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Design and Analysis of a Dual Input Buck-Boost Converter for Renewable Energy Application

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Abstract—The increasing price, exhaustible nature of fossil fuels and their impacts on environment have increased the interest in harvesting energy from renewable energy sources in current scenario. So effective utilization of renewable energy sources is an emerging research trend in the area of power system. But these renewable energy sources are highly intermittent in nature, unpredictable and also sensitive to climatic conditions, which makes difficulty in providing relaiable and quality power from stand alone renewable energy system. A hybrid energy system can make use of the complementing nature of various sources to overcome these difficulties. Development of suitable power electronic converters which interface multiple energy sources with different V-I characteristics is an essential requirement for the integration and efficient utilization of different renewable energy sources.In this paper a dual input buck-boost converter which can be used for renewable energy integration is presented. The computer simulation of the converter topology using MATLAB/ Simulink platform has been carried out and results are presented. This converter topology has low part count and offers simplicity in handling two non-linear V-I characteristic sources.

Index Terms— Dual input DC-DC converter, hybrid energy, multi input converter topologies, non linear V-I characteristic sources, solar-PV, wind, performance comparison.

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1 INTRODUCTION

Persistant increase in energy demand, large requirement of petroleum products, and growing concern about global warming has paved a way towards the exploration of alternative energy sources for different applications. Because these sources can be effectively used to overcome the energy deficit.

Nowadays many applications that use renewable energy sources require more than one source for their effective operation. Bcause usually the renewable energy sources are utilized as stand alone energy system in many applications. Eventhough Renewable energy sources are inexhaustible in nature,environmental friendly and sustainable, but providing reliable electricity from stand alone sources is infeasible. Thus the concept of Hybrid Renewable Energy System(HRES) came to exist which combines more than one renewable energy sources inorder to overcome the problems associated with the stand alone renewable energy system.

The diversified energy combination is mandatory for the proper utilization of renewable energy resources. For example, the hybrid combination of wind and solar photovoltaic gives high performance compared to their individual use. It is possible to obtain higher availability power system by the combination of more power sources. Recently the hybridization of energy system or sources is gaining more attention in the field of power system from all over the world. But a proper power electronic interface which combines various energy sources together is required to meet the desired power level[1], [2], [3], [4].

In conventional scheme, the energy sources to the load are connected through a single input power converter. But inorder to integrate more number of sources, the parallel combination of these single input converters are required which increases part count, overall weight, size and cost and also reduces the overall efficiency and reliability of the system. To overcome these problems, the concept of multiple input converters (MICs) came to exist.

Compactness, cost reduction, more expandability are the major advantages of the integration using MICs. The energy sources like fuel cell, battery, ultra capacitor, and renewable sources like, solar photovoltaic, wind etc with distinct V-I characteristics can be integrated through MICs to supply the load individually or simultaneously. So MICs are playing important role in interfacing different energy sources to form hybrid energy system that delivers reliable power.[5], [6],[7],[8],[9],[10],[11],[12],[13],[14],[15],[16],[17].

Several multi input converter topologies have been already reported in many of the literatures. The converters proposed in the literatures are of mainly two types: Isolated and non-isolated. The complexity of isolated converter is high compared to non-isolated converters due to the presence of single winding or multi winding transformers. So to reduce the complexity and overall cost of the system, most of the applications require a multi input converter which eliminates the use of transformers in their circuit. A multi input DC-DC converter has different operating modes like, buck, boost and buck-boost. Hence a multi input DC-DC converter which can perform both buck and boost operation of the input voltage is highly flexible compared to those converters which are capable of operating in one mode(either buck or boost).

In this paper design and analysis of a dual input buck-boost converter topology for reneable energy integration is presented. Compared to othe topologies, the topology mentioned in this paper is flexible for the selection of sources and also simple. The paper is organized in to the following sections. Section 2 deals with the working principle and operating mode of the dual input converters. Section 3 covers the analysis and design of the converter topology. The simulation results and performance comparison is presented in section 4. Conclusion is presented in section 5.

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2 Dual Input Buck-Boost Converter

2.1 Operation of Converter Topology

The structure of the dual input converter is shown in figure 1.

