ANALYSIS, SIMULATION AND HARDWARE IMPLEMENTATION OF BOOST DC-DC CONVERTER

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ABSTRACT

Nowadays, DC-DC Converters are widely used in Electric vehicles, trolley cars, marine hoists, Photovoltaic (PV) system, Uninterruptable power supplies (UPS) and fuel cell system. A DC –DC switching converter converts directly from fixed DC voltage to variable DC voltage. In this paper, the performance parameters of the dc-dc boost converter are analyzed. The converter is simulated using MATLAB/Simulink software and also the converters are implemented in Hardware. The converter is tested with constant duty cycle and variable input voltage in Continuous Conduction Mode (CCM).The simulation and Hardware implementation results of the converters are compared with theoretical results.

Keyword: *Boost DC-DC converter, Constant duty cycle, MATLAB/Simulink, Hardware Implementation, Comparison.*

1. INTRODUCTION

Renewable energy sources are wonderful options compared to non-renewable energy sources because they are limitless and they do not pollute our air and water like way burning fossil fuels will do. To make any renewable energy system efficient, they need to have the suitable converter. An efficient dc to dc converter is needed as the interface between a low-voltage fuel cell source and a high-voltage bus for inverter operation. DC-DC converters are more important component in power electronic interfaces such as photovoltaic power systems and fuel cells [1].
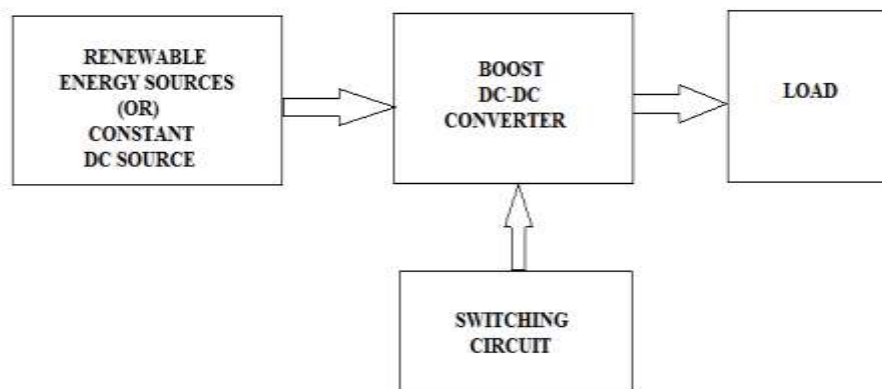

Fig -1: Block diagram of Boost dc-dc boost converter

Most renewable sources provide low voltage output hence they require booster in order to provide required high voltage output. The converter needs to be capable of high-power operation with a high voltage conversion ratio. A transformer is needed for both voltage boost and isolation [2][3]. The figure.1 shows the Block diagram of renewable energy Sources with Boost dc-dc converter. In this paper, analysis for steady state operation of boost dc-dc converter with various modes of operation is presented in part 2. Simulation models are obtained using *MATLAB/Simulink* and their results are compared with hardware experimental results are presented in part 3.

