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An integrated multi input DC-DC converter in hybrid energy system

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In this study, an integrated double input DC to DC buck-buck boost converter for high/low voltage energy source applications is presented. An integrated buck-buck boost converter which can step down or step up the input voltage according to output voltage required at the load end. A multi input converter can be used instead of single input converters to integrate different energy sources such as solar PV, wind energy system, fuel cell and diesel etc. The converter is designed considering double input, in which same or different type of two inputs can be used individually or simultaneously. The operation modes and the steady state analysis of the converter are delinated. Finally converter behavior observed by using Matlab/Simulink^{TM} enviornment for closed loop simulation with PI control scheme, the obatinaed results are presented in detailed manner.

Keywords: *Multi Input DC-DC converters (MICs), hybrid energy system,closed loop control*

1.0 INTRODUCTION

Multi input DC-DC converters (MICs) play vital role in hybrid energy system for integration of more than one energy source. Commonly in hybrid energy system two or more energy sources like solar, wind, biomass and commercial grid etc. are connected individual DC-DC converters and their outputs are connected to common DC bus. But such connections are too bulky, costly, complex l and less efficient. Due to this reason multiple single input DC-DC converters are replaced by single multiple input DC-DC converter. MICs [1-4] gives a regulated DC output with different V-I characteristics of input sources and inputs may share the load individually or simultaneously[5-9]. In MICs, major challenging task is control strategy for constant output with different inputs. The converter can be fed by two inputs sources with high and low voltage levels[10-15], it can work as multi-input converter and it gives output stepup or stepdown. Block diagram of MIC with two input soucres are shown in Figure 1. The paper is divided in to five sections, section 2 explains integrated double input buck-buck boost converter. Different modes of operation with equivalent circuits has been addressed in section 3. Section 4 explains steady state waveforms with closed loop operation and conclusions drawn are explained in section 5.

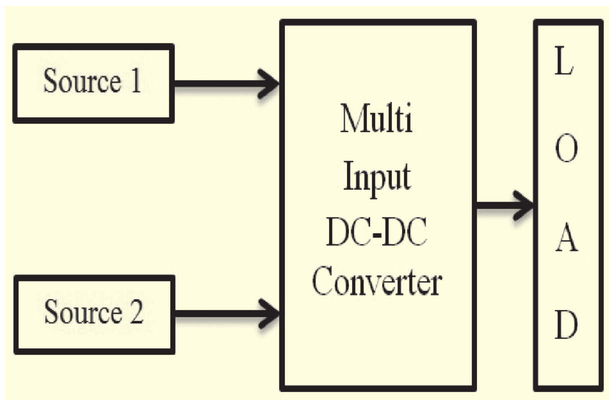

FIG. 1 BLOCK DIAGRAM OF MULTI INPUT CONVERTER

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2.0 INTEGRATED DOUBLE INPUT BUCK-BUCK BOOST CONVERTER

The circuit diagram of the an integrated double input buck/buck-boost converter is shown in Figure 2. The switches S_1 and S_2 both are works in same switching frequency with PWM control technique. This double input integrated DC-DC converter is explained for high / low input voltage sources and it operates as buck and buck-boost modes.

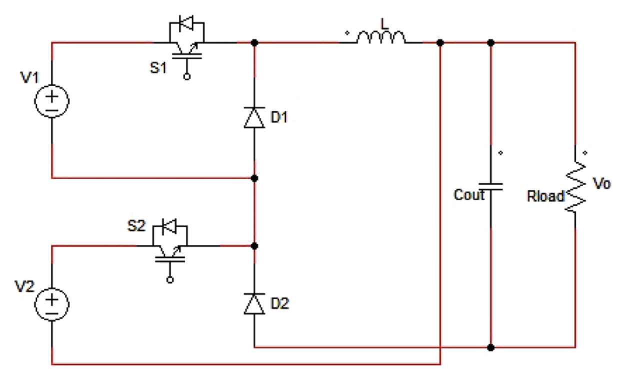

FIG. 2 INTEGRATED DOUBLE INPUT BUCK/BUCK-BOOST CONVERTER

From volt-second balance analysis the output voltage (V_o) can reprensted as

$$V_0 = \frac{d_1}{1-d_2}V_1 + \frac{d_2}{1-d_2}V_2 \quad ....(1)$$

Where d_1 and d_2 are the duty ratios of the switches S_1 and S_2 respectively.

