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Multi-Port DC-DC Converter for Simultaneous Buck and Boost Operation

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ABSTRACT
As the power system is moving towards zero carbon trace emission, DC- System (DCS) plays a vital role. Approximately all renewable resources are based on DCS, low rating smart devices also works on DC power, automobile industry is also switching towards DCS. Hence DC-Converters (DCC) are becoming extremely popular and essential. In this work a Multi-Port Converter (MPC) essentially DC is designed which is capable of connecting multiple DC units at a time with versatile voltage profile. Also, it can perform both buck as well as boost functioning to meet the power as well as voltage ratings of various sources as well as applications simultaneously. The advantages of proposed MPC are it employs only two switches and the switches has very low voltage ratings hence losses are reduced. Also, it offers negligible interference even at high switching frequencies. The proposed DC converter is designed for low voltage rating.
Keywords – Cascaded 5-level MLI (C-5-L-MLI) Multi-Level Inverter (MLI), Power Electronics Converters, PV-Panel, Voltage Source Inverter (VSI), Total Harmonic Distortion (THD).

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I. INTRODUCTION

The present-day power as well as distribution system is moving towards hybrid sources in-order to interface numerous-source with expanded voltage and power ranges. For interfacing multiple source with diverse voltage characteristics Multi-Port Converter (MPC) are essential [1]. These converters can interface numerous energy system and also applied to the electric vehicles and energy storage system for smooth operations among the loads and sources under various operation range of voltage [2]. The bidirectional DC–DC Converter (DCC) is one of these converters that can transfer the energy to load as well as load with bidirectional current flow pattern. This means when required it will transfer the power to the load and as per the requirement, the bidirectional DCC can be used to transfer the power supply energy to the DC link [3]. Fig. 1 describes the application of the MPC with hybrid sources.

In literature numerous bi-directional DCC are presented but they suffer the disadvantage in terms of component count, cost, low input ripple current, etc [4-6]. These converters have poor performances due to their low voltage conversion ratio, the voltage stress of the semiconductors is also high. Hence this paper presents a MPC with bi-directional feature [7]. This means that the MPC can perform simultaneous function of buck or boost converter. When the power from the hybrid source is sufficiently available it will charge the Battery Storage System (BSS) [8]. In the case of low voltage profile of the source it can also provide power to the source by draining the BSS. Hence the name bi-directional buck-boost MPC is used.

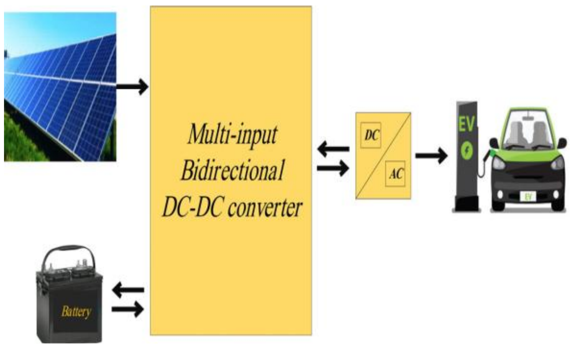

Fig. 1. Conceptual architecture of the proposed MPC.

II. MULTI-PORT DC-DC CONVERTERS

MP-DCC are highly utilized in industrial applications, for interfacing multiple hybrid resources at a time, in BSS and in automobile sector [9]. The increased applications of DCC have raised the need for newer topology with reduced component and high efficiency. The conventional DCC topologies are broadly classified as buck, boost, buck-boost, cuck, ZETA and SEPIC [10]. The typical arrangement CHB-MLI is presented in fig. 2. The DCC were also utilized widely but they suffer from high losses, more component requirement for the same voltage, high voltage stress across the switches and low efficiency [11]. To overcome these advantages, modification is made in the conventional topologies to obtain reduced component count, low voltage stress across the switches, high efficiency and are compact in size with modular structure [12]. Another advantage these converters have is, they can have multiple input with versatile voltage profile and the diversified output voltage can be generated as per the load demand [13].

The MP-DCC are classified into two types based on the transformer circuit topology: non isolated and isolated MPCs [14]. In isolated types, the transformer with multi-winding is used. It improves the voltage gain by increasing the number of turns and also, provides the isolation between the input-output port [15]. Nevertheless, it suffers the disadvantage of high-voltage stress and conduction losses. The non-isolated type has simple structure high voltage gain, low magnetic interference, low voltage stress, high efficiency, etc [16].

