A Dual Input DC-DC Converter for Hybrid Energy Integration

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***Abstract*— The integration of more than one energy sources for the effective utilization of non- conventional energy sources is a recent trend in the area of power system. But the development and implementation of a suitable power electronic interface is very much essential for the successful integration of those sources. In this paper, the analysis and implementation of a dual input bridge type DC-DC converter topology for hybrid energy system integration for DC microgrid application is discussed. The Computer simulations of the proposed converter topology using MATLAB/ Simulink platform has been carried out and results are presented. An experimental prototype is also built in the laboratory environment in order to verify the theoretical results.**

Keywords*— *Distributed generation, Micro grid, Multi input DC-DC converter, Power electronics, hybrid energy system

I. Introduction

The demand for electric power is drastically increasing as a result of large increase in the population and industrial growth. Conventional energy generation based on fossil fuels and other sources are excessively using to satisfy the increased power demand. But the current scenario discloses that, the existing conventional energy sources like fossil fuel etc. are not capable to meet the excess power demand in future, since their availability in the earth is rapidly vanishing. In addition, the power generation using fossil fuel etc. leads to the severe environmental issues like global warming, air pollution etc. The power generation based on the non-conventional energy sources likes solar, wind, bio mass, and fuel cell etc. are gaining more popularity especially in the field of distributed generation, since these sources are clean and non-polluting in nature. But the individual use of the energy sources like solar and wind etc. is not preferable due to their highly intermittent nature. Hence the concept of hybridization of energy systems is brought into practice.

Hybrid energy system is an advancing technology which is capable to meet the widely varying rural electricity needs by the proper integration of renewable sources with same or distinct voltage- current characteristics [1]. There are different combination of energy sources such as solar PV/wind, super capacitor/battery, fuel cell/solar PV etc. are possible to make an efficient hybrid energy system.

For the hybridization of energy source, a proper power electronic interfacing circuit is very much crucial or a mandatory one [2]. These power electronic interface circuit should be capable of integrating the sources with same or distinct V-I characteristics. In order to achieve the energy diversification from different sources, multiple independent single input converters are used in conventional scheme. There are many energy sources like solar PV (SPV), wind, fuel cell, battery and ultra-capacitor etc. which may have same or distinct voltage-current (V-I) characteristics [2,3]. As per the conventional methods, if multiple single input DC-DC converters are used to integrate these energy sources to get a common DC bus voltage at the output, it may results complexity in design procedures, increased cost, loss of compactness of the system, and less efficiency. So the idea of multiple input DC-DC converters are developed which attracts the attention of power electronic researchers from all over the world. Relatively simple and compact structure, reduced cost and complexity of the system are the main attractive features of the multi input DC-DC converters (MIC). By using MIC, it is possible to integrate more number of energy sources with less number of components compared to multiple single input DC-DC converters. Enhanced local power supply availability compared to conventional single input converters is also one of the potential merits of MIC [4-6].

In this a paper a novel dual input DC-DC converter for the effective integration of two sources having distinct V-I characteristics with lower part count is presented. Since one of the main aspects multi input converter is efficiency, which is heavily rely on the total number components, lower the part counts, higher will be the converter efficiency and vice versa. So the converter presented in this given work is having high efficiency compared to other multi input converter topologies. The analysis of the operating modes and design of the converter is carried out based on the fixed frequency switching strategy. The proposed topology is capable of delivering energy to the load either individually or simultaneously which elaborates its importance in the applications like hybrid electric vehicle, aerospace etc. This paper is arranged in to four sections. Section I gives the introduction and existing literature back ground, section II covers the working principle and operating modes of the proposed dual input converter. Simulation and experimental results of the converter are given in section III. Finally the conclusion is given the section IV.

II. Dual Input DC-DC Converter

The basic operating principle of multi input DC-DC converters and conventional single input DC-DC converters are almost similar. In both cases, the passive elements present in the converter charges for a specific time period and dissipate the energy stored in the element through appropriate load for the rest of the time period. The circuit representation of the proposed dual input DC-DC converter is shown in Fig. 1.

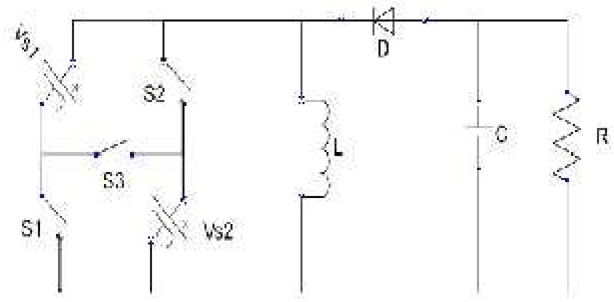


Fig. 1. Proposed dual input DC-DC converter.

