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Fuel Cell Based Interleaved Boost Converter for High Voltage Applications

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ABSTRACT

In this paper presents a fuel cell based interleaved boost converter for high voltage applications is proposed. An interleaved boost converter having two-winding coupled inductors for high step-up conversion with high efficiency is obtained. The proposed method of fuel cell based interleaved boost converter to operate in continuous conduction mode (CCM) over the discontinuous conduction mode operation results in large input current ripple and high peak current, which make the fuel cell stacks difficult to afford. Even though, the low-voltage stresses on semiconductor components are substantially lower than the output voltage. An interleaved boost converter not only reduces the current stress, decreases the conduction losses and reduced ripples in current waveform. In addition, due to the lossless passive clamp performance, leakage energy is recycled to the output terminal. The experimental tests have been performed by using a PIC 16F877A Microcontroller with fuel based interleaved boost converter is proposed method.

Keywords: *Fuel Cell, Interleaved Boost Converter, PIC Microcontroller, Pulse Width Modulation.*

I. INTRODUCTION

Recently, the cost increase of fossil fuel and new regulations of CO_2 emissions have strongly increased the interests in renewable energy sources. Hence, renewable energy sources such as fuel cells, solar energy, and wind power have been widely valued and employed. Fuel cells have been considered as an excellent candidate to replace the conventional diesel/gasoline in vehicles and emergency power sources. Fuel cells can provide clean energy to users without CO_2 emissions. Due to stable operation with high-efficiency and sustainable/ renewable fuel supply, fuel cell has been increasingly accepted as a competently alternative source for the future. The excellent features such as small size and high conversion efficiency make them valuable and potential [3]. Hence, the fuel cell is suitable as power supplies for energy source applications. The fuel cell with inertia characteristics as main power source cannot respond to load dynamics well. Therefore, lithium iron phosphate can be an excellent candidate for secondary source to react to fast dynamics and contribute to load peaking. The proposed converter with fuel cell input source is suitable to operate in continuous conduction mode (CCM) because the discontinuous conduction mode operation results in large input current ripple and high peak current, which make the fuel cell stacks difficult to afford. The proposed converter employs a switched capacitor and a voltage-doubler circuit for high step-up conversion ratio. The switched capacitor supplies an extra step-up performance; the voltage-doubler circuit lifts of the output voltage by increasing the turns ratio of coupled-inductor [1]. In this paper, high voltage-boosting converters are presented. High step-up converter has been widely used in the industry [7]. One of the applications of high voltage boost converters the DC/DC front end converter used in network telecommunication industry [2] [6]. DC-DC front end converter convert 48V DC supply from battery plant to 360V DC. The high voltage boost converters are constructed based on bootstrap capacitors and boost inductors. The converters are is based on the fact that the number of inductors is increased, and these inductors are connected in series during the demagnetizing period, thereby pumping the energy created by the input voltage and the energy stored in the inductors into the output terminal to obtain the high voltage conversion ratio. Modified boost converter was proposed which has higher conversion ratio than conventional boost converter. By changing the switching strategy, two different conversion ratio can be obtained. Therefore, the proposed converters can be used according to industrial applications. In rural areas renewable energy sources plays a key role in power generation and transmission [4]. Where the power transmission from conventional energy sources is complicated, bulky electric drives and utility applications required, power converter construction has been introduced as a substitute in medium voltage and high power requirements using Renewable Energy Systems. Additional merits of renewable power source are light, dirt free and pollution free operation. By using inverter module in order to meet the required load demand, it is better to integrate the renewable energy power with the application of drive connected system by using inverter module. An advanced power electronics converter is used to meet the high power load applications.

A new interleaved high step-up boost-fly back converter with voltage multiplier cell is proposed in this paper to avoid the extremely narrow turn-off period and to decrease the current ripple. The voltage multiplier module is composed of the secondary windings of the coupled inductors, a series capacitor, and two diodes. In addition, the switch voltage stress is reduced due to the transformer function of the coupled inductors, which makes low-voltage-rated MOSFETs offered to reduce the conduction losses and increases the lifetime of the input source [5]. Which makes the presented circuit uncomplicated to design and control, additional active device is not required for the proposed converter fed induction motor drive using inverter module.