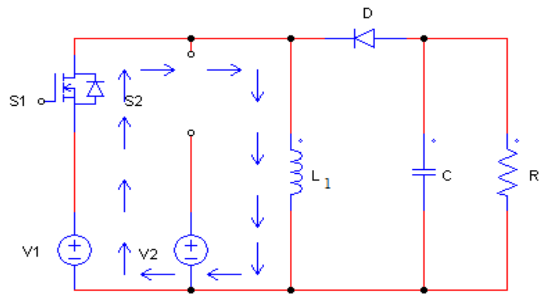
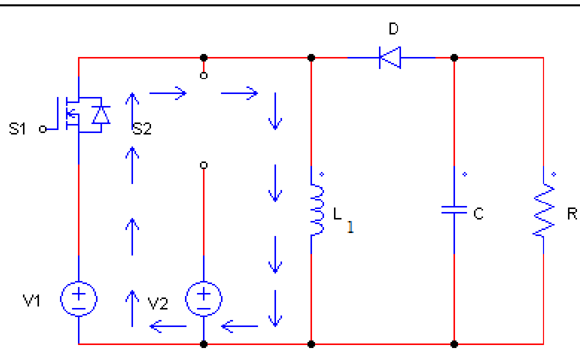


Fig. 1. Structure of the dual input converter

Here, the input sources are connected parallel through power semiconductor switches and share a common inductor (L). This configuration allows only unidirectional power flow from the sources. In this converter topology at least a switch (S1/S2) or a diode (D) is conducting at a time, hence current flow through the inductor is continuous in nature. Let S1 and S2 are the two switches associated with the dual input converter, which are operated with different turn-on and turn-off ratios for the same switching frequency. Power flow from each source ie., Source 1 and Source 2, to load is controlled by operating switches S1 and S2 with different duty ratios for the same switching frequency. Hence, it results three modes of operation of the converter.

2.2 Mode 1: S1 is ON and S2 is OFF

When switch S_1 is turned ON, Source 1 delivers energy to the inductor (L) as shown in Figure 2. During this mode, Switch S2 and Diode D are in OFF state.



The arrow marks indicates the current flow through the circuit when S1 ON and S2 OFF

2.3 Mode 2: S1 OFF and S2 ON

When switch S2 is turned ON, Source 2 delivers energy to the inductor (L) as shown in Figure 3.

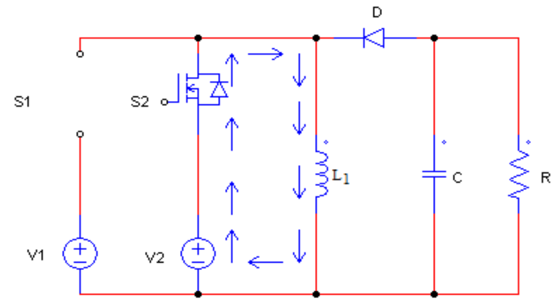


Fig. 3. Mode 2 operation of the dual input DC-DC converter

During this mode, Switch S_1 and Diode D are in OFF state and the inductor current starts from I_1 and reaches $I_{max.}$

2.4 Mode 3: S1 and S2 OFF

When both the switches are turned OFF, energy stored in the inductor is delivered to charge capacitor and supply the load as shown in Figure 4.

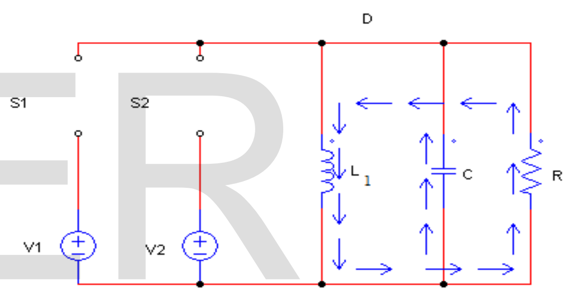


Fig. 4. Mode 3 operation of the dual input DC-DC converter

3 Analysis of the Converter Topology

3.1 Switching Schemes

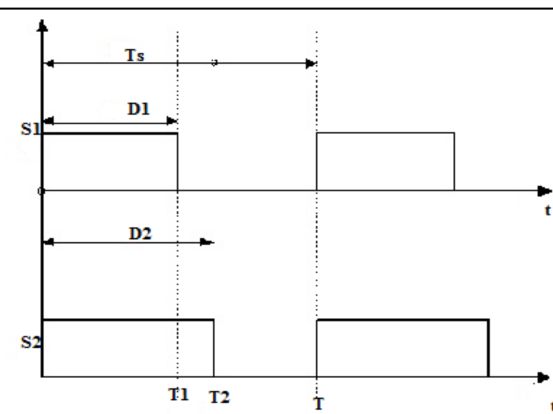


Fig. 5. Rising edge synchronization of gating pulses

Proper selection of control strategy adopted for gate pulse generation is essential for the effective working of the convert-