2. OPERATION AND ANALYSIS OF DC-DC BOOST CONVERTER

Boost converter provides output voltage greater than its input voltage. It is a switching converter that operates by periodically opening and closing an electronic static switch. It consists of DC voltage source V_{in}, inductor L, Controlled semiconductor switch S [MOSFET], Diode D, Capacitor C, Load Resistance R. MOSFET can be replaced by BJT or IGBT.when switch S is ON, the diode will become reverse biased and the inductor current will be increased. When switch S is OFF, the diode becomes forward biased and the inductor current tends to decrease and energy stored in the inductor will be released to the output circuit [6]. The switch can be made ON and OFF by using switching pulse circuit. There are two types of converters used. That is Isolated and Non-Isolated Boost converters. In this paper, Non -Isolated boost dc-dc converter is used. So there is no isolation circuit provided between switching pulse circuit and power circuit. Isolation is made by Isolation transformers or Optocouplers.The Circuit diagram of dc-dc boost converter is shown in figure 2.
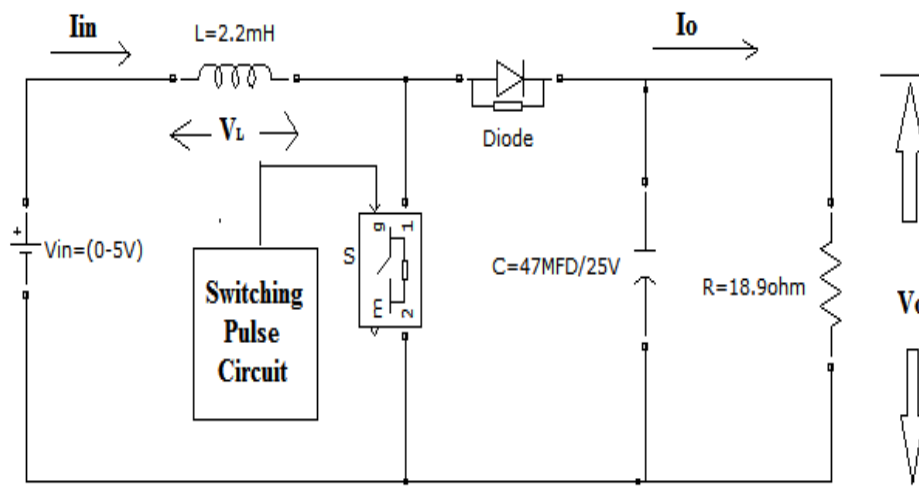

Fig -2: Circuit diagram of boost dc-dc boost converter

The boost converter can operate in two modes [4], which is Continuous Current Mode (CCM) and Discontinuous Current Mode (DCM). The value of inductor current determines these modes. In this paper, only Continuous Current Mode (CCM) is carried out for analysis [5]. In Continuous Current Mode (CCM) the load current is continuous and in Discontinuous Current Mode (DCM) the load current is discontinuous. The Circuit diagram of dc-dc boost converter in ON state that is when the switch is closed is shown in figure 3.
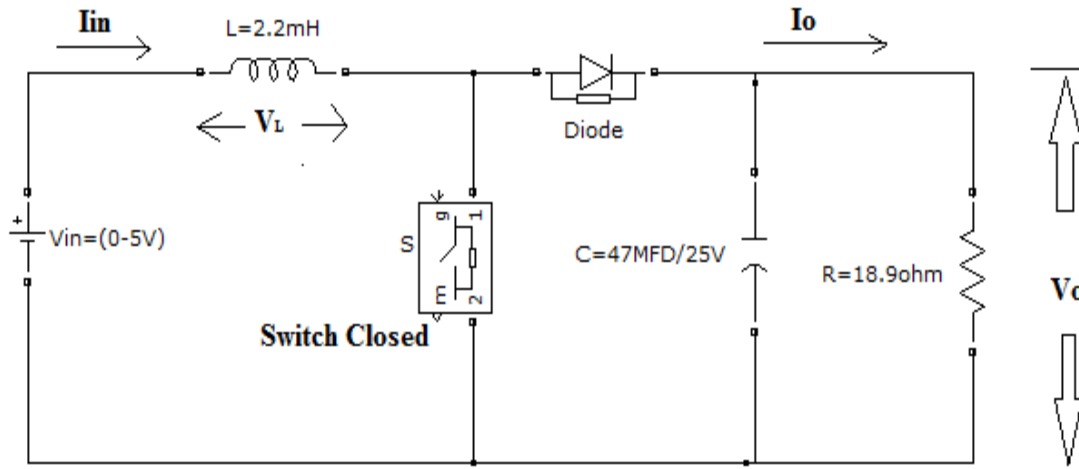
Fig -3: Circuit diagram of boost dc-dc converter when Switch is closed (ON-State).

