (MFC) and traditional ceramic types. Some advantages of Piezo electric elements are

- Voltages of 2-10 V are obtained
- High energy density
- No separate external energy source needed

Corresponding Author: K.S.S. Prasad, Electrical and Electronics Engineering, Bharath University, India.

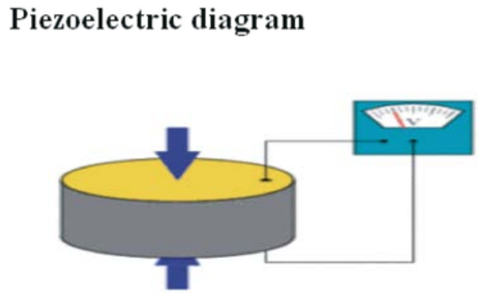

Fig.1(a): Piezoelectric diagram

- Compatible with Micro fabrication and Micro Power Generator

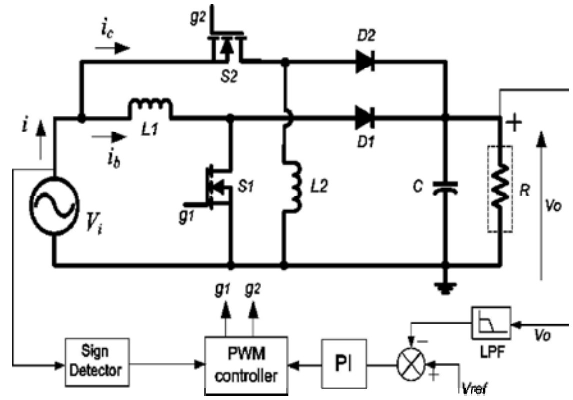

Fig. 2(a): Conventional circuit diagram

A piezoelectric disk generates a voltage when deformed (change in shape is greatly exaggerated. confirmed the existence of the converse effect and went on to obtain quantitative proof of the complete reversibility of electro-elasto-mechanical deformations in piezoelectric crystals. For the next few decades, piezoelectricity remained something of a laboratory curiosity. More work was done to explore and define the crystal structures that exhibited piezoelectricity [6].

The increasing numbers of independent mini a true electronic devices and their need for sufficient, reliable power supply make micro energy harvesting more appealing. While micro and macro energy harvesting are similar in principle, their scope and applications are fundamentally different. In the last decade, energy scavenger shave been utilized by a vast number of applications, including embedded and implanted sensor nodes for medical applications, distributed wireless sensor nodes for structural health monitoring, battery recharging, monitoring tire pressure in automobiles, powering unmanned vehicles and running security systems in household conditions. This trend has driven the development and advancement in energy harvesting materials and integration.

Human motion, low-frequency seismic vibrations and acoustic noise are some of the sources which can be exploited to harvest energy. There are three major energy transduction mechanisms to harvest energy, namely electrostatic, electromagnetic and piezoelectric approaches. Electrostatic (capacitive) energy harvesting is based on the phenomenon of changing capacitance of vibration-dependent varactors (variable capacitors). The initially charged varactors are separated by vibrations, there by transuding the mechanical energy into electrical energy. Vibrations are also transuded into electrical energy by electro-magnetic induction. A magnet induces current in a coil as it moves and magnetic field lines cross the coil. Piezo electric energy harvesting operates using the direct piezoelectric effect that converts mechanical strain into electrical current [7].

Conventional Circuit Diagram: A direct ac-to-dc converter is shown figure 2(a). The converter consists of a boost converter (inductor $L1$, switch $S1$ and diode, $D1$) in parallel with a buck-boost converter (inductor $L2$, switch $S2$ and diode $D2$).

In this converter, the negative output to input voltage gain of a buck-boost converter is utilized to step-up the negative half input voltage of the micro generator to a positive high-dc output voltage. The output dc bus is realized by using a single capacitor. The output capacitor is charged by the boost converter in the 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 [8].

It can be noted that to achieve the boost operation, the lower switches, ($S1$ and $S2$) of these two converters should be able to conduct in both the directions. In this case, without increasing the number of devices, the bidirectional conduction capability of the two MOSFETs ($S1$ and $S2$) can be used to achieve the boost operation. The control gate pulses for these two switches [9].

It can be seen that during the positive half cycle of the input voltage, $S2$ is kept ON for the entire half cycle and the gate pulse to $S1$ is controlled to achieve the boost operation. Likewise, in the negative half cycle, $S1$ is kept ON for the entire half cycle and $S2$ is controlled. To achieve the boost operation, these two topologies use single inductor compared to the two inductors used in the proposed converter in this study.

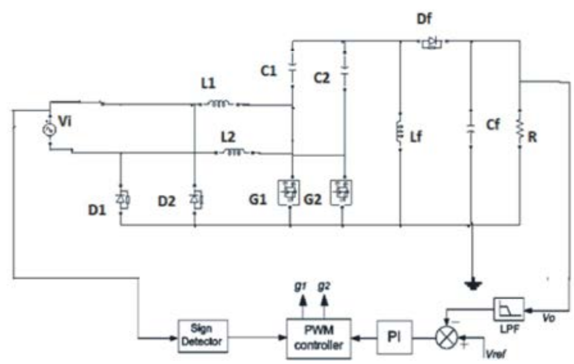

Fig. 3(a): Proposed ac-dc converter

However, there are several disadvantages in these converters. First, in these converters, there are two devices in the conduction path during charge or discharge of the boost inductor. In the converter, only a single device conducts during the charge or discharge of the inductors.