Another classification is based on the no. of input-output ports; Multi-Input-Single-Output (MISO), Single-Input-Multi-Output (SIMO) and Multi-Input-Multi-Output (MIMO) [17]. These types of MPCs are becoming very popular due to there modular structure and the capability to adjust its voltage gain as per the requirement [18]. In MISO multiple hybrid sources can be integrated to feed a single load as shown in figure 2. In SIMO converter, single DC source can feed the multiple loads as shown in figure 3. and in MIMO multiple sources can feed the multiple loads with diversified voltage level as shown in figure 4 [19]. The last but widely implemented topology is SISO that is Single-Input-Single-Output DC-converter. In this work also voltage and current control of closed loop SISO topology is presented as shown in figure 5 [20].

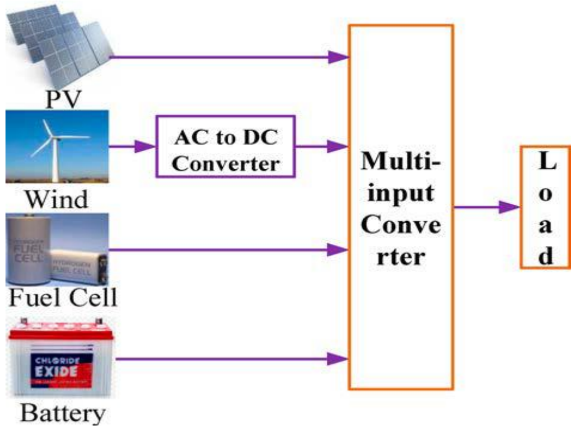

Fig. 2. MISO structure of MPC.

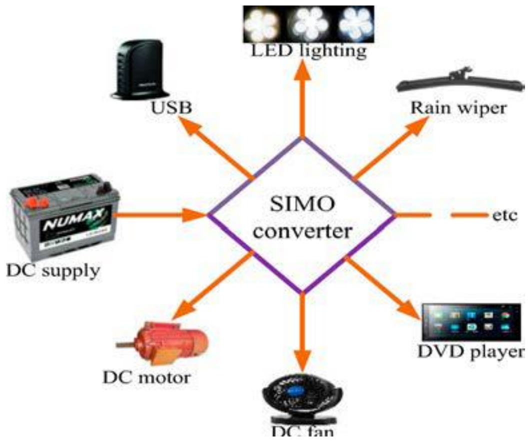

Fig. 3. SIMO structure of MPC

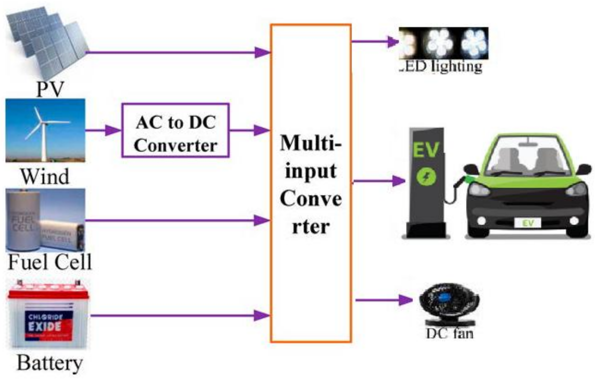

Fig. 4 MIMO structure of MPC.

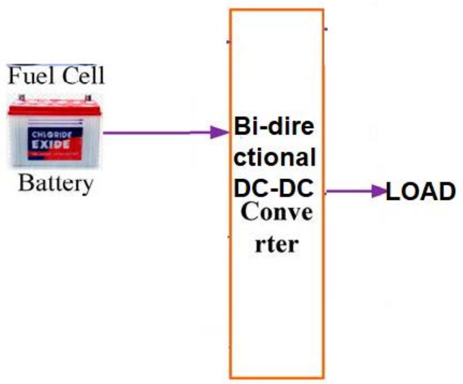

Fig. 5. Simulation model of proposed CHB-MLI

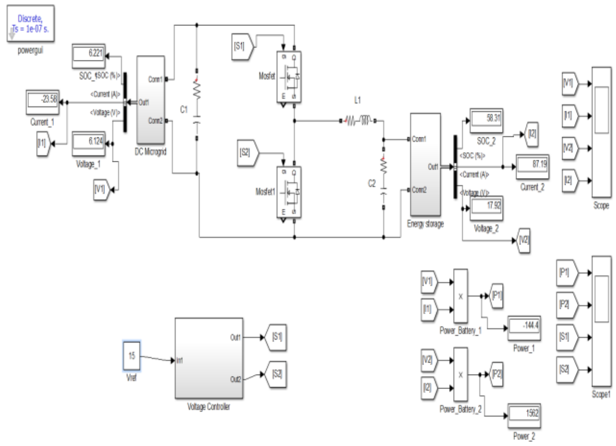

Fig. 6. Simulation model of the proposed DC converter.