Diode D is reverse biased, when the switch S is closed,. There is no current flow through the load causing the output stage to be isolated from the input. The voltage across the inductor is same as the input voltage [Vin]. The figure 4 shows the Circuit diagram of dc-dc boost converter when the switch is opened in OFF state[4].

$$V_L = V_{in} \tag{1}$$

$$L\frac{di_L}{dt} = V_{in} \tag{2}$$

$$\Delta i_{L_{(closed)}} = \frac{DTV_{in}}{L} \tag{3}$$

Where,

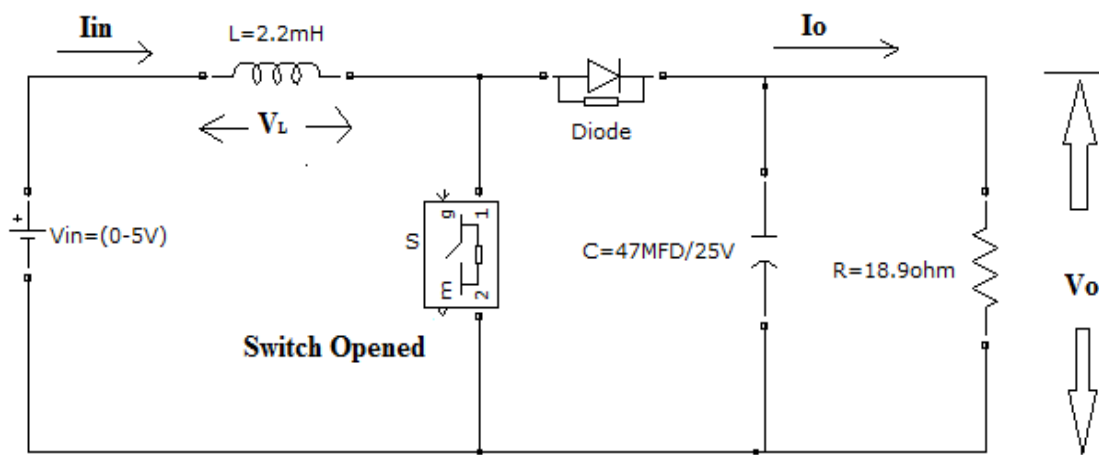V_L is the voltage across the inductor L and i_L is the current through the inductor L.

Fig -4: Circuit diagram of boost dc-dc converter when Switch is Opened (OFF-State).

Diode D is in forward biased, when switch S is opened. When the current flows towards the load will make the output to receive inductor stored energy and input voltage. This will cause the output voltage to be higher than the input voltage.

$$V_L = V_{in} - V_o \qquad (4)$$

$$L\frac{di_L}{dt} = V_{in} - V_o \qquad (5)$$

$$\Delta i_{L(opened)} = \frac{(V_{in}-V_o)(1-D)T}{L} \qquad (6)$$

Steady-state operation, $$\Delta i_{L(opened)} + \Delta i_{L(closed)} = 0 \qquad (7)$$

$$\frac{(V_{in}-V_o)(1-D)T}{L} + \frac{DTV_{in}}{L} = 0 \qquad (8)$$

$$\frac{V_o}{V_{in}} = \frac{1}{(1-D)} \qquad (9)$$

$$V_o = \frac{V_{in}}{(1-D)} \qquad (10)$$

Where D is duty cycle, T is the total time period for one cycle, V_{in} is the input voltage and V_o is the output voltage of the converter, i_L is current through the inductor L.

From the equation above, one can conclude that the output voltage will be higher than the input voltage.

Input power = Output power

$$V_{in}I_{in} = \frac{V_o^2}{R} \qquad (11)$$

$$V_{in}I_L = \frac{(\frac{V_{in}}{1-D})^2}{R} \qquad (12)$$

From the above equation (12) we can find average inductor current

$$I_L = \frac{V_{in}}{(1-D)^2 R} \qquad (13)$$

The maximum inductor current can be written as

$$I_{Lmax} = I_L + \frac{\Delta i_L}{2} = \frac{V_{in}}{(1-D)^2 R} + \frac{V_{in}DT}{2L} \qquad (14)$$

The minimum inductor current can be written as

$$I_{Lmin} = I_L - \frac{\Delta i_L}{2} = \frac{V_{in}}{(1-D)^2 R} - \frac{V_{in}DT}{2L} \qquad (15)$$

The minimum value of the inductor will determine the continuous current mode (CCM) operation of boost converter and the capacitor is used to reduce the voltage ripple. The minimum value of the inductance for continuous current mode can be written as

$$I_{Lmin} \geq 0 \qquad (16)$$

$$L_{min} = \frac{D(1-D)^2 TR}{2} \qquad (17)$$

$$L_{min} = \frac{D(1-D)^2 R}{2f} \tag{18}$$

Where, f is the switching frequency, R is the Load resistance.