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er topologies under different working stages. There are many ways to generate switching pulses for the converter topologies which depends on the individual or simultaneous energy utilization of the sources. Here rising edge synchronization of gate pulses which is shown in Figure 5 is considered for the analysis of the dual input converter topology.

The analysis of converter topology in buck-boost mode of operation is for rising edge synchronization has been carried out for continuous conduction mode of the inductor under steady sate condition. In steady state condition the average inductance voltage should be zero using volt-second balance equation. Inductor voltage and current will be computed as given in eqn. (1) & (2):

$$V_L = V_1 \quad (1)$$

$$I_L = \frac{1}{L_1}\int_0^{D_1T} V_1 dt + i(0) \quad (2)$$

The voltage-second balance in the inductor can be expressed as given in eqn. (3):

$$V_1T_1 + V_2(T_2 - T_1) - V_o(T - T_2) = 0 \quad (3)$$

$$V_1D_1 + V_2(D_2 - D_1) - V_O(1 - D_2) = 0 \quad (4)$$

When V1>V2; D1<D2; Output voltage of the dual input DC-DC converter is given by:

$$V_O = \frac{(V_1D_1 + V_2(D_2 - D_1))}{(1 - D_2)} \quad (5)$$

When V2>V1; D2<D1; Output voltage of the dual input DC-DC converter is given by:

$$V_O = \frac{(V_2D_1 + V_1(D_2 - D_1))}{1 - D_2} \quad (6)$$

4 Simulation Results and Descussion

Various parameters used in the simulation are mentioned in Table 1 for the continuous conduction mode (CCM) operation of inductor.

The simulation studiues of the dual input converter topology is performed for buck-boost mode of operation. Simulation results of switching pulses, source voltages, inductor current, inductor voltage, output current and output voltages are shown in figre 6 to figure 9. In this mode of operation, for the period (D_1T) the inductor is charged by voltage V1 and for the period $[(D_2 - D_1)T]$ the inductor is charged by voltage V2. Thus by adjusting the duty cycles D_1 & D_2, the inductor current can be controlled and hence the controlled output voltage is achieved. The simulation of the dual input DC-DC converter is carried out with ideal characteristics of various components present in the topology using MATLAB/Simulink environment.

TABLE 1
Simulation Parameters

Parameter	Specification
V_1[V]	170
V_2[V]	90
L[mH]	5
C[μF]	330
f[kHz]	20

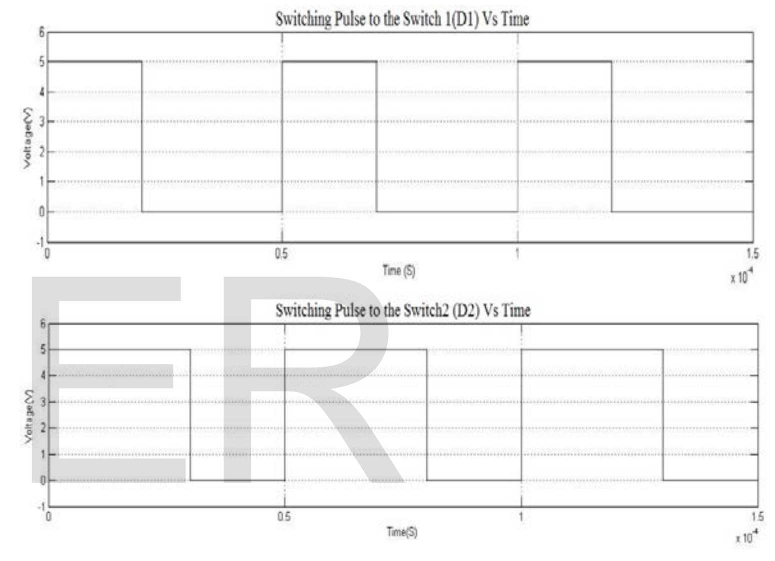

Fig. 6. Switching pulse (D1) and (D2)

