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A Non isolated Dual input Dual output DC-DC Boost Converter for Electric Vehicle Applications

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ABSTRACT: A new non isolated dual input dual output dc–dc boost converter is presented in this paper. This converter is applicable in hybridizing alternative energy sources in electric vehicles. By hybridization , advantages of different energy sources can be achieved and also in between input sources ,loads power can be flexibly distributed. Also, charging or discharging of energy storages by other input sources can be controlled properly. The proposed converter has several outputs with different voltage levels which makes it suitable for interfacing to multilevel inverters. Also, electric vehicles which uses dc motor have at least two different dc voltage levels, one for ventilation system and cabin lightening and other for supplying electric motor. The converter presented here has just one inductor. Depending on charging and discharging states of the energy storage system (ESS), two different power operation modes are defined for the converter. In order to modify system performance a PID controller is introduced . Further, Fuzzy control logic is included in it as it is widely used in machine control. The validity of the converter and its control performance are verified by MATLAB/SIMULINK

KEYWORDS: DC–DC converters, electric vehicle, hybrid power system, multiple-input–multiple-output (MIMO)

I.INTRODUCTION

Increasing rapidly population and energy consumption in the world, increasing oil and natural gas prices, and the depletion of fossil fuels are justifiable reasons for using electrical vehicles (EVs) instead of fossil-fuel vehicles. The interest in developing the EVs with clean and renewable energy sources as a replacement for fossil-fuel vehicles has therefore steadily increased. The EVs are introduced as a potential and attractive solution for transportation applications to provide environmentally friendly operation with the usage of clean and renewable energy sources. In this paper, a new multi input multi output non isolated converter based on combination of a multi input and a multi output converter is presented. This converter compared to similar cases has lesser number of elements and it can control power flow between sources with each other and load. Also, presented converter has several outputs that each one can have different voltage level.

II. BASIC DUAL INPUT DUAL OUTPUT DC-DC BOOST CONVERTER AND OPERATION MODES.

A non isolated dual input dual output DC–DC converter is presented. The structure of the converter with two-input two-output is shown in Fig.1 . In this figure, R_1 and R_2 are the model of load resistances that can represent the equivalent power feeding to a multilevel inverter. Four power switches S_1 , S_2 , S_3 and S_4 in the converter structure are the main controllable elements that control the power flow and output voltages of the converter. In this converter, source V_{in1} can deliver power to source V_{in2} but not vice versa. So, in EV applications, FC which cannot be charged is located where V_{in1} is placed in circuit. Also, usually where V_{in2} is placed, ESSs such as battery or SC which are chargeable are located. In this paper, FC is used as a generating power source and the battery is used as an ESS. Depending on the utilization state of the battery, two power operation modes are defined for this converter. In each

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mode, just three of the four switches are active, while one switch is inactive. When load power is high, both input sources deliver power to load, in such a condition, S_2 is inactive and switches S_1 , S_3 and S_4 are active. Also, when load power is low and V_{in2} is needed to be charged, V_{in1} not only supplies loads but also can charge V_{in2} . In this condition, switches S_1 , S_2 and S_4 are active and S_3 is inactive. Depending on the utilization state of the battery, two power operation modes are defined for this converter. First is battery discharging mode and second is battery charging mode.

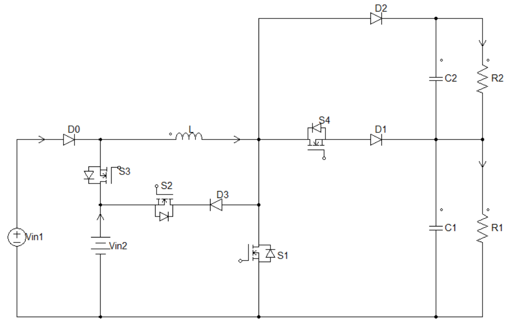

Fig.1: Converter with Dual-input, Dual-output

III.MODIFIED DUAL INPUT DUAL OUTPUT DC-DC CONVERTER WITH PID CONTROLLER.

In a closed-loop system, a controller is used to compare the output of a system with the required condition and convert the error into a control action which is designed to reduce the error and bring the output of the system back to the desired response. Closed-loop control systems have many advantages over open-loop systems. Fig. 2 shows block diagram of closed loop system with PID controller.

