International Journal of Electrical and Electronic Engineering & Telecommunications

ISSN 2319 – 2518 www.ijeetc.com
Special Issue, Vol. 1, No. 1, March 2015
National Level Technical Conference P&E- BiDD-2015

Research Paper

HIGH EFFICIENT SINGE STAGE BRIDGELESS STEP-UP CONVERTER FOR LOW VOLTAGE APPLICATIONS

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A high efficient single stage step up converter is proposed to work as bridgeless circuit for energy harvesting applications. Bridgeless step up converter is an arrangement of boost and buck-boost converter. The proposed topology avoids the complexity of bridge rectifier and efficiently step up the input voltage, reduces the losses and shares the same inductor and capacitor for the operation of both boost as well as buck-boost converter and reduces the size of the converter. The Low AC input voltage of 0.4 v is rectified and boosted to dc output voltage of 3.3 v satisfactorily and the results are achieved with the help of MATLAB software using simulink.

Keywords: Bridgeless, Single stage, Energy harvesting, Low voltage rectification

INTRODUCTION

The present world is suffering from scarcity of Power. Power Electronic converter are the key interface in energy harvesting system. Energy Harvesting is the process of electronically capturing and accumulating energy from a variety of energy sources or otherwise said to be unusable for any practical purpose. Energy harvesting sources include mechanical energy available from vibration, stress and strain, and other energy sources like biological, solar energy from all forms of light sources, electromagnetic energy that are captured via inductors, coils and capacitors. The devices such as sensors are typically used to convert unused energy sources and sunlight into electrical voltages and currents, which can then be harvested, stored and conditioned for many low voltage wearable electronics and wireless sensor applications therefore require AC power supplies or batteries.

Examples of Energy generators include materials such as, piezoelectric (PZT) crystals or fibre composites, solar photovoltaic cells, thermoelectric generators (TEGs), and electromagnetic inductor coils, etc. In most

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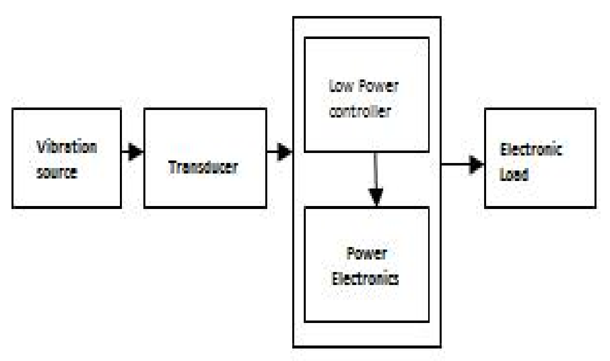
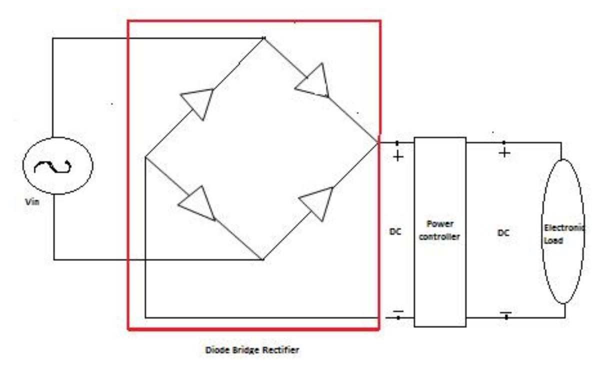
cases, these sources provide energy as spurious, random and otherwise irregular energy spikes or very low level amounts to allow adequate energy capture and technologies did not exist to capture this energy with great efficiency. The Proper Management of capturing and storing Low value of electrical energy charges can be achieved by Power electronic Converter and required high energy efficiency harvesting electronics. The Figure 1 shows the Low Voltage energy harvesting system. Where the energy source available from Light or vibration or any other source is considered and is converted to AC by Transducer of lower magnitude level. Further it is converted to dc and stepped up to an adequate voltage level by power electronic converters to supply the low level Loads. Thus power electronic converters forms the interface between Transducer and electronic Loads

Figure 1: Low Level Energy Harvesting System



Since the AC power generated is in the order of few milli volts and the electronic load needs a dc supply of the order of a few volts, hence there are two stages involved in this conversion process. They are rectification and boosting processes. So the conventional power converters subjected for energy harvesting circuits consist of a diode bridge rectifier is. and a dc/dc converter for stepping up the voltage shown in the below Figure 2.

