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High Gain DC-DC Converter with Minimum I/P Current Ripple for EV

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Abstract:
In this paper, a high gain step up DC-DC converter is proposed. The proposed converter has an advantage of high gain with a minimum duty ratio compared to the conventional boost DC-DC converter. The purpose of this converter is to minimize the input current ripple so as to increase the performance and efficiency of the fuel cell so that overall systems efficiency gets increased. Ripple content can be reduced by increasing the inductors value. But increasing inductors value increases the weight of the converter and also slows down the dynamic response of the system. Considering these things the proposed converter is designed in a such a way that the value of the inductors will not be an issue. The proposed converter has two switches which operate inversely. The results are studied by simulation in MATLAB and 100W prototype model has been implemented.

Keywords: High gain DC-DC converter, positive output voltage, minimum input current ripple.

I. INTRODUCTION

Today's world facing the problem of rapid depletion of fossil fuel, the storage of earth's petroleum resource is limited. Due to a large number of automobiles in use around the world has caused and continues to cause serious problems of environment and human life. Moreover Air pollution, global warming and Climate change are now serious problems. Global warming and atmosphere pollution are the recent challenges to the whole world. Governments of various countries are concentrating on the methods of reducing them. The burning of fossil fuel produces CO2 and it is highly responsible for environmental issues Electric Vehicles (EVs), Hybrid Electric Vehicles (HEVs) and Fuel Cell Electric Vehicles (FCEVs) have been typically proposed to replace conventional vehicles in the near future. EV and Fuel cell vehicle are two of the most promising alternatives for clean energy, scalability and environment impact. Since the output of the fuel cell is low voltage, usually a DC-DC converter is required for boosting the output voltage to a higher value. Therefore, this aim can be obtained by a DC-DC boost converter, that converts the unregulated DC input to a controlled DC output at the desired voltage level. There is increasing demand for renewable energy resource which in terms accept the high quality of energy. DC-DC converters are the essential part when it comes to Electrical and fuel cell Electric vehicles. Due to automotive constraints, these power converters need to have reliability, light in weight, small volume and has to have high efficiency. The main part is it should have low current/voltage ripple because the system's efficiency and performance will depend on these factors. Ripple content is harmful and needs to be minimized in case of fuel cell vehicle because it lowers the useful life of a cell and also decreases the performance of fuel cell which affects the overall efficiency of the system. There are other applications such as energy conversion system and power factor correction which require high voltage gain[1-3].

II. BASIC CONCEPTS OF THE CONVERTER

EV and FCV perform best when the motor of these vehicles gets proper voltage. Also in the case of FCV ripple content can hamper the performance and reduce the useful fuel cell life, which will affect the overall efficiency of the system. The proposed converter has 12V input & 48 V output with minimum input current ripple hence proposed converter will be very useful in EV and FCV. The traditional boost converter with a simple structure and high efficiency, as we all know, has the drawbacks such as limited voltage gain, negative output voltage, floating power switch, meanwhile discontinuous input and output currents.In the converters with coupled inductors, a higher-voltage gain can be achieved by increasing the turn ratio of the coupled inductors [7-8]. Using tapped inductor, input current ripple can be eliminated [5, 6], but tapped inductor increases the failure rate of the inductor. Referring to the above conclusion it is clear that every converter mentioned above has some deficiency. Some of these deficiencies can be overcome in a proposed new High gain DC-DC converter. The Proposed High gain DC-DC converter has a positive output voltage with a higher gain at suitable duty ratio and less ripple as compared with the traditional boost converter.

III. INTRODUCING THE PROPOSED CONVERTER

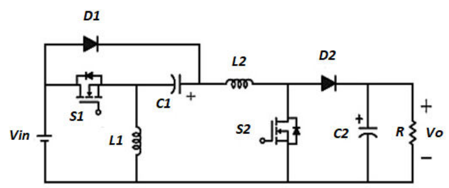

Figure.1. Proposed High gain DC-DC converter

The proposed converter is compact in size as the elements are less. It consists of two diodes, two capacitors, two inductors, two switches and a DC voltage source. The proposed converter minimizes the input current ripple and also the gain of the converter is high. Fig.1 shows the circuit diagram of the converter.

IV. BASIC OPERATING PRINCIPLE

The proposed converter operates in two modes i.e. given as state 1 and state 2. Operation of the given converter is in 2 states. The switch S1 and S2 operates inversely.

