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Design & Implementation of Controller Based Buck-Boost Converter for Small Wind Turbine

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Abstract: *This paper propose to design a controller based buck boost converter for the effective utilization of the wind machine. By implementing a controller based Buck-Boost converter, the voltage produced at the lower wind speeds can also be utilized effectively by boosting it to the rated charging voltage of the battery. Also if the wind speed is high, the DC output voltage will increase then the converter bucks this high voltage to the nominal battery charging voltage (48V), thereby protecting the battery from over charging voltage. Thus the effective utilization of the wind machine has been achieved by the use of the proposed controller based buck boost converter.*

Keywords: *Buck-boost converter, control circuit, continuous current mode, Pulse width modulation, small wind machine*

I. Introduction

The interest for green energy has expanded hugely in the previous couple of decades. Therefore, the utilization of renewable energy sources like sunlight based energy, wind energy and so forth, are picking up notoriety. Along these small wind machines are broadly utilized as a part of provincial ranges to produce electric power from wind energy. In small wind machines, if the wind speed is low then the yield voltage of the wind machine after amended into dc is less. The battery won't charge as it is lower than the appraised charging voltage. This happens more often than not in a day, since the wind speed in local areas is in the scope of 1 to 4 m/s. Accordingly, a productive control component is required, in order to use the wind control viably.

This study is proposed a plan on controller based buck-boost converter for the powerful usage of the wind machine. By executing a controller based buck-boost converter, the voltage created at the lower wind velocities can likewise be used viably by boosting it to the evaluated charging voltage of the battery. Additionally if the wind pace is high, the dc yield voltage will expand then the converter bucks this high voltage to the ostensible battery charging voltage accordingly shielding the battery from over charging voltage. The proposed framework is observed to be more conservative to easy to use and more proficient.

In 2013 N.Prakash, D.Ranithottungal and M.Sundaram worked on controller based buck-boost converter for wind energy system. In their worked, they discussed about the controller based converter for domestic wind machine. If the wind speed is low, the output voltage is not sufficient to charge the battery as it is lower than the rated charging voltage of the battery. This limits the overall efficiency of the wind machine to 20%. Implementing a controller based buck-boost converter, the voltage produced at the lower wind speeds can also be utilized effectively by boosting it to the rated charging voltage of the battery. If the wind speed is high, then the converter can also bucks the high voltage, thereby protecting the battery from over charging voltage[1].

In 2010 Dr. Horizon Gitano-Briggs worked on small wind turbine power controllers. He discussed on his worked to investigate control associated with small wind turbine systems, culminating in a detailed description of the peak power tracking controller utilizing a microcontroller running an impedance matching DC-DC converter between the turbine and the load[2].

In 2006 Eftichos Koutroulis and Kostas Kalaitzakis worked on MPPT for wind-energy-conversion applications. In their worked, they are discussed about the wind-generator maximum-power-point tracking (MPPT) system is presented which is the consisting of high efficiency buck-type dc/dc converter and a microcontroller-based control unit running the MPPT function. The advantages of the proposed MPPT method are that the WG operates at a variable speed[3].

In this paper it is discussed about the output voltage of wind turbine along with its storage system in DC. A buck-boost based converter is proposed to storage the DC output in battery.

II. Buck-Boost Converter

A Buck Boost Converter is a DC-DC regulator which provides an output voltage that may be less than or greater than the input voltage, hence the name “Buck-Boost”. A non-isolated topology of the buck-boost converter is shown in Fig. 1. The converter consists of dc input voltage source Vs, controlled switch S, inductor L, diode D, filter capacitor C, and load resistance R. With the switch on, the inductor current increases while the diode is maintained off. When the switch is turned off, the diode provides a path for the inductor current. The buck-boost converter waveforms are depicted in Fig. 2. The condition of a zero volt-second product for the inductor in steady state yields, Vs DT = -Vo (1-D) T. Hence, the dc voltage transfer function of the buck-boost converter is, Vo/Vs = - D/1-D. So the equation is, Vo = -DVs/1-D[4].

