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Hardware Testing, Designing and Simulation of Dual Input Buck-Buck DC-DC Converter Using H-Bridge Cells

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***Abstract*— Recent research in the development of clean power sources has become a main area to protect the environment and to overcome the energy crisis of the whole world. The energy storage unit is one of the most important aspects in the structure of hybrid electric vehicle and photo voltaic systems. Dual input DC-DC converters used in such energy storage unit to improve efficiency, performance and also to reduce cost, component count. In this paper, design of dual input Buck-Buck dc-dc converter using H-Bridge cells is presented. Replacement of semiconductor switches and operating characteristics of the converters were obtained with their voltage transfer ratios. The performances of the Buck-Buck dc-dc converters are simulated using MATLAB/simulink and MULTISIM. The Simulated output results were Compared and verified with Hardware and theoretical Results.**

***Index Terms*— Buck-Buck dc-dc converter, Voltage transfer ratio, MULTISIM, MATLAB/Simulink, Output voltage Comparison and Hardware Testing.**

I. Introduction

In hybrid electric vehicles, photo voltaic systems, fuel cell systems, the instantaneous power of input and output of power electronic converters are not same. However, the high specific power of ultra capacitors is the major reason of them being used as intermediate energy storage unit during acceleration, hill climbing, and regenerative braking. Energy storage system consists of battery or ultra capacitors. Several structure of combining batteries and ultra capacitors have been discussed by the previous researchers. Although there are several different types of dc-dc converter belongs to buck, boost and buck-boost topologies, have been developed to meet variety of application specific demands [1],[3]. The conventional approach of connecting the energy storage unit is by using independent converter. The independent converter with energy sources can be connected either in series or parallel in multiple input converters.

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If the sources are connected in series it has to conduct the same current and if the converters are connected in parallel it should have same voltage levels. Both the conditions are practically undesirable[12].

Instead of this, multi input dc-dc converter is used to connect multi Sources in a single system to give required load demand and also to improve efficiency [6], reduce overall cost; reduce component count, more stability and simple control. In this paper, only two inputs are used so it is named as dual input dc-dc Converter. Multi input converters can be constructed using either flux additivity or by systematic approach to design multi input converters through derivation [5][11]. Design of new converters from existing converters is complicated task. Hence In this paper, a systematic approach is given to design a converter through derivation by using H-Bridge cell as building block[1].

The fig.1 shows the block diagram of dual input buck –buck dc-dc converter. In this paper, Design of dual input dc-dc converter using H-bridge cells is presented in part II. Replacement of semiconductor switches of dual input dc-dc converter is presented in part III. Derivation of Output Voltage of converter is obtained in part IV.

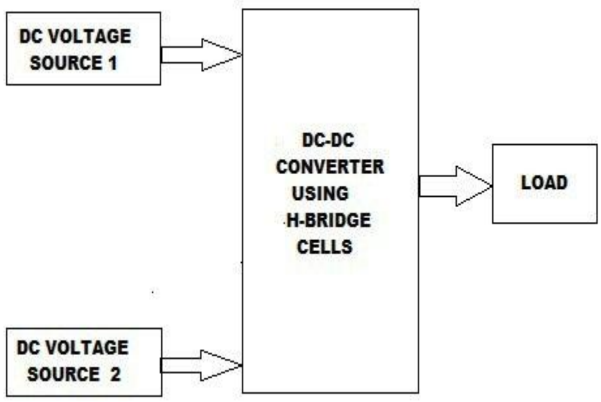

Fig.1.Block diagram of dual input buck-buck dc-dc converter

Simulation results using MATLAB/simulink are presented in part V. Comparison of Output voltages, Hardware Testing and MULTISIM Simulation results are presented in part VI.

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II. Design Of Dual Input Dc-Dc Converter Using H-Bridge Cells

The H-bridge cell consists of four switches with one voltage source is shown in fig.2. That is S_1,S_2,S_3,S_4 The voltage source can be a battery, ultra capacitor, PV system, or fuel cell system. The output voltage is equal to +V when the switches S_1 and S_3 are turned on. The output voltage is equal to -V, when the switches S_2 and S_4 are turned on.