State 1:
During this time interval [t2, t3], S2 is on and S1 is off. Here, L1 discharges its energy to C1. As a result C1 is charged. In this case, the energy of the output capacitor C2 is discharged to load.

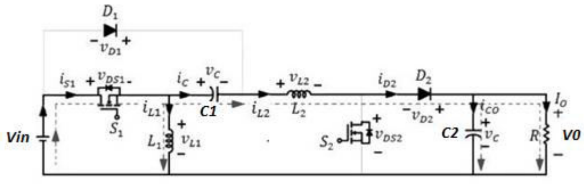

Figure.2 (a) Operation state 1

Fig.2(a) also shows the performance of the converters in this mode. Voltage and current relationships of the elements in this mode are as follows

$V_{L1}= V_{in}$

$V_{L2}= (V_{in}- V_{C1}- Vo)$

$I_{C1}= I_{L2}= I_{in}- I_{L1}$

$I_{C2}= I_{L2}- V_o/R$

State 2
During this time interval [t2, t3], S1 is off and S2 is on. Here, unlike the previous case, L1 discharges its energy to C1. In fact, C1 is charged. In this case, the energy of the output capacitor C2 is discharged to load. Fig.2 (b) also shows the performance of the converters in this mode.

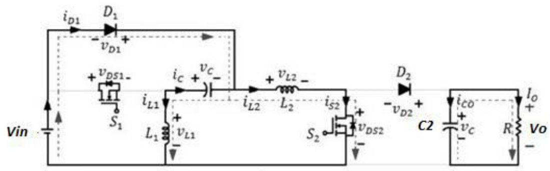

Figure. 2 (b) Operation state 2
Voltage and current relationships of the elements in this mode are as follows

$V_{L1}= (V_{in}+ V_{C1})$

$V_{L2}= V_{in}$

$I_{C1}= -I_{L1}= -\ (I_{in} - I_{L2})$

$I_{C2}= -V_o/R$

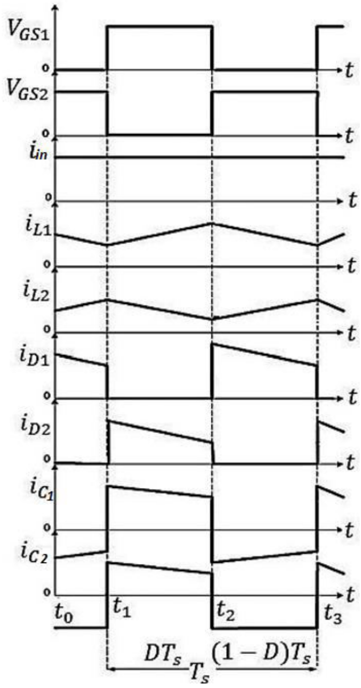

Figure. 3. Time domain waveform

Fig.3 shows the typical time domain waveforms for the proposed High gain DC-DC converter observed from these state of operation. The first and second waveform shows the switching pulses given to switch S1 and switch S2. The third waveform shows the input current waveform. The fourth and Fifth waveform shows current flowing through inductor L_1 and inductor L_2 respectively. Similarly sixth and seventh waveform shows current stresses on diode D_1 and D_2 respectively. These analytical waveforms are used to compare with the simulation results.

V. MATLAB SIMULATION

Based on the MATLAB software and Fig. 1, the simulation circuit of the High gain Dc-DC converter is constructed in the MATLAB simulations. Note that, circuit parameters here are chosen as: *Vin*=12V, *fs*=10kHz, *D*=0.50, *L*1=1mH, *L*2=1mH, *C*1=86μF, *C*2=86μF, *R*=25Ω. Fig. 5 shows the time-domain waveforms of the input voltage v_{in}, switch 1 pulse, switch 2 pulse, output voltage *v*0, Since the two power switches conduct inversely, two driving signal*s* is chosen. From Fig. 5, one can obtain that the inductors current *iL*1 and *iL*2 is (4.16A).

