

An integrated double input DC- DC buck converter in hybrid energy system

Chandrasekhar B*, Sanjay Lakshminarayanan** and Sudhir Kumar R***

Integration of more than one energy source depends on the power electronic converters is an interesting and challenging task for researchers. In this paper, integrated double input DC to DC converter for low voltage energy source applications is explained. Integrated buck converter which can step down the input voltage according to output voltage required at the load end. The converter is able to integrate different voltages of various energy sources such as solar photovoltaic, wind energy system, fuel cell and diesel etc. of relatively low voltage. The converter is designed considering double input, in which same or different type of two inputs can be used individually or simultaneously. Modes of operation of converter are described in detail, closed loop simulation with a PI controller using MATLAB/Simulink™ results are presented in detail.

Keywords: Double input DC-DC converter, hybrid energy system, closed loop control

1.0 INTRODUCTION

Now a days hybridization of the energy systems is more popular in the field of the electrical system. Power electronic converters have been key factor to interface different energy sources. In hybrid energy system [1-6] two or more Energy Sources such as solar, wind, biomass etc. are integrated for producing power without intermittent according to the weather conditions rather than to the power demanded. These problems can be minimized by using a suitable type of converter for different energy sources of relatively less voltage. According to the availability of energy sources (wind or solar PV systems or diesel generators or fuel cell), the output power may vary. The inputs may be working independently or simultaneously, which is described in this paper in detail. According to input voltage condition, the converter can be made work like a

step down DC-DC converter. The integrated buck converter can be fed by two inputs of relatively the same and low voltage energy sources like solar / fuel cell and wind / diesel, individually or simultaneously on the basis of availability or requirement of energy source. The same system can be made work multi-input converter also, in that case converter may work as buck or step down. The paper is organized such that double input converter system with their characteristics and closed loop control schemes are described in detail.

2.0 INTEGRATED DOUBLE INPUT BUCK / BUCK CONVERTER

Figure 1 gives a block diagram of hybrid energy system. Here two inputs connected to the converter.

*Energy Efficiency and Renewable Energy Division, Central Power Research Institute, Bangalore- 560080, chandrasekhar_srf@cpri.in

** Associate Professor, EEE Department, MS Ramaiah Institute of Technology, Bangalore-560054, sanjay.laks@gmail.com

***Energy Efficiency and Renewable Energy Division, Central Power Research Institute, Bangalore- 560080, sudhir@cpri.in

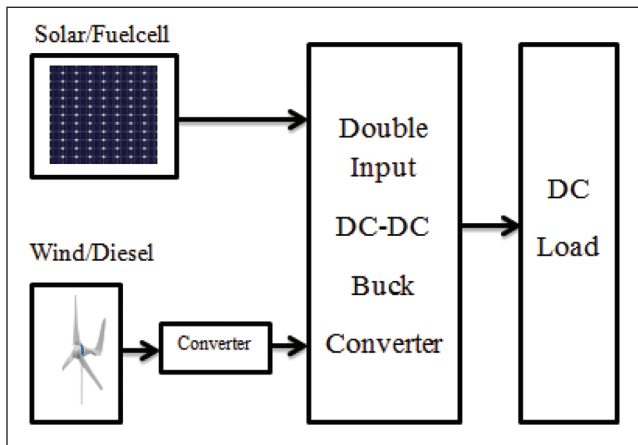


FIG. 1 BLOCK DIAGRAM OF MULTI INPUT DC/DC CONVERTER

Figure 2 shows the circuit diagram of an integrated double input buck-buck converter in *MATLAB/Simulink™* environment.

