AN EFFICIENT AC-DC STEP UP CONVERTER FOR LOW ENERGY HARVESTING

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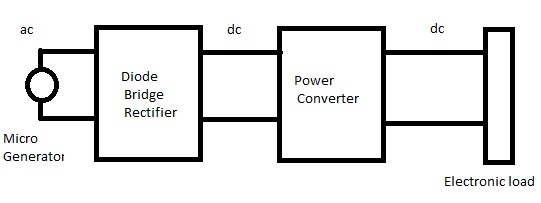
Abstract:

INTRODUCTION:

Self powered devices harvest the ambient energies by micro generators and can perform their operations without any continuous external power supply. 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 micro watts to tens of milli 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 electromagnetic micro generators have the

highest energy density. In this project the electromagnetic micro generators are considered.

The electromagnetic generators are typically spring–mass-damper–based resonance systems in which the small amplitude ambient mechanical vibrations are amplified into large amplitude translational movements and the mechanical energy of the motion is converted to electrical energy by electromagnetic coupling. The output voltage of an electromagnetic generator is ac type, but the electro loads require dc voltage for their operation. Therefore, the ac voltage of the electromagnetic micro generator output has to be proposed by a suitable power converter to produce the required dc voltage for the load.



**Fig:1.1** Conventional two stage conversion consisting diode bridge rectifier

One of the challenges with the electromagnetic generators is that due to the practical size limitations the output voltage level of the generators is very low (few hundreds of milli volts), whereas the electronic loads require much higher dc voltage (3.3 V). The conventional power converters reported for energy harvesting mostly consist of two stages: a diode bridge rectifier and a standard buck or boost ac-to-dc converter is shown in fig.1.1. However, there are major disadvantages in using the two-stage power converters to condition the outputs of the electromagnetic micro generators. First, for very low voltage electromagnetic micro generators rectification is not feasible by the use of conventional diodes. Second, if the diode bridge rectification is feasible, the forward voltage drops in the diodes will cause a large amount of losses and make the power conversion very inefficient. To address the problems of the conventional two-stage convertors, direct ac-to-dc converters are proposed. In these convertors bridge rectification is avoided and the micro generator power is processed only in a single stage boost type power converter is shown in fig1.2. A dual-polarity boost converter topology for direct ac-to-dc power converter is reported. 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. As the time periods of the resonance-based micro generators output voltages are normally in the order of milliseconds, very large voltage drops will occur in the capacitors during the half cycles when they are not charged by the converter. Extremely large capacitors will be required to achieve acceptable voltage ripple at the output dc terminals. This is not practical due to the size limitations of the micro generators.

Micro Generator ac

Buck converter

Electronic Load

Buck Boost Converter

Electronic Load

**Fig 1.2 direct ac to dc power conversion**

**1.2 PRINCIPLE OF OPERATION:**

The proposed converter as shown in figure 1.3, 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 of the micro generator to a positive high – dc output voltage.

Voltage1

v

+

-

Voltage Measurement

Voltage

voltage

To Workspace4

power

To Workspace3

current

To Workspace2

t

To Workspace1

G1

G2

Subsystem2

L1

L2

c

R

Product

g

m

C

E

S2

g

m

C

E

S1

D1`

D2

i

+

-

Current Measurement1

i

+

-

Current Measurement

Current

0

Clock

Vi



Fig1.3 proposed direct ac-to-dc converter

The output dc bus is realized by using a single capacitor. The output capacitor is the 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, it should be noted that to achieve the boost operation, the lower switches (S1and 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 IGBT’s ( IGBT1 & IGBT2) (S1 and S2) can achieve the boost operation The control gate pulses for these two switches are shown in fig. (1.3) 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 the 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 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.