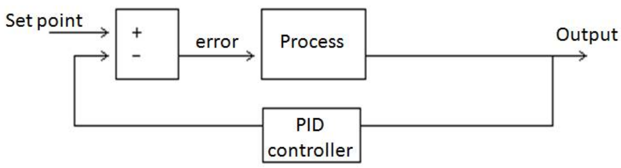

Fig.2: Block diagram of closed loop system (PID controller)

Open Loop Systems are simpler in their layout and hence are economical and stable too due to their simplicity. Since these are having a simple layout so are easier to construct. These systems do not have a feedback mechanism, so they are very inaccurate in terms of result output and hence they are unreliable too. Due to the absence of a feedback mechanism, they are unable to remove the disturbances occurring from external sources. Closed Loop Systems are more accurate than open loop systems due to their complex construction. They are equally accurate and are not disturbed in the presence of non-linearities. Since they are composed of a feedback mechanism, they clear out the errors between input and output signals, and hence remain unaffected to the external noise sources. They are relatively more complex in construction and hence it adds up to the cost making it costlier than open loop system. Since it consists of feedback loop, it may create oscillatory response of the system and it also reduces the overall gain of the system. It is less stable than open loop system but this disadvantage can be avoided, since we can make the sensitivity of the system very small so as to make the system as stable as possible.

IV. PROPOSED DUAL INPUT DUAL OUTPUT DC-DC CONVERTER WITH FUZZY CONTROL

A fuzzy control system is a control system based on fuzzy logic a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital

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logic, which operates on discrete values of either 1 or 0 (true or false) respectively. Fig. 3 shows block diagram of closed loop system with Fuzzy control.

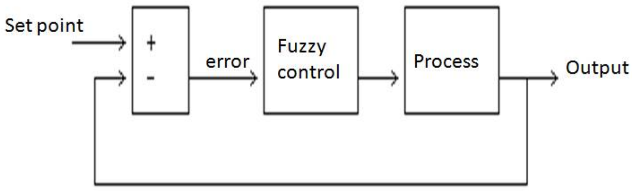

Fig.3: Block diagram of Fuzzy control

Fuzzy logic is widely used in machine control. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as the "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. This makes it easier to mechanize tasks that are already successfully performed by humans.

V. RESULTS AND DISCUSSION

For an input of 3 V and 8 V, switching frequency f_c as 10kHz and a 100Ω resistive load, the proposed dual input dual output converter was simulated in battery discharging mode by using MATLAB R2014a. Following are the parameters used for MATLAB simulation of the converter.

Table 5.1: Simulation Parameters

Simulation parameters	Values
Switching frequency	10kHz
DC Source (V_{in1})	3 V
Battery (V_{in2})	8 V
Inductor	3.2mH
Capacitors (C_1 , C_2)	22µF
Load resistance	100 Ω

SIMULINK MODEL OF BASIC DUAL INPUT DUAL OUTPUT CONVERTER

Fig.4 shows the Simulink model of the basic Dual input Dual output converter. Simulation is performed with 3 V and 8 V input sources and a 100 resistive load.

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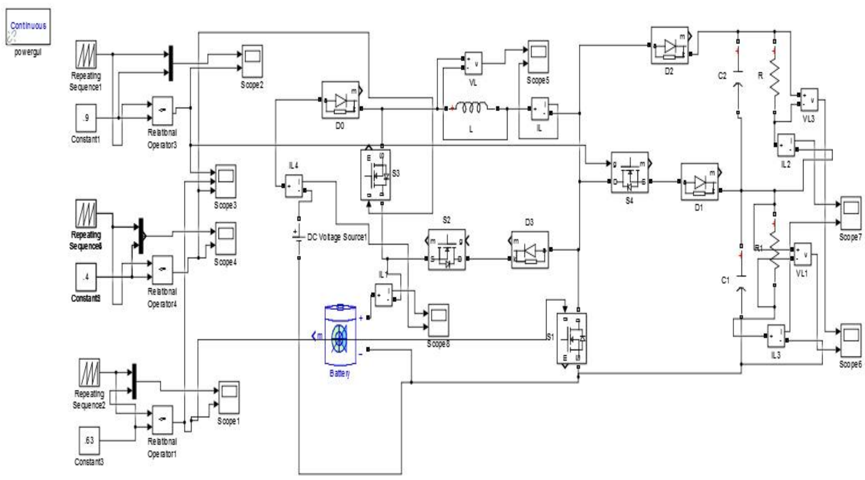

Fig.4: Simulink Model of basic Dual input Dual output converter

SIMULINK MODELS OF MODIFIED DUAL INPUT DUAL OUTPUT CONVERTER WITH PID CONTROLLER AND FUZZY CONTROLLER

Simulation is performed with 3 V and 8 V input sources and a 100Ω resistive load. Simulink model of the modified Dual input Dual output converter with PID Controller is shown in Fig.5.