Many applications call for high step-up dc–dc converters that do not require isolation. Some dc–dc converters can provide high step-up voltage gain, but with the penalty of either an extreme duty ratio or a large amount of circulating energy. DC–DC converters with coupled inductors can provide high voltage gain, but their efficiency is degraded by the losses associated with leakage inductors. Converters with active clamps recycle the leakage energy at the price of increasing topology complexity.

A family of high-efficiency, high step-up dc–dc converters with simple topologies is proposed in this paper. The proposed converters, which use diodes and coupled windings instead of active switches to realize functions similar to those of active clamps, perform better than their active-clamp counterparts. High efficiency is achieved because the leakage energy is recycled and the output rectifier reverse-recovery problem is alleviated.

II PROPOSED METHOD

The Interleaved Boost converter consists of two single Boost converters connected in parallel. The schematic diagram of Interleaved Boost Converter.

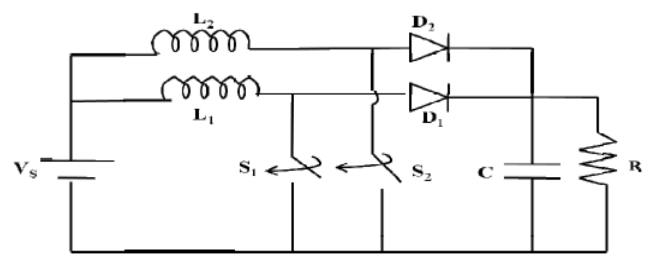

Fig. 1: Circuit Diagram of Interleaved Boost Converter

The input voltage V_s, L_1 and L_2 are the magnetizing inductances, S_1 and S_2 are semiconductor switches, D_1 and D_2 are diodes, C is an output capacitor and R is a load resistance respectively. The design involves the selection of inductors and output capacitor. In interleaved design both the inductors must be identical. In particular, the design assumes the room temperature operation over the entire input voltage without the air flow requirement. Inductor value can be calculated by assuming peak to peak inductor ripple to a certain percentage of about 20% of the output current corresponding to the individual phase. The average inductor current is determined as,

$$I_L(avg) = \frac{0.5 \times I_{out}}{1 - D_{max}}$$

Where I_{out} is the load current and D_{max} is the maximum duty cycle ratio and it is defined as,

$$D_{max} = \frac{V_{out}+V_d-V_{in(min)}}{V_{out}+V_d-V_{on}}$$

where V_{out} is the output voltage, V_d is the forward diode voltage drop, V_{on} is the on stage voltage of the MOSFET and V_{in} (min) is the minimum input voltage. Assuming peak inductor ripple current per phase (I_L) as 20% of the average inductor current, the peak inductor current is determined as follows,

$$I_{peak} = I_{L(avg)} + \frac{\Delta I_L}{2}$$

Assuming appropriate switching frequency, the inductor value is selected using the following equation,

$$L = \frac{(V_{in(min)}-V_{on})*D_{max}*(1-D_{max})}{f_s*I_{out}}$$

Knowing the minimum load current, L value can be designed which gives the critical value to maintain the converter in continuous mode of operation. By assuming appropriate peak to peak capacitor ripple, the output capacitor value can be obtained using the following equation,

$$\Delta V_{out} = \frac{I_{out(max)}*(1-D_{min})}{f_s*C_{out}}$$

Where D_{min} is the minimum duty cycle defined as,

$$D_{min} = \frac{V_{out}+V_d-V_{in(min)}}{V_{out}+V_d-V_{on}}$$

Interleaved boost converter with the use of zero current transition and a soft commutation technique operating in Critical Conduction Mode (C-DCM) was investigated. The turn-ON of the main switches occurs naturally at ZCS due to the operation of C-DCM and also the reverse recovery losses of the diodes are minimized. Generally to boost up the voltage level or else we can say to get the output voltage higher than the input, boost converters are used. However when these boost converters are operated for high ratios leading to some difficulties like higher voltage and current stress on the MOSFET & higher voltage. Hence as a solution for this, an interleaving technique for boost converter have been adopted. This approach can be used for higher power applications to produce high voltage gain compared to the simple boost converter.