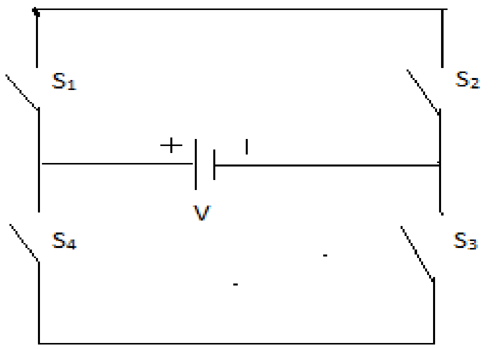

Fig.2.Circuit diagram of an H-Bridge cell.

The first stage of dual input buck-buck dc-dc converters is shown in fig.3. It is constructed by using the two cascaded H-bridge cells in series connection [1]. In dual input converters, it uses only one inductor.

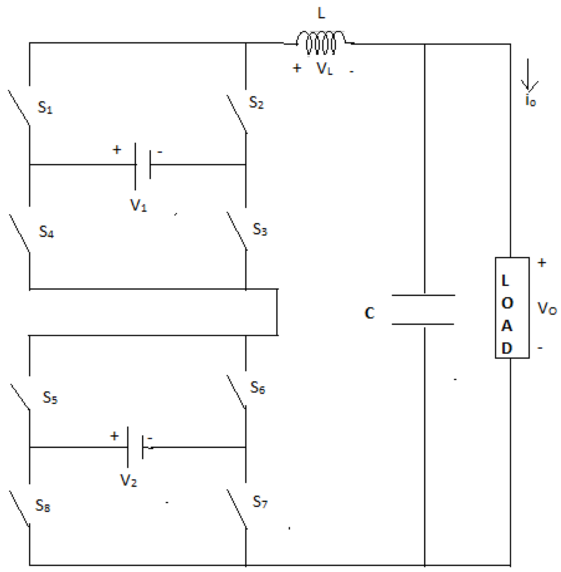

Fig.3 First stage of dual input buck-buck converter using H-bridge cells

According to the modes of operation given in table.I, The Switches are replaced by semiconductor switch or Diode or either short circuited or open circuited [8].The repeated switches in the four modes of operation as shown in the fig.3 are replaced by short circuited in the derived circuit; the switches which are not used in four modes are replaced by open circuited. Voltage drop across the inductor depends on the switches which are in ON condition.

The final stage of dual input buck-buck dc-dc converters is shown in fig.4.

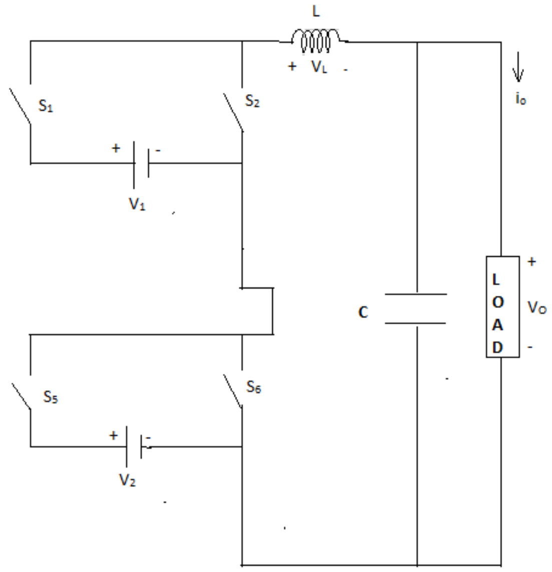

Fig.4 Final stage of dual input buck-buck converter using H-bridge cells

The basic idea in the synthesis of dual input dc-dc converters is to bring a new switching circuit which can be able to connect or disconnect two input sources such as a battery or photovoltaic system to charge an energy storage element individually or simultaneously. Inductor is used as an energy storage element in this circuit [2].

