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Topological Comparison of Dual-Input DC-DC Converters

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ABSTRACT

Dual input dc-dc converters have two input voltage sources or one input source and an energy storage system like ultra capacitor, PV, battery, super capacitors and a single output load. In order to process the power in hybrid energy systems using reduced part count, researchers have proposed several multi-input dc-dc power converter topologies to transfer power from different input voltage sources to the output. This paper compares non-isolated dual-input converter topologies topologically, based on the components count, various fields of application and different modes of operation for hybrid systems mainly used in electric vehicles and renewable energy systems composed of energy storage systems (ESSs) with different voltage-current characteristics. Dual input dc-dc converter topologies considered in this paper are investigated using MATLAB and PSIM software and output voltage and inductor current waveforms are shown.

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1. INTRODUCTION

Batteries, ultra capacitors, fuel cells, and solar arrays are widely used in electric and hybrid vehicles (EVs/HEVs) as an electric power source or an energy storage unit. In the structure of the electric power system of modern EVs/HEVs, more than one of these units may be employed to improve the performance and efficiency; hence utilization of a multi-input dc-dc converter is inevitable to obtain a regulated bus dc voltage.Multiple power converters grouped in non-isolated and isolated topologies have been studied The discussion deals with the topological and technological characteristics of the power converter for various environments (automotive, railway, aircraft and stationary) requiring high compactness.

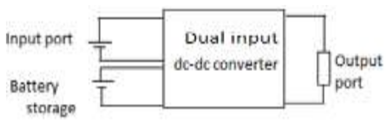


Figure 1. General block diagram of dual input DC-DC converter

2. DUAL INPUT DC-DC CONVERTER TOPOLOGIES

This section gives a comprehensive overview of the dual-input dc-dc converter interfaces potentially favourable for the hybrid power system, micro grid, energy storage system, satellite power system, electric and hybrid electric vehicle etc,. First, it gives an overview of the application of the multiport converter in various fields. Second, with respect to the topological development of a multiport power converter design.

This exhibits the importance of choosing the right dual-input power converter architecture and the related technology. In this context it is highlighted that the output power interface can be efficient, compact and reliable. The PV grid-connected system is recently becoming a fast growing segment in various countries. But, due to the low output voltage in PV arrays the conventional converters used are not able to satisfy the grid requirements [1]. In order to assure the grid voltage requirements dual input dc-dc converters can be used to replace the existing multiple converter topologies.

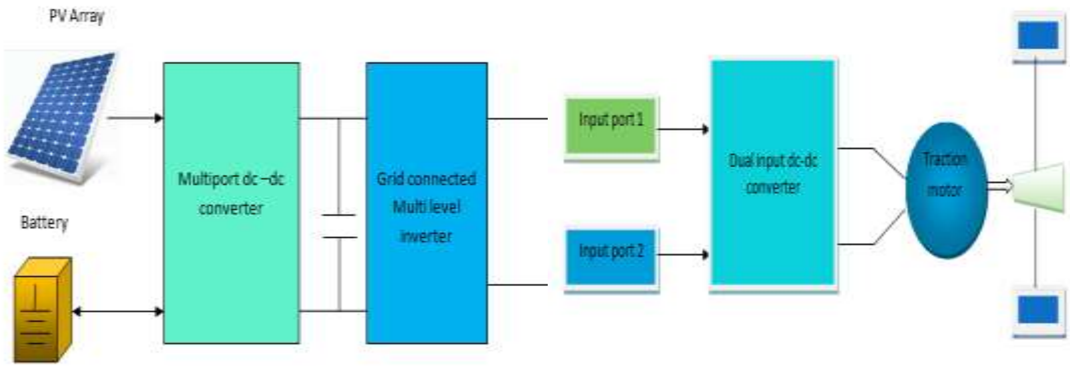


Figure 2a. Block diagram of dual input dc-dc converter for grid and traction system

Non-isolated dual input dc-dc converters have the advantage of a simple and compact topology, easy control, and low cost therefore most suitable for various applications compared to isolated converter topologies. As a result, there has been an increase in their usage in mobile applications. Various DC sources is growing interest to enhance the power train performance of the battery electric vehicles. To integrate these sources, multiport DC/DC power converters (MPCs) could play a considerable role in the future power trains and sustainable energy systems [2].