The ripple factor and the minimum value of capacitor for continuous current mode can be written as

$$\Delta Q = \frac{V_o DT}{R} = C\Delta V_o \tag{19}$$

$$\Delta V_o = \frac{V_o DT}{RC} = \frac{V_o D}{RCf} \tag{20}$$

$$r = \frac{\Delta V_o}{V_o} = \frac{D}{RCf} \tag{21}$$

$$C_{min} = \frac{V_o D}{\Delta V_o Rf} \tag{22}$$

Where, r is the ripple factor, ΔV_o is the change in output voltage.

3. SIMULATION MODEL AND HARDWARE IMPLEMENTATION OF DC-DC BOOST CONVERTER

. Simulation is used to predict the performance of the circuit before hardware implementation. The simulation model of dc-dc boost converter is shown in the fig 5.
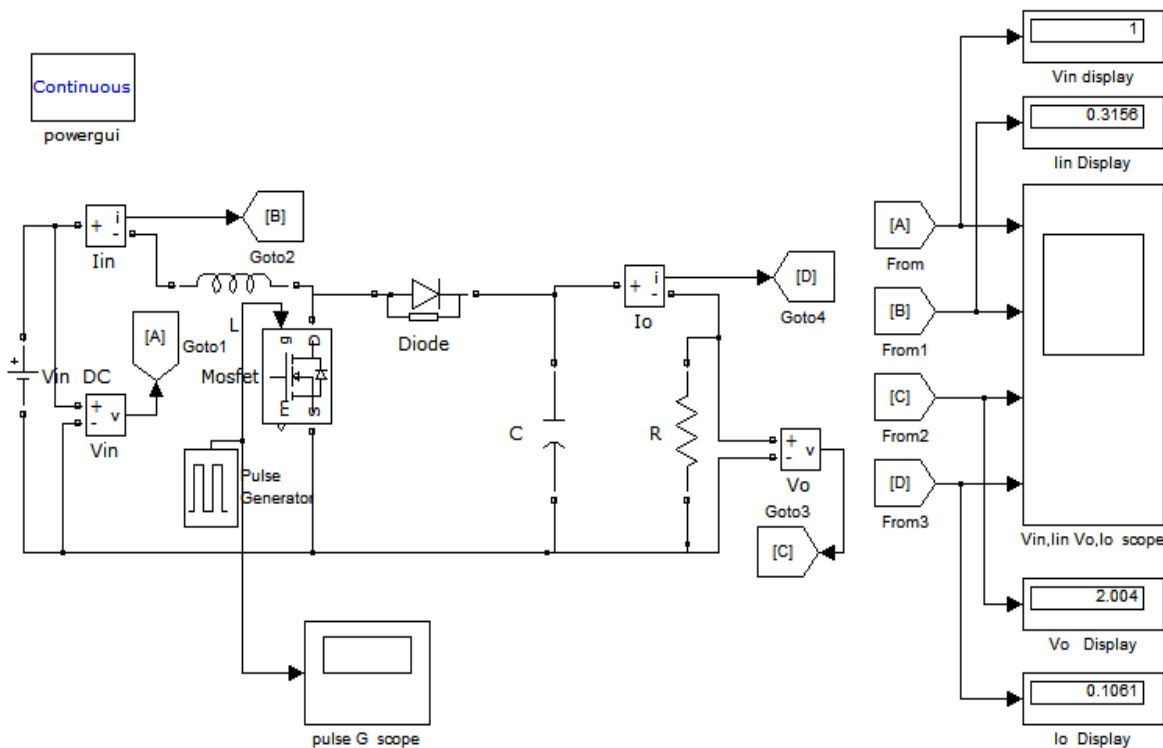

