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Hybrid DC-DC Converter with Dual Switch Topology for Solar

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ABSTRACT
The battery-operated vehicles, popularly known as EV has reduced the carbon emission tremendously in transportation industry. The batteries are charged either through the grid or the best option is hybrid green resources like PV, fuel cell, Super capacitors, etc., For smooth functioning of hybrid resources, Bi-directional DC-DC converters are primarily required so as to maintain the DC-bus voltage both at load terminal as well as at input terminal where PV-battery are connected. In this paper performance analysis of a dual switch DC-converter is presented with bi-directional topology. The converter designed to perform buck-boost operation with wide range of voltage diversity. While combining hybrid resources, environmental constraints of PV is also considered and MPPT is designed with neural network tuning to obtain the maximum operating point under variable irradiance conditions. This will help in extending the efficiency of the DC-converter proposed. The results are obtained in MATLAB simulation tool.

Keywords - Renewable Generation System, Bi-Directional DC Converters (BDDC), Electric Vehicles, Neural Network (NN), Hybrid Battery Storage System (HBSS), Maximum Power Point Tracking (MPPT).

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I. INTRODUCTION

Transformation of Traditional Power Grid System (TPGS) into the hybrid system due to the involvement of Renewable Generation System (RGS) and their respective conversion system requires frequent high rating converters both DC as well as DC↔AC. At generation side green evolution is at its peak and around 40% of total electricity is now obtained from green resources. On the other hand, at demand side DC applications are still in adaptation phase so as to reduce the carbon foot print. DC-applications requires Bi-Directional DC Converters (BDDC) which can flip its voltage as per the requirement. All the renewable generation needs DC-batteries to fulfil the environmental gap so as to increase the reliability in supply. For charging and discharging of these batteries BDDC are required. Other than usage in storage system, BDDC are frequently used in Electric Vehicles (EV). In EV technology, BDDC has dual applications. One in charging and discharging of Hybrid Battery Storage System (HBSS), another is switching voltages during starting, running and braking modes.

With added electrification in automotive designs, the power demands for start↔stop of EV and hybrid electric vehicles have increased significantly [1]. For ignition and breaking in EV, BDDC switches frequently between the buck and boost mode. Hence a precise with high switching frequency and efficient BDDC is necessary for worldwide adoption of EV with overall ranges of automobile including Low/Medium/High vehicles [2]. For example, in LV-EV for 200 A of current distributed on a 12-V bus requires a larger cross-section copper wire, hence system becomes costly. Besides high-current-distribution conduction loss also increases, hence 12-V system becomes less. A 48-V power system can resolve this issue therefore a BDDC is added to power the high-power components instead. Table 1 presents this case study where a conversion of DC-DC voltage (12V ↔ 48 V) is presented to coordinated the voltage switch during operational constraints in EV [3].

Hence development in the design of BDDC topologies is a burning topic for researcher to increase the utilization of the green resources [4]. This paper also presents a BDDC topology utilizing solar generation for charging of DC batteries. In this paper a dual switch BDDC is designed and tested under constant and variable irradiance conditions. A lot of work has been done in this field, but the novelty of the research is that, the BDDC design can work for high diversity range of voltage at input/output terminals and the controller design for switching control utilizes Neural Network (NN) tuning for generating gate pulse of the switches. Results are presented in both buck-boost mode performing charging and discharging of the battery.