3.0 DIFFERENT MODES OF OPERATION

The operation of the integrated double input converter is explained by different modes with equivalent circuits.

3.1 Mode I (S_1=ON, S_2 =OFF)

In this mode of operation switch S_1 and diode D_2 are in ON condition. The load is supported by voltage source V_1 through an inductor L. Mean time switch S_2 and diode D_1 are in OFF condition. The equivalent circuit of mode I is shown in Figure 3.

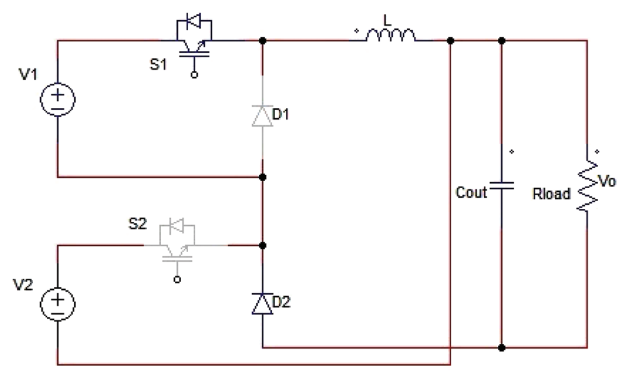

FIG. 3 EQUIVAENT CIRCUIT FOR MODE I OPERATION

3.2 Mode II (S_1=OFF, S_2 =ON)

The equivalent circuit of mode II operation is shown in Figure 4. In this mode switch S_2 and diode D_1 are in ON condition. The voltage source V_2 charges the inductor L, output capacitor supplies the load. The remaining switch S_1 and diode D_2 are in OFF condition.

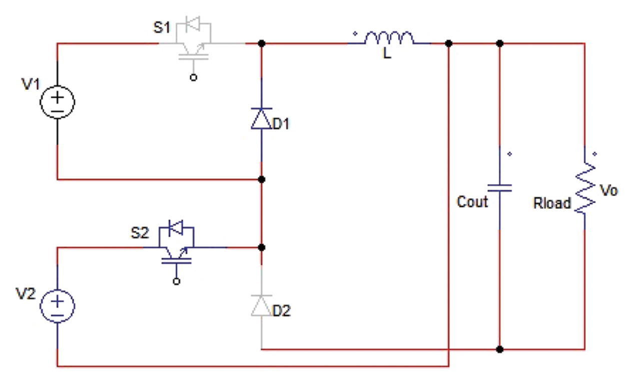

FIG. 4 EQUIVAENT CIRCUIT FOR MODE II OPERATION

3.3 Mode III (S_1=ON, S_2 =ON)

The equivalent circuit of mode III is shown in Figure 5. In this case switches S_1 and S_2 both are in ON condition. Both diodes D_1 and D_2 are in OFF condition. The load is supported by both voltage sources V_1 and V_2 simultaneously.

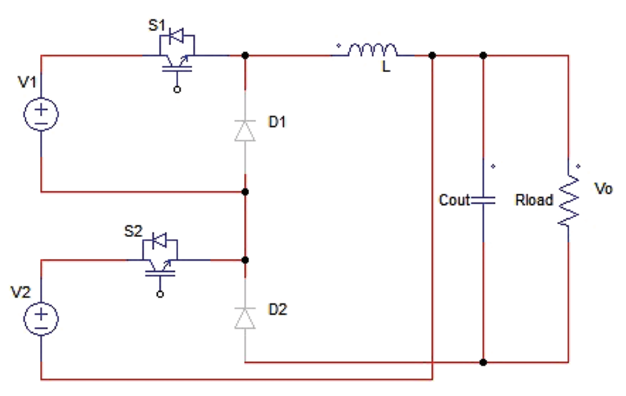

FIG. 5 EQUIVAENT CIRCUIT FOR MODE III OPERATION

3.4 Mode IV (S_1=OFF, S_2 =OFF)

The equivalent circuit of mode IV is shown in Figure 6. Both switches S_1 and S_2 are in OFF condition,the bypass path provided by diodes D_1 and D_2. The load is supplied from energy stored in inductor.