TABLE I
Voltage Across The Inductor In Dual Input Buck-Buck Converter Using H-Bridge Cells

Mode	ON condition switches	V_L	Description
I	S_1, S_3 S_6 &S_7	V_1-V_0	V_1 gives energy to the inductor
II	S_2, S_3,S_5 &S_7	V_2-V_0	V_2 gives energy to the inductor
III	S_2, S_3,S_6 &S_7	-V_0	Inductor dissipates Energy
IV	S_1, S_3,S_5 &S_7	V_1+V_2-V_0	V_1 &V_2 gives energy to the inductor

Considering the dual input buck-buck dc-dc converter, In mode I the V_1 supplies the energy to the inductor. In mode II, V_2 supplies the energy to the inductor, In mode III the inductor depletes the energy to the load [14], In mode IV, V_1 and V_2 supplies the energy to the inductor. The final designed circuit has only four switches.

In this paper until the power sources V_1 and V_2 are assumed to be power sources, which need not be charged. However if one of the sources is an energy storage unit, then it needs to be charged regularly. For this purpose the converter need to have bidirectional power capability this circuit can be used for bidirectional dc-dc converter by connecting a diode in parallel connection [2].

The final designed circuit has only four switches from the above designed circuit, one can conclude that the numbers of switches are reduced and the circuit has only one inductor [9]-[10]. The remaining switches are eliminated.

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III. Replacement of Semiconductor Switches For Dual Input Dc-Dc Converter

The switches are replaced by diodes, MOSFET for the designed dc-dc converters. Considering the buck-buck dc-dc converters that are in unidirectional power flow, switches S_4 and S_8 are eliminated from the circuit since it is not used in any mode. S_3 and S_7 are always ON so they can be short circuited.

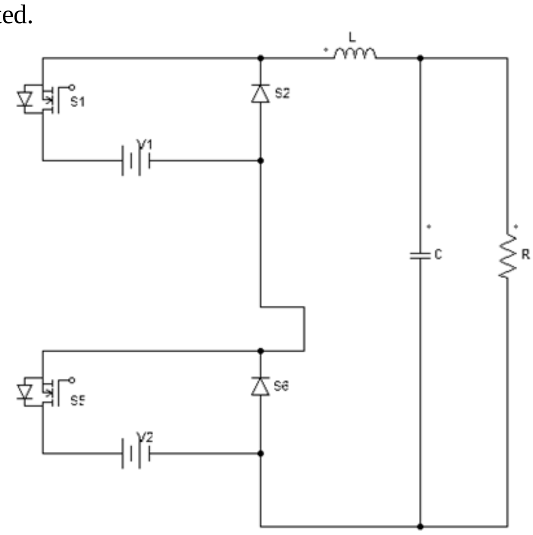

Fig.5..Circuit diagram of dual input buck-buck converter using H-bridge cells

If the power flow through the inductor is considered to be Unidirectional. i_L is always positive.

As switch S_2 conducts positive current and opposes negative current and positive voltage it can be replaced by a MOSFET. The MOSFET also can be replaced by any other static switches depending upon their current, voltage and power rating. In this paper MOSFET is used. The final derived dual input buck-buck dc-dc converter[4] is replaced by MOSFET and diodes is shown in fig.5.In this analysis, similar to the conventional single input dc-dc converter parasitic components will be neglected.

In the application of hybrid electric vehicle and photo voltaic system, V_1 or V_2 is a battery source.

IV. Derivation of Output Voltage Of Dual Input Dc-Dc Converter

The voltage transfer ratio gives the relation between the input voltages, output voltage, corresponding to their duty ratios

The switching pattern has four modes [9]. The table.I shows the voltage across inductor for different modes(I,II,III,IV) of operation of the converter. T_1,T_2,T_3,T_4 are the Time during I,II,III,IV modes.

$$T_1+T_2=d_1*T \quad (1)$$

$$T_1+T_3=d_2*T \quad (2)$$

$$T_1+T_2+T_3+T_4=T \quad (3)$$

Where T is the total time period of the switching patterns of S_1 and S_5 and d_1 and d_2 are the duty cycles of the switches S_1 and S_5 respectively.