Figure 2: Block Diagram of Conventional Power Converters



Diode bridge rectifier has several disadvantages as such

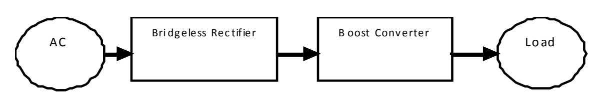
1. Due to increasing number of diodes losses also increases.
2. Input current increases more than the output current, as the diode losses are increased.
3. Energy harvesting becomes difficult as the rectifier offers non-linear load.

To overcome the disadvantage of Conventional two stage bridge rectifier, a new topology is proposed through a bridgeless step up converter, which is a unique combination of boost and buck-boost converter.

CIRCUIT OF NEW PROPOSED TOPOLOGY

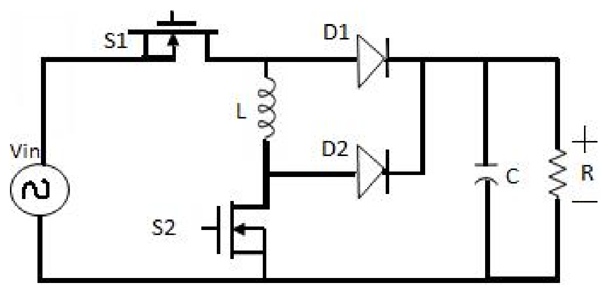
The Block diagram of Bridgeless step-up converter is shown below in Figure 3. New Topology Block diagram

Figure 3: New Topology Block Diagram



The new topology avoids the bridge rectification and the power is processed only in single stage boost power converter. The proposed single stage Bridgeless step-up converter is shown in below Figure 4. Proposed topology of Bridgeless step-up converter.

Figure 4: Proposed Topology of Bridgeless Step-Up Converter



The Bridgeless Step-up converter is unique integration of boost and buck-boost converter to condition the positive and negative half portion of the input ac voltage. Bridgeless boost rectifier makes use of two semiconductor and only one capacitor and inductor and thereby omits the rectifier. The proposed converter operate as a boost converter with S1, L and D1 which is in parallel with the buck-boost converter formed by S2, L and D2.

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 participates in negative voltage cycle as it has ability to step up the input voltage with a reverse polarity. Beside the boost and buck - boost topologies, could share the same inductor and capacitor to meet the miniature size and weight requirements. The Boost converter charges the output capacitor during positive half cycle and Buck-Boost converter charges output capacitor during negative half cycle.

When the input voltage is positive, S1 is turned ON and D1 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 S2 and reverse biasing D2.

MODES OF OPERATION

The Converter operates under DCM, and therefore reduces the switch turn ON and turn OFF losses and increases the efficiency. The DCM operating modes of the proposed boost rectifier are shown in Fig. 5. Each cycle of the input ac voltage can be divided into six operation modes. Modes I-III the converter operates as a boost circuit and illustrate the circuit operation during positive input cycle, where S1 is turned ON while D1 is reverse biased. The operation during negative input cycle is demonstrated in Modes IV-VI, where S2 is turned ON while D2 is reverse biased. In these modes, the converter operates similar to a buck-boost circuit.

Mode 1: Switch S2 is turned ON under ZCS condition to reduce switching losses. Inductor current is energised by the input voltage as both S1 and S2 are conducting. Energy is stored in output filter capacitor C.