II. POWER BI-DIRECTIONAL DC-DC CONVERTER (BDDC)

Considering the wide diversity of EV range, the BDDC is designed for high range of voltage conversion in either direction to ensure that the voltage of HBSS and EV DC bus can be efficiently matched in accordance to the environmental condition of the RGS [5]. In EV due to high switching frequencies of BDDC, measures have to be taken to minimize the electromagnetic interference (EMI) hence the input/output terminals of BDDC should be commonly grounded [6]. High ripples at the input side can damage the life of HBSS, current of BDDC should be continuous to improve the durability of the power batteries/storage system [7]. In high rating EVs, stress on current and voltage is a threat to the reliability of the BDDC, hence BDDC should reduce the stresses across the switches to avoid the possibility of damage [8, 9]. In addition, BDDC must have high conversion efficiency to avoid the heating and energy dissipation causing losses across the semiconductor devices [10]. All the above-mentioned qualities is impossible to accommodate in a single BDDC topology. Numerous topologies are available in literature to best suit the requirement of the BDDC applications [11]. The existing BDDC types are: Non-isolated and Isolated BDDC. Non-isolated BDDC is a network composed of capacitor, inductor as well as switches to realize direct DC–DC conversion [12]. A transformer is added between DC↔DC in the non-isolated topology for DC↔AC↔DC conversion [13, 14]. The detailed classification of BDDC is shown in Figure 1.

This paper presents a BDDC topology having dual switch configuration which can be implemented to the wide range of voltage conversion with high gain. The switches of the converter are triggered as per the MPPT algorithm which is assisted by neural network technique for the fast and accurate convergence of the maximum point. The converter can work in boost as well as buck mode. Also, the boost buck conversion is very smooth with high conversion gain and efficiency. The proposed topology is designed in MATLAB software and results are presented in both the mode. The gate pulses are controlled using voltage controller.

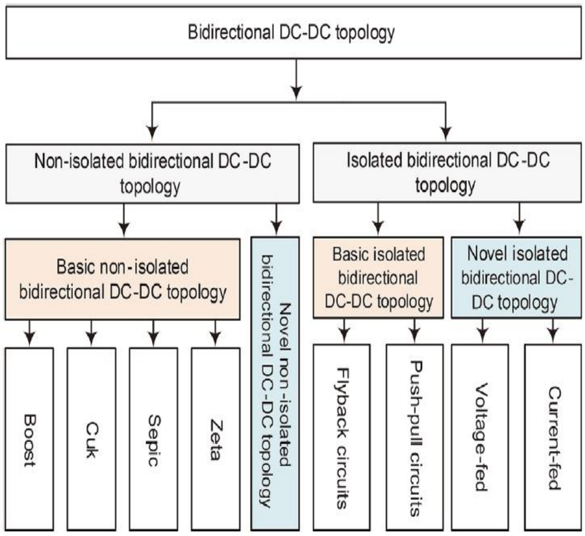

Fig. 1. Classification of BDDC topologies.

III. PROPOSED WORK

This paper presents a DC-converter with bidirectional feature for charging and discharging of batteries connected at input side as well as output side. Input side battery is powered by PV power whereas at the output terminal of BDDC, battery of EV is connected. The schematic diagram of proposed system is shown in figure 2. The BDDC designed, controls the battery status at both the ends and maintains the DC-voltage at EV side at variable voltage conditions. PV side battery, takes into account the variation in irradiance, results are also presented without connecting the PV side battery and the output obtained from PV is directly fed to the BDDC. The PV system includes the PV-array and Maximum Power Point Tracking (MPPT) algorithm. Incremental and conductance MPPT algorithm is employed to track the maximum voltage and current of solar. The PID controller is used to control the gate pulses of the two switches of BDDC. The NN helps in tuning of quickly and accurately gains of PID controller with varying operating conditions. The input layer receives the data to be processed, the hidden layer treats the network, and the output NN layer displays the network replies. This is the structure of a NN which is shown in figure 3. Because NN doesn't require a physical model or complicated mathematical calculations, it is frequently utilised for MPPT control.

