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# Low Voltage Energy Harvesting With CukAnd Buck Boost Converter

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**Abstract**:-The conventional two-stage power converters with bridge rectifiers are inefficient and may not be practical for the low-voltage micro-generators. This paper 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. A cuk circuit and a buck boost circuit are connected parallel to an AC input voltage. During positive half cycle cuk circuit is working and during negative half cycle buck boost circuit is working. When an input of 400mV is given a regulated dc output of 3.5V is obtained from a dc bus having a single capacitor charged by both the circuits. The results are verified by MATLAB Simulink model. Voltage and current waveforms are presented to validate the proposed converter topology and control schemes.

**Keywords:-**micro-generator,cukconverter,buck boost converter,energy, rectification.

## I. INTRODUCTION

Reduced power requirements of the analog and digital circuits have led to the development of self-powered devices. These devices harvest energy from the ambient and convert it into usable electric power by using micro-generators. Various types of energy harvesting micro-generators and their associated power electronic circuits are reported in the literature [1]-[8]. Among these micro-generators, the inertial micro-generators, which harvest energy from the vibrations or the motions of the ambient, are currently the focus of many research groups [2]-[6], [8]-[13].

The power level of inertial micro-generators is normally very low, ranging from few micro-watts to tens of milliwatts. Such micro-generators typically have an ac voltage. However, the loads require steady dc bus for their operation. Hence, power electronic converters are used to condition the outputs of the micro-generators and to provide the required dc bus to the loads.

Inertial micro-generators can be classified into three types based on the nature of the damping forces: electromagnetic, piezoelectric, and electrostatic [5]-[10], [12]-[16]. Due to the practical size limitations, the output voltages of the inertial micro generators are very low; typically about few hundred millivolts. However, the dc-bus voltages required for the loads are much higher (for example 3.3 V). Hence, boost type power converters with high input-to-output step-up ratio are needed as the interface between the micro-generators and the loads. It should be noted that the damping force in a micro-generator can be controlled by changing the load resistance connected to its coil.

The conventional power converters, reported for energy harvesting, mostly consist of two stages: a diode bridge rectifier and a standard buck or boost dc-to-dc converter **(*Fig 1*).**

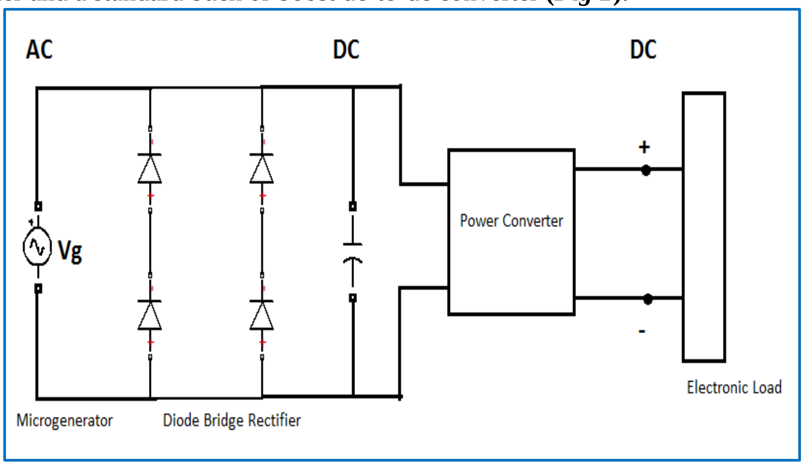



**Fig.1 conventional two stage converter**

However, there are major disadvantages in using the conventional two-stage power converters to condition the outputs of the micro-generators. Firstly, for very low voltage micro-generators, the output voltage can be so small that its rectification will not be feasible by the use of conventional diodes. Secondly, if 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. New direct ac-to-dc power converter topologies without conventional diode bridge rectifiers but with input current control capability, could offer good solutions to address the problems of the conventional two-stage power converters.