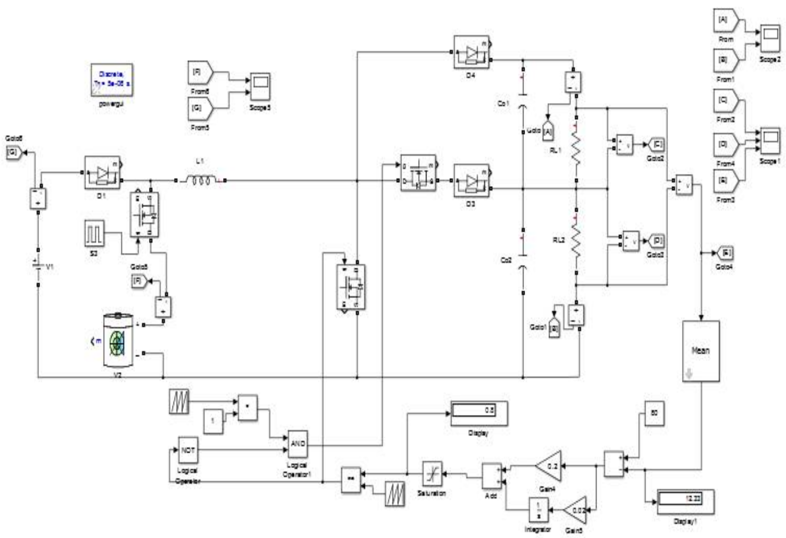

Fig.5: Simulink Model of Modified Dual input Dual output converter with PID Controller

Simulink model of the modified Dual input Dual output converter with Fuzzy Controller is shown in Fig.6.

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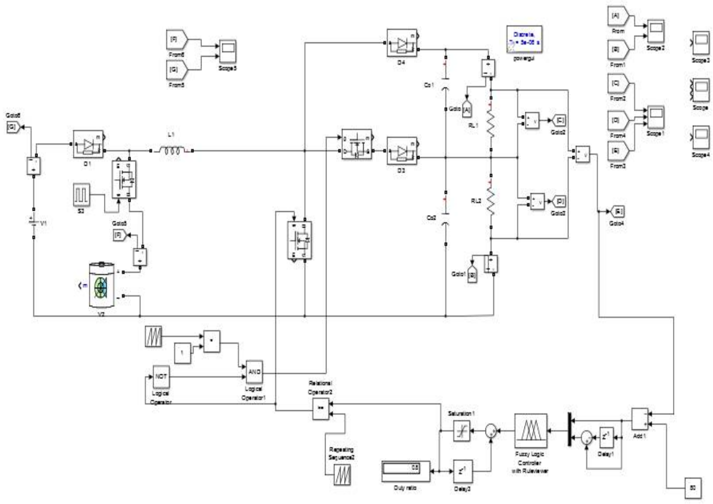

Fig.6: Simulink Model of Modified Dual input Dual output converter with Fuzzy Controller

The performance of the proposed converter can be analyzed using various parameters such as maximum output voltages, output currents, ripples in output etc.
Section below includes different level output voltages of open loop system and closed loop system with both in PID and Fuzzy controller. For an input of 3 V and 8 V, and switching frequency f_c as 10kHz simulation is carried out.

OPEN LOOP SYSTEM OUTPUT VOLTAGE

Fig.7 shows the level 1 and 2 output voltages of the Basic Dual input Dual output DC-DC boost converter.