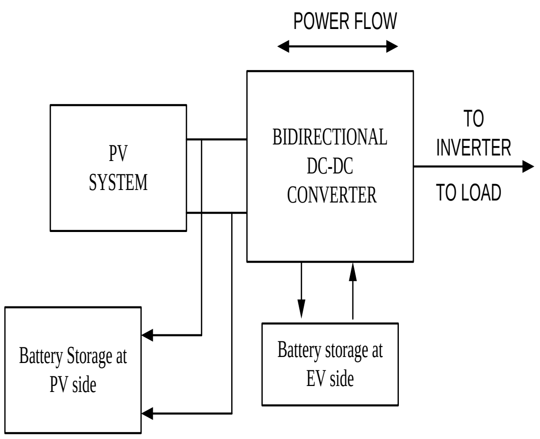

Fig. 2. Schematic of proposed BDDC topologies.

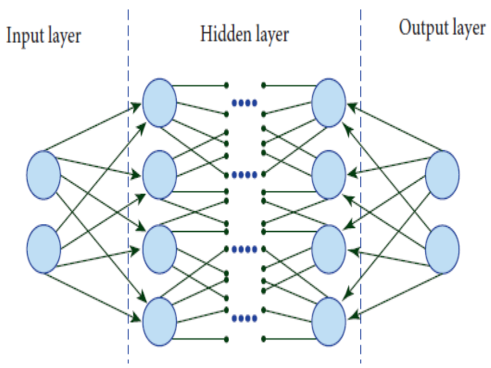

Fig. 3. Neural topology.

IV. SIMULATION RESULTS

The simulation results for the proposed system had been obtained in matlab simulation software as shown in figure 4. The proposed BDDC work on dual mode of boost↔buck considering variations in solar irradiations and change in EV requirement during ignition and breaking. During ignition high voltage is required and during breaking power is fed back to the system, hence bidirectional converters help in simultaneous charging and discharging of the batteries. The proposed BDDC is powered by PV-power at the input terminal as shown in figure 5. The two switches S1 and S2 controls the boost↔buck operation during. The topology in both the modes of operation are shown in figure 5.

The proposed BDDC is analysed for constant and variable solar irradiations. A PV module is considered with max. voltage of 30.7 V and max current rated is 8.15 A. The design parameters for the BDDC are given in table 1. The simulation results are firstly presented for boost mode showing the input-output voltages and current.

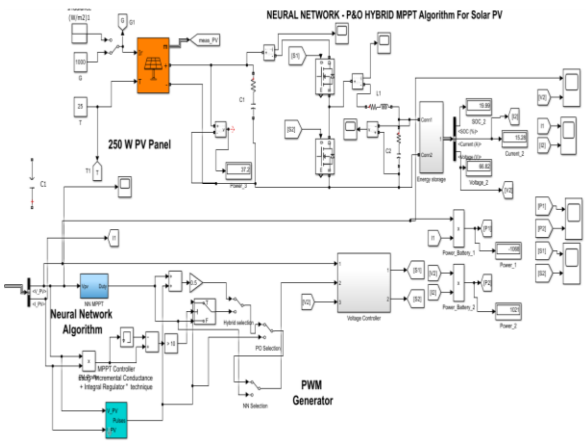

Fig. 4. Simulation model.

Table.1 BDDC Design Parameters

Parameters	Values
F	50Hz
Fs	10 KHz
D_1	0.4
D_2	0.6
C_1	1000 μF
C_2	100 μF
R_1	0.01
R_2	0.1
L_1	20mH
Proportional gain	1.5
Integral gain	25

a. Boost operation with constant Irradiations

The solar irradiance is kept constant at 1000 w/m2 to test the performance of the BDDC in boost mode. The PV-array generates 9000 w at 70 V. This voltage is fed to the BDDC which boost it upto 200

V as shown in figure 6. The switching status under this condition is shown in figure 7.

