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A Two Input DC-DC Buck Converter for Hybrid Renewable Energy System with PI controller

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Abstract: Integration of more than one energy source depends on the power electronic converters is an interesting and challenging task for researchers. In this paper, an integrated two input DC to DC buck 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 two input, in which same or different type of two inputs can be used individually or simultaneously. Modes of operation of Dc-DC buck 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 Buck converter, Composite energy system, closed loop control

1. Introduction:

Now a day's Hybridization of the energy systems is more popular in the field of the electrical system applications. Power electronic converters have been key factor to interface and integrate different energy sources. In Hybrid energy system [1-6] two or more Energy Sources such as solar, wind, Biomass, battery, 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 or battery based), 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 two input converter system with their characteristics and closed loop control schemes are described in detail.

2. Related work:

The Hybrid Energy System (HES) shall accommodate more than one distinct voltage-current characteristic of renewable energy sources like solar-PV, wind etc., and storages like a battery, ultra capacitor, fuel cell, etc. [7–9]. A power electronic interface is mandatory to integrate these input energy sources. Parallel connected single-input DC-DC converters are widely used in the conventional scheme and this result in substantial complexity in control strategies, increased cost, loss of compactness and system efficiency. Hence, the idea of multi-input DC-DC converters (MICs) has been introduced to surpass the demerits of conventional methods. Simple and compact structure, lower system complexity and reduced cost are the main attractive features of MICs. Compared to single-input converters, MICs can provide a reliable power supply, which is one of the potential merits of MICs [10–12].

3. Proposed work:

3.1 Block Diagram of Integrated Double Input Buck/Buck Converter

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

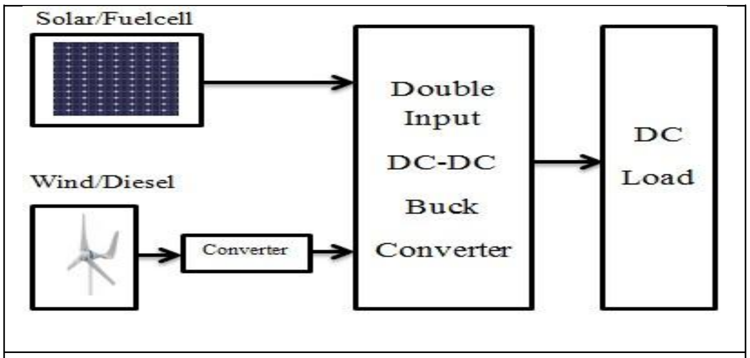

Fig 1 Block Diagram of Multi Input Dc/Dcconverter

3.2 Circuit Diagram of Integrated Double Input Buck/Buck Converter

Figure 2 shows the circuit diagram of an integrated double input buck-buck converter.

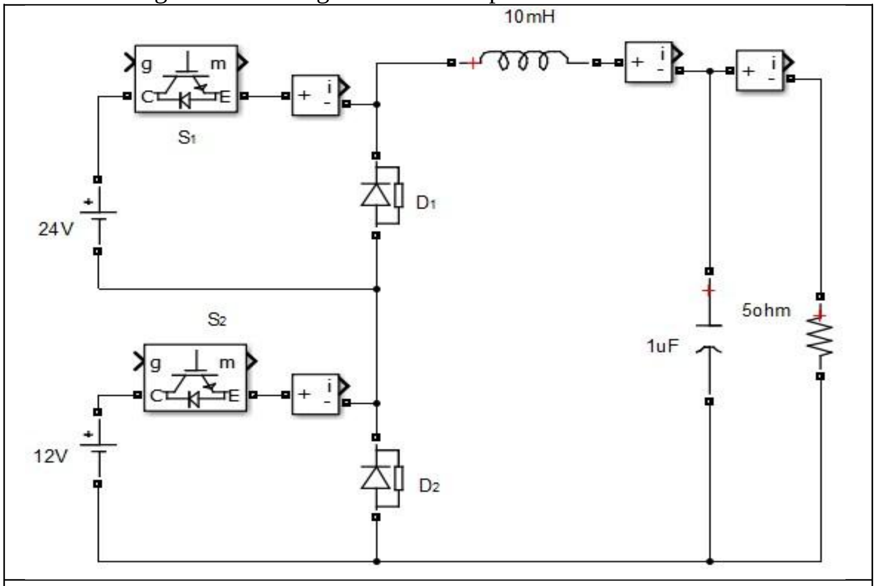

Fig 2 Integrated Buck-Buck Converter

3.3 Basic Opeartion of Integrated Buck/Buck Converter

Here two different DC voltage sources connect 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

$$D=T_{on}/T_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where D is the Duty cycle,

T_{ON} is the ON period of the switch, T_{OFF} is the OFF period of the switch,

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

3.4 Modes Of Opeartion Of Integrated Buck/Buck Converter

Different operational modes of integrated buck-buck converter [13-15] are represented in Table 1 and the equivalent circuits of each mode of operation are represented in Figure 3 to Figure 6.