Fig -5: Simulation model of boost dc-dc converter using MATLAB/Simulink

Fig.6 shows the switching pulse for dc-dc boost converter. The Fig.7 shows the input voltage (Vin), Output voltage (Vo), Input current (Iin) and Output load current (Io).
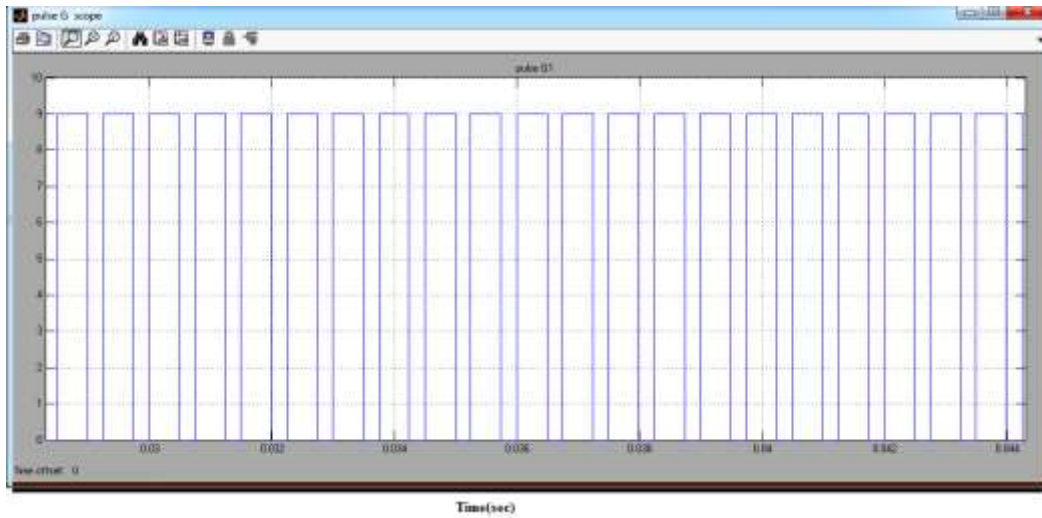

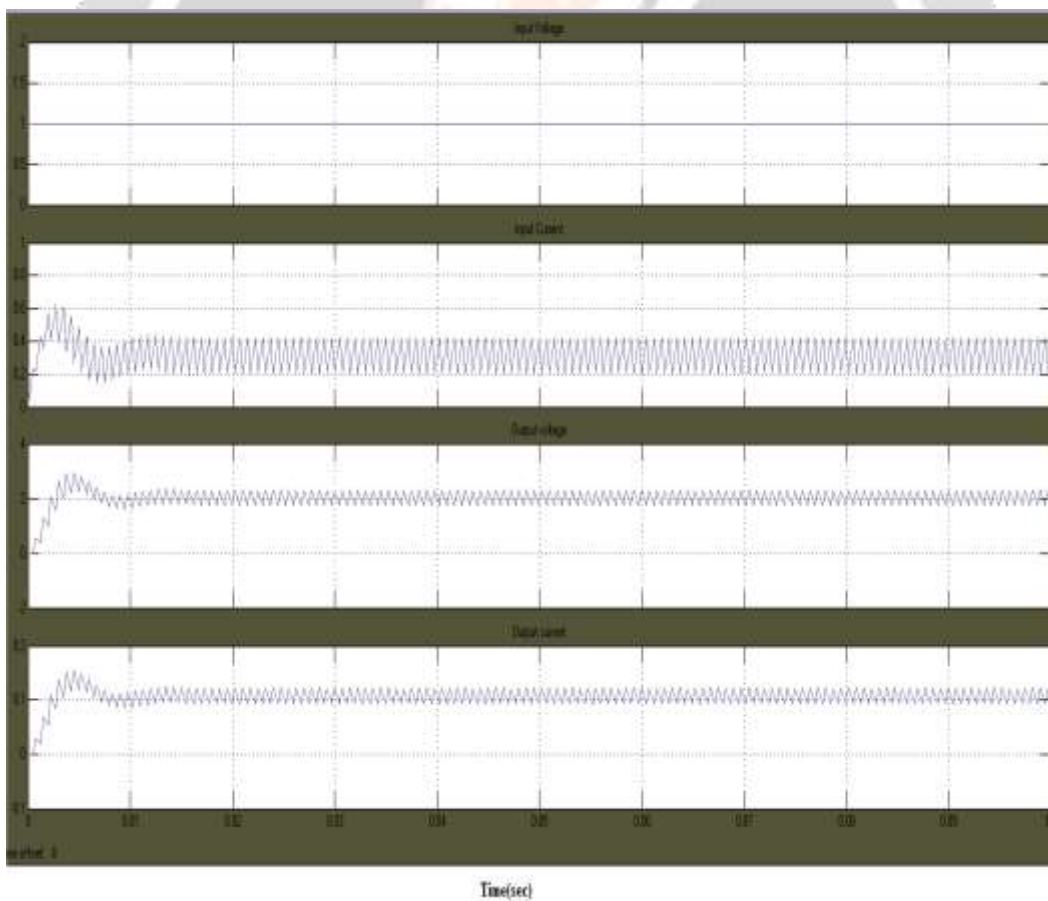**Fig -6**: Switching pulses of boost dc-dc converter using MATLAB/Simulink