In this paper, analysis of the proposed converter is presentedappropriate control schemes are proposed to operate the converter for high voltage step-up application. The operations and the implementations of the control scheme are presented in detail. Simulations are carried out in MATLAB Simulink for the verification of the design

## II. PROPOPSED DIRECT AC-TO-DC CONVERTER:

**Basic Principle of the proposed converter:**

An ac-to-dc converter is proposed in this paper which is highly efficient than conventional method for converting directly ac to a regulated boosted dc. *Fig.2* explains the basic principle of the proposed converter.

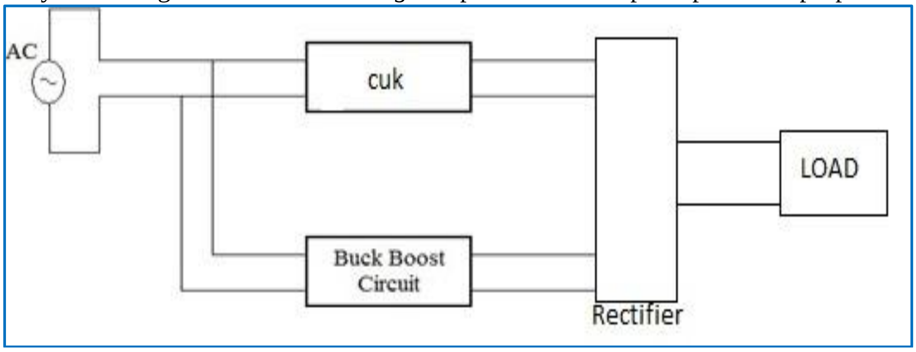



**Fig.2 proposed converter**

A Cuk circuit and a Buck Boost circuit are connected parallel to an AC input voltage. During positive half cycle cuk circuit is working and during negative half cycle buck boost circuit is working.Since both the circuits have negative gain a full controlled rectifier is provided. The regulated dc output is obtained from a dc bus having a single capacitor charged by both the circuits. Since the rectifier is transferred from input side to output side the drop in voltage caused by the thyristor switches is negligible because it is placed after boosting the voltage.The proposed converter converts 400mV ac voltage into 3.5V dc.

## III. REALIZATION OF PROPOSED CONVERTER

The proposed converter, as shown in *Fig. 3*, consists of a cuk converter (inductor L1,inductor L2,capacitor C1 , switch S1 , and diode, D1 ) in parallel with a buck–boost converter (inductor L3 , 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 cuk converter in the positive half cycle and by the buck–boost converter in the negative half cycle with the help of a full controlled rectifier.

