International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 18 (2015) pp 38923-38930

Comparison of Two Dual Input DC-DC Converter Topologies for Renewable Energy Integration

Sivaprasad A, Kumaravel S, Ashok S.

Department of Electrical Engineering,
National Institute of Technology Calicut, Kerala, India – 673 601

Abstract
Proper integration of more than one energy sources is an emerging research trend in the area of power system. Development of suitable power electronic converters which interface multiple energy sources with different V-I characteristics is an essential requirement for the integration of different renewable energy sources. In this paper two non isolated dual input DC-DC converter topologies are compared as an interface between energy source systems. Two converters are differentiated based on the connection strategy of two sources. In one topology the parallel connection of two sources are discussed, while in latter the series connection of sources are discussed. The comparison of the topologies are carried out based on the parameters like converter efficiency, number of components, voltage stress across the switches, etc. The Computer simulations of both topologies using MATLAB/ Simulink platform has been carried out and results are presented to compare the performance of the discussed dual input DC-DC converter topologies.

Keywords— Dual input DC-DC converter, hybrid energy, series connection and parallel connection of sources

I. Introduction

The growing concern about fossil fuel depletion, drastic raise in oil price, global warming etc lead to the development of alternative energy sources which have high efficiency and low emission. Recently many of the applications require more number of power sources. Normally, for the effective operation of distributed generation system and or micro grid system, the use of more than one kind of energy source is preferred. The energy combination in diversified manner is mandatory for the proper utilization of renewable energy resources. For example, the hybrid combination of wind and solar photovoltaic gives better performance compared to their individual use. Thus in recent times, the hybridization of energy system or sources are 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.[1-4]

Previously, the parallel connection of different single input power converters are suggested for the integration of different energy sources. But more complexity, high cost, and less reliability are the major drawbacks of this type of integration. In order to overcome these drawbacks, 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. Thus MICs are playing important role in interfacing different energy sources to form a hybrid energy system that delivers reliable power. MICs have a crucial role in the field of distributed generation, PV-wind hybrid energy system, electric vehicular technology, micro grid based power supply system etc.[5-18]

In this paper two non isolated dual input DC-DC buck-boost converter topologies are compared. Converter topology I is meant for energy diversification from two parallel connected sources with distinct V-I characteristics and can supply the load individually. Converter topology II is meant for energy diversification from two series connected sources which can supply the load either individually or simultaneously. In MICs efficiency is one of the most important aspects which mainly depend on the total number of components. So higher the component count, lesser will be the efficiency. Thus the parameters like, converter efficiency, number of components etc. are taken for the performance comparison of both topologies. [17]

The paper is organized into five sections. Section II and III deals with the working principle and operating modes of the converter topology I and converter topology II. Section IV covers analysis of the converter topologies and section V presents the simulation of both topologies and their performance comparison. Conclusion is presented in section VI.

II. Operation of Converter Topology I

The structure of converter topology I in which two sources are connected in parallel is shown in Figure 1. In this configuration, the input sources are connected in parallel through power semiconductor switches and share a common inductor (L). This configuration allows only unidirectional power flow from the sources. Continuous conduction mode results, if the inductor current is greater than zero in the steady state.

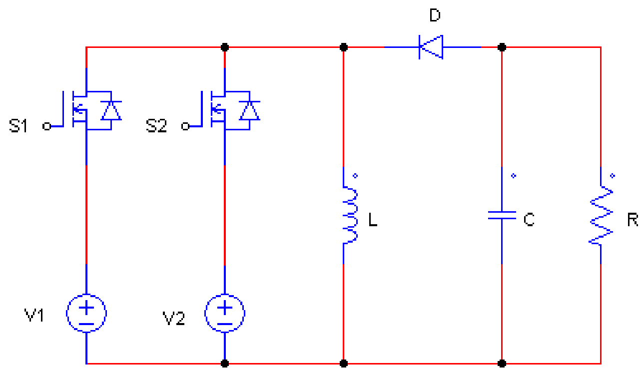


Figure 1. Structure of the converter topology I

Let S_1 and S_2 are the two switches associated with the converter topology I. They are operated with different turn-on and turn-off ratios for the same switching frequency. Power flow from each source to load is controlled by duty cycles D_1, and D_2 respectively. By adjusting the duty ratios D_1 and D_2, the power flow from source one and source two can be controlled. In this case, the source can supply the load individually only. The operation of the converter topology I can be explained as following cases.

Case I: S_1 is ON and S_2 is OFF

When switch S_1 is turned ON, Source 1 delivers energy to the inductor (L) as shown in Figure 2.