Fig -7: Input and Output voltage, Current of boost dc-dc converter using MATLAB/Simulink

The Fig.8 shows the circuit diagram for hardware implementation. It has two circuit stages one is switching pulse circuit and another one is Boost dc-dc converter circuit.
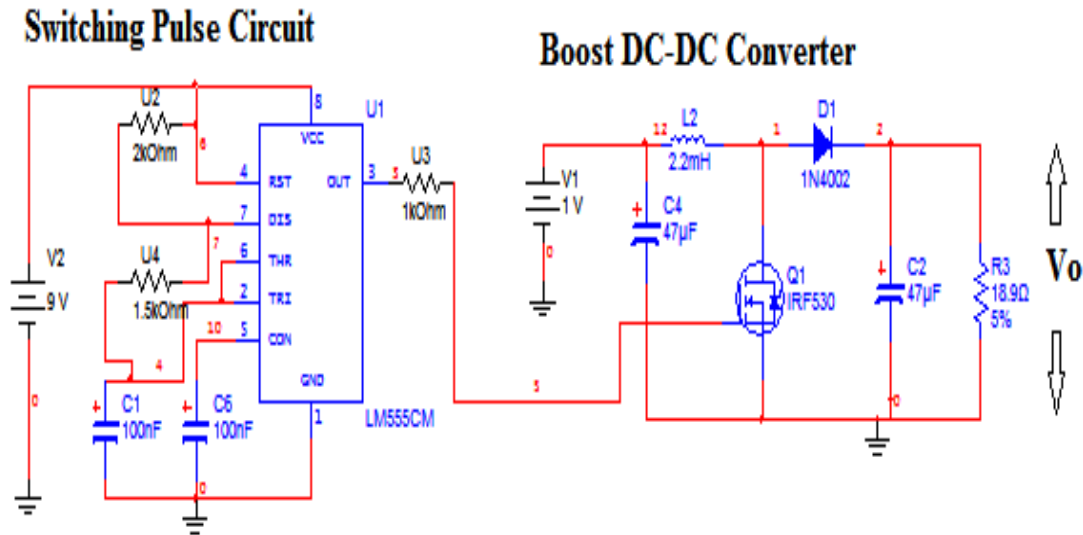

Fig -8: Switching pulse Circuit and Boost DC-DC Converter for Hardware Implementation