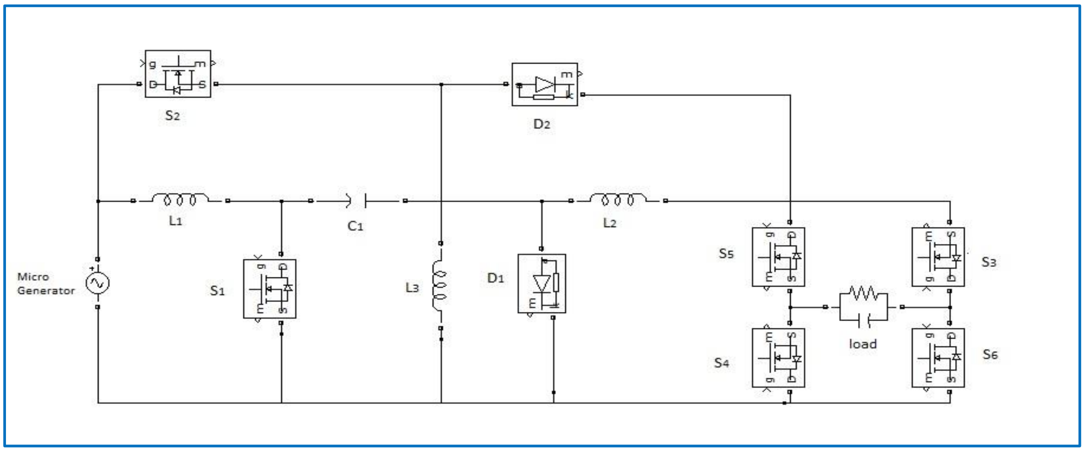



**Fig 3 circuit diagram of proposed converter**

During positive half cycle cuk converter operates and an important advantage of this topology is a continuous current at both the input and the output of the converter. Disadvantages of the cuk converter include a high number of reactive components and high current stresses on the switch S1, the diode D1, and the capacitor *C*1.. When the switch is *on*, the diode is *off* and the capacitor *C*1 is discharged by the inductor *L*2 current. With the switch in the *off* state, the diode conducts currents of the inductors *L*1 and *L*2 whereas capacitor *C*1 is charged by the inductor *L*1 current.

## IV. MODES OF OPERATION

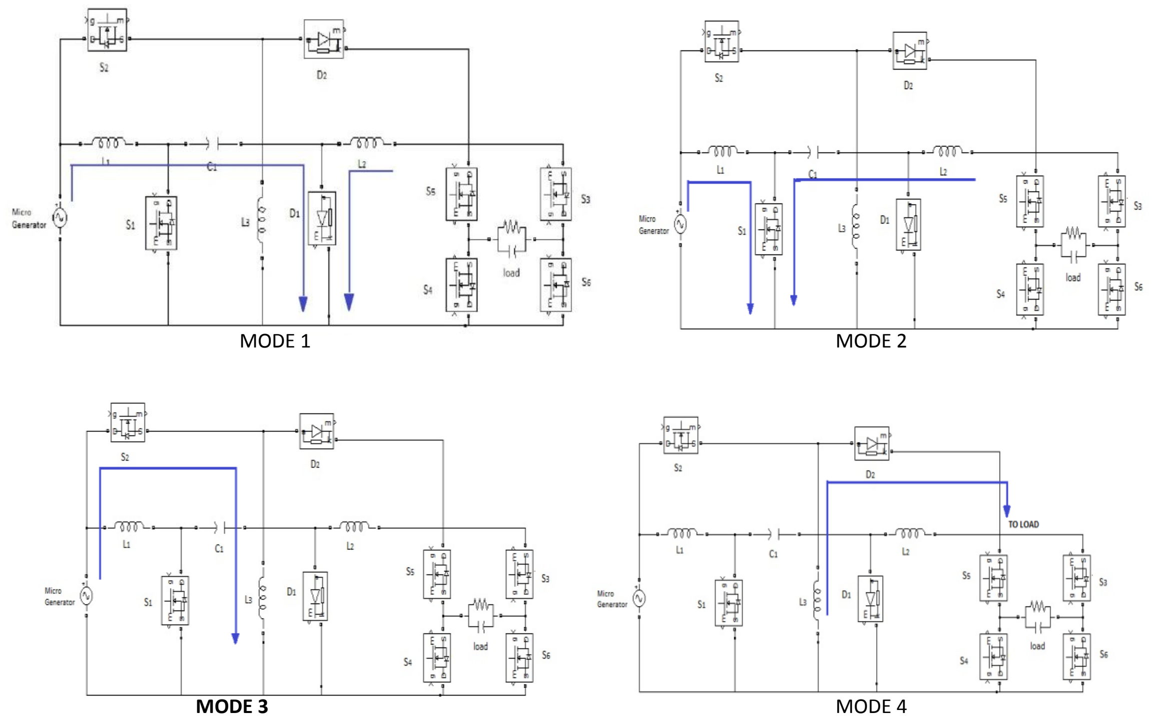



**Fig 4 modes of operation**

Mode 1 operation occurs in positive half cycle of the input sinewave .During mode 1 switch S1 is open and current flows through L1 , C1 and diode D1 and the capacitor get charged from the source and the energy stored in the inductor L2 will get discharged through diode D1.