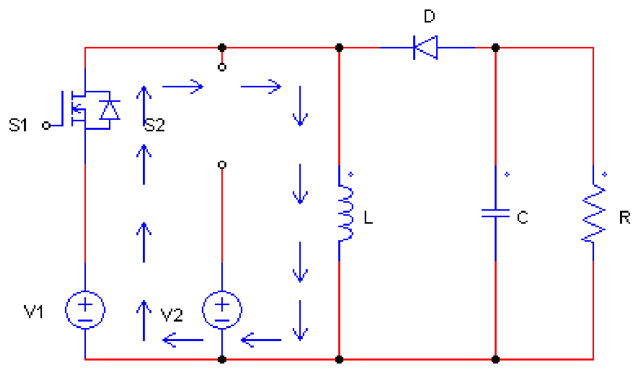


Figure 2. Converter topology I with switch S_1 closed and S_2 open

The arrow marks indicates the current flow through the circuit when S_1 ON and S_2 OFF

Case 2: S_1 OFF and S_2 ON

When switch S_2 is turned ON, Source 2 delivers energy to the inductor (L) as shown in Figure 3

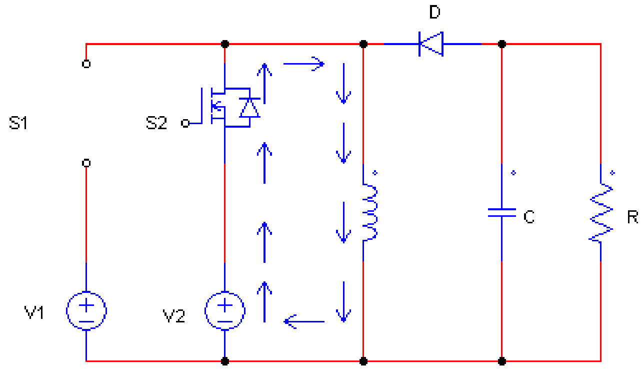


Figure 3. Converter topology I with switch S_2 closed and S_1 open

Case 3: S_1 and S_2 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.

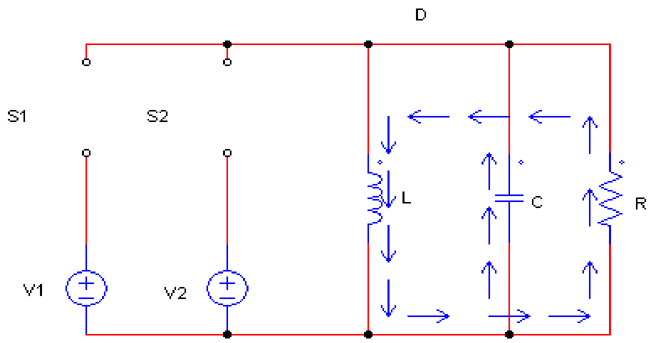


Figure 4. Converter topology I with switches S_1 and S_2 are opened

III. Operation of Converter Topology II

In this configuration input sources are connected in series through power semiconductor switches which shares a common inductor. The structure of converter topology II is shown in Figure 5.

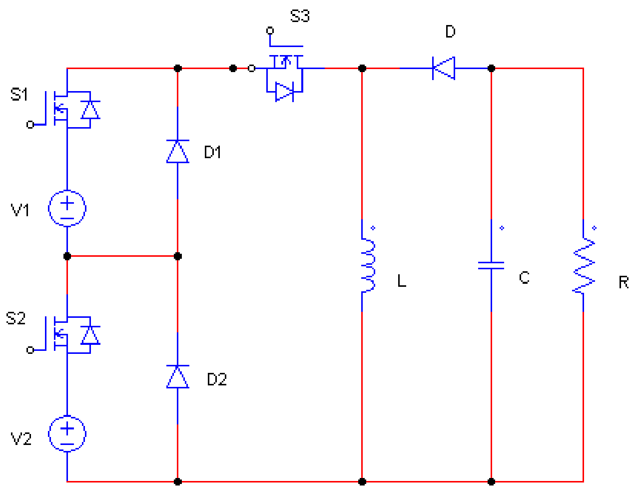


Figure 5. Structure of the converter topology II

Compared to parallel connected topology (converter topology I) it has one power semi conductor switch and two diodes as additional components. Generally the switches S_1 and S_2 decide the working state and the switch S_3 determines the mode of operation. Here the buck-boost mode of operation of the converter topology is discussed. In this case the sources can supply the load individually or simultaneously. The operation of the converter topology I can be explained as following cases. The switch S_3 is assumed to be ON in all the cases except the final case.