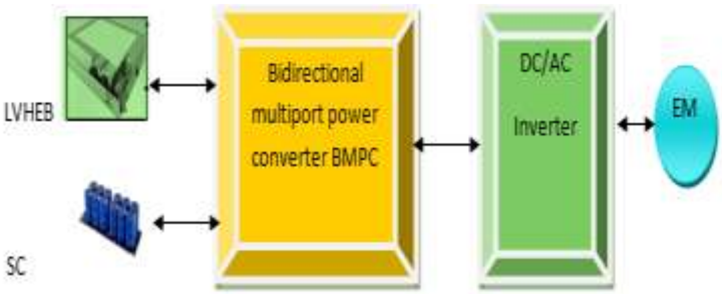


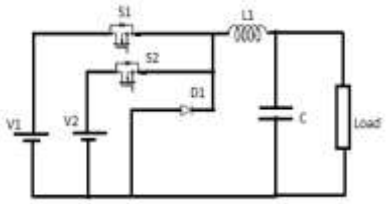
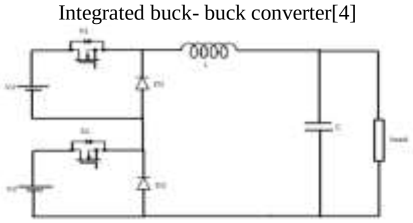
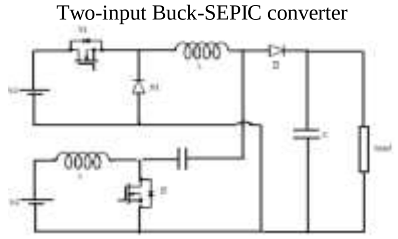
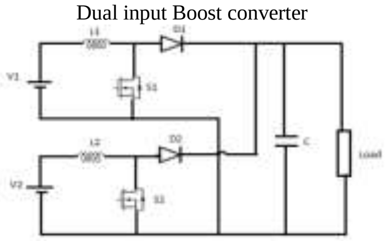
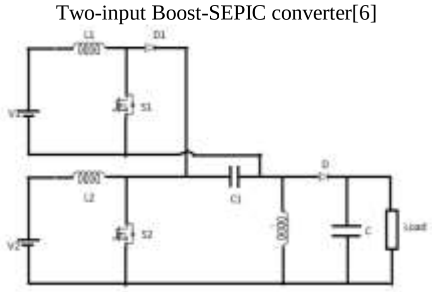
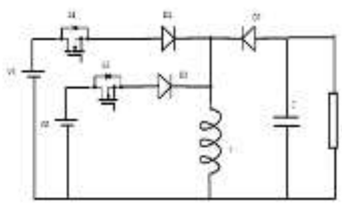
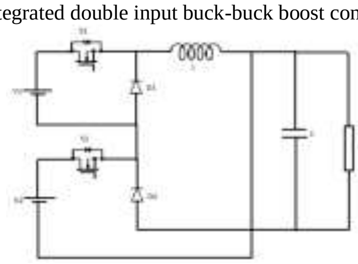
Figure 2b. Block diagram of bidirectional dual input dc-dc converter

Comparison with respect to the behaviour of the different dual input dc-dc converter whether it is operated in the buck mode, boost mode or buck boost mode of operation and the derived converters based on the buck, boost and buck boost basic converter topologies.

Table 1 depicts the dual input dc-dc converter topologies having similaties based on the basic converter topologies under which few converters are grouped under the same category. The output voltage equation for the DIDC converters given in the table above can be used to calculate the output voltage s for various input voltages.

There are several other topologies in the literature which are derived from the available single input and dual input topologies by incorporating the basic pulsating cell like voltage and current source cell in the existing topologies the new topologies can be derived. One of the new topologies by including the PVSC cell is shown in Figure 3 the similaties in the two topologies is clearly visible. These are derived from th parallel connected boost converter topology.

