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Design and Analysis of Fuel Cell fed SEPIC Converter

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ABSTRACT:This paper only represents the design and analysis of Single Ended Primary Inductance Converter(SEPIC) which is belongs to dc/dc converter family for a single phase 230V Fuel Cell based system and also deals with the selection of suitable active and passive components. The SEPIC converter provides the output DC voltage like buck boost converter and it allows a range of dc voltage to be adjusted to maintain a constant voltage output in any system. This paper talks about the importance of SEPIC converter in fuel cell system and this will validate the reasons of using SEPIC converters instead of other dc-dc converters by proper simulation work. Further the harmonic analysis also performed to make this proposed system as an alternative among all other DC-DC Converters in renewable energy applications.

KEYWORDS:SEPIC converter, DC to DC Converter, Fuel Cell System, Harmonic analysis.

I.INTRODUCTION

In recent years the interest in generating electricity from renewable energy sources like solar, wind, fuel cell, etc. is gaining more popularity in both private and public sectors, the reason for this growing interest is remarkable in all the ways. The Fuel Cell is one of the most active and popular research areas among renewable energy sources.

Fuel Cell technology is one of the effective and most widely used renewable energy technologies for standalone system [1]. Different portable electronic equipment have benefited from a power converter is able to achieve high efficiency with a wide input and output voltage ranges with in a miniaturize size. Still conventional power converter failed to maintain a wide operation range with high efficiency, particularly when the low and high voltage conversion has to be taken place. These required characteristics can be obtained in a single ended primary inductor converter (SEPIC). Some limitation in conventional buck boost converter like inverted output ,pulsating input current, high voltage stress make it unreliable for wide range of operation. So to get rid of this SEPIC converter is used [2-4]. SEPIC is a DC to DC converter and is capable of operating in either step up or step down mode and widely used in battery operated system which may be electric vehicle or other types of vehicles [6].

There are five main types of dc-dc converters. Buck converters can only reduce voltage, boost converters can only increase voltage, and buck-boost, Cuk, and SEPIC converters can increase or decrease the voltage form one particular level [7, 8]. Buck-boost converters can be cheaper and simple circuit because they only require a single inductor and a capacitor in its structure. However, these converters suffer from a high amount of input current ripple and power semiconducting switch stresses. This ripple and stress on these switches can create harmonics and degrade the performance; In many real time applications these harmonics eliminates using a large capacitor or an LC filter. Also, this often makes the buck-boost expensive or inefficient [3]. Another issue that can oppose the usage of buck-boost converters is the fact that they invert the voltage from the input waveform. Even Cuk converters have the possibility to solve both of these problems by using an extra capacitor and inductor. But the real truth is, both Cuk and buck-boost converter operation cause large amounts of electrical stress on the components, this can result in device failure or overheating of associate elements. But SEPIC converters are having the capability to solve both of these problems [3].

Some limitation in conventional buck boost converter like inverted output ,pulsating input current, high voltage stress make it unreliable for wide range of operation. So to overcome this difficulty the unique SEPIC DC to DC converter is used. In this paper ideal method of selecting and designing passive component of SEPIC is described in conversion ratio chapter, which is a kind of DC-DC converter that provides a positive regulated output voltage from

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an input voltage irrespective of the supply voltage polarity. The simulation result of SEPIC is well presented by designing suitable open loop Simulink model. Harmonic analysis of the output waveform also studied in this proposed paper.