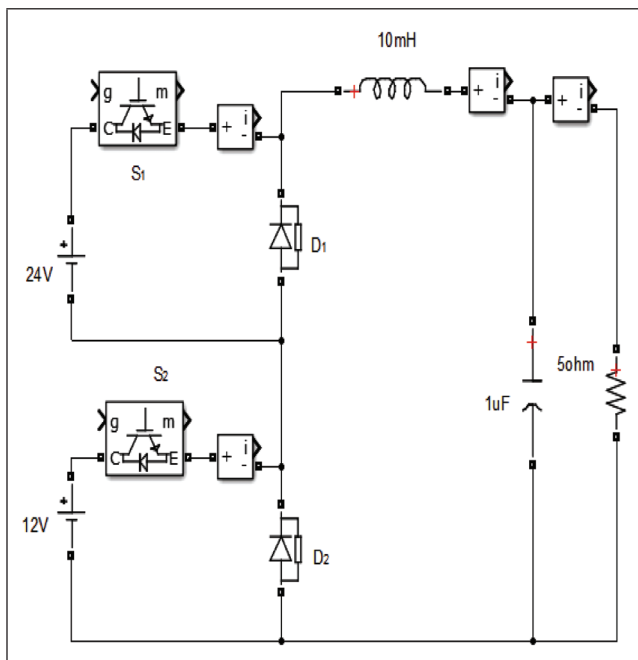


FIG. 2 INTEGRATED BUCK-BUCK CONVERTER

Here two different DC voltage sources connected to the converter. In these converters, regulated DC output voltage is obtained although the input voltage is changing. The regulation of output voltage is obtained based on the on-time of the switch, pulse width and the switching frequency. Variation in output voltage can be made by variation in reference voltage and thus the duty cycle (D) can be varied. The duty ratio is defined as the ratio of the on-time of the switch and the total switching period.

Duty cycle is given as

$$D = T_{on} / T_s \quad \dots(1)$$

Where, D is the duty cycle

T_{ON} is the ON period of the switch

T_S is the total time period, i.e. $(T_{ON} + T_{OFF})$

2.1 Modes of operation

TABLE 1						
MODES OF OPERATION						
Mode	S_1	S_2	D_1	D_2	Inductor	Load Supports
I	ON	OFF	OFF	ON	Charges	V_{s1}
II	OFF	ON	ON	OFF	Charges	V_{s2}
III	OFF	OFF	ON	ON	Discharge	Inductor
IV	ON	ON	OFF	OFF	Charges	$V_{s1} \& V_{s2}$

Different operational modes of integrated buck-buck converter [7-8] is represented in Table 1 and the equivalent circuits of each mode of operation is represented in Figure 3 to Figure 6.

In mode I and II both switches alternatively ON and OFF. Mode I load is supported by source 1 and mode II source 2 supplies the load.

Mode III both switches are OFF stored energy in inductor supports the load.

Mode IV both switches are ON so both sources supplies the load and inductor also charged. [10-12]