Voltage second balance equation of the inductor is given by

$$T_1*(V_1-V_0)+T_2*(V_1+V_2+V_0)+T_3*(V_2-V_0)+T_4*(-V_0)=0 \quad (4)$$

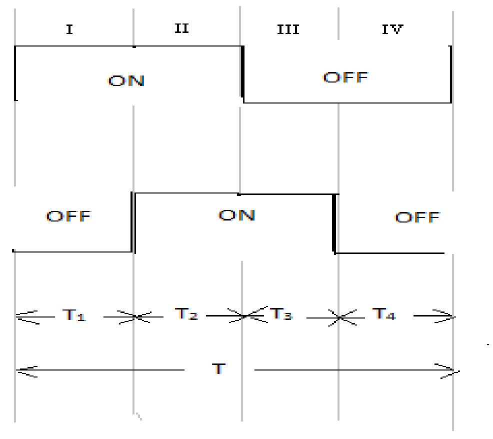

Fig.6 .Switching pattern of dual input dc-dc converter

The fig.6 .shows the switching patterns of switches S_1 and S_5.

By combining the (1) (2) (3) and (4),which gives the voltage transfer ratio of the dual input buck-buck dc-dc converter using H-bridge cells given in equation(5).

$$V_0=d_1*V_1+d_2*V_2 \quad (5)$$

V. Simulation And Results using Matlab

The simulation model and the output results are verified using MATLAB/simulink and MULTISIM.

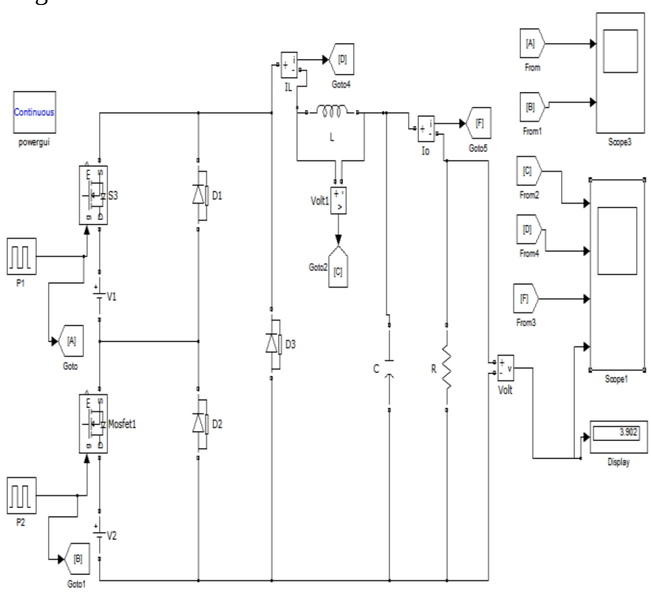

Fig.7.Simulation model of dual input buck-buck converter using MATLAB

The simulation model of buck-buck converter using MATLAB/simulink is shown in the fig.7 . Two input voltage sources (V_1, V_2) are used.

The values of inductance and capacitance are L=200 mH and C=80 µF were used for both the converter. Similar to the

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conventional single input converter this converter also operates in continuous conduction mode. The peak to peak ripple current[7] of the converter is at its maximum level when the input voltages $V1$ and $V2$ are equal. The duty ratio for d_1=0.5, d_2=0.5 at a switching frequency of 100 kHz for switches $S1$ and $S5$ respectively [13]-[15].

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To operate the converter in this mode, the value of the inductance should be greater than critical inductance.