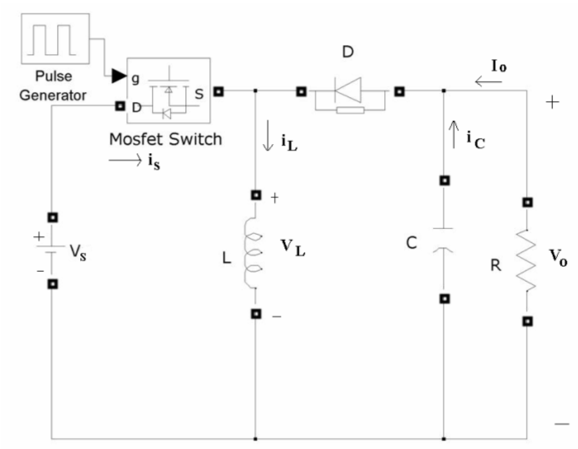

Figure 1: Diagram of Buck-Boost Converter

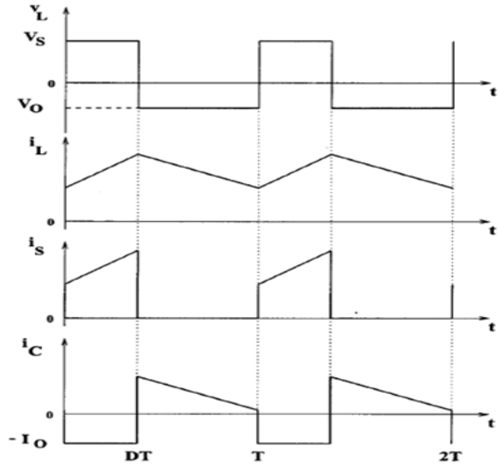

Figure 2: Waveforms of Buck-Boost Converter

III. Design Of Controller Based Buck-Boost Converter

A. System block diagram

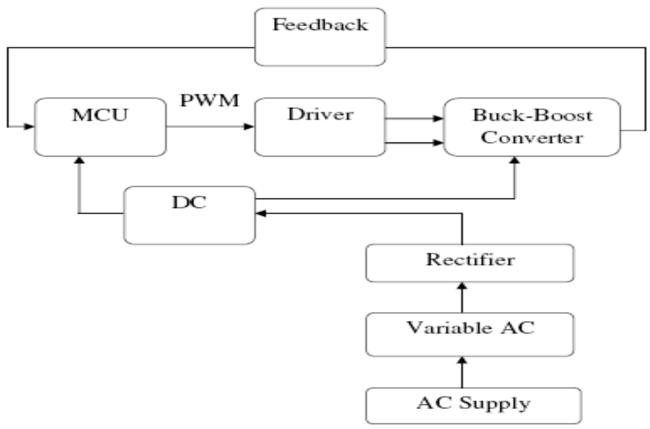

Figure 3: Methodology of the system

In the Fig. 3 From wind machine we get AC output. Here we have used internal AC supply as input to our system. The output we get from wind machine is variable due to variation in wind speed. Here a voltage regulator is used to vary the supplied ac power. It is an useful to test the buck boost part by keeping the voltage above or below the nominal battery charging voltage deliberately. Rectifier part is used to convert AC into DC. As DC to DC buck-boost converters work with DC, it is necessary to convert AC to DC. A capacitor is used after rectifier part to get ripple free output. Rectified DC output provided to drain of the switches in buck-boost part and to microcontroller unit through sensing component.

Microcontroller unit is the decision making part of the system whether to buck or boost. It gets DC input through a sensing component to measure input voltage. It is also connected to a feedback across the load to check the desired voltage is obtained or not. Microcontroller provides an output which is 5V. But it is not enough to open the gate of MOSFET in Buck-Boost part. It is required to maintain a 12V DC to turn on gate switches. Driver used to provide 12V DC supply for opening the gate of MOSFET which is dependent on MCU output signal. DC-DC converters are power electronic circuits that convert a dc voltage to a different dc voltage level, often providing a regulated output. In this system nominal battery charging voltage is 48V. The main purpose of DC-DC buck-boost converter is to provide fixed 48V DC output regardless of input voltage is lower or higher than 48V. Microcontroller takes decision whether to buck or boost. According to the decision converter provides the desired output voltage.

