



Design of a Simple Boost Converter for Double Chamber Microbial Fuel Cell Application

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ABSTRACT

The main purpose of this paper is to generate eco-friendly electricity using MFC technology and then increase the same energy to a usable form for those who have not connected to a regular electricity grid. Therefore, power electronic converters are used to boost the energy from MFC because of the added advantages of their ability to store the harvested energy. These converters are diode-based which is generally used to boost the voltage, and normally these harvesters departed a lot from the poor efficiency due to diode losses. MOSFETs can be used to reduce the loss of these diodes because MOSFET has lower conduction loss; an isolated gate signal is required for the MOSFET, which tends to be floating after replacement. This paper presents harvesting energy from MFC and designing a boost converter. Design and implementation of the boost converter using MATLAB/SIMULINK. A simple boost converter has been fabricated using easily available materials to provide continuous power. Simulation and hardware results are presented to verify the functionality of the converter.

Keywords: Boost Converter, Microbial Fuel Cell (MFC)

I. INTRODUCTION

Several researchers have worked on the power electronic converter to improve the input voltage at a small range. The outline of the DC-DC converter for thermal energy sources from body heat is described. The converter, output voltage is found to be 210mV for 35mV load voltage and the generated voltage is maximum, it is 6 times higher than the load voltage with the frequency of 36GHz. This type of converter is used for energy harvesting applications in embedded electronic devices [1]. An experiment to develop a low voltage boost converter for micro generator-based energy harvest. The type of electronic converter used in the micro-generator appliances has two classifications: a diode bridge rectifier and a dc-dc converter. But the diode bridge rectifier due to its ability to generate extremely low output voltage is not used for electromagnetic micro-generators. Development of ac to dc power converter topology to get efficient and maximum energy generation from low voltage micro-generator has been discussed [2]. To get optimum and efficient energy, the author has come up with the idea of a direct AC-DC power electronic

converter topology that can harvest energy from low voltage micro-generators. This adds to increasing efficiency, lowering the unit count and size of the converters and it is important for circuit amalgamation. The performance of the system is measured by the voltage flowing in the load manufactured by a low voltage micro-generator [3]. The construction and operation of 12V/24V closed loop boost converter for solar-powered LED lighting system. This method of the converter is used for low power factor and low energy harvesting. The circuit has a closed-loop boost converter, solar photovoltaic module, and LED lighting module. The function of a closed-loop boost converter is utilized to transform a minimum level dc input voltage to a maximum level dc voltage required for the load. To get the proper output of the converter, the closed-loop voltage feedback method is used. In-circuit board, usually the boost converter, timer circuit, amplifier circuit and LED light circuits are outlined and executed. The overall efficiency of the system was 95% [4,5].

For low-power applications, KY boost converter has a high voltage conversion ratio compared to the SEPIC converter. The simulations have been performed by keeping identical input voltage for both the converters and the duty cycle of 50% and the results are taken for voltage and current ripple, also a comparison of their output voltages. Hence, KY Boost Converter can be one ideal best suited High gain converter for Renewable Applications [6]. A boost converter to obtain constant output voltage from one renewable energy source such as wave energy. The converter is outlined for the purpose to make sure that the harvested voltage of the Wave Energy Conversion System (WECS) will give a stable output voltage from a variable input voltage. Thus the model succeeds in giving the expected result capable enough to generate a stable harvested voltage from variable input voltage [7]. A DC-DC converter for photovoltaic (PV) implementations, which is a three-phase interleaved. The test results acquired from a 24V/260V, 500W prototype converter prove the converter suitability for maximum step-up voltage conversion [8]. Both low and high power application demands the use of a DC/DC converter. The two-phase interleaved converter is used to boost the output voltage to 400V with maximum efficiency of around 98%. Further using an interleaving device stress can be lowered and result in an increase in efficiency [9].

II. Design of Boost Converter

There are many available resources from which the DC input to a boost converter can be made such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos, and DC generators. Due to its output voltage being equal to or greater than its input voltage, the boost converter is different from the Buck Converter.