Case 1: S_1 ON and S_2 OFF
When switch S_1 is turned ON, Source 1 delivers energy to the inductor (L) as shown in Figure 6.

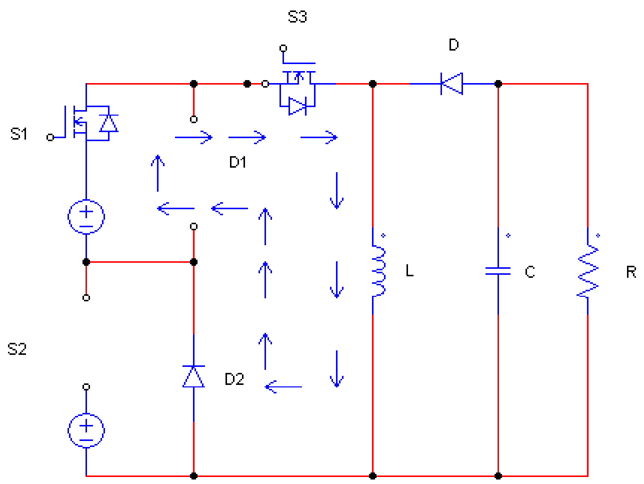


Figure 6. Converter topology II with switch S_1 closed and S_2 open

Case 2: S_1 OFF and S_2 ON
When switch S_2 is turned ON, Source 2 delivers energy to the inductor (L) as shown in Figure 7.

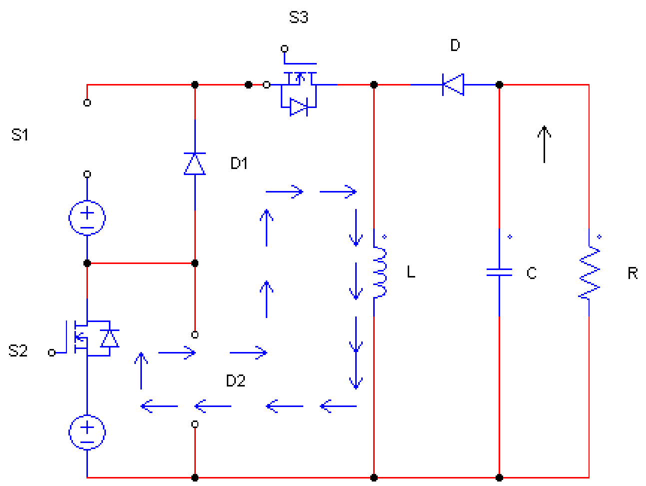


Figure 7. Converter topology II with switch S_1 closed and S_2 open

Case 3: S_1 and S_2 ON
In this case both sources come in series and the added energy from both sources are charging the inductor (L).

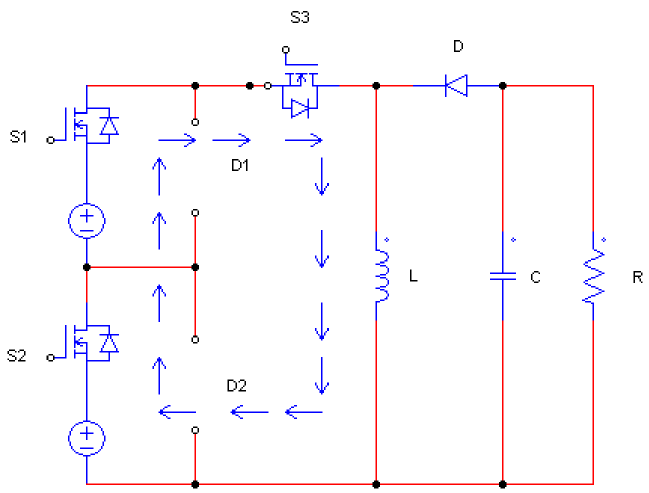


Figure 8. Converter topology II with switches S_1 and S_2 are closed

Case 4: S_1 and S_2 OFF
When both the switches are turned OFF, energy stored in the inductor is delivered to the load as shown in Figure 9.