Mode 2: Switch S2 is turned OFF. The energy stored in the inductor during mode 1 is transferred to the load. During this Mode diode D2 is turned ON so switching loss occurs

Mode 3: D2 is automatically turned OFF as soon as inductor current becomes zero. Load is energised by the energy stored Capacitor

Mode 4: During negative input cycle S1 is

Figure 5a: Operating Mode 1 Proposed Converter

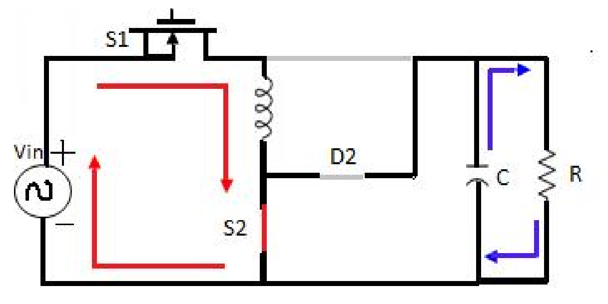


Figure 5b: Operating Mode 2 Proposed Converter

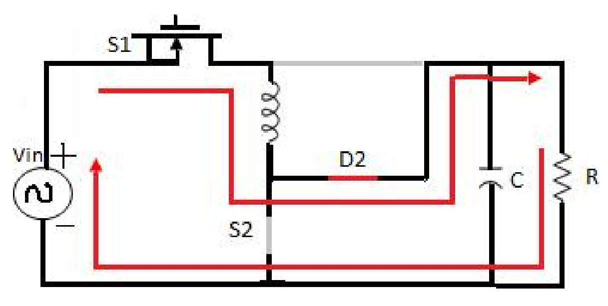


Figure 5c: Operating Mode 3 Proposed Converter

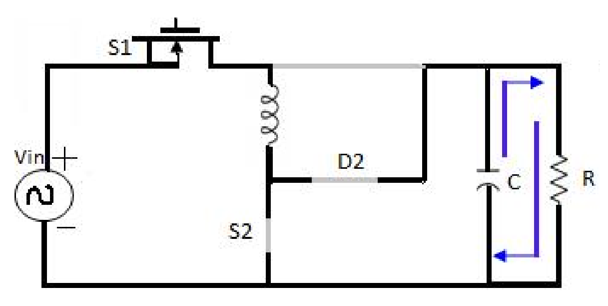


Figure 5d: Operating Mode 4 Proposed Converter

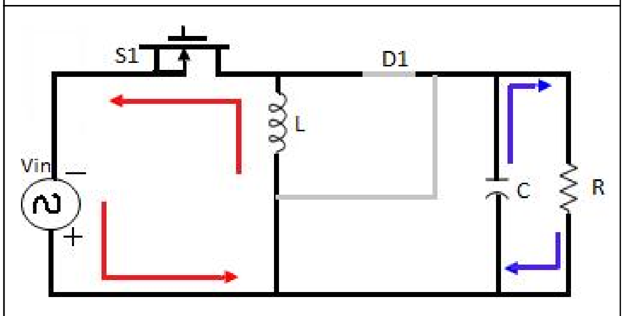


Figure 5e: Operating Mode 5 Proposed Converter

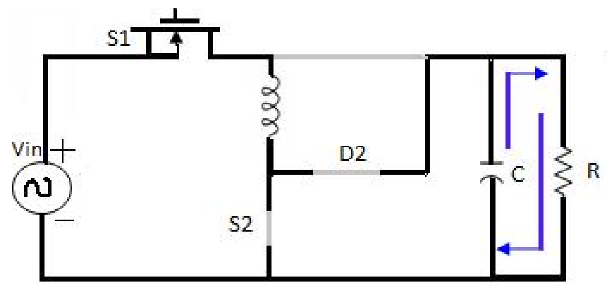
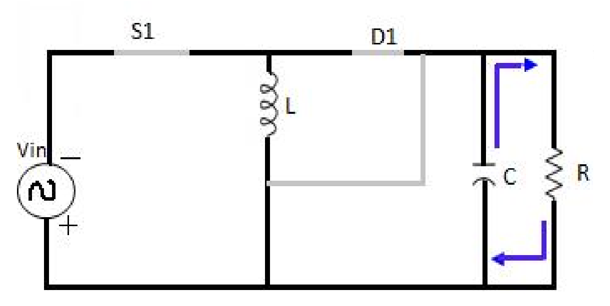


Figure 5f: Operating Mode 6 Proposed Converter



turned ON under ZCS condition. The energy is transferred to inductor L. And the Load is fed by Capacitor again.