(a)Value of Critical Inductance

$$L_{critical} = \frac{R(1-d1-d2)}{2fs} \quad (6)$$

(b)Ratio of peak to peak ripple voltage

$$\frac{\Delta Vo}{Vo} = \frac{1-d1-d2}{8Ls fs^2} \quad (7)$$

Where,

ΔVo is the peak to peak ripple voltage
d_1 is the duty ratio of switch S_1
d_2 is the duty ratio of switch S_2
f_s is the switching frequency
L_s is the inductance
R is the Load Resistor
V_o is the output voltage

The switching signals of buck-buck converter using MATLAB/simulink is shown in the fig.8. The simulation results of buck-buck converter using MATLAB are shown in the fig.9. The output simulated results shows the inductor voltage, inductor current, load current and output voltage.

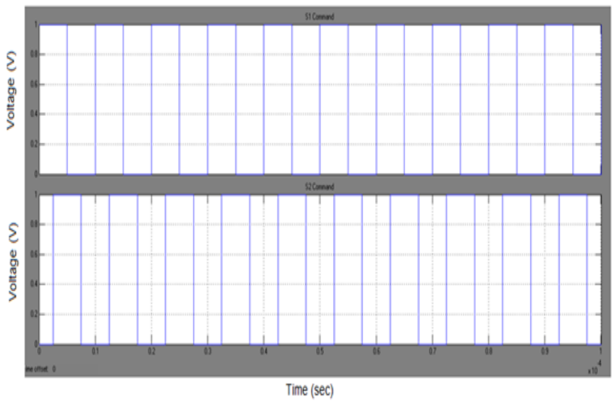

Fig.8 .Switching signals of dual input buck-buck dc-dc converter using MATLAB

Each switching signal has same duty ratio but phase shifted by an angle 180 degrees. Pulse width modulation technique is used in this converter.

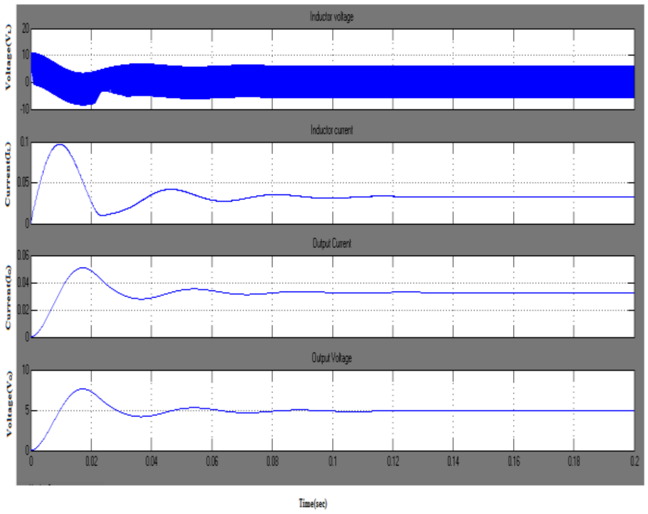

Fig.9.Simulation results of Dual input buck-buck dc-dc converter using MATLAB

VI. Hardware Testing And Multisim Simulation Results

The simulation models of buck-buck converter using MULTISIM is shown in the fig.10. Two input voltage sources (V_1, V_2) are used.