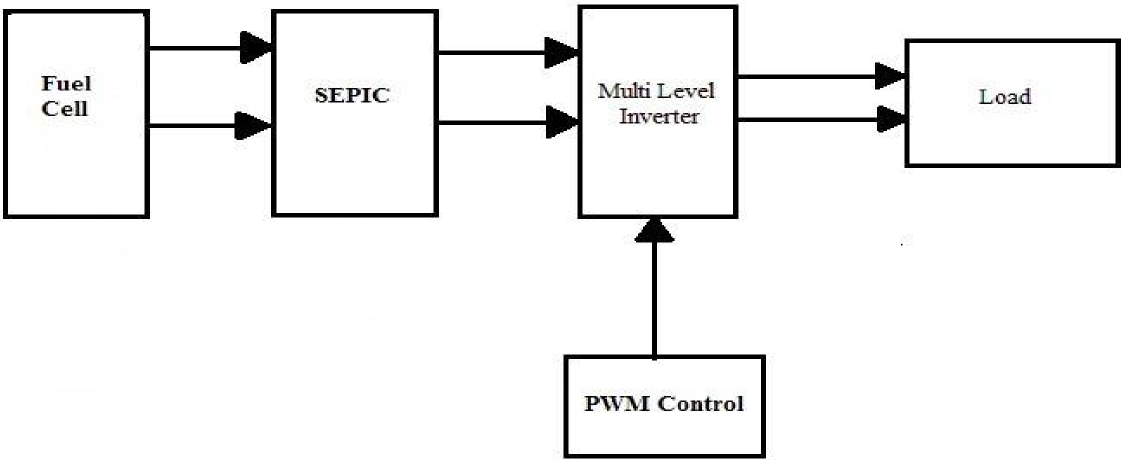

Fig.1. Block Diagram of the Proposed System

The proposed system consists of Fuel Cell, SEPIC converter, Multi Level Inverter and the 230 V, 50 Hz, 1 Phase active standalone load as depicted in figure.1. The detailed explanations are described in the following chapters.

II. PRINCIPLE OF OPERATION OF SEPIC

The optimum SEPIC converter have low component stresses, low energy storage requirements and it provides non inverted output not like the conventional boost or the buck converter, the SEPIC also has minimal active components to reduce the switching losses.

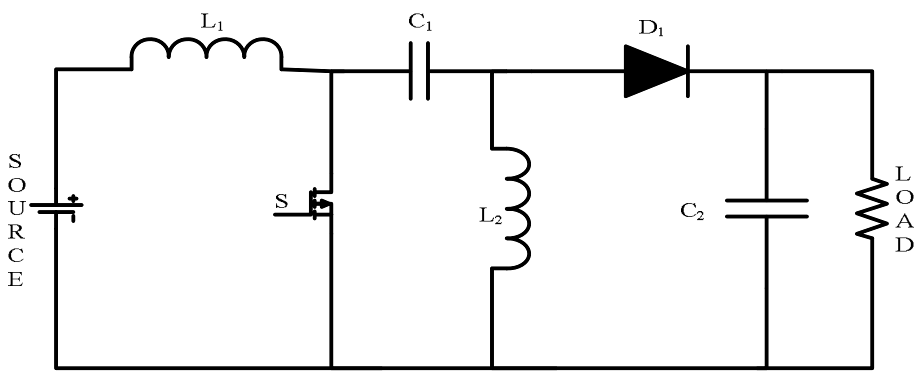

Fig.2. Single Ended Primary Inductance Converter

Apart from a MOSFET switch SEPIC is having two inductors and two capacitors as shown in the figure namely L_1, L_2, C_1 and C_2 respectively, along with that Diode D_1 is used to provide a non-inverted output as an output.

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III.WORKING STATES AND PARAMETER SELECTION

When the pulse is given to the MOSFET gate terminal, the MOSFET will turn on and the input side inductor is charged by the input voltage and the load side inductor is charged by the nearby capacitor 1.At the same time the diode is in off condition and the output is maintained by capacitor 2, it is called as mode 1 operation. At the time of absence of gate pulse, the MOSFET will get turned off and the inductors output through the diode to the load and the capacitors are charged during the mode 2 operation, only during this mode 2 the diode will get turned ON.

A. CONVERSION RATIO

The voltage and current conversion ratios of the proposed fuel cell fed SEPIC converter is determined as follows,assuming that 100% power conversion efficiency is possible in that case.

$$M = \frac{V0}{Vin} = \frac{Iin}{I0} \ldots \quad (1)$$

Where Iinis input current and Io is refer to output current.

The SEPIC converter duty cycle derived as

$$D = \frac{Vout+VD}{Vin+Vout+VD} \ldots \quad (2)$$

V_D is the forward voltage drop across the diode (D), Vinis refers to input voltage and Vout is output voltage value. The maximum duty cycle is as follows

$$Dmax = \frac{Vout+VD}{Vin(min)+Vout+VD} \ldots \quad (3)$$

The input side inductor value is selected based on the following equation

$$L = \frac{Vin(min)*Dmax}{\Delta IL*fs} \ldots \quad (4)$$

ΔIL is the peak-to-peak ripple current at the minimum input voltage and fs is the switching frequency.