Here power (P) = voltage (V) x current (I),

i. Design Calculation:

$$L = \frac{V_{in} * (V_0 - V_{in})}{\Delta I * f_s * V_0} = \frac{5 * (12 - 5)}{0.042 * 10^3 * 12} = 68 \mu H$$

$$C = \frac{I_0 * D}{\Delta V * f_s} = \frac{0.4167 * 0.6}{10e-3 * 10^3} = 25 \mu F$$

$$D = \frac{V_0 - V_{in}}{V_0} = \frac{12 - 5}{12} = 60\%$$

V_{in} = Input DC voltage from MFC V_0 = Output voltage of boost converter

ΔI_l = Ripple current requirement of circuit output (0.01A for the circuit)

ΔV_o = Ripple voltage requirement of circuit output (0.1V for the circuit)

f_s = Switching frequency (1MHz is chosen from data sheet)

D = duty cycle

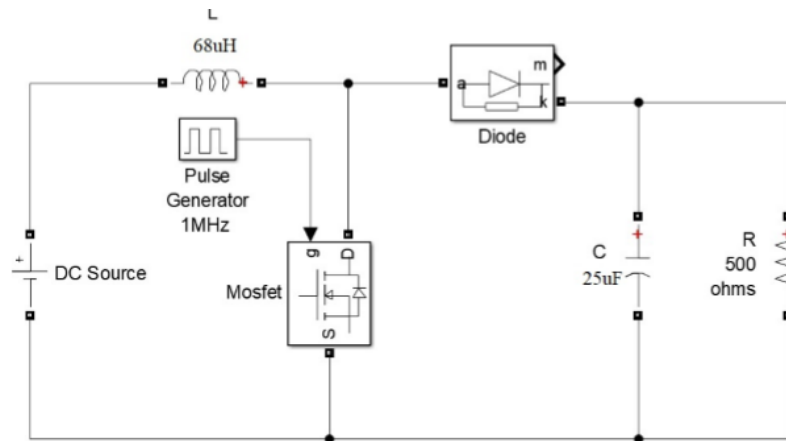


Fig-1: Simulink circuit of the boost converter

ii. Inverter circuit

An electronic device has the ability to convert DC into AC at a known voltage and frequency. For example, in our home alternative current is used to charge the appliances with a current of 230V, 50Hz, but lack AC power, the appliances can still be charged by using an inverter such as a 12V DC. Thus, the appliances can be used to charge DC; the electrical devices that work on AC. Inverters are the photovoltaic systems used for charging appliances such as isolated houses, mountain huts, camper vans, and boats, and are also used in grid-connected photovoltaic systems.

Inverters are used in many applications, from electric motors; to switch off current supply to lighting. The inverter also comes under the rectifier inverter group are charged by alternative current and are used to alter the voltage and frequency of the output alternating current in the function of the input voltage

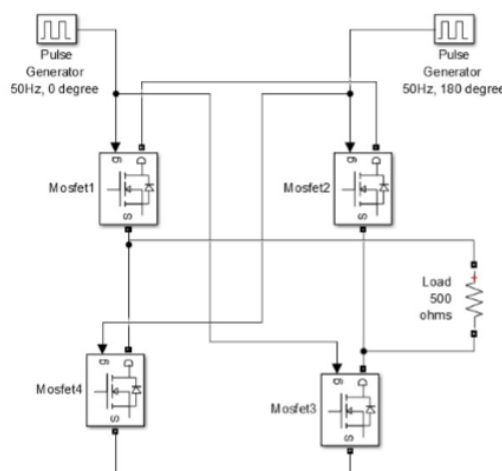


Fig-2: Single-level H- Bridge inverter with MOSFET

iii. Circuit Configurations

The circuit shown in the Fig-3 is a converter circuit for the conversion of 5V to 230V. The output which comes as a rectangular waveform is converted into a sine waveform using RC Filter. The initial step includes the conversion of 5V to 12V by an inductor in the boost circuit. The capacitor filter is used to minimize the ripple of the waveform. Then 50Hz single-level inverter is activated using a pulse width modulator and then it is converted from a 12V DC to 12V AC rectangular waveform. Then the transformer is used to convert 12V to 230V AC.