In this converter, the input sources can be connected to the load either individually or simultaneously with the proper operation of the power switches available in the circuit. Here the sources are sharing a common inductor at the output side and any one of the switches (S_1, S_2 or S_3) or diode is conducting at a time, so that the inductor current can be continuous in nature. Only unidirectional power flow is considered in this work. The power flow from both sources to the load side can be managed by adjusting the duty ratios of respective semi-conductor switches (S_1, S_2 and S_3) connected to the sources with same switching frequency. The dual input DC-DC converter presented in this paper has four modes of operation. In mode 1**,** switch S_1 is conducting and first voltage source (Vs1) is delivering energy to the inductor. Hence, in this mode, semi-conductor switches S_2, S_3 and diode D are in non-conducting state.

In this mode 2 operation, switch S_3 is turned ON. Here, the conduction of switch S_3 helps to make a series combination of both input sources together. So in this particular mode of operation, both voltage sources simultaneously delivers energy to the inductor The switches S_1, S_2 and diode are in non-conducting state. In mode 3, the switch S2 alone is conducting, while the remaining switches such as S1, S3 and diode are in OFF state. So, the second voltage source (Vs2) alone delivers energy to the inductor. Finally in mode 4, all the switches (S1, S2 and S3) are in OFF state and the diode D become forward biased. Hence the stored energy in the inductor is delivered to the load and also used to charge the capacitor at the output side.

The analysis of the converter topology in buck-boost mode of operation has been conducted 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. The expression for the average inductor voltage over a cycle is given in (1).

$$\text{The average inductor voltage} = \int_0^T V_L = 0 \qquad (1)$$

From Fig. 2, the voltage-second balance in the inductor can be given as:

$$V_1T_1 + (V_1 + V_2)(T_3) + V_2(T_2) - V_0T_4 = 0 \qquad (2)$$

Dividing eqn. (1) by T,

$$V_1D_1 + (V_1 + V_2)D_3 + V_2(D_2) - V_O(1-(D_1 + D_2 + D_3)) = 0 \qquad (3)$$

The output voltage of the proposed converter is given by

$$V_O = \frac{(V_1D_1 + (V_1 + V_2)D_2 + V_2D_3)}{1-(D_1 + D_2 + D_3)} \qquad (4)$$

Here, V_1 is the source voltage 1, V_2 is the source voltage 2, and D_1, D2 and D_3 are the duty ratios corresponding to the switches S_1, S_2 and S_3.

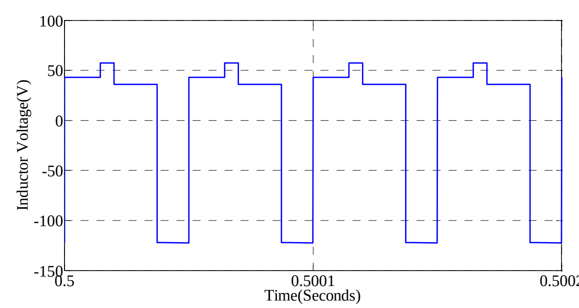
III. Results and Discussion

A. *Simulation Results*

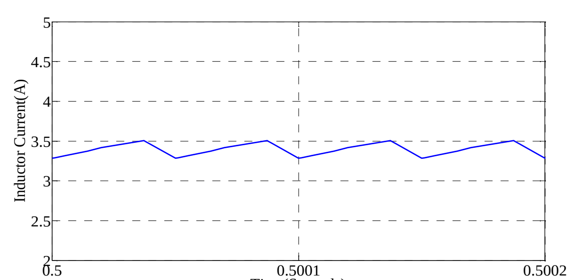
The simulation studies of the proposed converter has been carried out in MATLAB/Simulink platform by considering the ideal behavior of different components presents in the converter. The switches are realized by MOSFET with a switching frequency of 20 kHz. Specification of different parameters used for the simulation studies are given in Table I. The simulation has been performed by considering the duty ratio D1 as 28%, D2 as 34 % and D3 as 10 % in order to get the required output voltage. Simulation results of inductor voltage, inductor current, output voltage and output current for the proposed converter in boost mode of operation are shown in Fig. 2. There will be slight changes in the simulation results with non-ideal parameters, and in the experimental results also from the ideal case due to the voltage drops and losses associated with it.