However at the high power application, the vast reverse-recovery current from the diode cause again a problem. The problems may be extra switching losses & rigorous electromagnetic interference noise. When the MOSFET is switched on, the diode cannot be immediately switched off. Consequently, the output side capacitor is connected to ground; at that instant of time very large current spikes arise both at the switch& at the rectifier, which will cause EMI noise & extra switching losses.

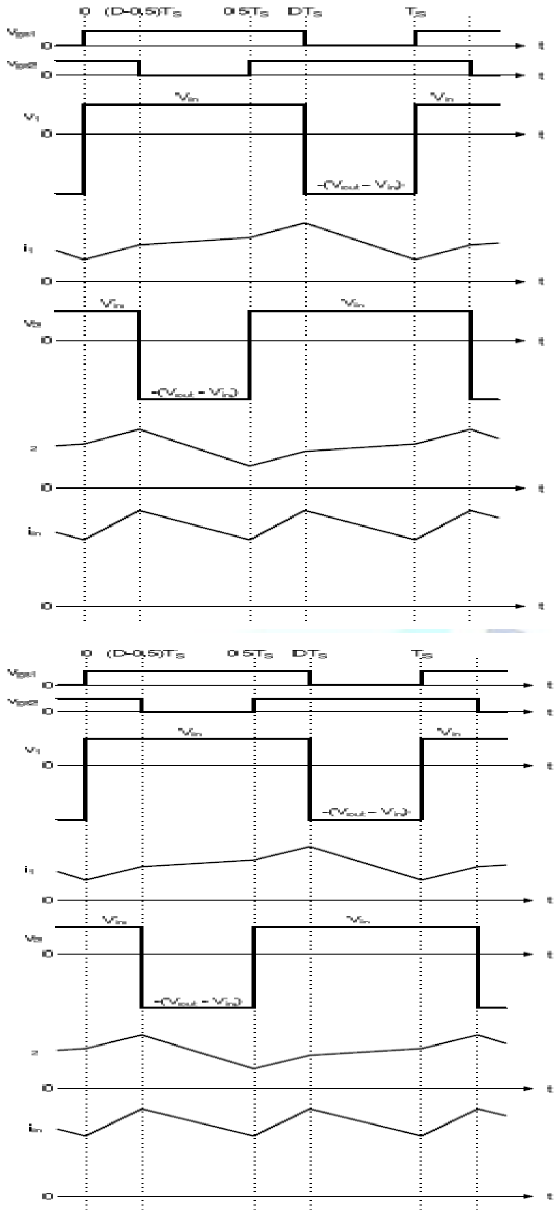

Fig.2: Waveform

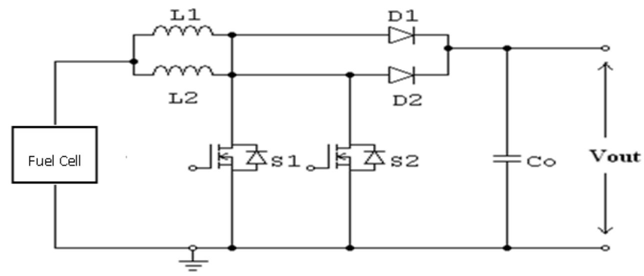

Fig. 3: Fuel cell Based Interleaved Boost Converter

2.1 Block Diagram

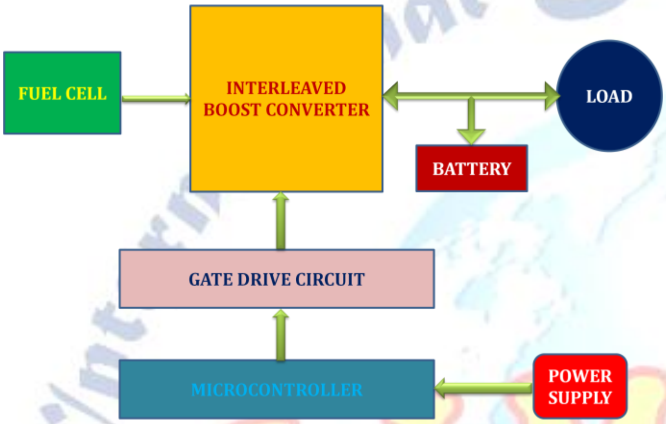

Fig. 4: Block Diagram

2.2 Circuit Diagram

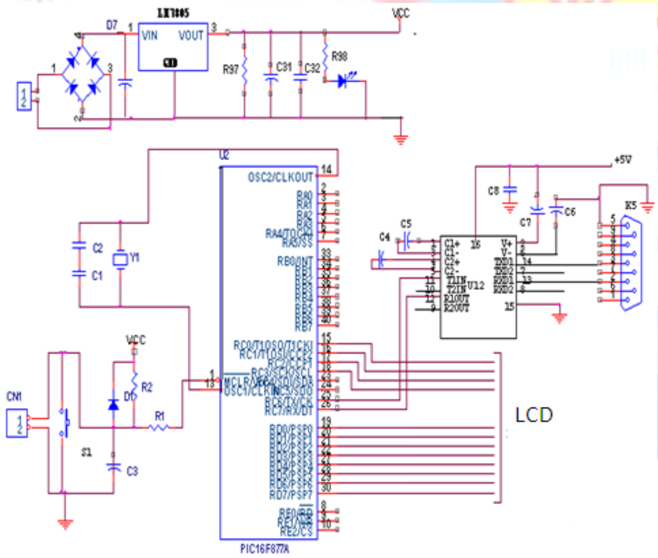

Fig. 5: Circuit Diagram

2.3 *PIC Microcontroller*