Mode 2 operation also occurs during the positive half cycle of input sine wave. During mode 2 switch S1 is ON The current from the source flows through L1 and switch S1. During the process the capacitor, C1 discharges through the load.

Mode 3 operation occurs in negative half cycle of input sine wave. During mode 3 switch S2 is closed and the inductor L3 gets charged from the source.

Mode 4 also occurs in the negative half cycle of the input sine wave. During mode 4 switch S2 get opened and stored energy from inductor L3 get discharged through the load.

## V. SIMULATION MODEL

The proposed direct ac to boost dc converter circuit is simulated using corresponding SIMULINK model of the circuit in MATLAB. Both open loop and closed loop operation of the circuit is modeled and simulated. The simulation is done for obtaining a dc output voltage, $V_o$=3.5V from a sinusoidal input voltage of peak, $V_p$=400mV and frequency 100Hz.

A resonance-based electromagnetic micro-generator, producing 400 mV peak sinusoidal output voltage, with 100-Hz frequency is considered in this study for verification of the proposedconverter topology .The micro-generator is designed as an 400mv ac voltage source .Circuit parameters used for the simulation model are L1=200µH,L2=200µH,L3=4.8µH,C1=.43µF.

For closed loop operation the Simulink model of cuk-buck boost converteris created as follows