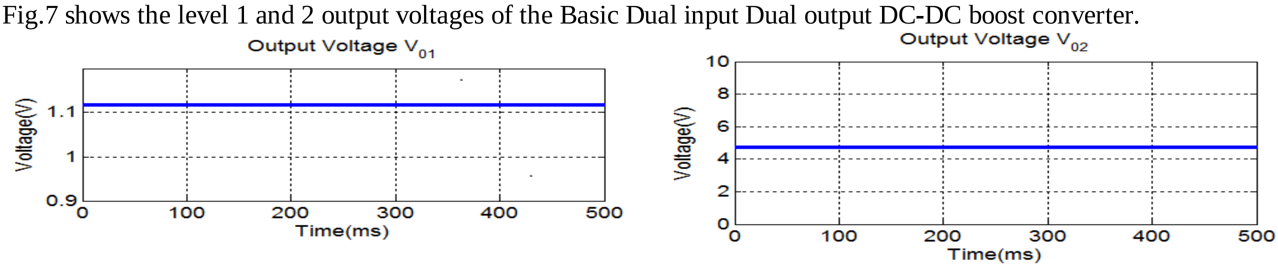

Fig.7: Output voltages V_{O1} , V_{O2}

It is observed that Level 1 output voltage is V_{O1}= 1.11 V and Level 2 output voltage is V_{O2}= 4.68 V.

CLOSED LOOP SYSTEM WITH PID CONTROLLER OUTPUT VOLTAGE

Fig.8 shows the level 1 output voltage V_{O1} and level 2 output voltage V_{O2} respectively of Dual input Dual output DC-DC boost converter with PID Controller.

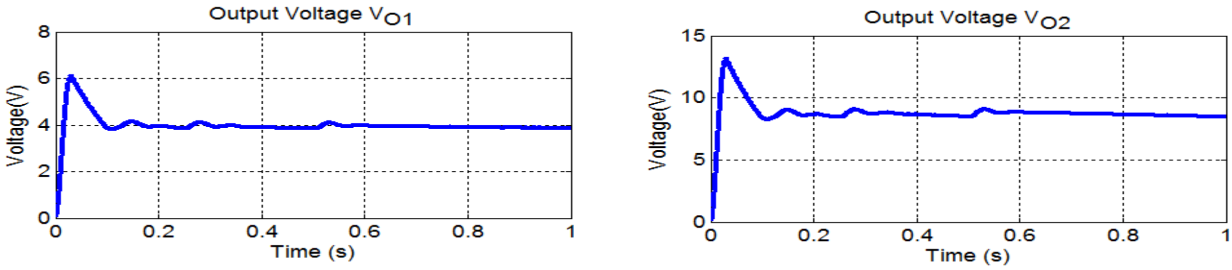

Fig.8: Output voltages V_{O1} , V_{O2}

It is observed that Level 1 output voltage is V_{O1}= 3.86 V, Level 2 output voltage is V_{O2}= 8.47 V and total output voltage V_T = 12.33 V.

CLOSED LOOP SYSTEM WITH FUZZY CONTROLLER OUTPUT VOLTAGE

Fig.9 shows the level 1 output voltage V_{O1} and level 2 output voltage V_{O2} respectively of Dual input Dual output DC-DC boost converter with Fuzzy Controller.

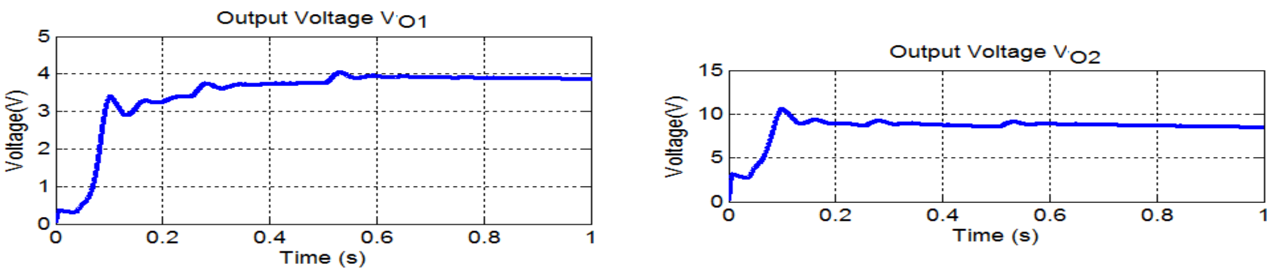

Fig.9: Output voltages V_{O1} , V_{O2}

It is observed that Level 1 output voltage is V_{O1}= 3.86 V, Level 2 output voltage is V_{O2}= 8.47 V and total output voltage V_T= 12.33 V.