III. SIMULATION MODELLING

In this work a SISO MPC is proposed with simultaneous boost and buck operation. The proposed converter is designed for low voltage rating of 6 V input side and 20 voltage output side in case of boost converter and vice-versa for buck converter. The designed simulation model of the DC-DC converter is shown in figure 6. A Dc-microgrid is designed which is the replica of hybrid sources. The microgrid is comprised of a battery B1 Nickel-mettal-Hydride battery with nominal voltage of 6V, rated capacity of 6.5 Ah, Initial charge state as 10 % and battery response time of 0.5 sec. the input battery is then connected to the series RC branch to stabilize the input. Two mosfet switches are cascaded and the output is obtained across C2. At the output side another battery B2 is connected whose ratings are 20 V. this battery perform the function of BSS. The state of charge (SOC) for this battery is 60%. Which means battery will be charged to 60 % of its rated capacity. The parameter table is given in Table 1.

Table 1 Basic parameters for PV module

Symbol	Parameter
B1	6 V
B2	20 V
C1	1000 µ F
C2	20 µ F
L	13 mH
Switching frequency	10 K Hz
Kp	1.5
K_I	25

The controller is designedin voltage control mode. To design the controller a constant reference value is set for the batteries for charging and discharging purpose. The set value of voltage is compared with the system input and output voltages. The controller is designed using PI controller whoes gains are given in table 1. The output of the PI controller is fed to the 2-level pulsewidth generation block which generates the gate pulses for the two switches. Among the two switches either of the one is ONN at at time . The system is analysed firstly for boost mode. In this mode the B1 is the input voltage of 6 V. it suuplies the load which is in the form of B2 having voltage value of 20 V, this means the voltage gain of the designed DCC is 3. The DCC supplies the voltage till B1 is equal to B2. This means the B2 will be charged till the V1=V2. That is both voltages are equal as shown in figure 7. In this figure the input voltage, input cutrent, output voltage and output cuurent are compared together. The input voltage is initially at 6 V and varies to 7.5 V. the output voltage is initially 20 V and varies upto 7.9 voltgae till the V1=V2, since V1 is charging the V2. In this input current is negative since it is supplying current to the B2. Output current is positive since it is receiveing power as shown in figure 8. In this mode switch S1 is OFF and it have zero binary display as shown in figure 8 port 3 and switch S2 is ONN and it have one binary display. The input power is negative and output power is positive.