In mode I & II both switches alternatively ON & 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

Table 1

Different 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}

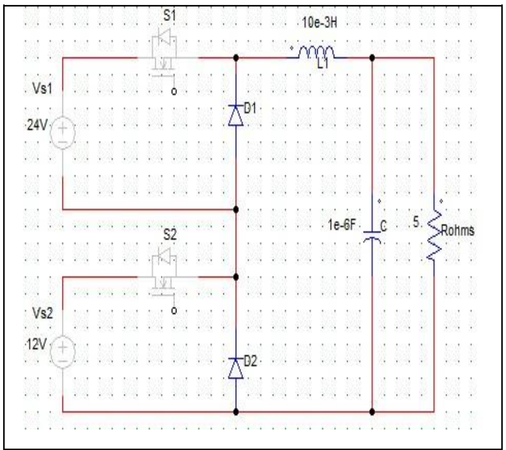

FIG 3 MODE I OPERATION

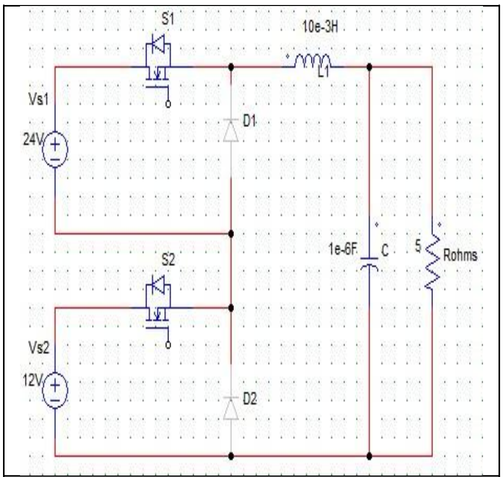

FIG 4 MODE II OPERATION

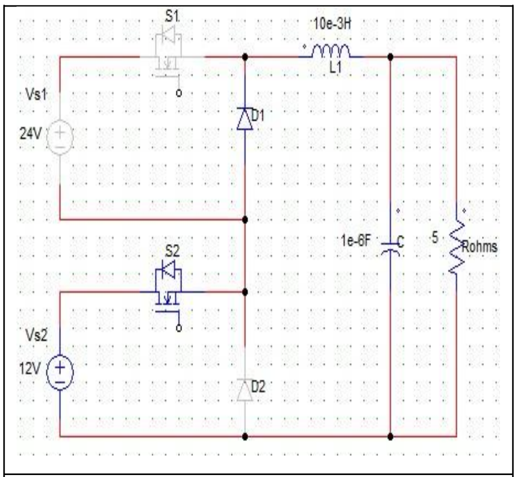

FIG 5 MODE III OPERATION

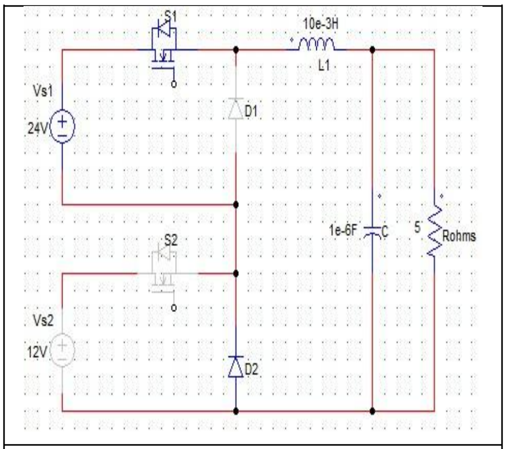

FIG 6 MODE IV OPERATION

3.5 Waveforms of Integrated Buck/Buck Converter

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

$$V_0 = V_1 D_1 + V_2 D_2 \text{ …………………… (2)}$$

The typical waveforms of the converter, gate signals of switches S1 & S2 (Vg_1, Vg_2), 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 [16-19].

4. Performance evaluation:

4.1 Closed Loop Simulation

The closed loop simulation with a PI controller as shown in Figure 8. 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.