TABLE I. Simulation Parameters for Dual Input DC-DC Converter

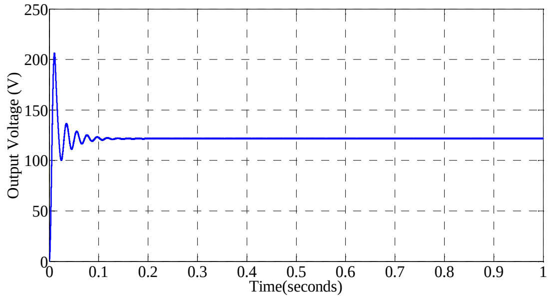
Parameter	Specifications
Source 1 input voltage (V_1)	50 V
Source 2 input voltage (V_2)	36 V
Inductor (L)	10 mH
Capacitor (C)	100 μF
Switching frequency (*f*)	20 kHz
Output Voltage (V_0)	120 V



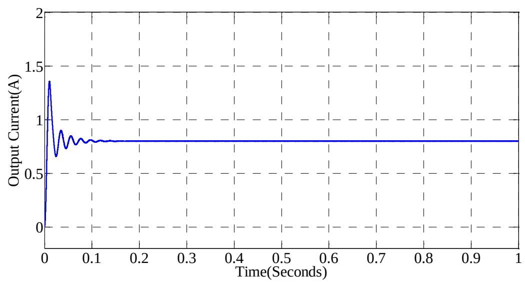
(a)



(b)

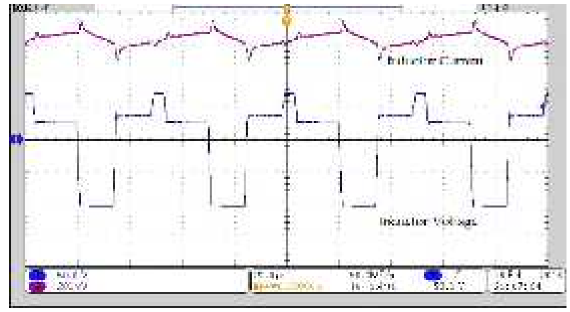


(c)

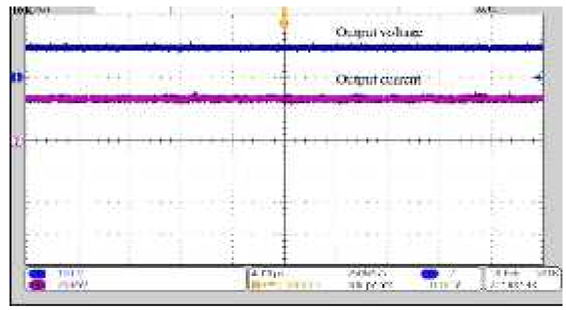


(d)

Fig. 2. Results obtained from simulation of the proposed DC-DC converter (a) Inductor voltage, (b) Inductor Current (c) Output voltage across the load (d) Output current through the Load for D_1 =0.28, D_3=0.10, and D_2=0.34.



(a)



(b)

Fig .4. Waveforms obtained from the experimental prototype of the dual input DC-DC converter (a) Inductor voltage and current, (b) Output voltage and current for D_1 =0.28, D_3=0.10, and D_2=0.34.

B. Experimental Results

In order to check the feasibility of the proposed converter, an experimental prototype has been fabricated in the laboratory environment as shown in Fig. 3. The converter prototype is tested with two different voltage levels for the validation of experimental setup with the simulation results. The switching pulses are developed using LabVIEW 2013 software and the real time interfacing of the pulses has been accomplished with the help of NI Crio-9081 controller, with NI 9401 digital input and output module. The parameters for the experimental validations are taken as V1= 50 V, V2 =36 V, L= 10 mH, C = 470 µF, and switching frequency of 20 kHz. The switches are realized by IRFP 460 MOSFET and diode is realized by MUR 860 ultra-fast diode with low forward voltage drop. The experimental results of gate pulses, source voltages, inductor voltage, inductor current, output voltage and output current are shown in Fig. 4.

Fig. 3. Experimental prototype of the dual input DC-DC converter

IV. CONCLUSION

A multi input DC-DC converter for integrating the hybrid energy sources such as solar-PV, wind, fuel cell, super capacitor etc. for DC microgrid application has been proposed in this paper. The proposed converter is well sufficient for energy diversification from the different V-I characteristic source either individually or simultaneously. The proposed converter is having compact structure with low component counts which enhances the converter efficiency. Finally, the simulation and experimental validation of the proposed converter has been carried out in order to reconfirm the correctness of the proposed topology.

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