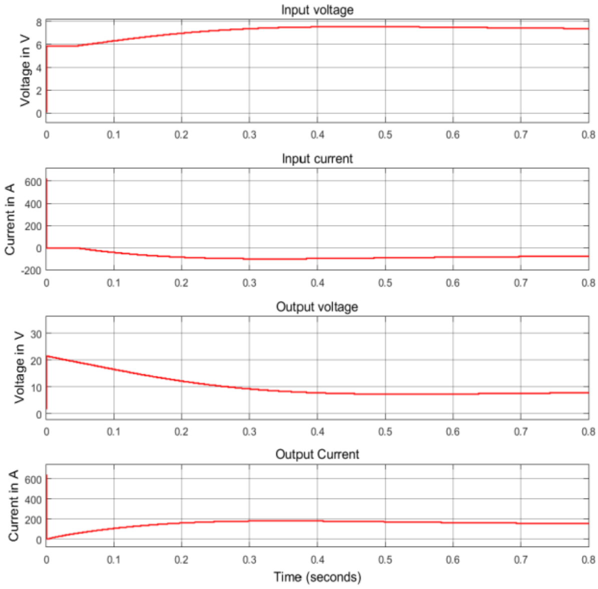

Fig. 7. Input-output voltages and current of the proposed DCC in boost mode

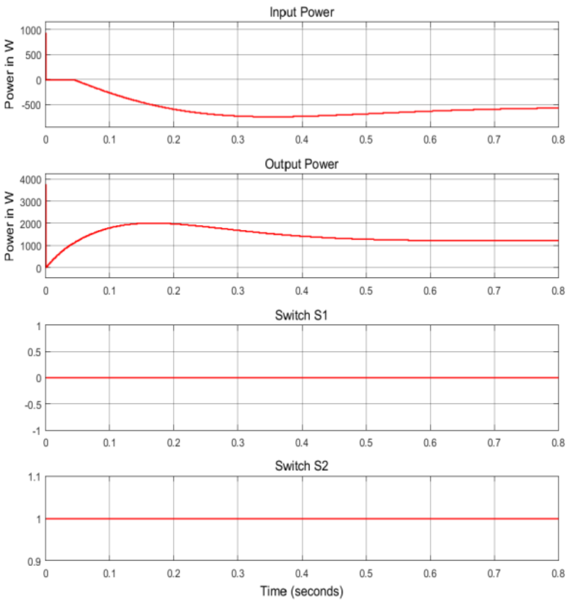

Fig. 8. Input-output power and switching state of the proposed DCC in boost mode

In the proposed design the converter can simultaneously works on buck topology. to analyse the performance under the buck mode ratings of the batteries are interchanged. This means in this mode the B1 is the input voltage of 20 V. it suuplies the load which is in the form of B2 having voltage value of 6 V, this means the voltage is stepped down by the factor 3. The DCC supplies the voltage till B1 is equal to B2. This means the B1 will be discharged till the V1=V2. That is both voltages are equal as shown in figure 9. In this figure the input voltage, input cutrent, output voltage and output cuurent are compared together. The input voltage is initially at 20 V and varies to 15 V. the output voltage is initially 20 V and varies upto 7.5 voltgae till it discharged to 10 %, since V1 is discharging to attain V2. In this input current is positive since it is receiving current from the B2. Output current is negative since it is supplying power as shown in figure 10. In this mode switch S1 is ONN and it have zero binary display as shown in figure 8 port 3 and switch S2 is OFF and it have one binary display. The input power is negative and output power is positive.

Hence the results shows that the proposed DC-Dc converter successfully works on bidirectional mode. This means it can perform the functioning of boost as well as buck converter. When the input side battery is fully charged it will supply the required power to the load or it will charge the BSS. If the input battery is completely discharged or the source power is less than the load one, the BSS will charge the input battery.

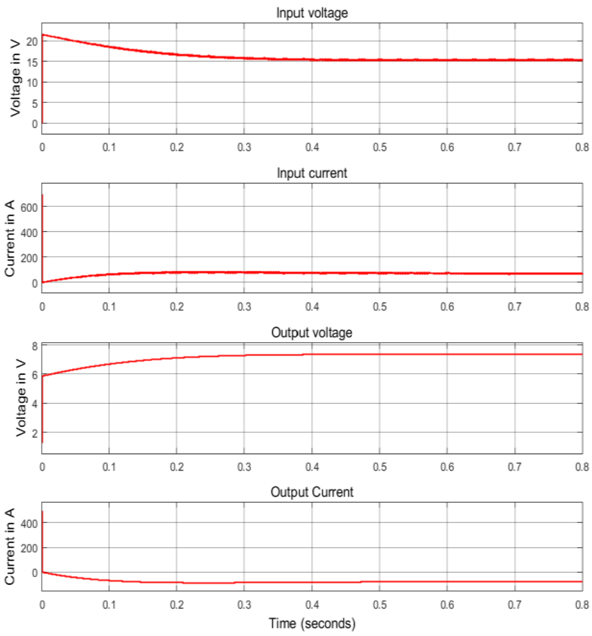

Fig. 9. Input-output voltages and current of the proposed DCC in buck mode

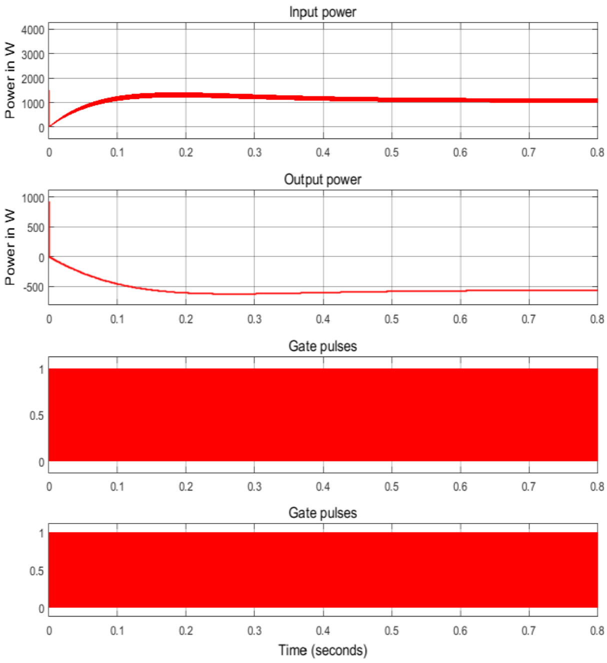

Fig.10. Input-output power and switching state of the proposed DCC in buck mode

IV. CONCLUSION

In this paper, a new non-isolated DC–DC converter with the bidirectional property was proposed, which has immense application for hybrid source and energy storage system. The presented structure can operate in both step-up and step-down states in a bidirectional manner. The presented converter can transfer energy to the load by using independent power DC supply. The suggested structure has advantages as a simple structure with a low component count, the low peak voltage of the switches, and high voltage gain in boost and buck operations. The absence of extendable input ports is the most notable shortcoming of the proposed converter, which can be taken into account for future researches. However, the proposed converter has two input ports. The proposed converter operation analysis and technological survey of numerous MPCs as DCC with constraint in operations are provided. The comparison result was carried out to depict the recommended topology's effectiveness in both buck and boost mode.

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