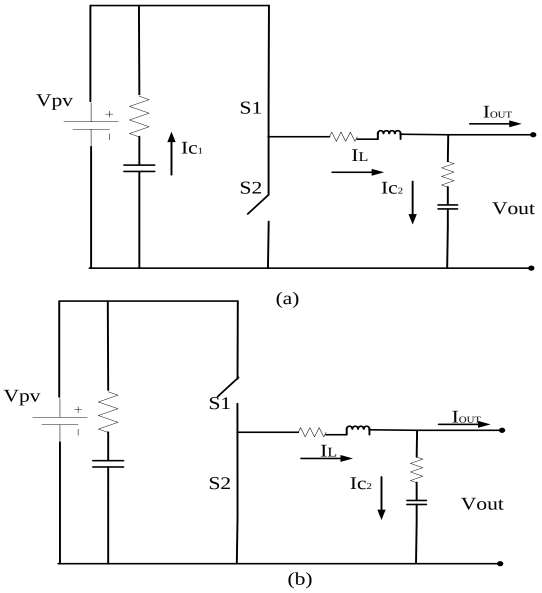

Fig. 5. Single line diagram of proposed BDDC topologies.

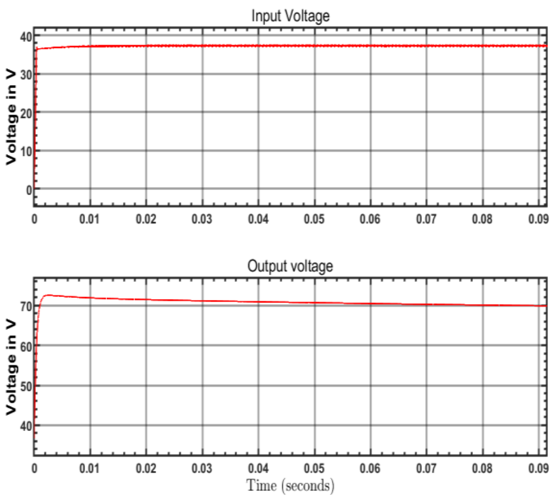

Fig. 6. Input/Output voltage under boost mode.

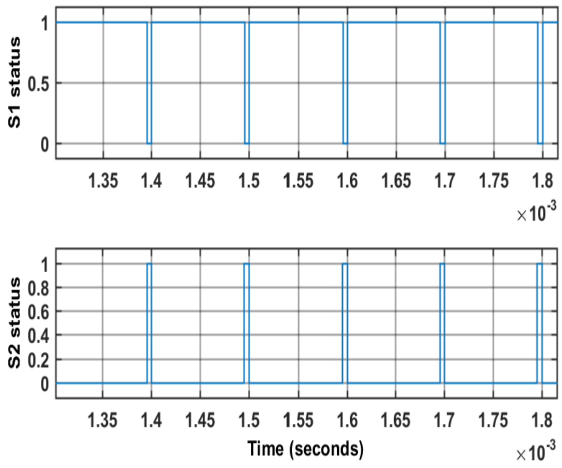

Fig. 7. Switch status under boost mode.

b. Buck operation with constant Irradiations

In buck mode, the flow of current is reverse from EV battery to towards PV system. This is the case when braking is applied, or the battery is overcharged so as to maintain the voltage level as predefined one at both the terminals. In this mode also, the solar irradiance is kept constant. The input/output voltage under such condition is shown in figure 8 with respective currents as per the figure 9. From the figure 9, it can be seen that the current i1 at input side is flowing in reverse direction which shows the bidirectional feature of the BDDC where input voltage is 70 V which is reduced to 25 V. The inductor current under this condition is shown in figure 10.

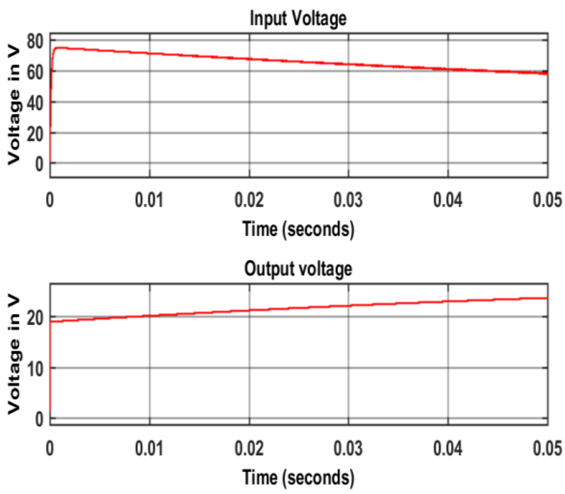

Fig. 8. Input/output voltage under buck mode with constant irradiance.