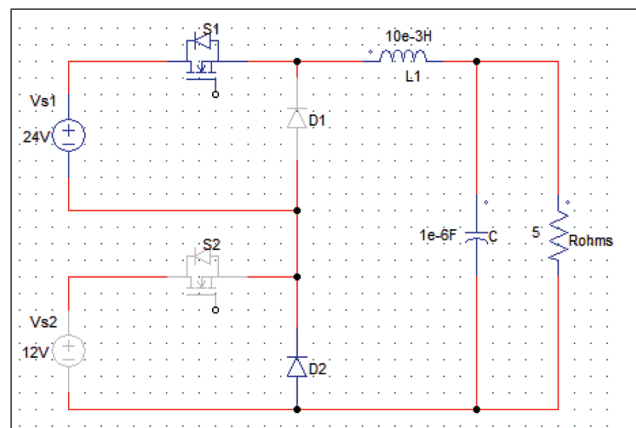


FIG. 3 MODE I OPERATION

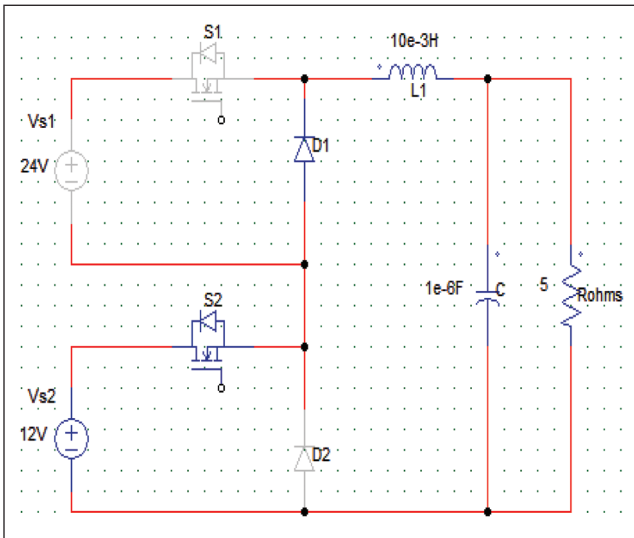


FIG. 4 MODE II OPERATION

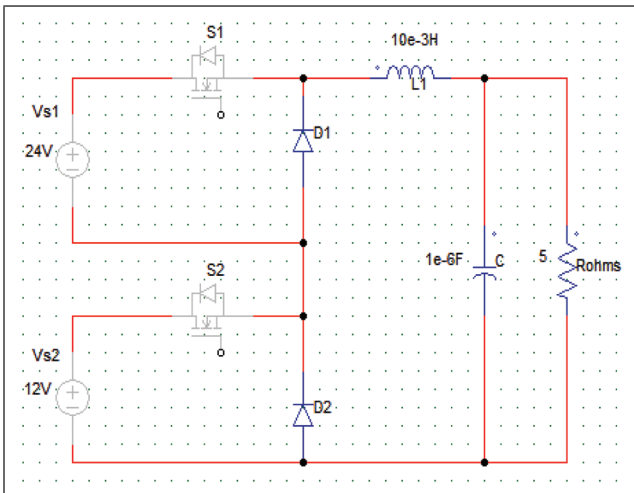


FIG. 5 MODE III OPERATION

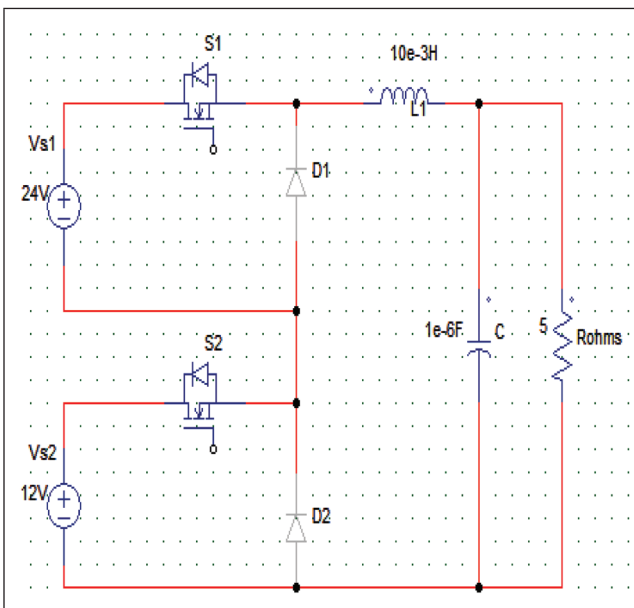


FIG. 6 MODE IV OPERATION

The output voltage V_o is given by (applying volt-second balance theorem)

$$V_o = V_1 D_1 + V_2 D_2 \quad \dots(2)$$

The typical waveforms of the converter, gate signals of switches S_1 & S_2 (V_{g1} , V_{g2}), the voltage across the inductor (V_L), current through the inductor (I_L), both source input currents (I_1 , I_2) shown in Figure 7.

In addition, the double input converter does not require synchronization for maximizing the output power of the converter depending on the load requirements [13-16].