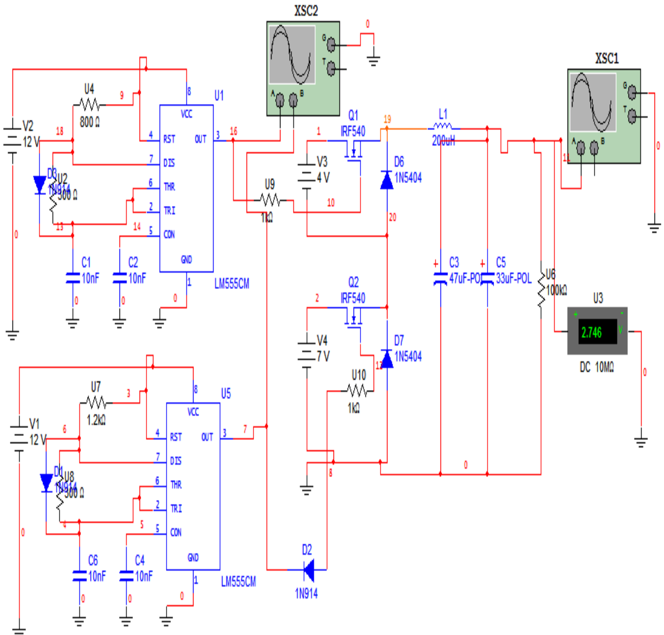

Fig.10.Simulation model of dual input buck-buck dc-dc converter using MULTISIM

The 555 timer is a versatile and its application include oscillator, square and ramp generator, multivibrator. It can provide time delay, ranging from microseconds to hours. Switching signals are generated using 555 timer in astable mode of operation. The duty cycle of the converter can be changed by varying capacitance and resistors.

Duty cycle

$$D = \frac{R_A}{(R_A+2R_B)} \quad (8)$$

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Switching frequency

$$f_s = \frac{1.45}{(R_A + 2R_B)C} \quad (9)$$

Where,

R_A, R_B are the resistors
C is the Capacitance

The Switching signals and simulation results of buck-buck converter using MULTISIM is shown in the figs.11,12 respectively

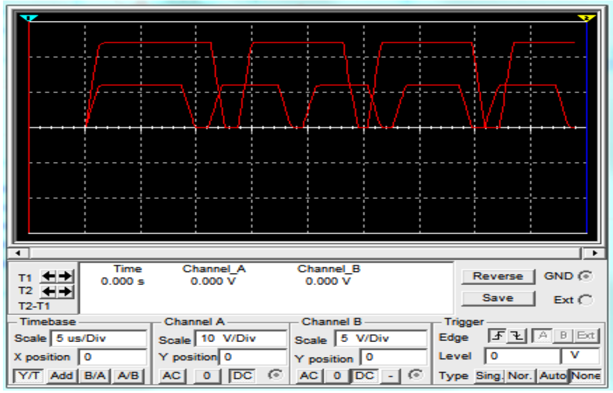

Fig.11.Switching signals of dual input buck-buck dc-dc converter using MULTISIM

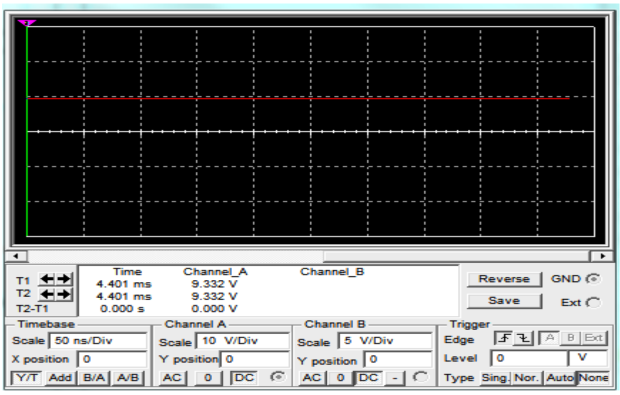

Fig.12.Simulation results of dual input buck-buck dc-dc converter using MULTISIM

Before implementation of hardware the values of the components can be selected in this software. The switching signals are given directly to the converter switches without any isolation. So this type of converter can be used only for low input voltage sources. For high power applications, we need to have high power rating of components and isolation.

The specification of the components used in the Converter is given in Table II.

TABLE II
SPECIFICATIONS OF COMPONENTS

DEVICE	SPECIFICATIONS
MOSFET	IRF540
Diode	1N5404
Capacitance	80 µF
Inductance	200µH

The components are used in the hardware is same as mentioned in the Fig.10. The circuit is tested in hardware which is shown in the figs.13, 14.