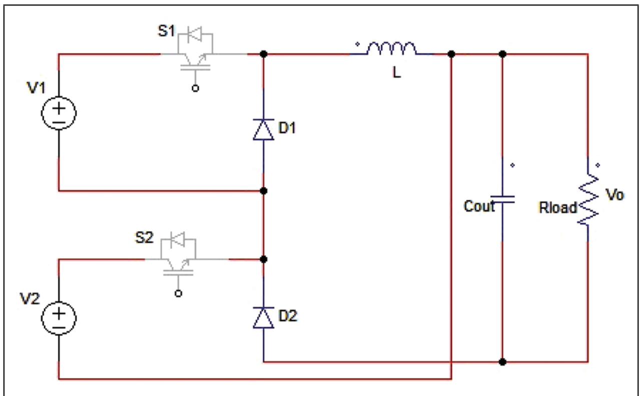

FIG. 6 EQUIVAENT CIRCUIT FOR MODE IV OPERATION

The different modes of working states and inductor charge and discharge are shown in Table 1.

TABLE 1

DIFFERENT MODES OF SWITCHING OPERATION

Mode	S_1	S_2	D_1	D_2	Inductor	Load Supports
I	ON	OFF	OFF	ON	Charges	V_1
II	OFF	ON	ON	OFF	Charges	V_2
III	ON	ON	OFF	OFF	Charges	V_1 and V_2
IV	OFF	OFF	ON	ON	Discharge	Inductor

The steady state waveforms for gate signals S_1 and S_2 (V_{S1}, V_{S2}), voltage across the inductor (V_L) are shown in Figure 6.

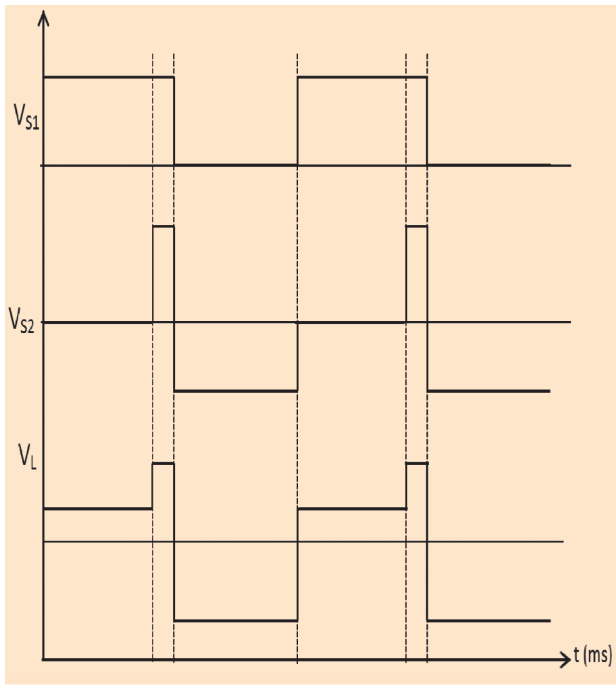

FIG. 7 TYPICAL WAVEFORMS OF INTEGRATED BUCK- BUCK BOOST CONVERTER

4.0 SIMULATION RESULTS

MICs with two input sources high/low have been considered for simulation study. The converter is analyzed for Continuous Conduction Mode (CCM) under steady state and transient conditions. Closed loop simulation circuit with PI controller is shown in Figure 7.