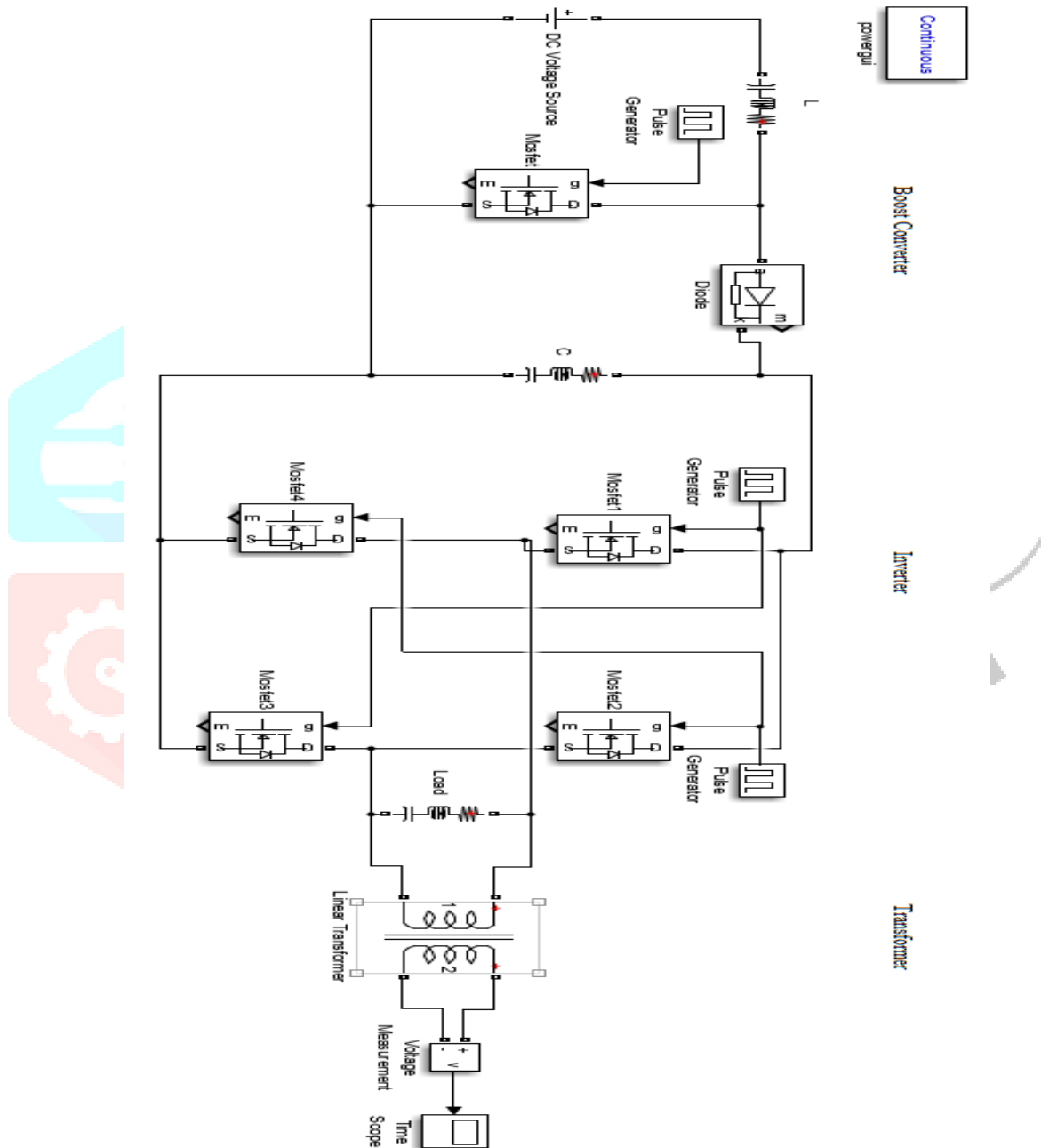


Fig-3: Simulink circuit of complete boost converter from 5V-220V

III. RESULTS AND DISCUSSIONS

As shown in Fig-4 the graph is the plot of voltage vs. time (in ms). Due to DC ripple voltage, the first wave will be having harmonic and then after the first cycle, the rectangular waveform is observed.