The Switching pulses (PWM pulses) are generated by IC 555 timer in astable mode of operation. Duty cycles are varied by varying the resistance pot R_1. The duty cycle and switching frequency are determined by R_2 and C1. Depending upon the switching frequency and duty cycle, the output voltage of the converter is varied. The boost dc-dc converter consists of MOSFET (IRF 530), Diode (1N4002), Capacitors (47MFD), Load Resistor (18.9 Ohms) and Inductor (2.2 mH).
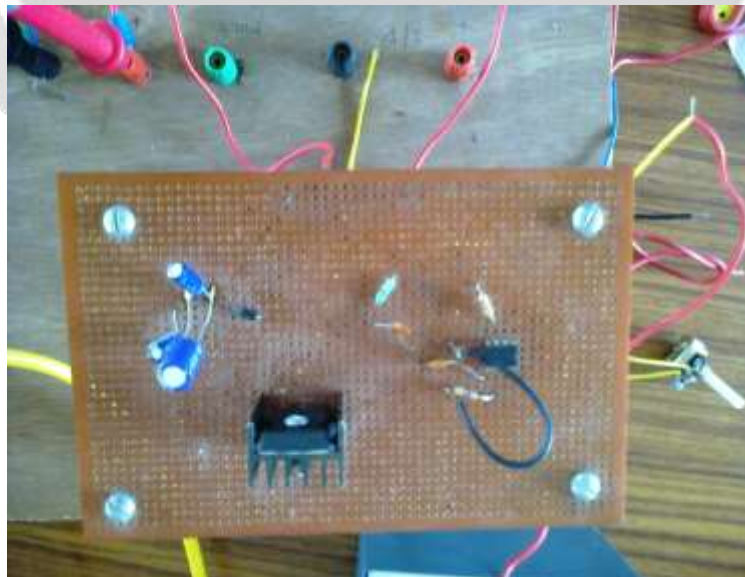

Fig -9: Hardware Implementation of boost dc-dc converter

The Fig.9 shows the Hardware Implementation of boost dc-dc converter. The switching pulse and Output voltage are measured using CRO. The Output voltage and Output load current are measured by Two Multi meters as shown in Fig.10. Overall view of Hardware implantation of the DC-DC Boost converter is shown in Fig.11.

Fig -10: Waveforms for Switching Pulses, Output voltage and Output load Current in Hardware Implementation
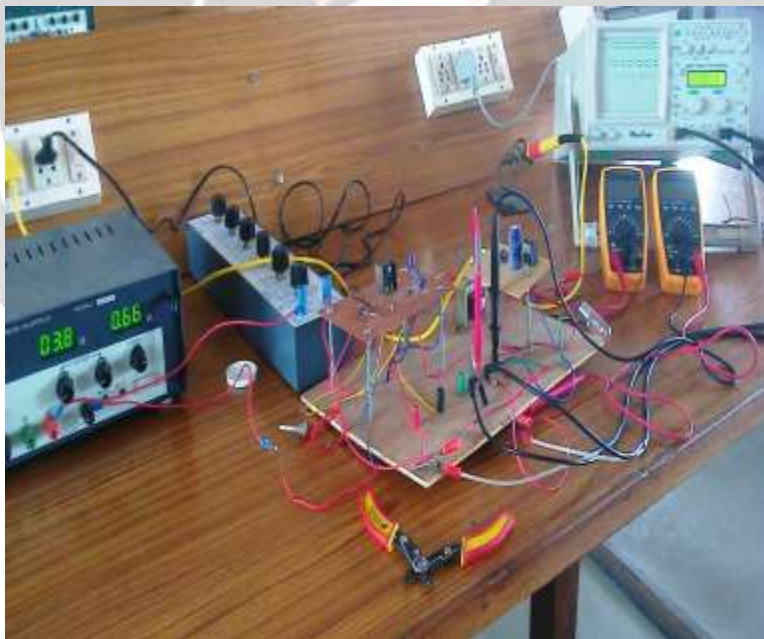

Fig -11: Overall view of Implementation of DC-DC Boost Converter

The input voltages are varied from 1Volts to 3.5 Volts in Regulated Power Supply at 0.66 duty cycle (Kept Constant). Corresponding Input currents, Output voltages, Output Currents are measured. The Output voltage is

calculated by using equation (10). Output load current is calculated by Io= (Vo/R).These values are Compared with Theoretical values and Simulated values as shown in the Table.1