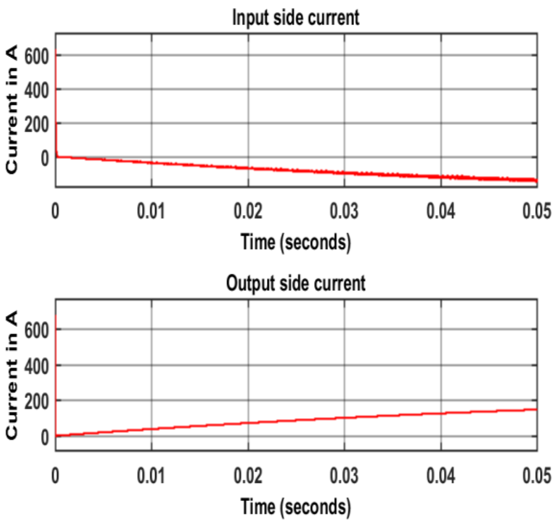

Fig. 9. Input/output current for buck mode with constant irradiance.

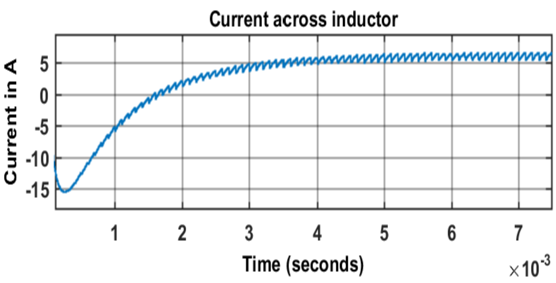

Fig. 10. Inductor current for buck mode.

c. Boost/Buck operation with Variable Irradiations

Now the designed system has been analysed for variable irradiance for boost mode. The irradiance is varied from 1000-600 w/m2 as shown in graph of figure 11. The switch status for this condition is shown in figure 12.

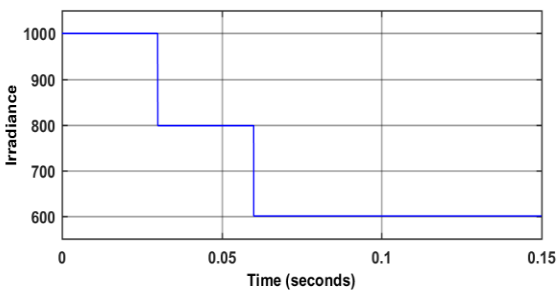

Fig. 11. Variable irradiance graph.

The voltage at input and output side for boost mode under variable irradiance condition is shown in figure 13. And in buck mode the voltage at input side is 150 V, which is reduced to 20 V as shown in figure 14. From both the figures of voltages in boost and buck mode, it can be seen that though irradiance is varying but does not affect the voltages at the terminals of the BDDC. The inductor current under this condition is shown in figure 15.

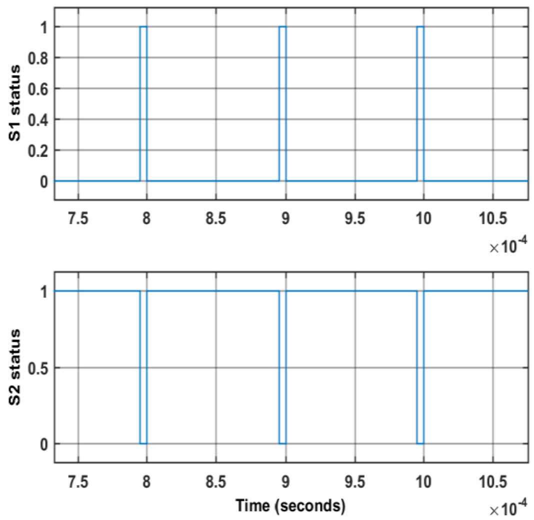

Fig. 12. Switch status under the condition of variable irradiance with buck
mode.