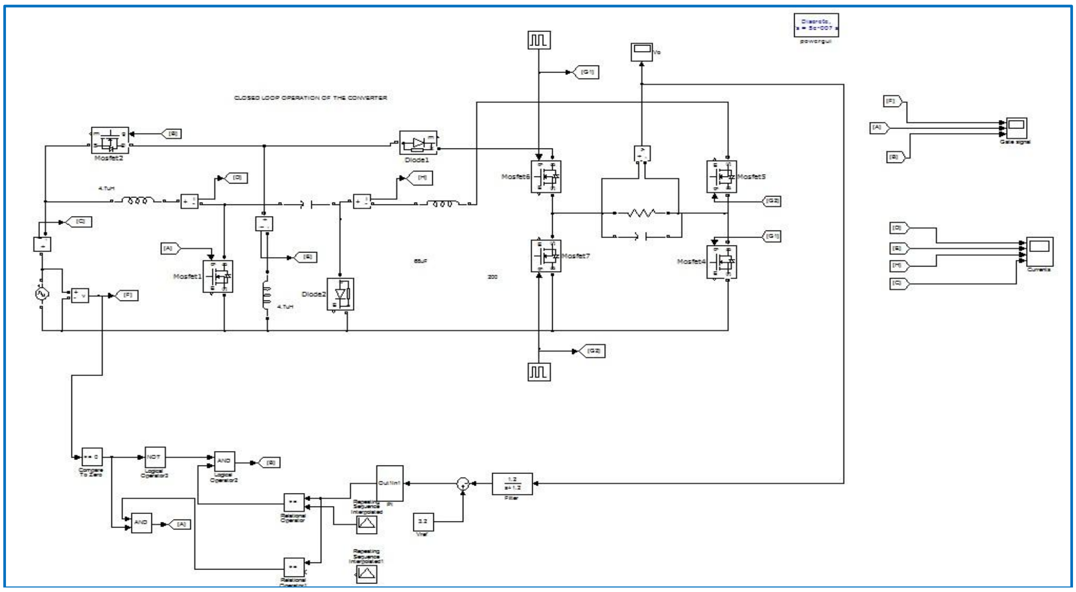


**Fig 5 simulation circuit**

## VI. SIMULATION RESULTS

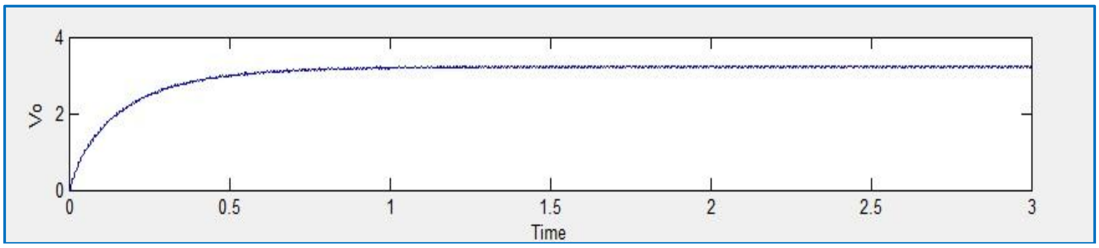
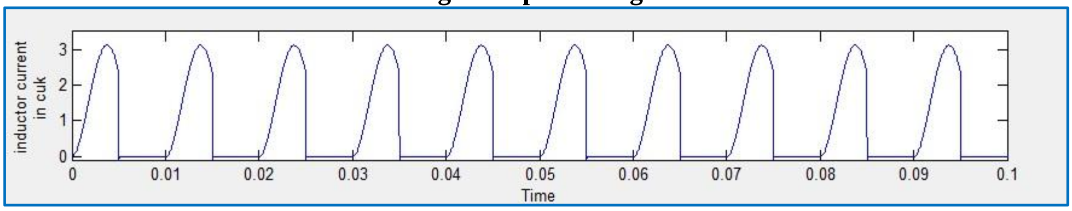
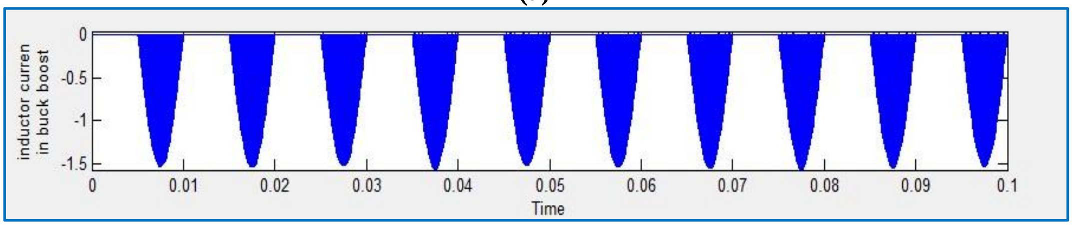


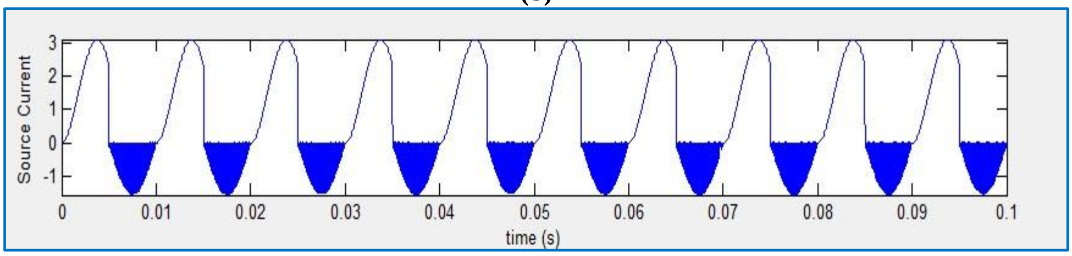

**Fig 6 Output Voltage**




**(a)**




**(b)**




**(c)**

**Fig 7 : (a) Current Through Inductor L1 in cuk converter (b) Current Through Inductor L2 in buck boost converter (c) Source Current**

Advantages obtained with the cuk converter is that both the input current and the current feeding the output stage is having reduced ripple content and this has reduced external filtering requirements..

## VII. CONCLUSION

In this paper, a novel efficient direct ac-to-dc boost converter is proposed.The presented direct ac-to-dc low voltage energy-harvesting converter avoids the conventional bridge rectification and achieves higher efficiency.The proposed converter consists of a cuk converter in parallel with a buck–boost converter. An output of 3.5V was obtained from 400mV ac source. The converter input and output current was having reduced ripple current due to cuk converter and it reduced the external filter requirements.

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