PIC stands for peripheral interface controller; it is a type of microcontroller component that is used in the development of electronics, computers, robotics and similar devices. The PIC was introduced by Microchip Technology and is based on Harvard computing architecture where code and data are placed in separate registers to increase input/output throughout. PIC microcontroller was widely used for experimental and modern applications because of its low price, wide range of applications and high quality, ease of availability.

2.5 PIN Diagram

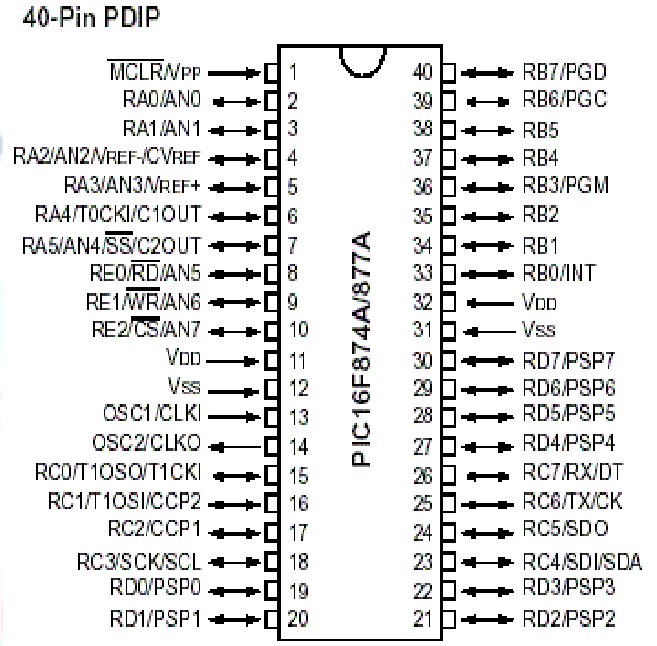

Fig. 6: Pin diagram of IC 16F877A

Features of PIC16F877A

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle
- Up to 8K x 14 words of Flash Program emory,
- Interrupt capability (up to 14 internal/external)
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)