Table 2	
Design Parameters	
Inductance (L)	10 mH
Capacitance (C)	1 uF
Load resistance (R_L)	5 ohms
Switching frequency (f_S)	10 kHz

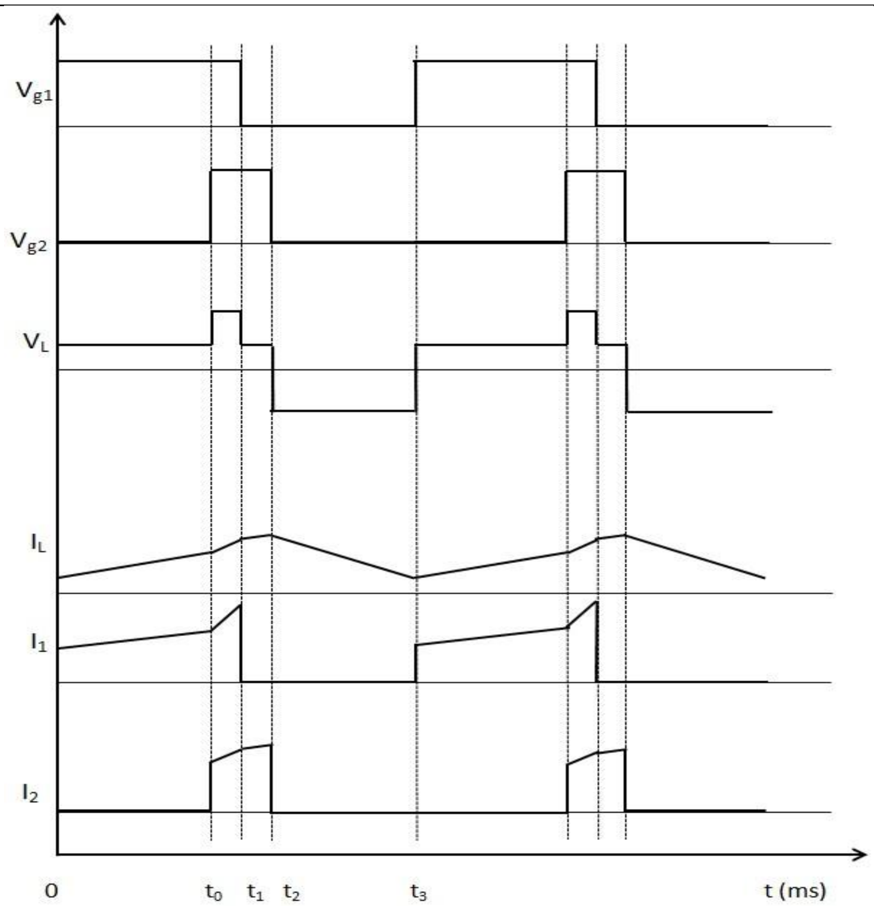

FIG 7 TYPICAL WAVEFORMS OF INTEGRATED BUCK-BUCK CONVERTER

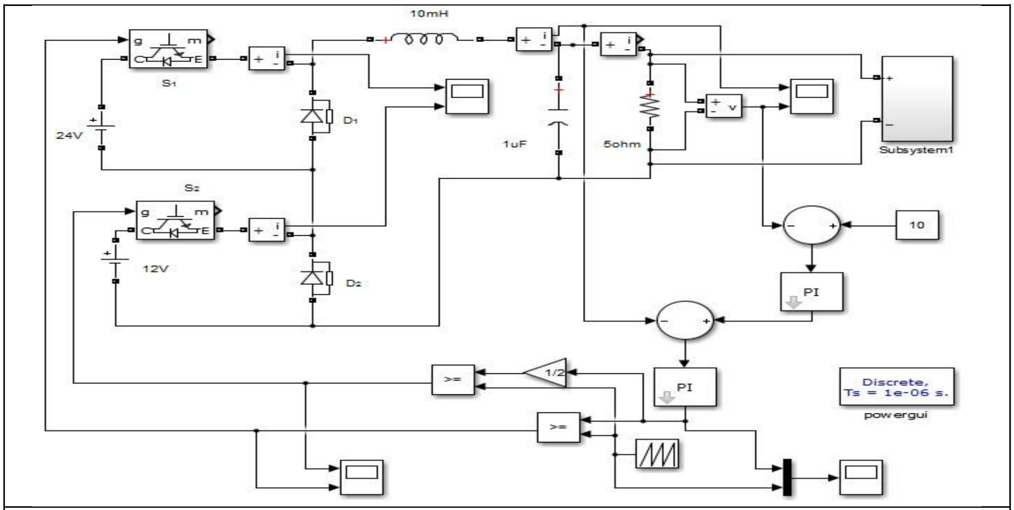

FIG 8 CLOSED LOOP SIMULATION OF INTEGRATED BUCK-BUCK CONVERTER

4.2 Sub Circuit of Various Laods

The sub-circuit of various loads connected to the converter is shown in Figure 9.