Table 1. Different Dual Input Topologies with Similarities

Category	Topology	Output voltage Equation
	Double input buck converter[3] 	$V_O = d_1 * V_1 + d_2 * V_2$
Buck based Multiport topologies	Integrated buck- buck converter[4] 	$V_O = d_1 * V_1 + d_2 * V_2$
	Two-input Buck-SEPIC converter 	$V_0=d_1V_1+V_2(d_2/(1-d_2))$
	Dual input Boost converter 	$V_0=V_2/(1-d_2)+V_1/(1-d_1)$
Boost based Multiport topologies	Two-input Boost-SEPIC converter[6] 	$V_0=V_2/(1-d_2)-V_1/(1-d_1)$
	Double input buck boost converter[5] 	$V_0=V_1d_1+V_2d_2/(1-d_1-d_2)$
Buck boost based Multiport topologies	Integrated double input buck-buck boost converter 	$V_O=(V_1d_1+V_2d_2)/(1-d_2)$

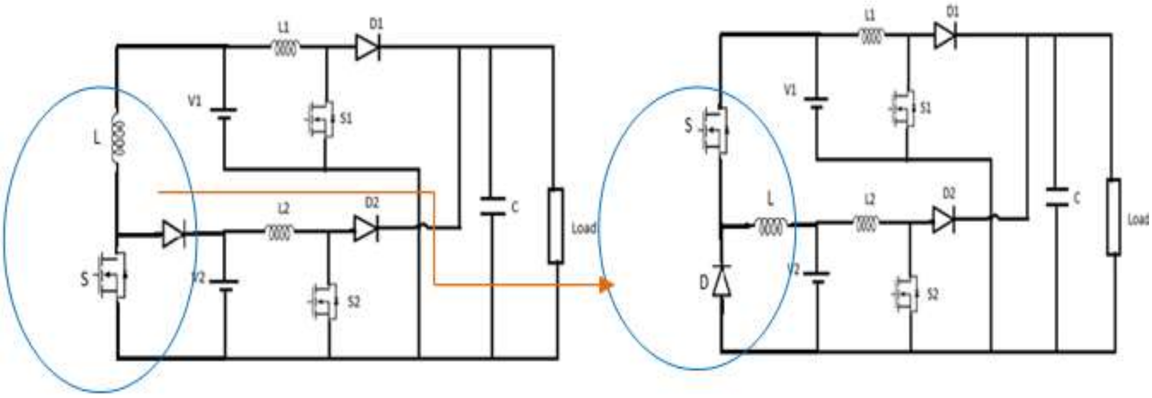


Figure 3. Derived dual input dc-dc converter topology

In this paper, a non isolated dual input DC/DC converter proposed has capability to operate either in buck, boost or buck–boost mode of operation with possibility of bidirectional power flow and is capable for energy diversification from renewable and storage energy sources individually or simultaneously [7].

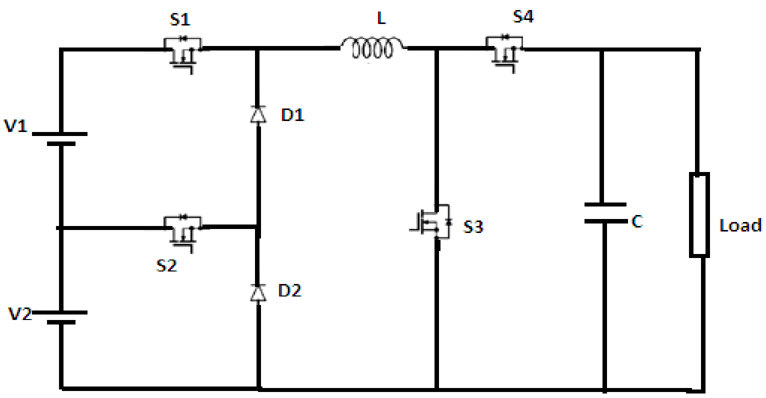
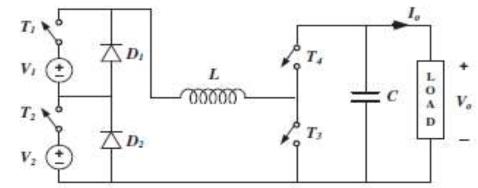
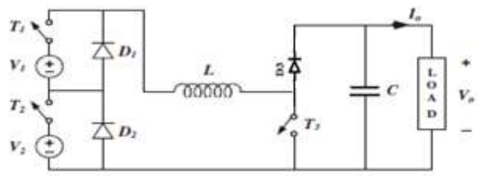
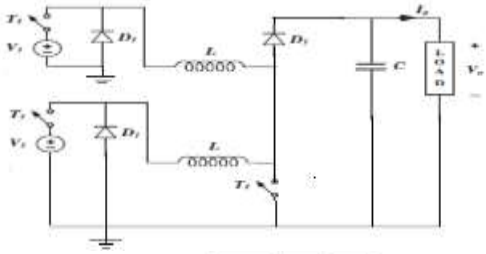
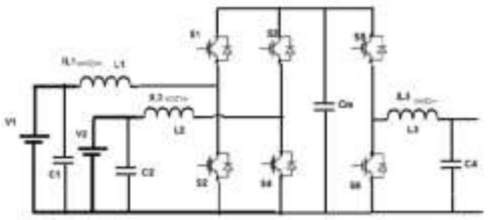