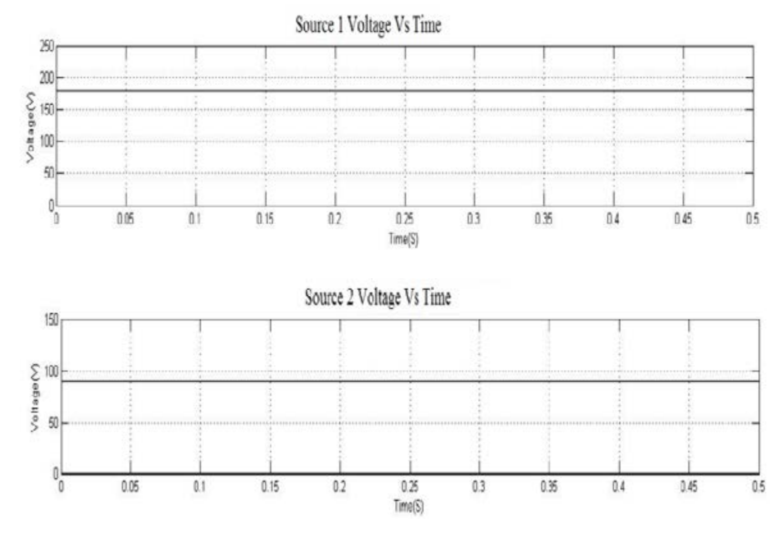

Fig. 7. The source 1 and source 2 voltages

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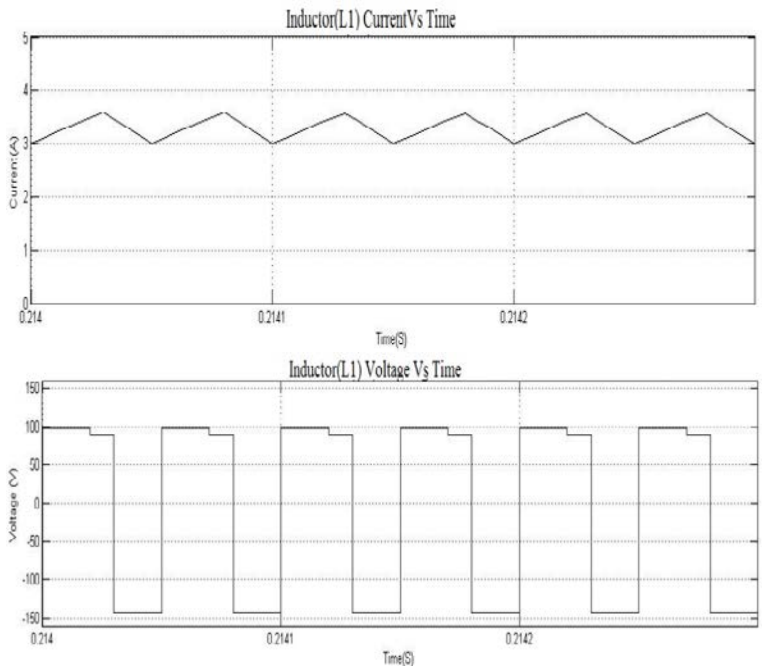