VI. EXPERIMENTAL SETUP AND RESULTS

Hardware setup is done in printed circuit board (PCB) as well as bread board. Control circuit is made in bread board and power circuit in printed circuit board. The implementation of the prototype of Dual input Dual output DC-DC Boost converter circuit requires two main steps, first is the software implementation. Once the programming is done accurately for generating gate switching for switching devices, the hardware implementation of the circuit can be carried out. Software programming is done in PIC16F877A micro controller. The switches used are MOSFET IFR540 along with its driver TLP250 which is an optocoupler used to isolate and protect microcontroller from any damage, and also to provide the required gating to turn on switches. The switching pulses of each switch is generated using PIC16F877A microcontroller by a delay program which uses four PORTB pins (pin 33 - pin 36).

The top view of the experimental set up of hardware prototype is shown in Fig.10 . To control MOSFET (IRF540) pulses are created using PIC16F877A microcontroller . These control pulses are amplified using an optocoupler TLP250. Essential pulses for turning MOSFETs have to be 15 V for ON-state and 0 volts for OFF-state. Isolation between power and control circuit is done by a TLP250 Driver/Optocoupler IC. Port B of PIC is used as output for taking pulses. This voltage won't be able to drive the switches in to conduction. Therefore driver IC is used which is TLP250. The TLP250 is an optocoupler, which isolates control circuit and power circuit. The input voltage to driver IC should be in the range of 12 V to 30 V. By connecting two 9 V batteries in series an 18 V can be obtained which is provided as input to the TLP250.The TLP250 is an 8 pin dual in line package. The output of TLP is taken from either pin no. 6 or 7. Pin no.3 and 5 is the ground of control circuit and power circuit respectively. The driver output is

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connected to the gate of the switches through a resistor. Power diode is used in the power circuit in order to withstand high voltage and current. DSO is used for analysis of output waveforms.

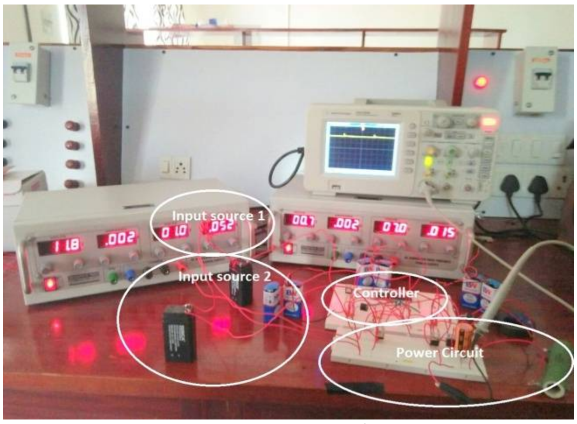

Fig.10: Experimental Setup of the converter

The experimental results of the prototype are given here. Programming is performed in mikroC software. For the hardware prototype, 22µF capacitor and 100Ω, 5W load resistor is used. Gate pulses for the switches S_1, S_3 are shown below.

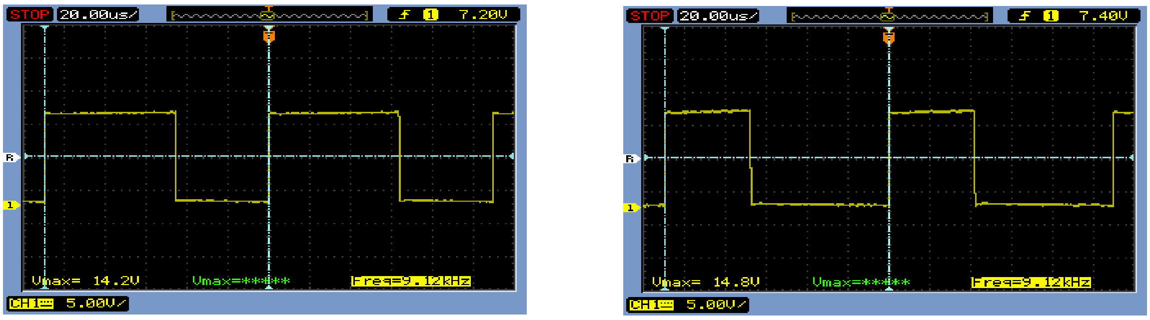

Fig.11: Gate pulses for the switches S_1, S_3

Switch S_2 is completely absent in this mode. Gate pulse for the switch S_4 is shown in the Fig.12.