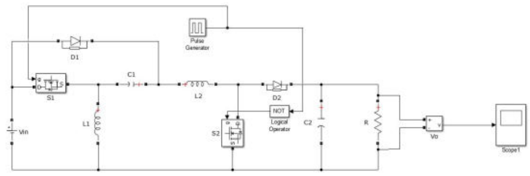

Figure.4. Open loop simulation

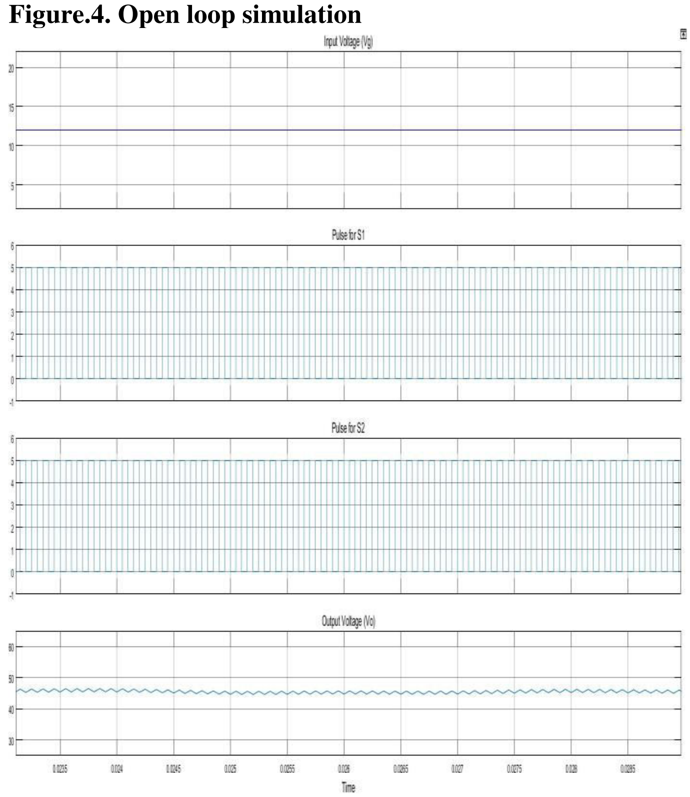

Figure.5. Simulation results of open loop

Figure 5 shows the open loop simulation results. The first waveform shows the input voltage given to the converter which is of 12V DC. The second and third waveform shows the pulses given to the switch S1 and S2. The switches operate inversely so the pulses are opposite of each other. The fourth waveform shows the output voltage and here one can clearly observe that the output voltage is near to 46V DC.

VI. DESIGN EQUATIONS

According to the allowable inductor's ripple currents (ΔI_{L1}, ΔI_{L2}), capacitor voltages (ΔV_{c}, ΔV_{C0}), the voltage across inductor's and capacitor's currents, capacitors and inductors values can be achieved as

$$L_1 = \frac{DVin}{2\Delta IL1} Ts$$

$$L_2 = \frac{Vin(1-D)}{2\Delta IL2} Ts$$

$$C_1 = \frac{Vin}{2R\Delta Vc1} Ts$$

$$C_2 = \frac{Vin}{2R\Delta Vc2} \frac{1-D}{D} Ts$$

Applying the volt-second balance principle to L2 and voltage across C1, converter gain can be achieved as

$$M = \frac{Vo}{Vin} = \frac{1}{D(1-D)}$$

Here, *D* is the duty cycle, which represents the proportion of the power switches turn-on time to the whole switching cycle. Applying the charge–second balance principle to C and CO, the average inductors current (IL_1, IL_2) and also the average input current (Ig) are obtained