Fig. 8. The inductor current and voltage

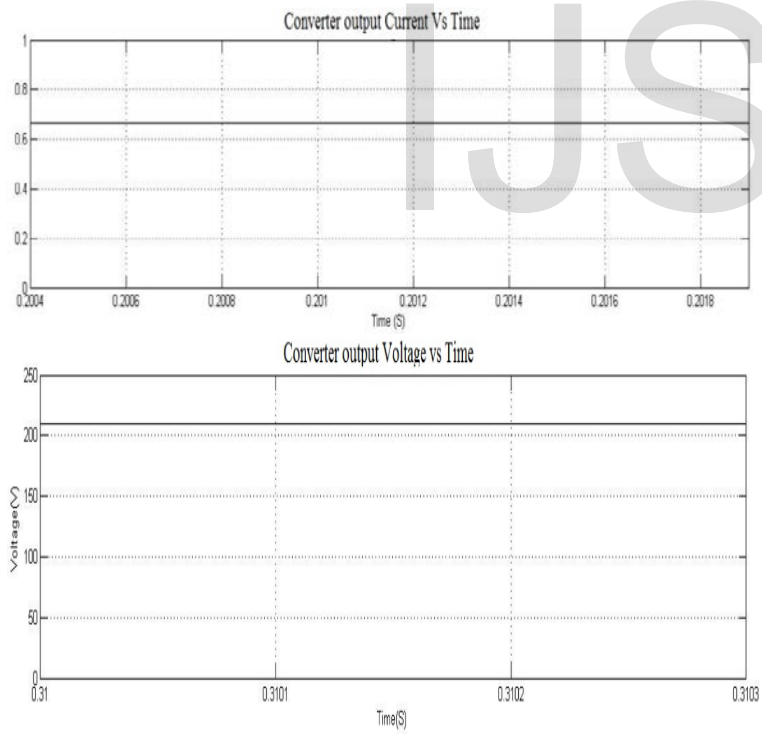

Fig. 9. The Converter output current and voltage

4.1 Performance Comparison

The performance analysisi of the dual input converter topology has been carried out by using the variations in duty ratios D1 and D2. By keeping D1 = 30%, duty ratio D2 has been varied from 0- 70%. Similarly, By keeping D2 = 30%, duty ratio D1 has been varied from 0- 70%. Performance comparison among the ideal calculation and result obtained from software simulation are closely matching as shown in Figure 10 and 11.

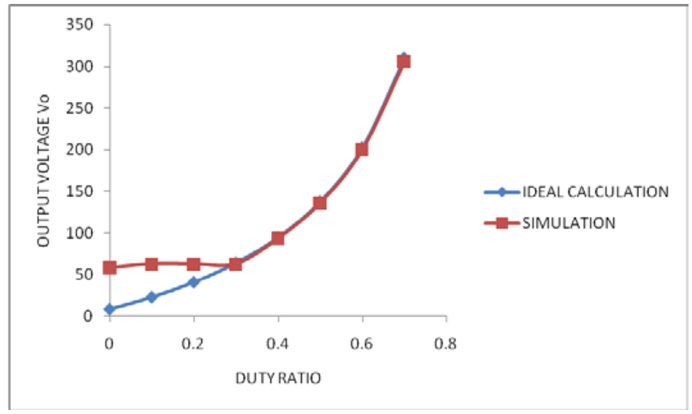

Fig. 10. Variation in output voltage due to variation in D2 at D1 =30%

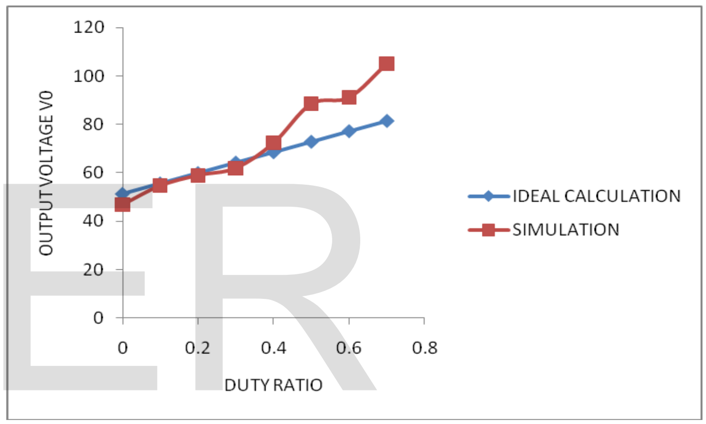

Fig. 11. Variation in output voltage due to variation in D1 at D2=30%

5 Conclusion

Design and analysis of the dual - input DC-DC converter for the integration of energy sources such as solar-PV, wind, fuel cell etc. for various applications has been discussed in this paper. This dual input DC-DC converter has the advantage of low component counts and simplified structure. This converter is capable of operating in different modes of operation such as boost, buck, and buck - boost. Due to this capability of operating in different modes, these converter topologies are attained an important role in the energy diversification of different sources. Analysis of the dual - input DC-DC converter with the simulation results is presented. Performance comparison between the ideal calculation and results obtained from simulation are closely matched.

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