Proposed Circuit Diagram: When a buck-boost interleaved converter circuit are shown as in fig3(a).

The proposed converter, as shown in Fig.3(a) consists of a buck-boost interleaved converter (inductor *L*1, L2,Lf switch *S*1,S2 and diode, *D*1,D2,Df). In this converter, the negative output to input voltage gain of a buck-boost converter is utilized to step-up the negative half input voltage of the micro generator to a positive high-dc output voltage. The output dc bus is realized by using a single capacitor. The output capacitor is charged by the boost converter in the 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.

The converter operation can be divided mainly in four modes.Mode-1 and Mode-2 are for the buck-boost interleaved converter operation during the positive half cycle of input voltage.Under Mode-1 the Buck-boost switch S1 is ON and the current in the L1 inductor is builds.During Mode-2 the switch is turned OFF and the capacitor C1 is charged inductance L1 is discharged.The other two modes:Mode-3 and Mode-4 are for the Buck-boost interleaved converter operation during the negative half cycle of the input voltage..Under Mode-3 buck-boost switch S2 is ON and the current in the L2 inductor is builds. During Mode-4,buck-boost interleaved switch S2is turned OFF and the stored energy of inducctor L2 is discharged and capacitor C2 is charged.Buck-boost interleaved converter operating in the positive half cycle this known as sepic converter, The same converter is operating in negative half cycle is known as cuk converter. First, in these converters, there are two devices in the conduction path during charge or discharge of the Buck-boost inductor. In the proposed converter, only a single device conducts during the charge or discharge of the inductors.

In the converter, proposed in this paper, any MOSFET is operated only for a half cycle of the input ac voltage.

RESULTS AND DICUSSIONS

Boost and Buck-Boost Converter: When an AC input to the boost converter has an 0.4 V and this boost converter has to step-up the AC input voltage 4 V for an high power application. They simulation circuit for boost and buck-boost converter are shown in fig 4(a).

Input Voltage: When an AC input to this boost converter has an 0.4V are shown in fig. 4(b)

Output Voltage and Current: When an output voltage and current of boost and buck-boost is 4V are shown in fig.4(c).

Sepic Converter: When an simulation circuit of buck-boost interleaved converter is operated in the positive half cycle the converter is known sepic converter are shown in fig.4(d)