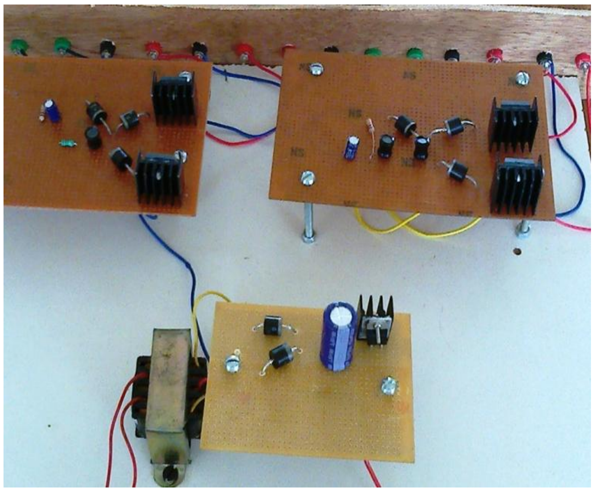

Fig.13. Hardware model of dual input buck-buck dc-dc converter

Fig.14.Hardware Output voltage of dual input buck-buck dc-dc converter

The converters are designed and simulated in open loop system. Comparison of simulated output voltage, Hardware output voltage of buck-buck converter for various input voltages are given in the table.III.

MATLAB					
Dual input converter topology	Duty cycle (d1, d2)	V1	V2	Theoretical value (V_0)	Simulated value (V_0)
Buck-buck	0.5	3	6	4.5	3.89
	0.5	4	7	5.5	4.87
	0.5	5	8	6.5	5.91
	0.5	6	9	7.5	6.89
	0.5	10	10	10	9.41
MULTISIM					
Buck-buck	0.5	3	6	4.5	3.69
	0.5	4	7	5.5	5.40
	0.5	5	8	6.5	6.72
	0.5	6	9	7.5	7.80
	0.5	10	10	10	8.71
HARDWARE					
Buck-buck	0.5	3	6	4.5	1.72
	0.5	4	7	5.5	3.24
	0.5	5	8	6.5	4.10
	0.5	6	9	7.5	5.39
	0.5	10	10	10	7.91

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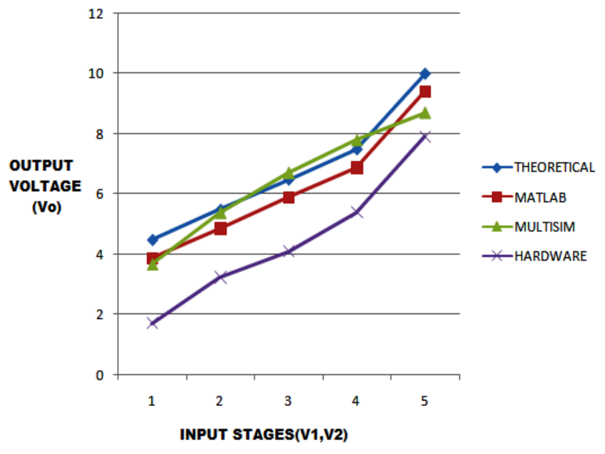

Fig.15. Output voltage Comparison of dual input buck-buck dc-dc converter

The simulation and hardware output voltage of the converter is shown in Fig 15. From the above chart we can find the difference between the output voltage of the converter under simulation and hardware. The converter is tested with various input voltages. The hardware output voltage is very low when compared to theoretical and simulation results. For example, when the theoretical Output voltage is 6.5Volts and Practical Output voltage is 4.1 Volts. This is due to switching loss and control circuit of the converter. In this paper, 555 Timer in astable mode of operation is used to switch the MOSFET. The exact triggering of pulse for the switches is very difficult in this control circuit.

VII. CONCLUSION

The buck-buck dc-dc converter topology were designed through derivation by using H-bridge cells as a building block. These two converters use only one inductor which reduces the size, component count and cost of the converter. The operating performance is verified and compared using simulated results and Hardware results. Simulation and theoretical results almost agree with each other but hardware results are not agreed with each other. There are so difference between hardware and theoretical results. This is due control circuits. Future expansion of the project is to implement a dual input dc-dc converter with closed loop control and soft switching techniques.

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