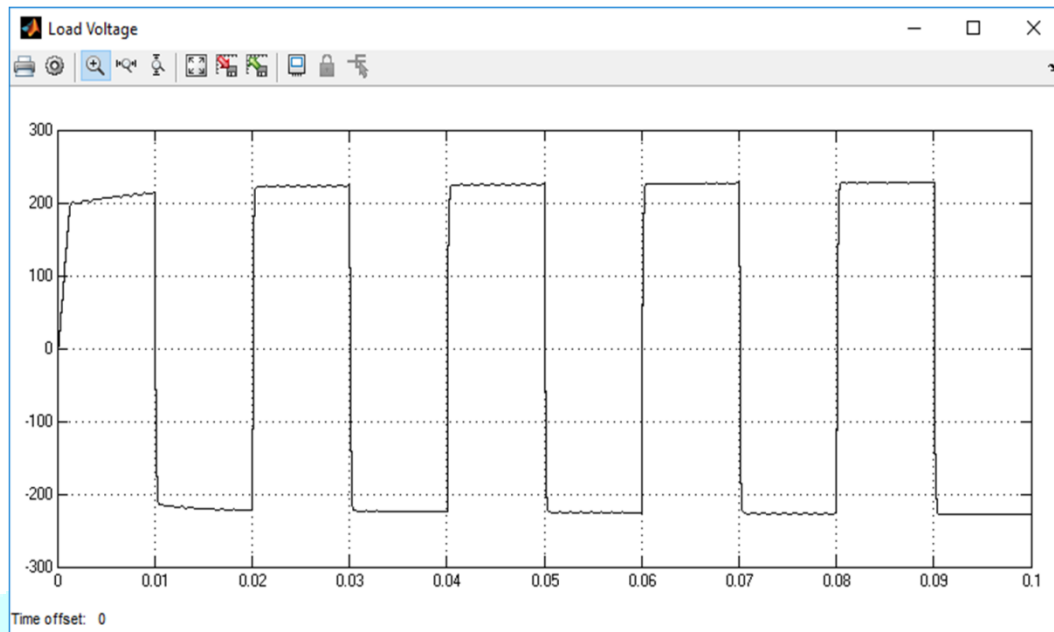


Fig-4: Output of Simulation circuit

The Fig-5 describes the resultant generated from the converter circuit for 5V, 0.05A at the lab condition using Regulated Power Supply (RPS). The voltage is set as per the MFC output since the output current of the MFC is very less; the RPS is used for the setting of the voltage and current.



Fig-5: Result of the converter circuit

Another alternating way for the increase in the voltage is using more than three MFC and then for each of them, the inverter is connected. All the inverters are then cascaded together and thus the concept of a multilevel inverter could be used to get increased ac voltage. The advantage of this kind of circuit is the

reduction of harmonics which could be done by increasing the levels of inverters. The main problem with this circuit is that of cost. The investment for this kind of circuit is high and the current will be low.

VI. MFC- Electrical Characteristics

The amount of electricity generated from MFC is little i.e. voltage generation depends on the size of the reactor and electrodes, however, the current is extremely small because which power density of electrodes is little. At the point when suggested in industries, the size of the reactor is huge and hence successive series connection will be an increase in voltage and parallel connection can be implemented for an increase in current. In this experimental work, rod electrodes, as well as plate electrodes, have been used for electrical energy generation.

This leads to a reduced power density compared to mesh electrodes. For non-industrial purposes, the amount of output produced can be used by boosting and converting the small amount of voltage into a usable structure. Additionally, the boosted voltage should be free from ripples, harmonics, and distortions. This is accomplished by utilizing converters and inverters.

Coming up with the energy efficiently from MFC is the main purpose of the presenting thesis. MFC utilizes organic matter, such as wastewater and slurry to harvest electricity. Utilizing the micro-organisms to harvest electric power is the basic plan of the MFC. The micro-organisms oxidize their food resource and electrons are generated. Once not opening the circuit, electrons will starts flowing and electrical energy is going to be produced. In the ongoing investigations, the MFC is superior to delivering a massive amount of power to be well thought-out as a power source.

i. Voltage-Current Polarization Curve

The polarization plot is the relation connecting the voltage and therefore the electric current of MFC. All MFC systems are different and may have dissimilar output power, however, generally, they have a familiar form of polarization curves. Considering two different MFCs as shown in Fig-6, it indicates that, they have a similar form of the curve with different current and voltage values.

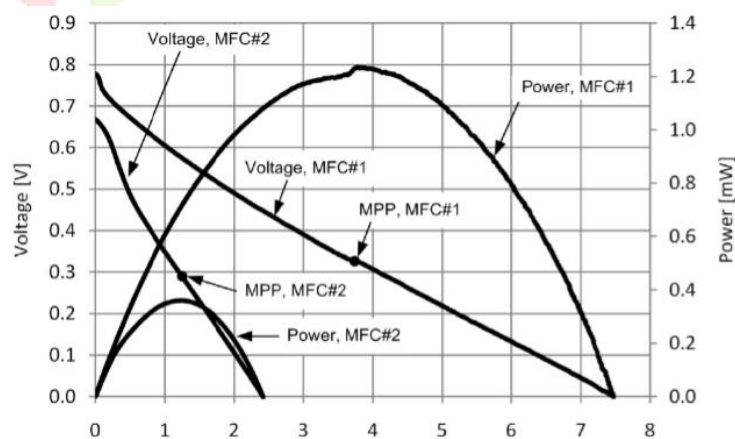


Fig- 6: Polarization curve

ii. Internal Resistance

When the terminals are open, the terminal voltage of the MFC is generally 0.7 V and this terminal voltage value will decrease while connecting an external resistance to the MFC because the current is flowing

through the MFC. The main factors affecting the internal resistance of MFC are reactor dimension and atmospheric circumstances.