Mode 5: S1 is turned OFF. The energy stored in inductor L during mode 4 is transferred to the load. Inductor current decreases linearly. Diode D1 is turned ON.

Mode 6: D1 is turned OFF when inductor current decreases to zero. The load is continuously powered by energy stored in the output capacitor C.

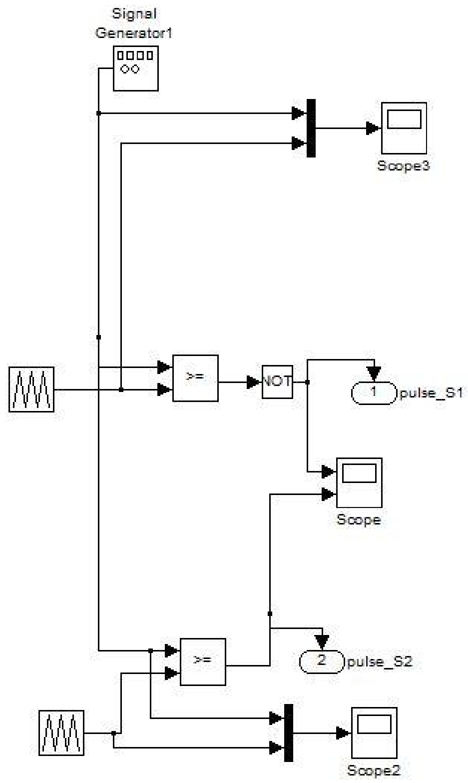
Due to the DCM operation, the input current sensor can be eliminated and switching loss can be reduced. Moreover, the control scheme of DCM operation is relatively simpler. Since the circuit size can be reduced and the efficiency can be enhanced, DCM operation is more suitable than the Continu-ous Conduction Mode (CCM) operation.

SIMULTION RESULT

The result is obtained with the MATLAB software using simulink. Simulation circuit for a bridgeless boost rectifier with input voltage 0.4 V and output voltage boosted upto 3.3 V is achieved. The Simulation model for gate signal to the switches S1 and S2 are shown in below Figure 6.

During the positive input cycle, S1 is turned ON, while S2 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 as shown below

Figure 6: Simulation Model for Gate Signal Generation



The above simulation results are achieved for closed loop circuit of bridgeless step up converter

Figure 7: Shows the Waveforms of Input Voltage, Gate Signals of both Boost and Buck-Boost Converter

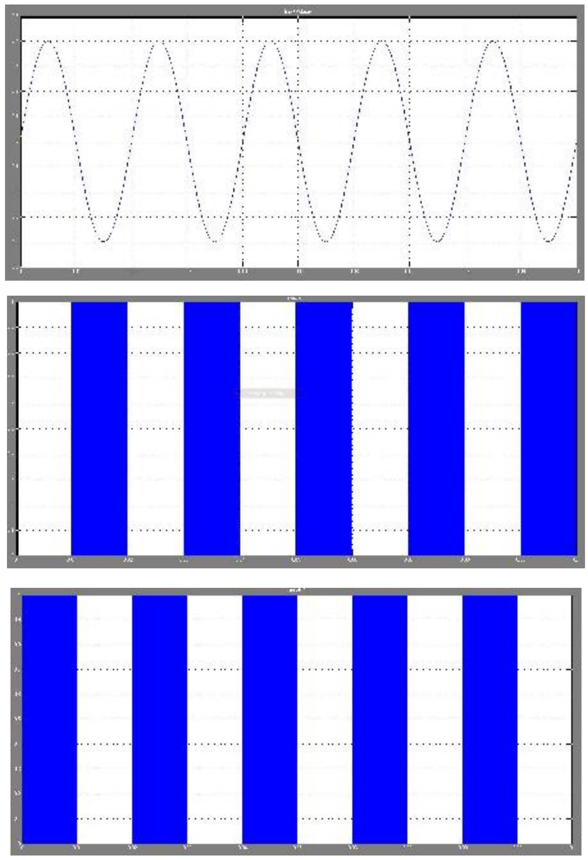
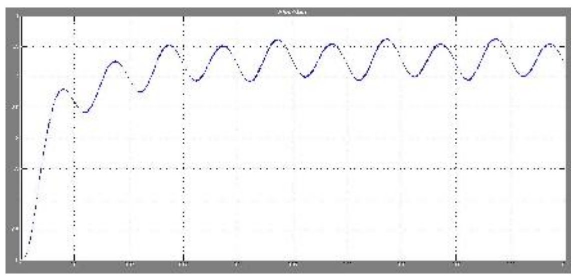