However, there are several disadvantages in these two devices in the conduction path during the charge or discharge of the boost inductor in the proposed converter, only a single device conducts during the charge or discharge of the conductors. In the converter , proposed in this paper , any IGBT is operated only for a half cycle of the input ac voltage, whereas, in H-bridge – type converter, the IGBTs, used for the boost operation (S1 and S2) are operated for the entire cycle of the input ac voltage . Therefore, the device conduction looses in the proposed converter are reduced by more than a factor or two.

In energy harvesting applications, as the power level is very low, these losses are significant compared to the total output power. Second, as the IGBT’s are designed for forward conduction, in the reverse conduction mode they offer higher ON- State Resistance. This further increases the conduction losses in the H-bridge topologies. Third, the input voltage polarity has to be sensed to control S1 and S2, but in the H-bridge topologies, the input voltage source is floating with respect to the output voltage ground. Therefore, the implementation of the control circuit is difficult. This can be easily implemented in the proposed converter. Furthermore, it can be mentioned that although the proposed converter uses two inductors (L1 and L2), they do not operate in the same half cycle. Therefore the total losses are almost equal to the losses of the single inductor used in the H-bridge converters.

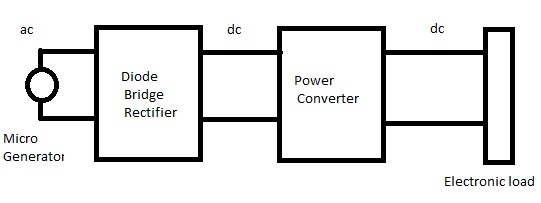
In this project, detailed analysis of the proposed converter is presented. Closed form relations are derived between the input power, the input frequency, the duty cycle, and various circuit parameters of the converter. Based on this analysis, appropriate control schemes are proposed to operate the converter. For high voltage step-up application, a simplified control strategy is presented that uses equal inductors for both converters. Design guidelines are presented to select the components of the converter. A converter is designed based on the analysis. In a practical energy-harvesting scenario, the controller and the IGBT driver circuit of the converter are required to be self starting and they should be s powered by the energy harvesting system.

In this project an auxiliary self-starting power circuit is proposed for powering the controller and the IGBT drivers. The operations and the implementations of the control scheme and the self-starting circuits are present in detail. Simulations are carried out for the verification of the design, the proposed control schemes, and the proposed self-starting circuit. A prototype of the converter is build and detailed experimental results are presented for the validation. Finally, a comprehensive loss analysis of the converter is carried out and the converter performances are presented.

**Table:1 Circuit components of the converter**

|  |  |  |
| --- | --- | --- |
| **Circuit Components** | **Name** | **Ratings** |
| Inductor | L1, L2 | 4.7uH |
| Inductor resistance | RL | 30mΩ |
| IGBT | S1,S2 | 20V, 2A |
| Schottky diode | D1,D2 | 23V, 1A |
| Schottky diode forward voltage | Vf | 0.23V |
| Load resistance | RL | 200Ω |
| Capacitor | C | 68uF |

**1.3 Block Diagrams:**

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**Fig:1.4** Conventional two stage conversion consisting diode bridge rectifier

Electronic Load

Boost converter

Micro Generator ac

Buck Converter

**Fig 1.5 direct ac to dc power conversion**

**CHAPTER- 2**

**2. DIRECT AC-TO-DC CONVERTER**

**2.1 INTRODUCTION**:

The design aspects of the micro generator comprises spring, coil and rear earth magnet have been addressed. The theoretical analyses of the electromagnetic micro generator are established. Firstly, steady state analysis has been undertaken to determine the practical performance of the device. It is found that the generator will produce more power in applications with high frequency of vibration. Secondly, electromagnetic analysis is established to calculate the generated power on the load. It is found that the output power

Can be maximized when the impedance of the coil is less than the load impedance and when using a magnet with high magnetic field.

Mechanical parameters like (damping factor, resonant frequency, proof mass and maximum displacement) and magnetic parameters like (load resistance, coil resistance, and the magnetic field) have been adjusted to optimize the output power through a comprehensive theoretical study.