iii. Maximum PowerPoint

The polarization curve is showing Maximum Power Point (MPP) of MFC. When an external resistance is similar to that of internal resistance the MPP of MFC can be obtained as showing in the figure. The internal resistance value of the MFC mainly depends on the changes in environmental conditions. Therefore, generally in most the situation, it is considered a constant value.

There is an extremity of functioning where the maximum power can be generated from the MFC. The highest power production from MFC takes place when external resistance is equivalent to the internal resistance connected with the MFC. The MPP can be observed in the polarization curves that are described in Fig-6. The internal resistance of the MFC differs based on the atmospheric conditions, but in several observations, it can be assumed to be invariable. The maximum power can be obtained using DC-DC converters.

V. MFC Electrical Energy Production

To utilize the electricity produced by the MFC system, a voltaic circuit should be associated to generate that energy. Various energy producers have been utilized in the ongoing years MFC investigation, including resistors and power electronic converters.

MFC energy extraction is mainly classified into two categories, such as passive energy extractors and active energy extractors will be discussed in the following sub-sections.

i. Passive Energy Extraction

Resistors

Proper utilization of an external resistor is the very basic idea in extracting energy from the MFC and the same techniques have been widely used. The current starts flowing through the resistor while an external resistor is in connection with the MFC.

The voltage of MFC is given by,

$$V_{MFC1} = I * R_{ext1}$$

Where,

V_{MFC1} is the output voltage of MFC, across an external resistor;

I is current flowing through resistance,

R_{ext1} is external resistor resistance.

At this point, once this current I passing through the resistance, the extracted energy is going to be dissipated within the resistance. Extracted energy can be shown by this power dissipation.

Supercapacitors

Utilizing a supercapacitor is more helpful than utilizing a resistor as a result of the supercapacitor stores the energy rather than consuming it within the resistor. Supercapacitor is an easy technique to produce and store the energy of the MFC, parallely connected to the MFC.

VI. ACTIVE ENERGY EXTRACTION: POWER ELECTRONICS CONVERTERS

Energy harvesting using the passive energy extraction method from MFC is not helpful, since the usage of resistors consumes energy and capacitors will lead to voltage drop. Once a supercapacitor is linked to MFC, the current will start flowing and charge a supercapacitor, and ultimately voltage of the supercapacitor would be equivalent to the voltage of MFC. Therefore the energy can stop moving, which can discontinue the energy harvesting from MFC.

The best method to harvest energy from MFC is using active energy liberation by power electronics converters. The capacitor stores the energy and therefore voltage of MFC would be nurtured within the attractive boundaries when the use of converters. The inductance, duty cycle, and switching frequency are the fundamentals for energy extraction.

i. Boost Converter

The use of a boost converter is to increase the voltage generated from the MFC system to a usable limit. To know the performance of the designed boost converter for MFC application is discussed as follows. The energy generated from MFC is stored in a rechargeable battery and the same battery can be directly connected to this designed boost converter. This converter will supply output voltage ranging from 220 V to 230 V as shown in the figure. The Fig-7 shows the open-circuit voltage generated from MFC to the converter circuit for 5V, 0.05A at the lab condition using Regulated Power Supply (RPS). Because voltage generated from MFC was not stored in rechargeable battery so using RPS showed results for the boost converter. The voltage and current are set as per the MFC generation.

Another alternating way for the increase in the voltage is using more than three MFC and then for each of them, the inverter is connected. All the inverters are then cascaded together and thus the concept of a multilevel inverter could be used to get increased ac voltage. The advantage of this kind of circuit is the reduction of harmonics which could be done by increasing the levels of inverters.



Fig- 7: Fabricated boost converter for continuous output using RPS.



Fig- 8: Output of boost converter

VII. CONCLUSION

Microbial Fuel Cell (MFC) offers great promise for sustainable energy production and water treatment and this work has significantly contributed to the development of innovative engineering solutions for industrial and domestic applications. In particular, continuous flow solutions and optimizations of anode materials have been developed that can promote the general use of MFC technology and have also fabricated a simple booster converter.

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