III HARDWARE IMPLEMENATION

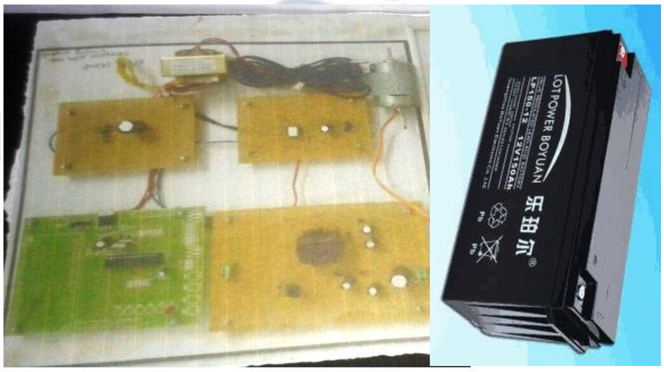

Fig. 7: Photograph of Hardware

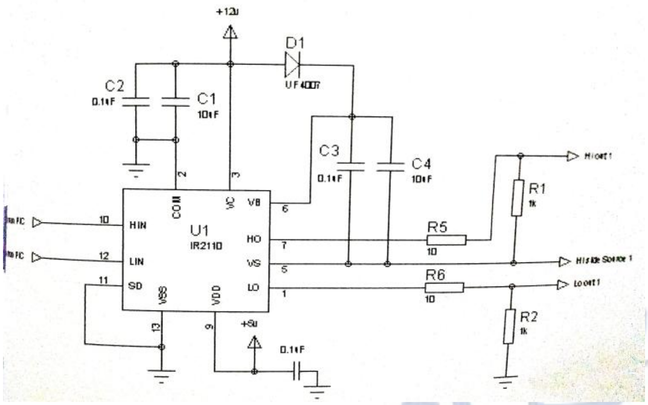

Fig. 8: Circuit Diagram of MOSFET Driver Circuit

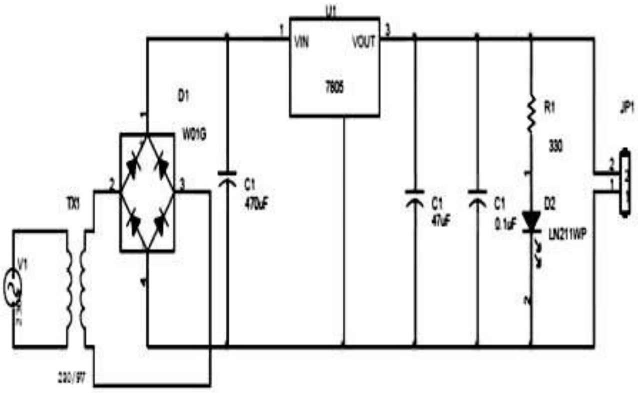

Fig.9: Power Circuit for Microcontroller

IV CONCLUSION

This paper presents a detailed design and analysis of an interleaved boost converter for a switching frequency of 50 kHz and different ripple reducing techniques. The high voltage gain converter is far suitable for applications where a high step up voltage is required, as in some renewable energy systems, which use, for example photovoltaic panels and/or fuel cells. Thus large step-up voltage, low switching stress and high efficiency are expected from this topology. As the power demand from these supply increases, a single boost converter may be insufficient. One of the disadvantages is that the input current ripple and output voltage ripple is more. In order to overcome this disadvantage of a single boost converter an interleaved boost converter can be implemented. Hardware implementation was also carried out, the results were found to be satisfactory reducing ripple. To boost up the voltage level boost converter is adopted with interleaving technique. It has added some advantages like, can be used for high ratios, also for high power application. Three boost converters are connected in parallel manner, they are studied and simulated properly and presented here with all the required results.

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