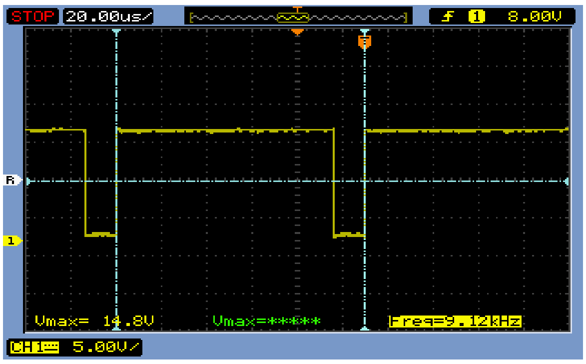

Fig.12: Gate pulse for the switch S_4

OUTPUT VOLTAGES

Fig.13 shows the output voltages of the converter in two different voltage levels as V_{O1} and V_{O2}. PIC16F877A is programmed to output the gate pulses to the switches in the circuit.

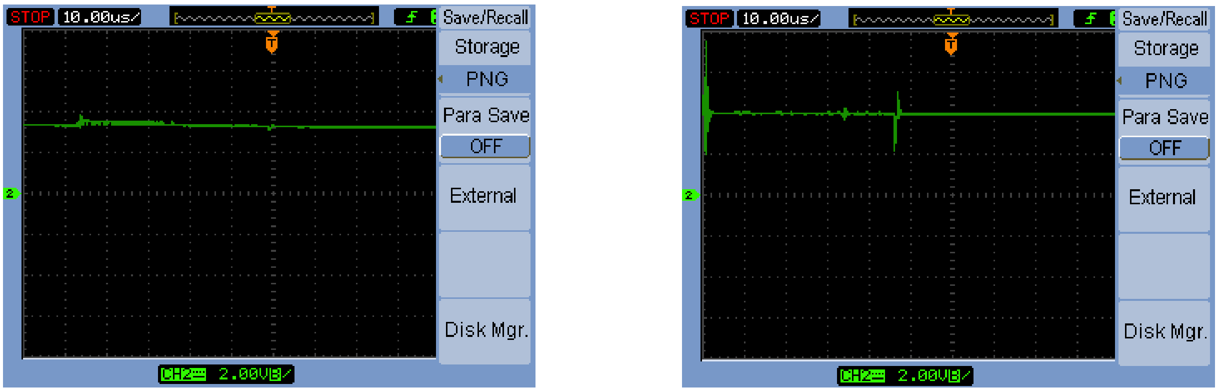

Fig.13: Level 1 output voltage V_{O1} and Level 2 output voltage V_{O2}

The output voltages obtained are V_{O1}=3.8 V and V_{O2}= 8.5 V. The different output voltage levels makes the converter suitable for interfacing to multilevel inverters. By introducing Fuzzy control logic, total output voltage is increased by 2.13 times while comparing open loop system . And also, Overshoot in output voltage can be effectively reduced.

VII.CONCLUSION

A new dual input dual output dc - dc boost converter with unified structure for hybridizing of power sources in electric vehicles is proposed in this paper. The proposed converter has just one inductor. The proposed converter can be used for transferring energy between different energy resources such as FC, PV, and ESSs like battery and SC . It is possible to have several outputs with different voltage levels. The converter has two main operation modes which in battery discharging mode both of input sources deliver power to output and in battery charging mode one of the input sources not only supplies loads but also delivers power to the other source (battery). Closed loop control of the converter is designed. In order to improve system performance Fuzzy control logic is introduced here. It has some advantages. Furthermore, fuzzy logic is well suited to low-cost implementations. Such systems can be easily upgraded by adding new rules to improve performance or add new features. In many cases, fuzzy control can be used to improve existing traditional controller systems by adding an extra layer of intelligence to the current control method. Outputs with different dc voltage levels are appropriate for connection to multilevel inverters. Also, electric vehicles which use dc motors have at least two different dc voltage levels, one for ventilation system and cabin lightening and other for supplying electric motor. Finally, operation of this converter is experimentally verified using low-power range prototype.

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