TheRMS current is given by

$$Ic(rms) = Iout * \sqrt{(Vout} + VD)/Vin(min) \ldots \quad (5)$$

The value of power conversion efficiency of the proposed fuel cell based SEPICconverter increases as D become smaller. As an overall result, conduction and switching losses of active switches and DC resistive losses of inductors and capacitors is reduced to a great extent not like that of any other converter.

The input current waveform is continuous in case of SEPIC because it is having an inductor in the input side like boost converter, the waveform might be triangular in shape. Based on this inductor value the input, output capacitor values and output diode values will be designed. This diode is selected based on the withstanding capability of peak current and the reverse voltage. The input capacitor is also used to limit the ripple current as much as possible. When switch is in turned ON condition the output capacitor supplied the output current.

IV.SIMULATION RESULTS

The scope of this section is to review the simulation results of the Passive elements like capacitor, inductor, diode and switches of SEPIC converter with suitable different method. The simulations are performed on the proposed SEPIC's circuits with the parameters listed in Table I, using Matlab/Simulink platform.

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TABLE I
PARAMETERS OF MODIFIED SEPIC

PARAMETER	SYMBOL	VALUE
Input Voltage	Vin	15 to 24 V
Output Voltages	V1 and V2	110 to 120 V
Inductor	L	110µH
Capacitors	C and Cp	5µF and 300µF
Switching Frequency	fs	1kHz
Range of Duty ratio	D	0.3 to 0.9