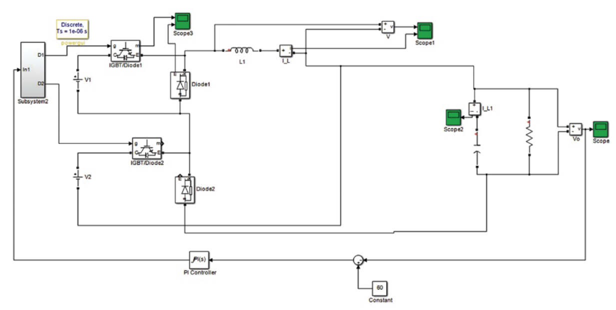

FIG. 8 INTEGRATED DOUBLE INPUT BUCK-BUCK BOOST CONVERTER UNDER CLOSED LOOP

The gate pulses for the switches S_1 and S_2 are shown in Figure 8 with fixed switching frequency. The simulation parameters are given in Table 2.

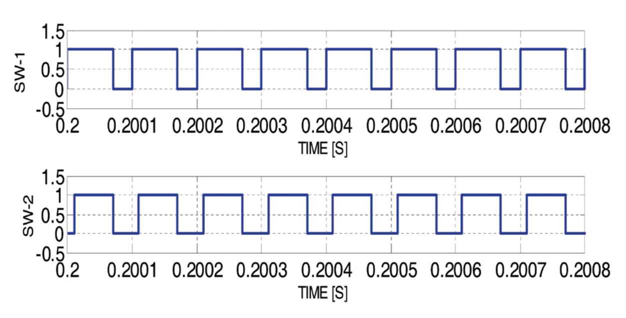

FIG. 9 SWITCHING SIGNALS FOR SWITCHES S_1 AND S_2

TABLE 2	
Simulation Parameters	
Inductance (L)	10 mH
Capacitance (C)	220 uF
Load resistance (R_L)	5 ohms
Switching frequency (f_s)	10 kHz

Under open loop simulation study the converter output voltage is shown in Figure 9. in boost mode of operation.

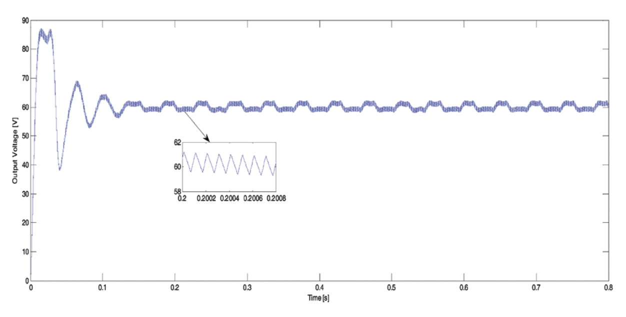

FIG. 10 OUTPUT VOLTAGE IN OPEN LOOP SYSTEM

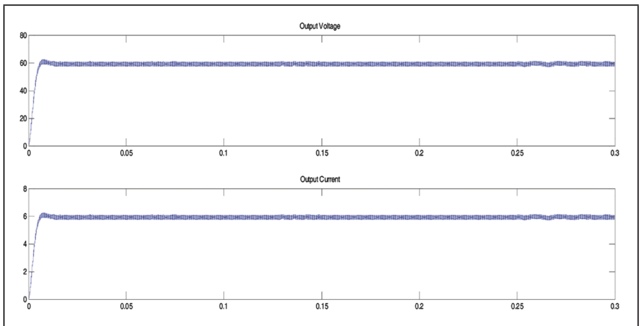

FIG. 11 OUTPUT VOLTAGE AND CURRENTS IN CLOSED LOOP CONDITION

In closed loop operation the output voltage and currents are shown in Figure 10.

The output ripple voltage and currents are observed in closed loop simulation, they are shown in Figure 11. This can be suppress by proper designing of inductor and output capacitors.

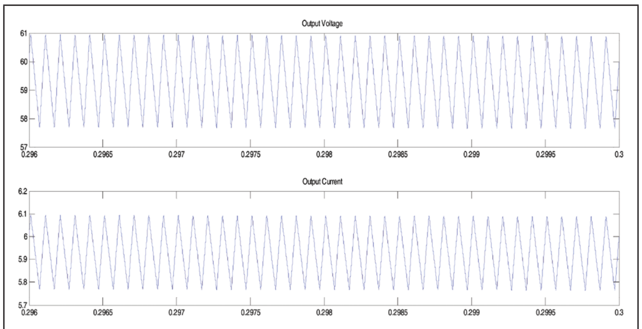

FIG. 12 OUTPUT RIPPLE VOLTAGE AND RIPPLE CURRENT IN CLOSED LOOP

4.1 Advantages of MICs

i) The main advantages of MICs are given by

ii) Single stage conversion

iii) Less number of components

iv) Cost effective

v) More reliable

vi) Compact size

vii) More flexible for distributed generation and hybrid energy systems

Continuous power flow to the load

MICs can be more suitable for Micro grid and Nano grid applications for electrifying remote areas without dependency on utility grid.