Table -1: Simulated and Hardware results of DC-DC Boost Converter

Input Voltage (Vin)	Theoretical Values		Simulated Values			Practical values		
	Output Voltage (Vo)	Output Current (Io)	Output Voltage (Vo)	Output Current (Io)	Input Current (Iin)	Output Voltage (Vo)	Output Current (Io)	Input Current (Iin)
1	2.94	0.16	2.01	0.11	0.32	1.59	0.031	0.1
1.5	4.41	0.23	3.39	0.18	0.53	2.78	0.042	0.14
2	5.88	0.31	4.78	0.25	0.75	4.23	0.053	0.18
2.5	7.35	0.39	6.16	0.33	0.97	5.82	0.064	0.24
3	8.82	0.46	7.54	0.39	1.18	7.10	0.072	0.38
3.5	10.29	0.54	8.93	0.47	1.40	7.72	0.076	0.52

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The Input and Output voltages are compared with the help of bar chart as shown in Fig.12.These values are almost agreed with each other.
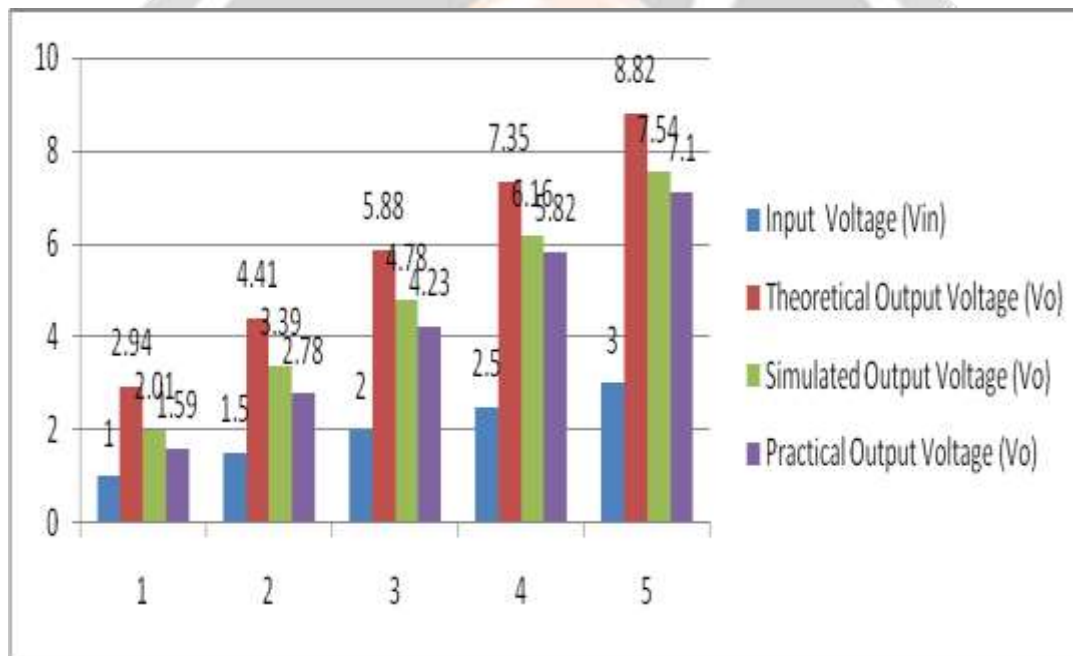

Fig -12: Output Voltage Comparison chart of DC-DC Boost Converter

4. CONCLUSIONS

The performance parameters of the boost dc-dc converter are analysed with various modes of operation in steady state analysis. The boost dc-dc converter is simulated using MATLAB/simulink and also implemented in Hardware. The converter is tested from input voltage from 1Volts to 3.5 Volts and constant duty cycle of 0.66. Simulation and Hardware implemented results almost agree with theoretical results. By using this converter we can step up the input voltage. The converters can be used with battery, photovoltaic system, fuel cell system for automotive applications like hybrid electric vehicle.

5. REFERENCES

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BIOGRAPHY

A.Thiyagarajan had obtained his B.E-Electrical and Electronics Engineering from Government College of Technology, Coimbatore in the year 2010 & M.E -Power Electronics and Drives from Government College of Technology, Coimbatore in the year 2012. He is presently working as an Assistant Professor in the department of Electrical and Electronics Engineering, Karpagam Institute of Technology, Coimbatore, Tamilnadu, India. His area of research includes Multi input DC-DC converter, Interleaved Boost DC-DC converter, LED drivers.