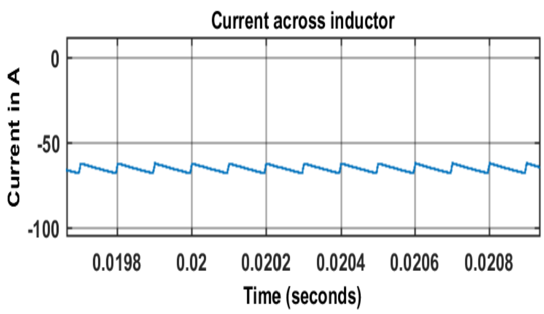

Fig. 13. Inductor current for variable irradiance.

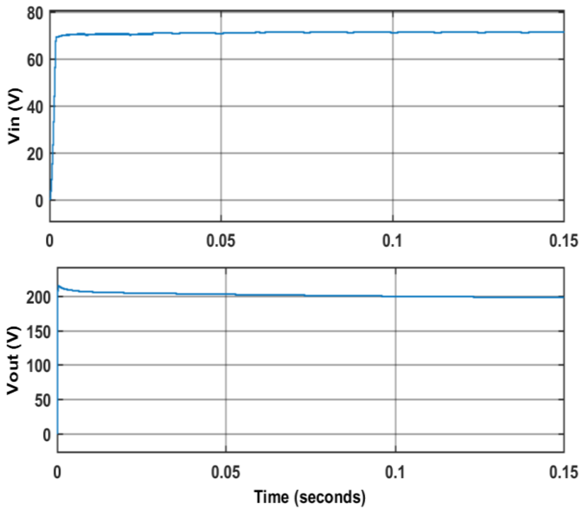

Fig. 14. Input/Output voltage under boost mode with variable irradiations.

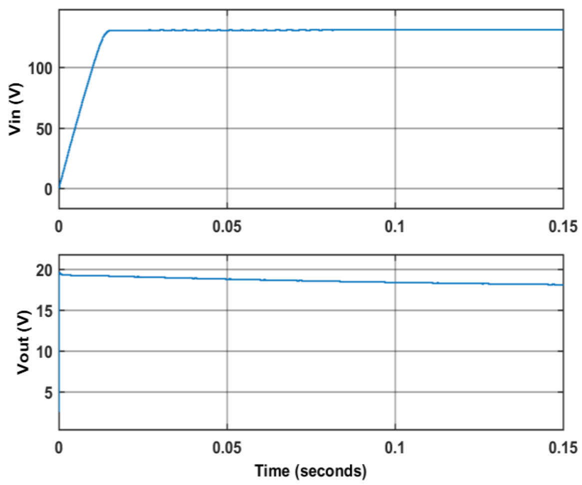

Fig. 15. Input/Output voltage under buck mode with variable irradiations.

V. CONCLUSION

The DC battery system is increasing in numerous operations as a result of green energy system and so the bidirectional DC converters. This paper presents one such application of BDDC in EV. The battery system used in input side of the BDDC is charged via solar power and at the output side battery. Solar energy is continuously varying in nature hence a MPPT incremental and conduct. Algorithm is employed to track the max. point of voltage and current generation from PV. To increase the tracking and for fast response, In this paper neural network is employed in conjunction with the MPPT. The proposed BDDC is tested under varying and constant irradiance for both boost-buck operation. The output obtained is unaffected by irradiation variation and a smooth boost-buck operation is verified. Results obtained at various voltage ranges to justifies the diversity of the design which fulfil the requirement of EV.

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