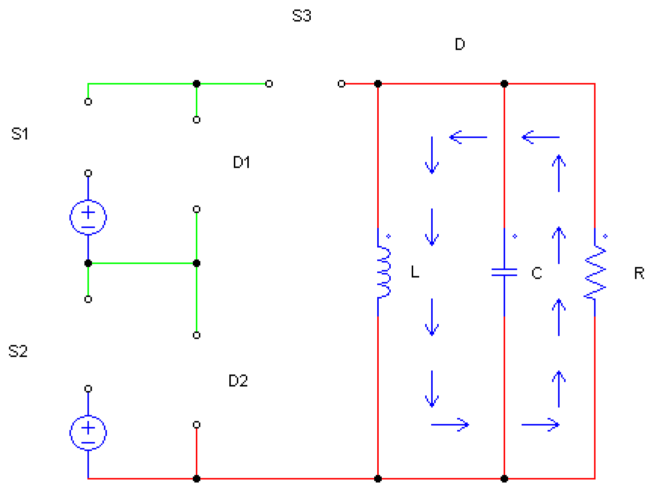


Figure 9. Converter topology II with switches S_1 and S_2 are opened

IV. Analysis of Converter Topologies

A. Switching Schemes

Proper selection of control strategy adopted for gate pulse generation is essential for the effective working of the converter 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 10 is considered for the analysis of the respective converter topologies.

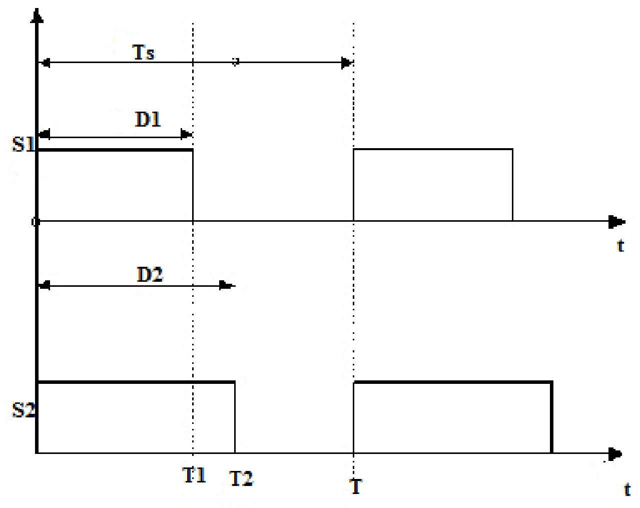


Figure 10. Rising edge synchronization of gating pulses

B. Analytical analysis

i) Converter topology I

The analysis of converter topology I 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. Therefore from Figure 10, the voltage-second balance on inductor is expressed as:

$$V_1T_1 + V_2(T_2 - T_1) - V_o(T - T_2) = 0 \tag{1}$$

Dividing eqn. (1) by T:

$$V_1D_1 + V_2(D_2 - D_1) - V_O(1 - D_2) = 0 \tag{2}$$

When $V_1 > V_2$; Output voltage of converter topology I is given by:

$$V_O = \frac{V_1D_1 + V_2(D_2 - D_1)}{1 - D_2} \tag{3}$$

When $V_2 > V_1$; Output voltage of converter topology I is given by:

$$V_O = \frac{V_2D_1 + V_1(D_2 - D_1)}{1 - D_2} \tag{4}$$

ii) Converter topology II

In the case of converter topology II also, the volt-second balance equation can be derived in a similar way of converter topology I.

$$(V_1 + V_2)T_1 + V_2(T_2 - T_1) - V_o(T - T_2) = 0 \tag{5}$$

Dividing eqn. (5) by T

$$(V_1 + V_2)D_1 + V_2(D_2 - D_1) - V_O(1 - D_2) = 0 \tag{6}$$

The output voltage of converter topology II is given by:

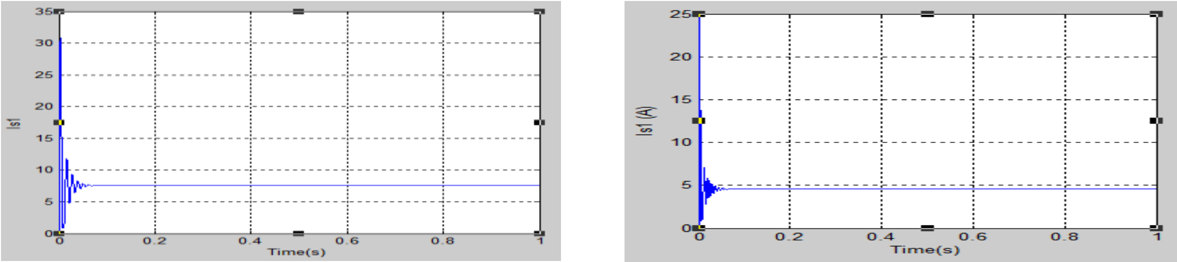
$$V_O = \frac{V_1D_1 + V_2D_2}{(1 - D_2)} \tag{7}$$

V. Simulation Results and Discussion

Various parameters used in the simulation are mentioned in Table 1 for the continuous conduction mode (CCM) operation of inductor. Simulation studies of converter topology I and converter topology II are performed for Buck-boost mode of operation. Simulation results of switching signals, input currents, inductor current, voltage stress across the switches, output voltage, load current, and efficiency for Buck- boost mode of operation are shown in Figure 11. In the Buck-boost mode of operation, for the period [$(0, D_1T)$] the inductor is charged by voltage V_1 in the case of Converter topology I and V_1+V_2 in the case of Converter topology II, and for the period [$((D_2 - D_1)T)$] the inductor is charged by voltage V_2 in both cases. 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 respective dual input DC-DC converters are carried out with ideal characteristics of various components of the proposed converter topology in the MATLAB/Simulink environment.