5.0 CONCLUSION

In this paper, an integrated double input DC-DC converter has been studied for different operating modes and various equivalent circuits are presented. Simulation results are used to verify the system behavior under closed loop and openloop conditions with PI controller. The main observation made from results is that, even if inputs change, the output voltage is regulated for 60 V.

FUTURE WORK

- Engy storage for backup
- Implementation of various control schemes like PID, Fuzzy logic etc.
- Power flow management for whole system
- Extension for 'n' input integrated DC-DC converters.

REFERENCES

[1] B C Sekhar, L Sanjay and R S Kumar, An integrated double input DC-DC buck converter in hybrid energy system, The Journal of CPRI, Vol. 11, No. 02, pp. 401-406, June 2015.

[2] Zubair Rehman, Ibrahim A-Bahadly and Subhas Mukhopadhyay, Multi input DC-DC converters in renewable energy applications, Renewable and sustainable Energy reviews, Elesiever, pp. 521 – 539, 2015.

[3] B C Sekhar, L Sanjay and R S Kumar, Multi input DC-DC converters for hybrid renewable energy systems - an overview, The Journal of CPRI, Vol. 11, No. 1, pp. 155-160, March 2015.

[4] B G Dobbs and P L Chapman, A Multiple-Input DC-DC Converter Topology, IEEE Power Electronics Letters, pp. 06-09, March 2003.

[5] H J Chiu, H M Huang, L W Lin and M H T Seng, A Multiple-Input DC-DC Converter for Renewable Energy Systems, IEEE, pp. 1304-1308, 2005.

[6] Y M Chen, Y C Liu, and S H Lin, Double-Input PWM DC/DC Converter for High-/Low-Voltage Sources, IEEE Transactions on Industrial Electronics, Vol. 53, No. 5, October 2006.

[7] Y M Chen, Y C Liu, and F Y Wu, Multi-Input DC-DC Converter Based on the Multiwinding Transformer for Renewable Energy Applications , IEEE transactions on industry applications, Vol. 38, No. 4, August 2002.

[8] Y M Chen, Y C Liu, S C Hung and C S Cheng, Multi-Input Inverter for Grid Connected Hybrid PV/Wind Power System, IEEE transactions on power electronics, Vol. 22, No. 3, May 2007.

[9] Y M Chen, Y C Liu, and F Y Wu, Multi-Input DC/DC Converter with Ripple-Free Input Currents, IEEE PESC, Vol. 2, pp.796-802, June 2002.

[10] P L Chapman, A multiple-input DC-DC converter, IEEE Power Electronics Letters Vol. 1, No. 1, pp. 6-9, March 2003.

[11] K P Yalamnchili, M Ferdowsi and K Corzine, New double Input DC-DC Converters for automotive applications, proceedings of the IEEE conference, pp. 1–6, 2006.

[12] L Kumar and S Jain, Multi input DC-DC converter topology for Hybrid energy system, IET Power. Electron, Vol. 6, No. 8, pp. 1483–1501, March 2013.

[13] M Gavris, O Cornea and N Muntean, Multi input DC-DC topologies in renewable energy systems- A general review, IEEE International Symposium, Subotica, Serbia, pp. 123-128, 2011.

[14] Yalamnchili K P, Ferdowsi M and Corzine K, New double Input DC-DC Converters for automotive applications, proceedings of the IEEE conference, pp. 1–6, 2006.

[15] M H Rashid, Power Electronics: Circuits, Devices, and Applications, Pearson Education India, New Delhi, 2004