Figure 4. Dual input dc-dc converter topology [7]

3. COMPARATIVE ANALYSIS DUAL INPUT TOPOLOGIES

Dual input dc dc converter topologies few are taken here for comparison. The features of these converters and their advantages are listed in Table 2.

Table 2. Comparison of DIDC Topologies and its features

Sno	Dual input topologies	Features	advantages
1		This bi-directional converter does not require separate inductors for each input.	In this converter buck/boost capability during propulsion with the advantage of fewer active switch requirements.
2		Inductor can be charged by multiple voltage sources individually or simultaneously.	Allow active power sharing between their input sources.
3		This converter has three power switches three power diodes and two inductors.	Efficiency this converter topology is better than the existing dc-dc converter topology
4		This converter has six power switches with internal diodes and three inductors.	This bi-directional converter can act as dual input single output or single input dual output converter.

4. SIMULATION RESULTS AND ANALYSIS

The topologies 2 and 3 mentioned in the above Table 2 is considered for the simulation analysis. MATLAB and PSIM software tools are used to simulate the converter circuits with Vdc1=50 V, DUTY CYCLE=50 %, Vdc2=50 V, LOAD=1000 ohms, Fs=10 kHz, C0=3000 µF, L1=L2=150 mH and the corresponding converters output voltage and current waveform are shown below.

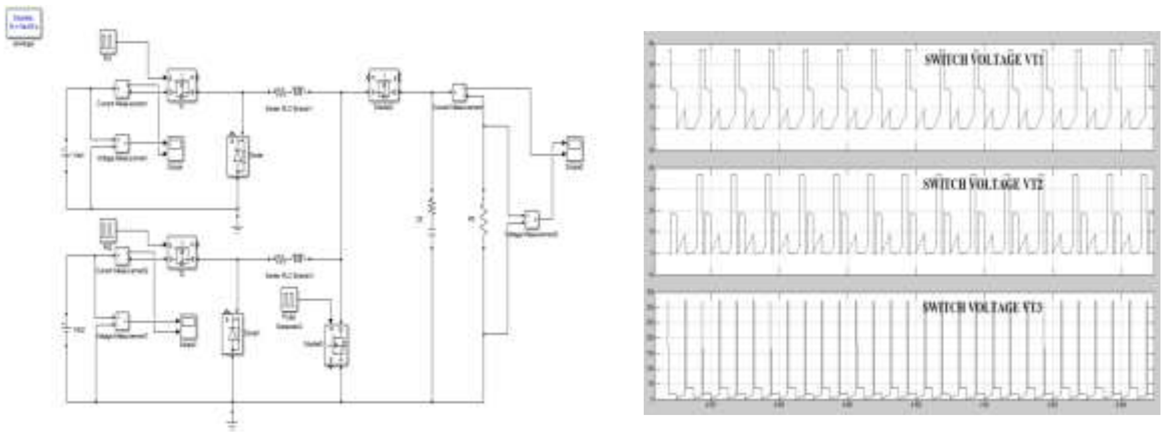


Figure 5. Dual input dc-dc converter topology circuit (Table 2(3)) and simulated switch voltage waveforms