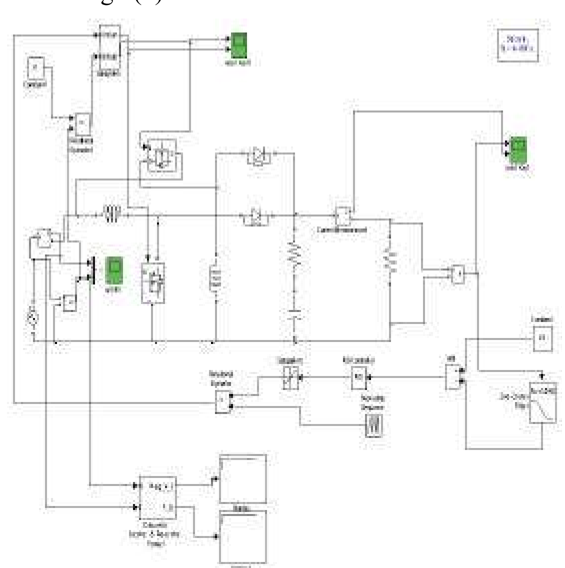

Fig. 4(a): Simulation circuit for boost and buck-boost converter

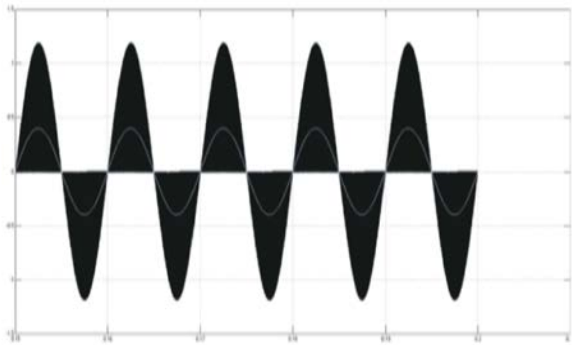

Fig. 4(b): Simulation of input voltage

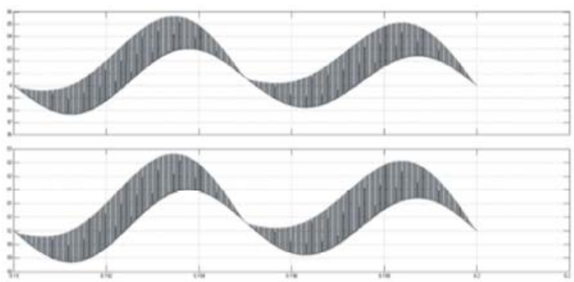

Fig. 4(c): Simulation of output voltage and current

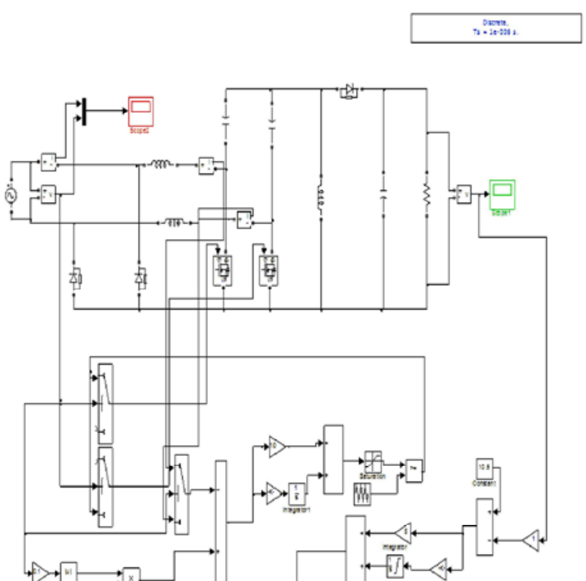

Fig.4(d) simulation circuit of sepic converter.

Input Voltage: When an AC input to buck-boost interleaved circuit has an 4V are shown as in fig.4(e).

Output Voltage: When an DC output voltage is 10V in positive voltage are shown in fig.4(f).

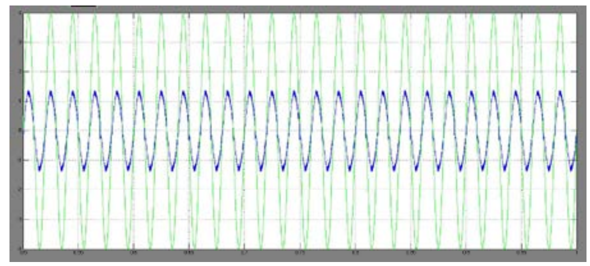

Fig. 4(e): Input voltage.

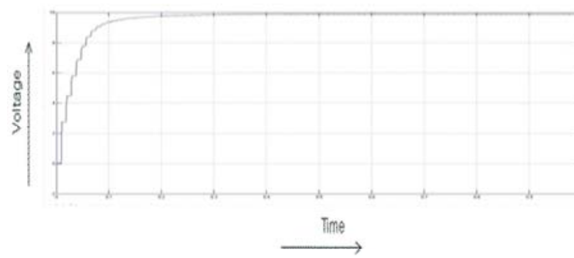

Fig. 4(f): Output voltage.

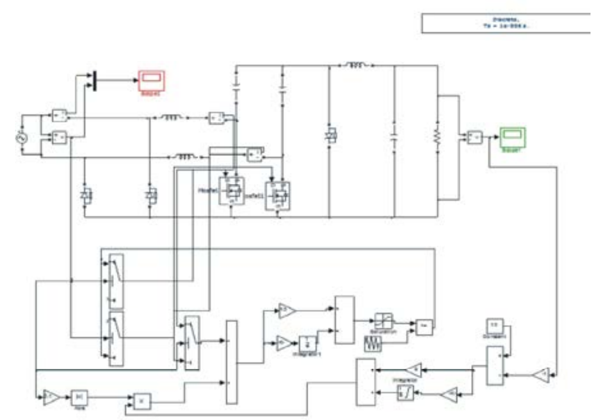

Fig. 4(g): Simulation circuit of cuk converter.

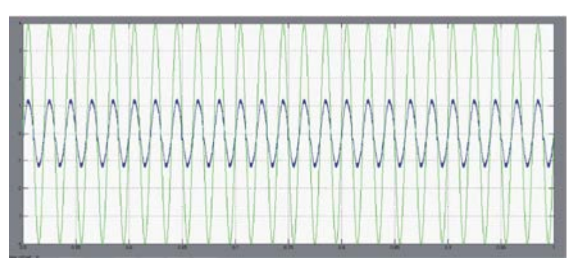

Fig. 4(h): Input voltage.

Fig. 4(i): Output voltage.

Buck-Boost Interleaved Converter: When an simulation circuit of buck-boost interleaved converter operated in the negative half cycle is known as cuk converter are shown in fig.4(g).

Input Voltage: When an AC input to buck-boost interleaved circuit has an 4V are shown as in fig.4(h).

Output Voltage: When an DC output voltage is 10V in negative voltage are shown in fig.4(i).

CONCLUSION

Thus, the Input signal is 4V, which is interleaved that is parallelizing this input voltage. For the purpose of cuk and sepic operation. When an normal buck-boost is used for an DC-DC converter (or) AC-AC converter and this, project is AC-DC converter, we can step-up this output voltage. The direct ac-to-dc low voltage piezo electric micro generator energy-harvesting converter avoids the conventional bridge rectification and achieves higher efficiency. The proposed converter consists of a cuk and sepic converter. The negative gain of the cuk converter is utilized to boost the voltage of the negative half cycle of the micro generator to positive dc voltage.A simplified control scheme is proposed for high-voltage step-up application.

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