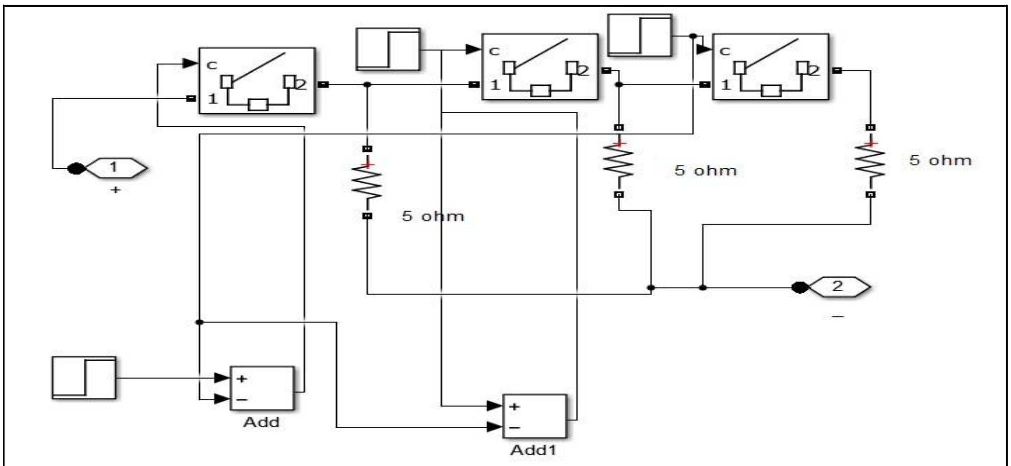

FIG 9 SUB CIRCUIT

4.3 Gating Signal Pattern

The gate signals to drive the switches S_1 and S_2 are shown in Figure 10.

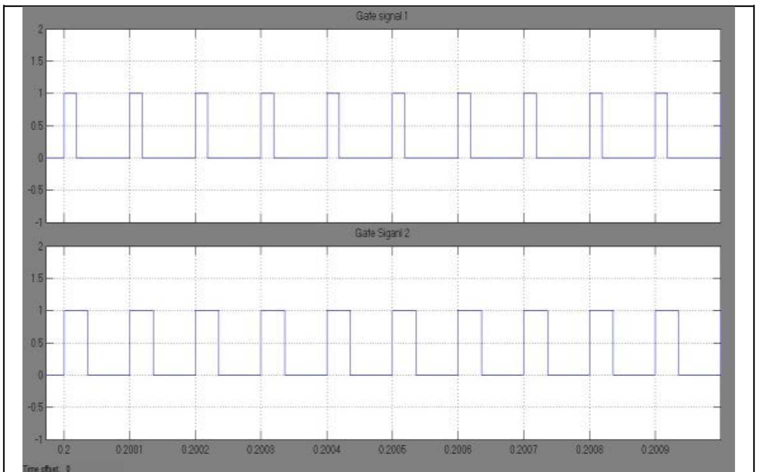

FIG 10 GATE SIGNALS FOR SWITCHES

4.4 Results of Simulation

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

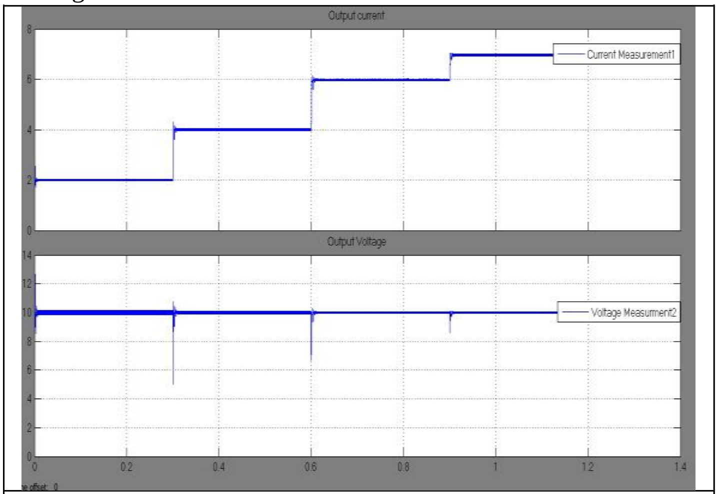

Fig 10 Output Current and Volatge

5. 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.

5.1 Advantages

The advantages of Integrated DC-DC buck converters [1-6] [13-20] are

- Usage of Single inductor.
- One stage conversion.
- Numbers of components are less.
- Space needed for the system is low.
- High reliability.
- Efficiency is very high.
- Conduction losses are low.

4.5 Future Scope of Work

- Converter performance can be further increased using PID controller.
- Converter can be modified to incorporate more than two DC inputs

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