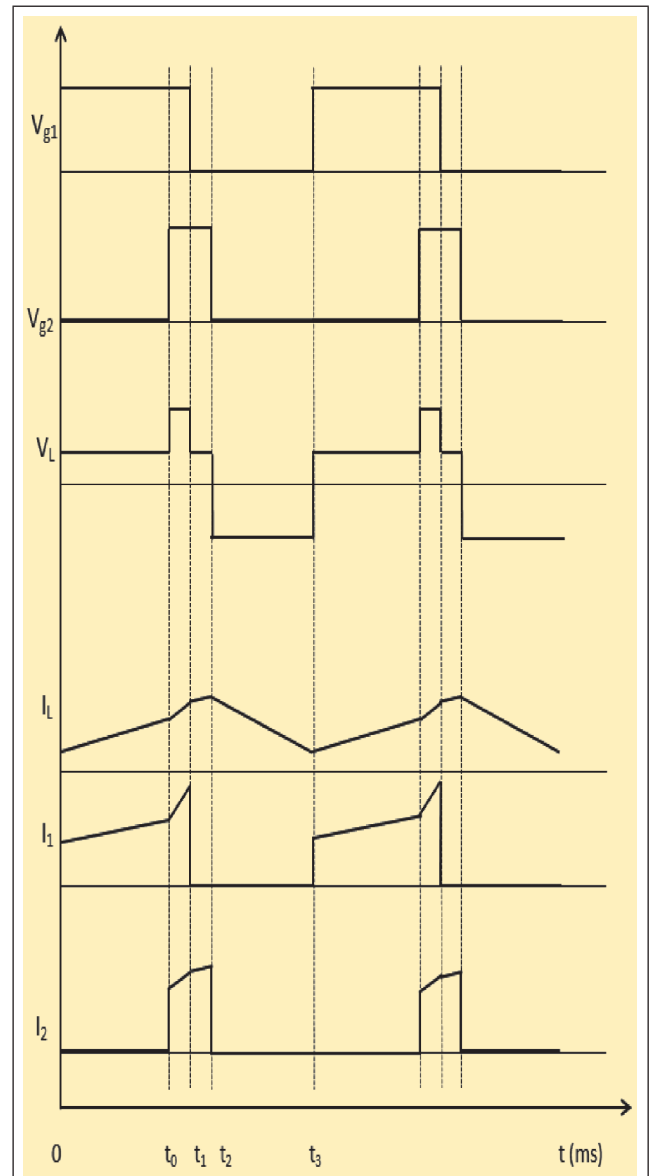


FIG. 7 TYPICAL WAVEFORMS OF INTEGRATED BUCK-BUCK CONVERTER

3.0 CLOSED LOOP SIMULATION

The closed loop simulation with a PI controller as shown in Figure 7. The controller controls the output voltage with reference of constant value. The following design parameters Table 2 are used for simulation of the in MATLAB / Simulink™ software.

3.1 DESIGN PARAMETERS

TABLE 2	
DESIGN PARAMETERS	
Inductance (L)	10 mH
Capacitance (C)	1 μF
Load resistance (R _L)	5 ohms
Switching frequency (f _s)	10 kHz

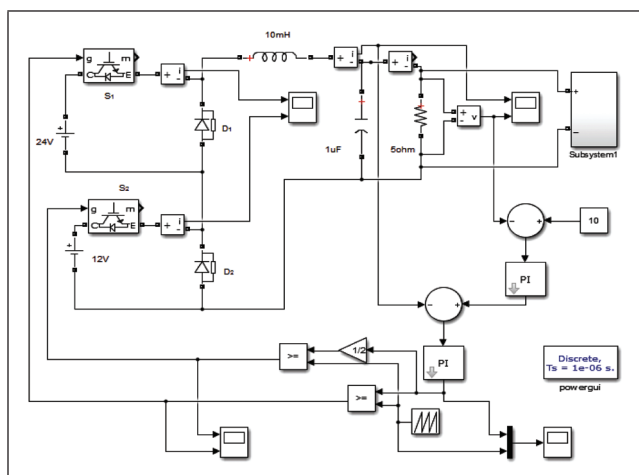


FIG. 8 CLOSED LOOP SIMULATION OF INTEGRATED BUCK-BUCK CONVERTER

Various loads are sub-circuited separately, the sub-circuit is shown in Figure 8.