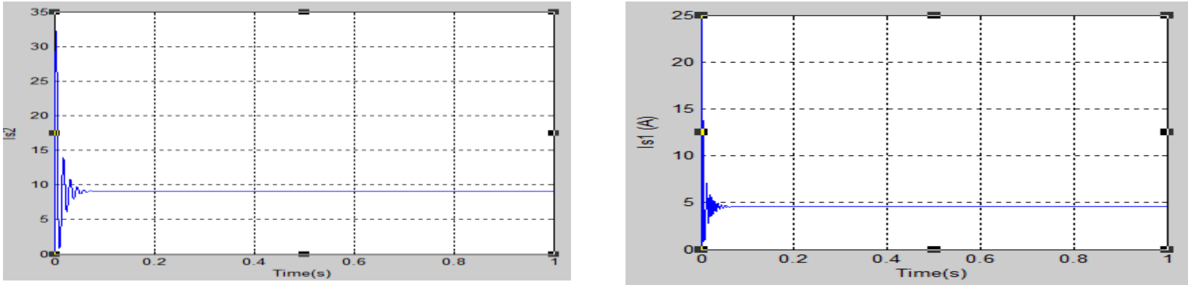
Simulation Waveform of Converter topology I | Simulation waveform of converter topology II

Source Current Is_1(A)



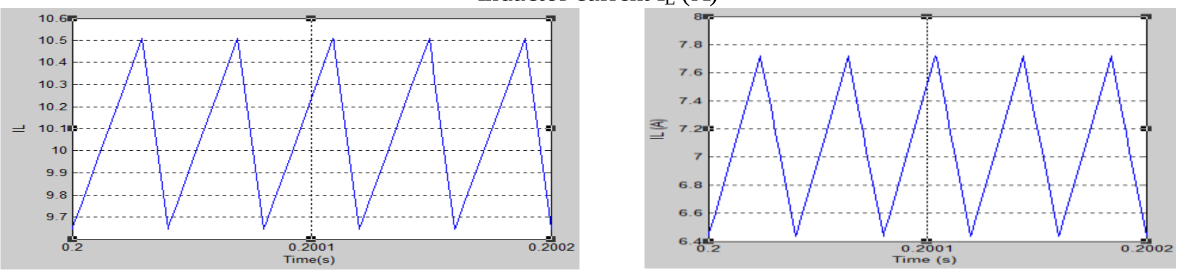
(i)

Source Current Is_2(A)



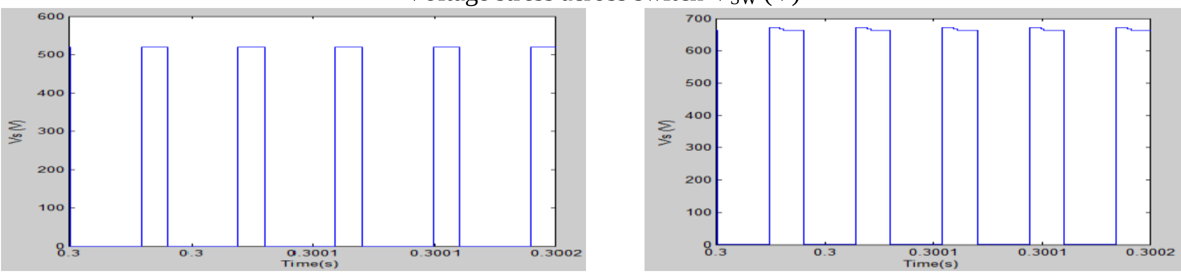
(ii)

Inductor current I_L (A)