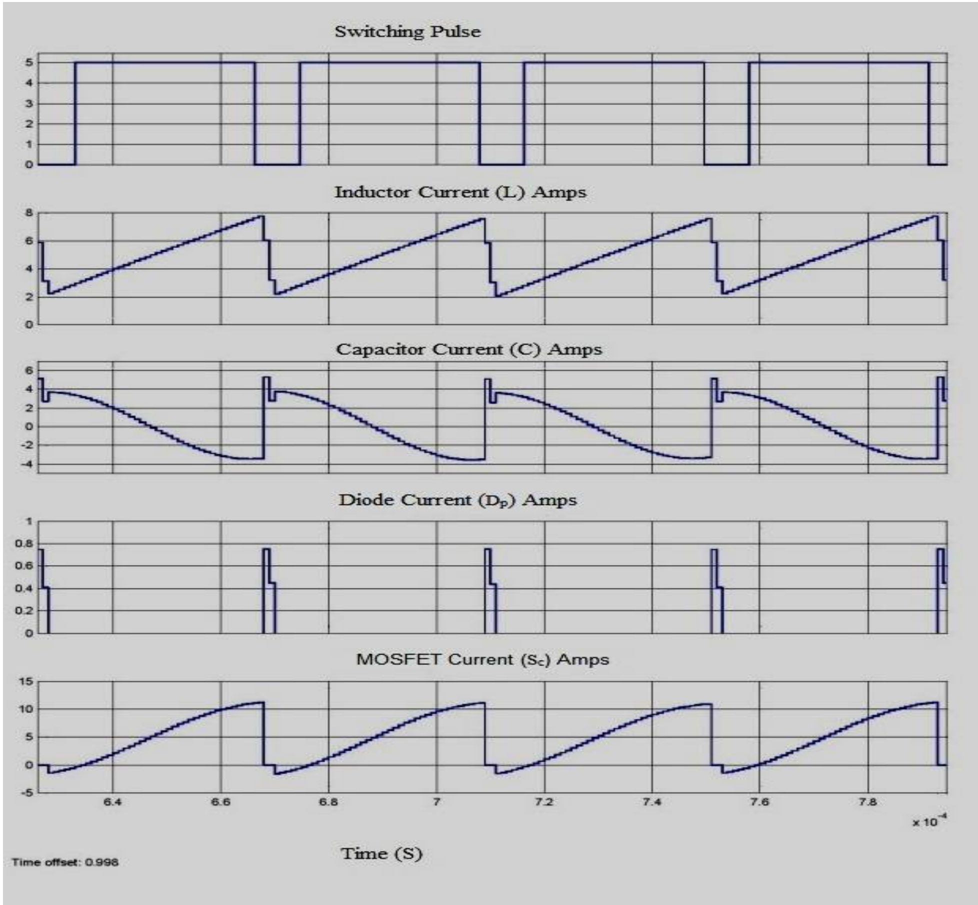

Fig.3. SEPIC Converter simulation results

Figure.3. Shows the SEPIC converter components working states while giving pulses to the switch. The switch S will get turn ON after receiving the pulse signal, at that time inductors will get charging, at the same time the capacitor and diode will be in OFF position, then after the turn ON period the switch S will go to OFF condition, at that incident inductors will discharge the stored energy during Turn ON time. The capacitor and diode will turn ON by the inductor charge, with this, the capacitor will get charged and the cycle repeats over and over till the requirements completion. This above waveforms comprises of switching pulse, inductor current nature, capacitor current and

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MOSFET switching current nature. If one can take a particular point and analyses the nature of SEPIC converter means it explains the characteristics of all passive elements used in the circuit.

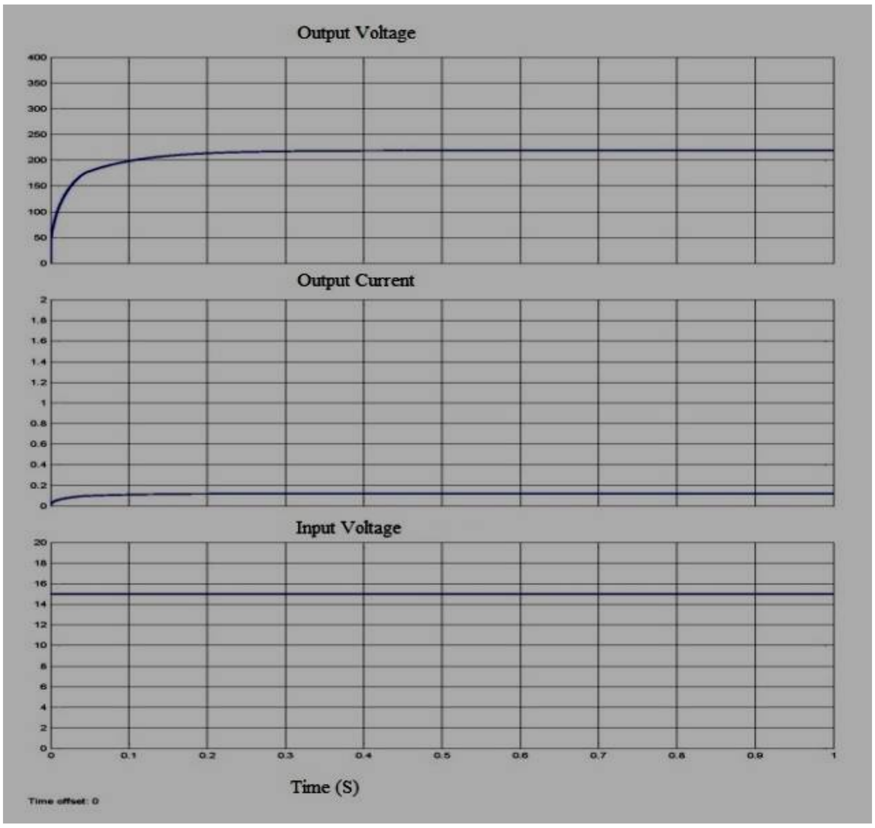

Fig.4. Proposed Converter Output voltage and current

Figure.4. shows the output voltage and current of SEPIC converter waveform along with the input voltage to the converter. For various input voltages the output voltage is taken to strengthen the stability of the proposed converter system. The output waveform is having non disturbance nature, this will also state that the SEPIC having less amount of harmonic content. This converter can also be used as a multi-port DC-DC converter in future [10].

V. CONCLUSION

All the specification and values of passive components for designing of a Fuel Cell based SEPIC was designed to provide high gain regulated DC to DC voltage to the system. It is prove that from this simulation result SEPIC is having more advantages than other DC to DC converters. Also it provides non inverted fixed output not like that in Buck-Boost converter; conversion ratio will also be in a high range. Thus the SEPIC having more advantages for fuel cell based renewable energy system.

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