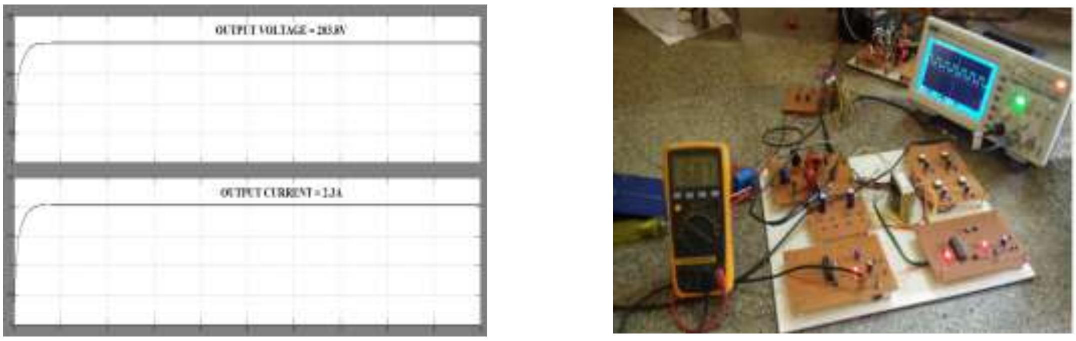


Figure 6(a). Simulated output voltage waveforms and hardware setup–DIDC topology Table 2(3)

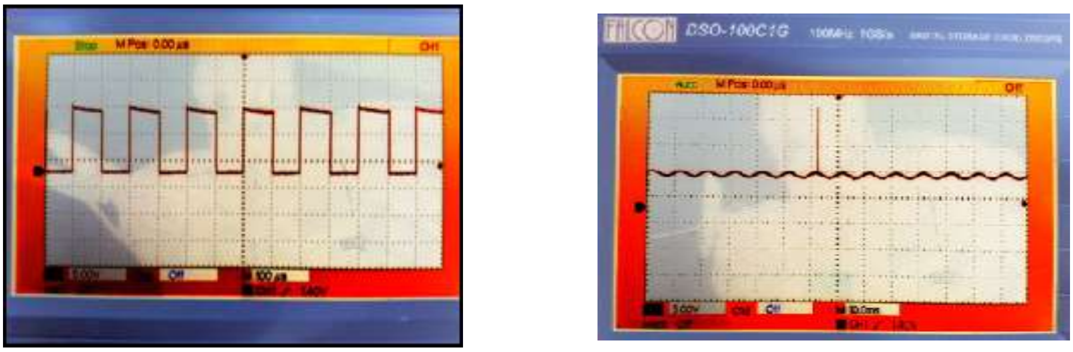
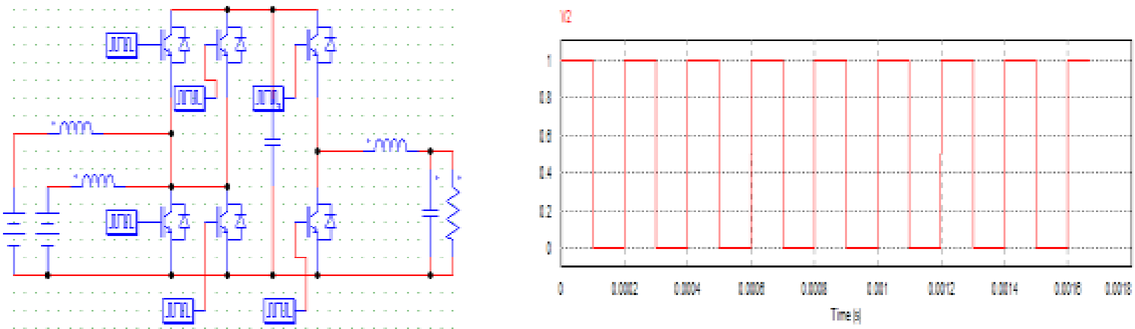


Figure 6(b). Experimental results: switch voltage and output voltage waveform

A bi-directional cascaded DC-DC converter that can operate in both buck and boost modes with a wide range of voltage levels in either direction is necessary to achieve the objective. The CBB-CIM converter can also be used in the V2G mode with the battery pack and ultra-capacitor bank serving as multiple input sources, and a DC external load connected in the circuit shown in Figure 7.