Figure 8: Shows the Output Voltage is Regulated at 3.3 v dc with Approximately 0.4 v Input Voltage



The input is considered to be a sinusoidal input voltage with a frequency of 50 Hz. The simulated output is boosted to nominal 3.3 v dc. The values chosen for L = 4.7 µH, C = 100 µF, R = 275 ohms.

Figure 10: Shows the Output Current and Inductor Current of Bridgeless Step-Up Converter

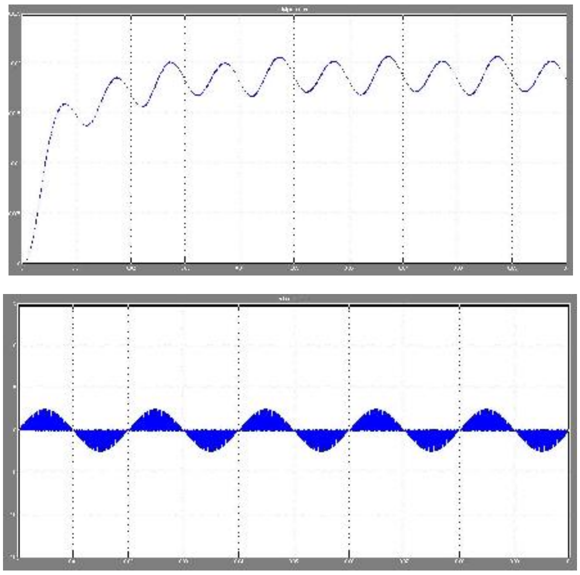
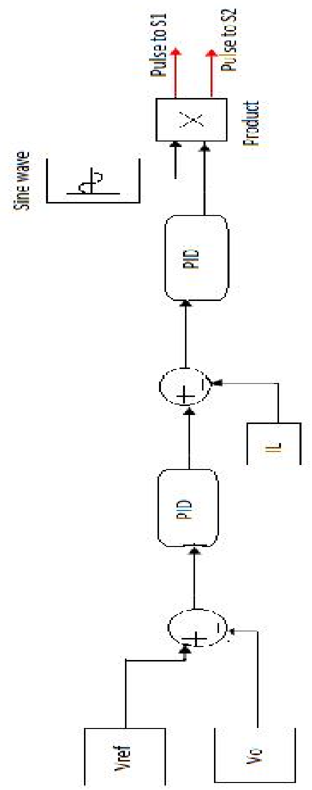


Figure 10: Control Strategy of Closed Loop



CONTROL STRATEGY

The control scheme for the proposed converter is shown in Figure 10. Here, the output voltage is being compared with the reference voltage, and the error signal is passed to the PID controller then again compared with the Inductor current and generated error signal then given to PID controller which controls the current and finally multiplied along with the sine wave and a product given as a gate signal to the boost and buck-boost respectively.

CONCLUSION

The bridgeless Step up converter is simulated using MATLAB/SIMULINK. The topology combines a boost converter and a buck-boost converter to condition the positive input cycles, respectively. Only one inductor and one filter capacitor are required in this topology. The topology successfully boosts the 0.4 v, 50 Hz ac to 3.3 v dc. The output voltage regulated to 3.3 v through closed loop control. In comparison to state-of-art bridgeless rectifiers, this study employs the minimum number of passive energy storage components, and achieves the maximum conversion efficiency. The future research will be focused on investigating and designing for much more voltage for various other applications with closed loop and the distortion in the input current can be reduced by designing a suitable circuit.

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