$$IL_1 = \frac{V}{R(1-D)}$$

$$IL_2 = \frac{V}{RD}$$

$$I_g = \frac{V}{RD(1-D)}$$

VII. COMPAIRING THE RIPPLE CONTENT

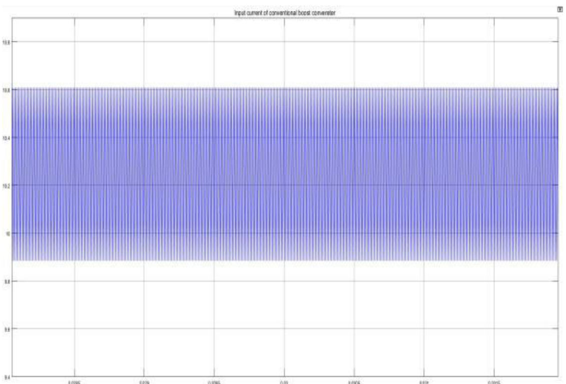

Figure.6. Input current waveform of a conventional boost converter

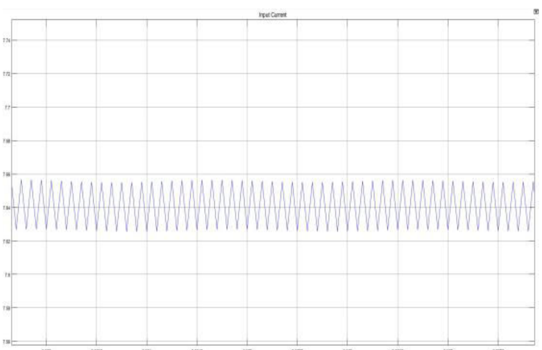

Figure.7. Input current waveform of the proposed converter

For comparing the input current ripple we have done MATLAB simulation of the conventional boost converter and Proposed high gain converter. The results are as shown in the above figures. Fig.6 shows input current waveforms of a conventional boost converter where one can see the ripple content is so high . Fig.7 shows the input current waveform of the proposed converter as one can see the ripple content is far less compared to the conventional boost converter. So it is clear that this converter not only has high gain but also minimizes the input current ripple effectively.

VIII. EXPERIMENTAL RESULTS

A 100W prototype is built to verify the proposed converter. Fig.8 shows the prototype model. A TLP250 IC is used with Arduino uno for gate pulses. The topology is implemented in hardware. Desired specifications of the converter and the components used are as follows

Input Voltage(Vin): 12V
Output Voltage(Vo):48V
Switching Frequency(Fs):10KHz
Capacitor(C1):86.80µF
Capacitor(C2): 86.80µF
Switches S1 and S2:
Inductor (L1 and L2))=720 µH

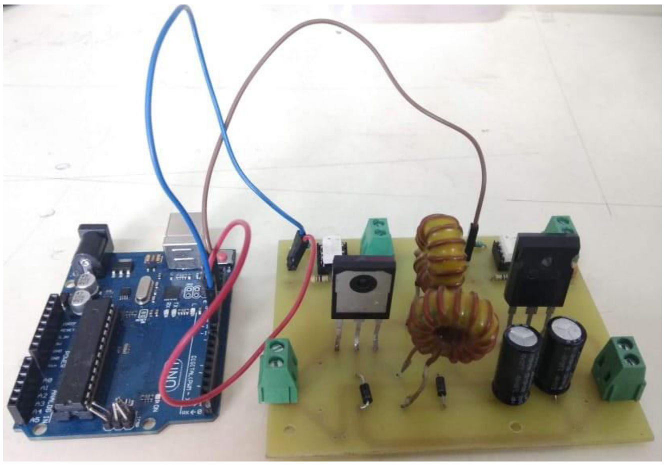

Figure. 8. 100W Prototype model of the converter

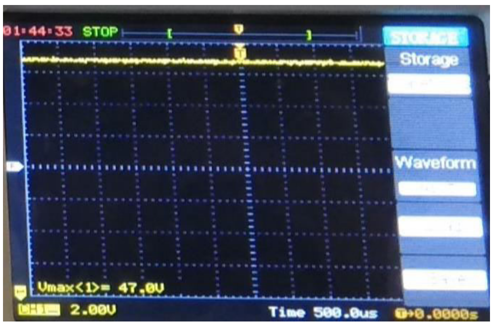

Figure.9. Output voltage of proposed converter

Duty cycle is of 0.5, the output voltage is checked on DSO and is as shown in fig.9 The prototype has an output of 47 V which is close to 48 V. The circuit has been operated in open loop.

IX. APPLICATIONS

- Hybrid/electric vehicles
- Fuel cell vehicles
- Energy conversion system

- Solar cell applications

X. CONCLUSIONS

This converter has not only the high gain but also the input current ripple can be eliminated. Actually the proposed converter can cancel the input current ripple at selectable duty cycle without using any transformers. The number of elements in the proposed converter in eliminated input current ripple mode is less than the converter described. So, the proposed converter would cost less. In addition, the converter's efficiency compared with the converter in is higher. Also, the efficiency of the converter in the first case compared with the conventional cascade booster is higher. In general, this converter achieves a wide range of voltage gain and cancels the input current ripple without using any transformers. The minimum voltage gain of the converter in the operation mode is four. Finally, a laboratory sample of the converter is made and the accuracy of the converter is studied.

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