(a) (b)

Figure 7. (a) CBB-CIM dc-dc converter topology, (b)PSIM simulated switch voltage waveform

Figure 8 shows the simulated resulted of the converter considered for a particular input voltage shows the corresponding inductor current and output voltage waveforms. Graph shown in Figure 9 gives the variations in input voltages the changes in the output voltage in the converter.

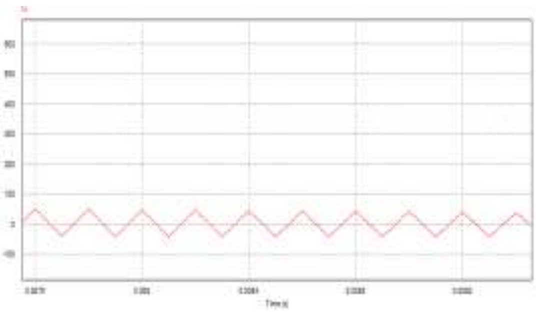


Figure 8. (a) Inductor current waveform

(b)Hardware experimental setup

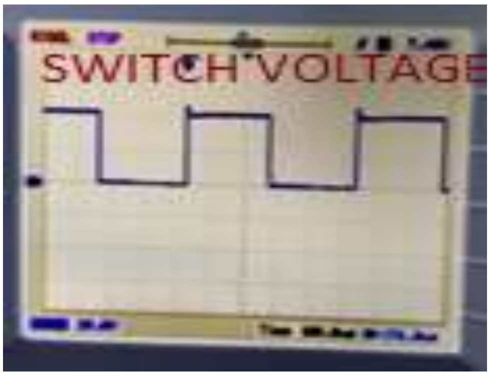
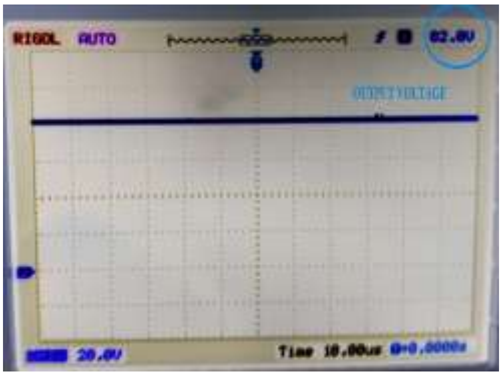


Figure 9.(a) switch S1 voltage waveform



(b) output voltage waveform

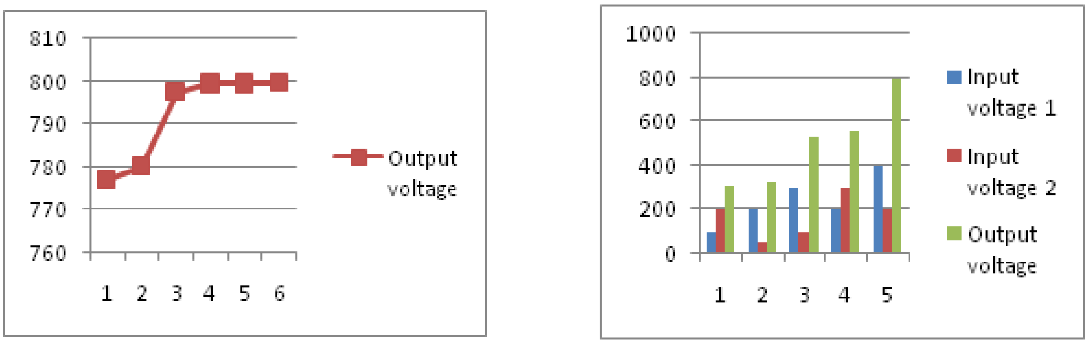


Figure 9(c) Graphs showing the response of the converter for input voltage variations

5. CONCLUSION

Dual input dc-dc converter topologies are compared in this paper based on the various applications, structure, reliability, cost, number of the components used in the converter. This paper gives an overall view about the available dual input dc-dc converter topologies discussed by various researches and also suggests the upcoming researches to select a suitable DIDC converter for the specific application. For comparison two different dual input dc-dc converter from the literature is considerd and simulation results prove their feasibility and reliability for various application they act both in uni direction and bidirectional modes of operation.

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