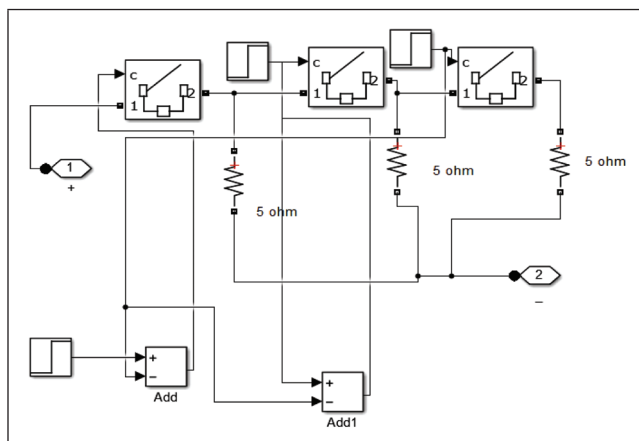


FIG. 9 SUB CIRCUIT

The gate signals to drive the switches S₁ and S₂ are shown in Figure 9.

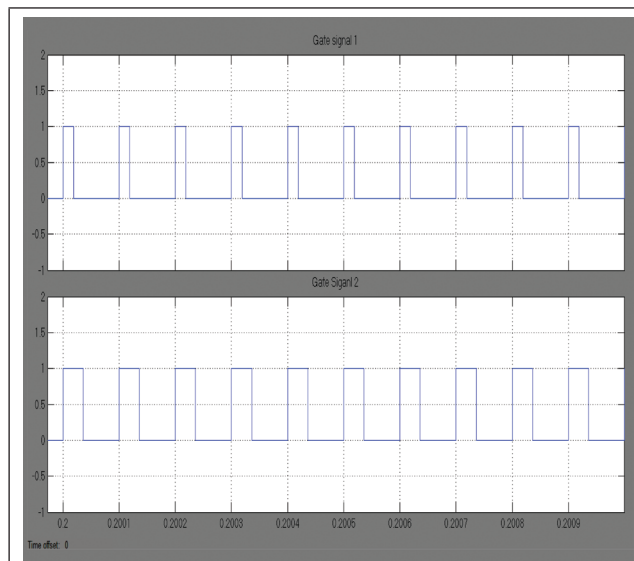


FIG. 10 GATE SIGNALS FOR SWITCHES

In simulation for different load values the output voltage is constant, only the current is changing if load increases, it is shown Figure 10.

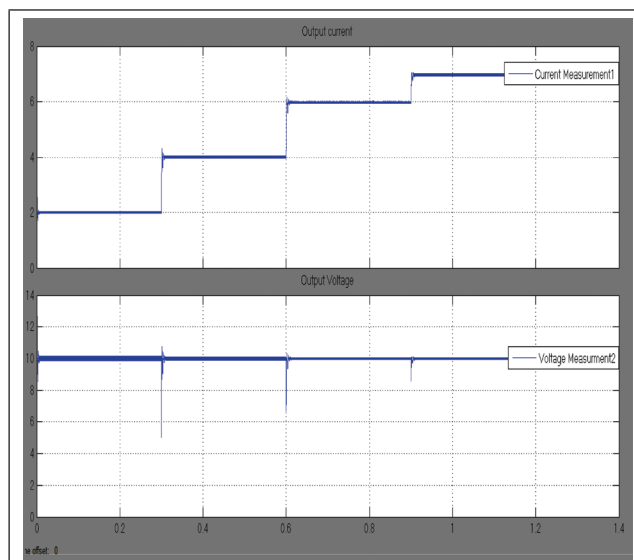


FIG. 11 OUTPUT CURRENT AND VOLATGE

4.0 ADVANTAGES

The advantages of integrated DC-DC buck converters from [1-14] are

- Single inductor.
- Single stage conversion.
- Less number of components.

- Less space needed for the system
- More reliable.
- High efficiency.
- Low conduction losses.

5.0 CONCLUSIONS

The converter is able to maintain constant voltage at the load end and it is able to work as a double input buck converter. The closed loop simulation with PI controller results shows that the output voltage is regulated to 10 V, if the load changes, only the output current changes and the output voltage is maintained constant.

FUTURE WORK

- Improvement of the converter performance using PID controller.
- Modify the converter to incorporate more than two DC inputs

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