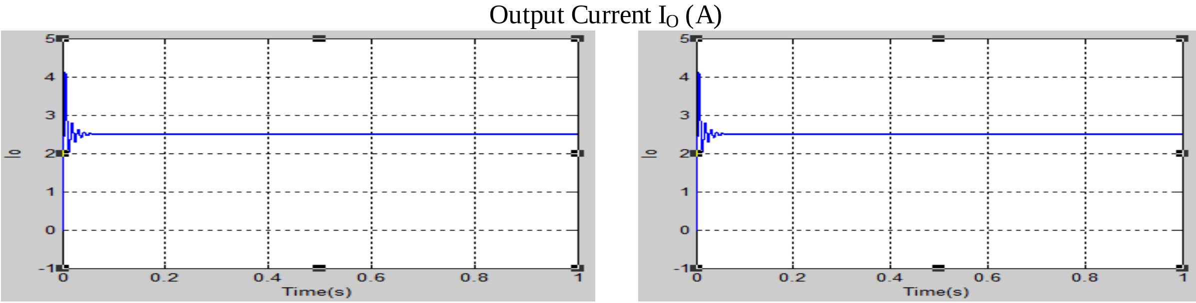
(iii)

Voltage stress across switch V_{SW} (V)



(iv)

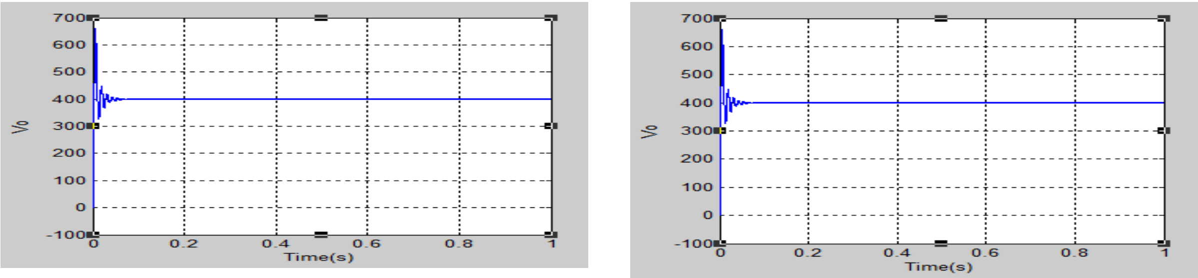
Output Current I_O (A)



(v)

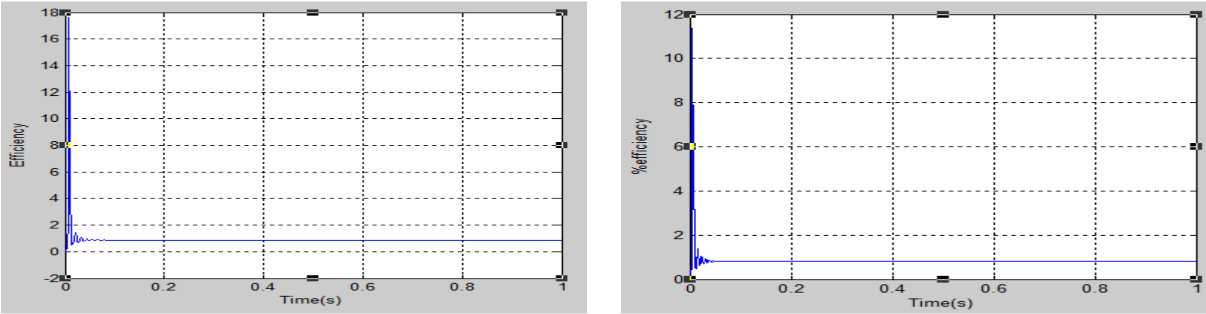
Output voltage V_O (V)

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 18 (2015) pp 38923-38930



(vi)

Efficiency (η)



(vii)

Figure 11. Waveforms obtained from open loop simulation of converter topology I and II(i) Source current Is_1 , (ii)Source current Is_2, (iii)Inductor current I_L, (iv) Voltage stress across switches V_{SW}, (v) Output current through the load I_O (vi) Output voltage across the load V_O (vii) Efficiency of the converter

Table 1: Simulation Parametres

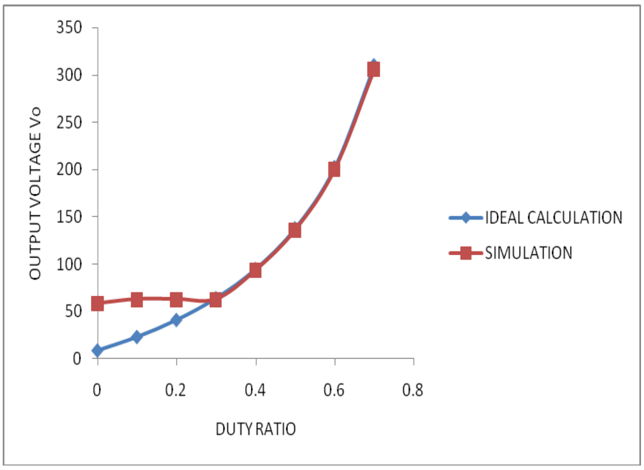
V_1[V]	150
V_2[V]	120
D_1[%]	73
D_2[%]	77
L[mH]	40
C[μF]	100
f[kHz]	25
V_0[V]	400
Load resistor (Ω)	160
Output power(kW)	1000

Table 2: Comparison of different parameters

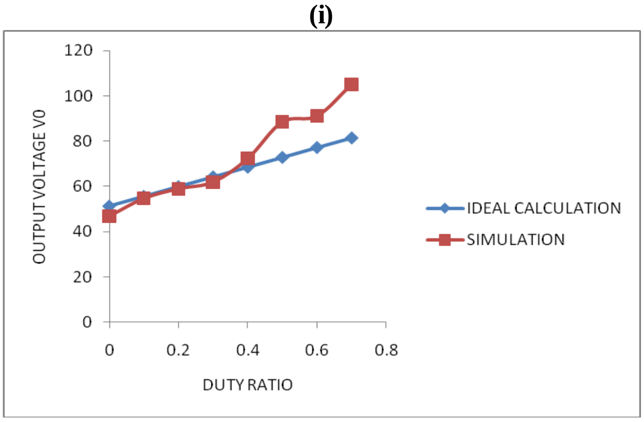
Combination	No. of Switches	No. of passive components	No. of diodes	% Efficiency	Voltage Stress across the switch(V)
Parallel	2	2	3	88.01	440
Series	3	2	3	81.56	670

Performance Comparison

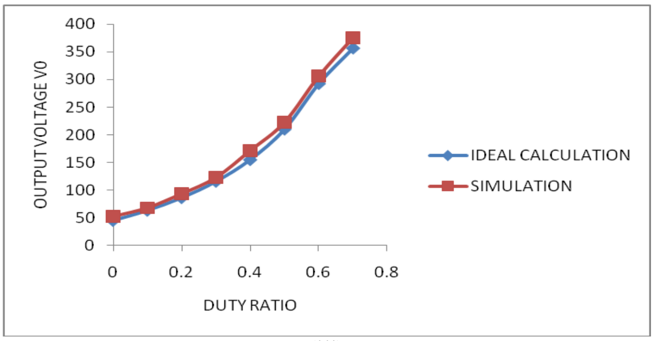
Performance analysis has been carried out for both converter topologies by varying the duty ratioD1 and D2. By keeping D1 = 30%, duty ratio D2 has been varied from 0- 70%. Similarly, By keeping D2 = 30%, duty ratio D1 has been varied from 0- 70%.. Performance comparison among the ideal calculation and result obtained from software simulation are closely matching as shown in Figure 12 [(i) -(iv)]



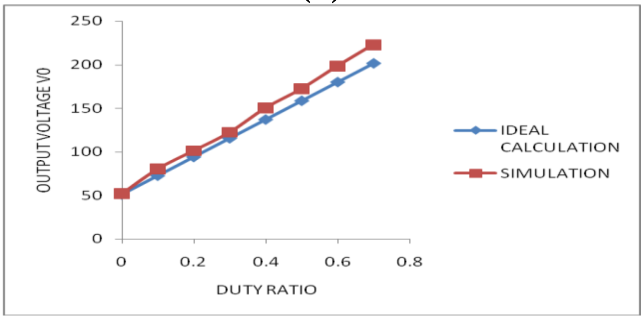
(i)



(ii)



(iii)



(iv)

Figure 12. Variation in output voltag: (i) due to variation in D2 at D1 =30% for converter topology I (ii) due to variation in D1 at D2=30% for converter topolgy I (iii)) due to variation in D2 at D1 =30% for converter topology II (iv) due to variation in D1 at D2=30% for converter topolgy II for V1=150V , V2=120 V

VI. Conclusion

A comparison of two dual - input DC-DC converter (Converter topology I and Converter topology II) for the integration of energy sources such as solar-PV, wind, ultra capacitor, fuel cell etc. for various applications has been carried out in this paper. Both converter topologies are capable for 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. Brief analyses of both converter topologies with the simulation results are presented. Efficiency, voltage stress across the switches, number of components etc. are some of the parameters taken for the comparison purpose. From the performance comparison, the converter with two parallel connected sources (Converter topology I) is found to be better than the converter with two series connected sources (Converter topology II) in terms of efficiency, voltage stress across the switches and part counts.

References

[1] K. Kobayashi, *et al.*, "Novel Solar-Cell Power Supply System Using a Multiple-Input DC/DC Converter," *IEEE Transactions on Industrial Electronics*, vol. 53, pp. 281-286, 2005.

[2] C. Yaow-Ming, *et al.*, "Multi-input DC/DC converter based on the multiwinding transformer for renewable energy applications," *IEEE Transactions on Industry Applications*, vol. 38, pp. 1096-1104, 2002.

[3] F. Caricchi, *et al.*, "Testing of a new DC/DC converter topology for integrated wind-photovoltaic generating systems," in *Power Electronics and Applications, 1993., Fifth European Conference on*, 1993, pp. 83-88 vol.8.

[4] Yan Li; Xinbo Ruan; Dongsheng Yang; Fuxin Liu;, "Modeling, analysis
and design for hybrid power systems with dual-input DC-DC converter," Energy Conversion Congress and Exposition, 2009. ECCE 2009. IEEE, vol., no., pp.3203-3210, 20-24 Sept. 2009.

[5] Matsuo, H.; Wen zhong Lin; Kurokawa, F.; Shigemizu, T.; Watanabe, N.; "Characteristics of the multiple-input DC-DC converter, " industrial Electronics, IEEE Transactions on , vol.5I, no.3, pp. 625- 631, June 2004.

[6] B. G. Dobbs and P. L. Chapman, "A multiple-input DC-DC converter, " IEEE Powe Electron Lett., vol. 1, no. 1, pp. 6-9, Mar. 2003.

[7] A. Kwasinski, "Identification of Feasible Topologies for Multiple- Input DC-DC Converters," *IEEE Transactions on Power Electronics*, vol. 24, pp. 856-861, 2009.

[8] L. Yuan-Chuan and C. Yaow-Ming, "A Systematic Approach to Synthesizing Multi-Input DC/DC Converters," in *Power Electronics Specialists Conference, 2007. PESC 2007. IEEE*, 2007, pp. 2626- 2632.

[9] Khaligh, A.; Jian Cao; Young-Joo Lee; , "A Multiple-lnput DC-DC Converter Topology, " Power Electronics, IEEE Transactions on , vo1.24, no.3, pp.862-868, March 2009.

[10] A. Kwasinski and P. T. Krein, "Multiple-input dc-dc converters to enhance local availability in grids using distributed generation resources," in *Applied Power Electronics Conference, APEC 2007 - Twenty Second Annual IEEE*, 2007, pp. 1657-1663.

[11] H. Tao, *et al.*, "Multi-input bidirectional DC-DC converter combining DC-link and magnetic-coupling for fuel cell systems," in *Industry Applications Conference, 2005. Fortieth IAS Annual Meeting. Conference Record of the 2005*, 2005, pp. 2021-2028 Vol. 3.

[12] N. D. Benavides and P. L. Chapman, "Power budgeting of a multipleinput buck-boost converter," *IEEE Transactions on Power Electronics*, vol. 20, pp. 1303-1309, 2005.

[13] Solero, L.; Lidozzi, A; Pomilio, J.A.; , "Design of multiple-input power converter for hybrid vehicles, " Power Electronics, IEEE Transactions on , vo1.20, no.5, pp. 1007- 1016, Sept. 2005.

[14] S. H. Choung and A. Kwasinski, "Multiple-input DC-DC converter topologies comparison," in *Industrial Electronics, 2008. IECON 2008. 34th Annual Conference of IEEE*, 2008, pp. 2359-2364.

[15] Yaow-Ming Chen; Yuan-Chuan Liu; Sheng-Hsien Lin; , "Double-lnput PWM DC/DC Converter for High-/Low-Voltage Sources, " Industrial Electronics, IEEE Transactions on , vo1.53, no.5, pp.l538-l545, Oct. 2006.

[16] "Multiple-input DC-DC power converter for power-flow management in hybrid vehicles, " lndustry Applications Conference, 2002. 37th lAS Annual Meeting. Conference Record of the , vol.3, no., pp. 1578- IS8S voi. 3, 2002.

[17] Kumar L, Jain S. A novel multiple input DC–DC converter for electric vehicular applications. In: Transportation electrification conference and Expo (ITEC), IEEE 18–20 June 2012. p. 1–6.

[18] Gummi, K.; Ferdowsi, M.; , "Double-Input DC-DC Power Electronic Converters for Electric-Drive Vehicles-Topology Exploration and Synthesis Using a Single-Pole Triple-Throw Switch, " industrial Electronics, IEEE Transactions on , vol.57, no.2, pp.6l7-623, Feb. 2010.