B. Buck-Boost Controller Circuit

The integral part of Buck-Boost converter design is to choose proper values of an inductor (L) and Capacitor (C) because the output voltage depends on the L and C values. The inductor and capacitor also play a major role in filtering the output from the circuit to provide stiff DC. For the effective charging of the battery the buck-boost controller must operate in Continuous Current Mode (CCM). In order that the buck boost converter operates in CCM, optimum values of inductor and capacitor must be chosen because if their values are higher than the cost of winding, core size will also be high. If their values are low, then the high switching frequency is needed to obtain the same voltage level. This increases the cost of the switch involved. Therefore it is necessary to choose optimum values of L and C.

The generated AC output voltage from alternator of the wind system is converted to DC voltage by a bridge rectifier and due to variation in AC; the respective DC output shows variation. This rectified dc voltage stands as input to the proposed system. Input voltage is provided to the drain of the MOSFET (IRFP460) referred as Q1 in fig 4 and Microcontroller detects the voltage level by ADC pin through a sensing component which is connected to dc bus line referred as VDD in Fig 4. Another ADC pin is connected with the feedback across the load to sense the final output voltage. PIC16F73 is 8 bit microcontroller so it receives the input as bits from 0 to 255. Hence, any input value will be converted into bits to obtain proper result. The microcontroller has in built PWM and duty cycle of PWM signal adjusted based on ADC pin input values. When the input voltage is greater than 48V, the ADC pin of microcontroller senses it and takes immediate decision for buck conversion. Hence according to the decision, microcontroller CCP2 con register generates the PWM signal to MOSFET driver and duty cycle of PWM adjusted in a way to draw 48V from input voltage(>48V). But if we want to open the MOSFET gate for switching, then 12V is needed in gate with respect to source. As output signal provided by Microcontroller is 5V, MOSFET driver (TLP250) is used to trigger the gate. Hence MOSFET switch allows the voltage between drain to source and maintain 48V in buck mode. On the other hand when the voltage is less than 48V, the ADC pin of microcontroller sense it and take a decision for boost converting.

In that time microcontroller CCP1 con register send the PWM signal in MOSFET driver (low side driver), then high side MOSFET driver just remained on and allows the voltage it gets from input, to pass between drain to source. That time PWM is passed through the driver (low side driver) and MOSFET getting on and off control to maintain 48V voltage in boost mode. Before the final output voltage is served to the load a feedback option is settled to check the desired output voltage is obtained or not. Thus by using controller the voltage obtained at lower wind speeds and higher wind speed can be effectively utilized to get a fixed output voltage used to charge the battery.

In the Fig. 5 we showed the controller part, MOSFET switch driver, rectifier part, buck-boost converter and display of our system. The output of the system is 48V. If the input voltage is greater than 48V then the converter will be worked as buck mode and the input voltage is less than 48V then the converter worked as boost mode and maintain 48V all the time to charge the battery.

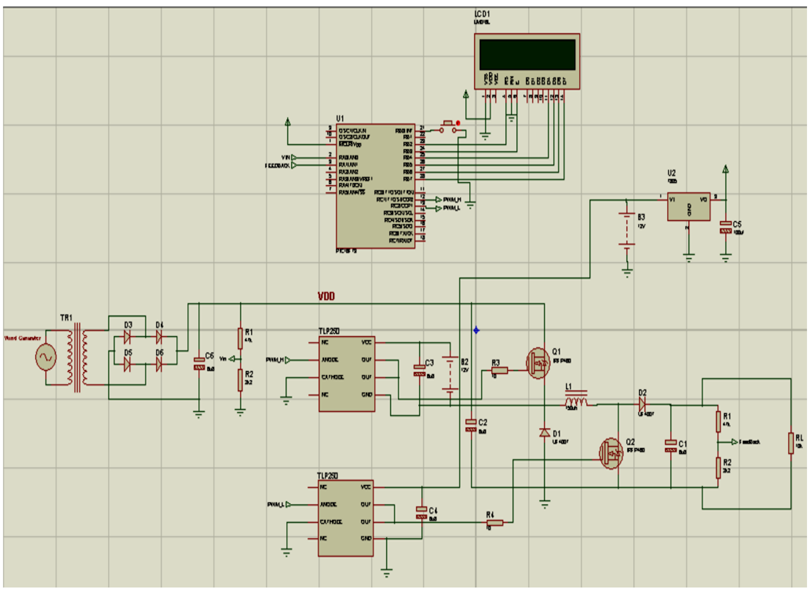

Figure 4: Schematic diagram of controller based buck-boost converter

C. **Hardware Implementation**

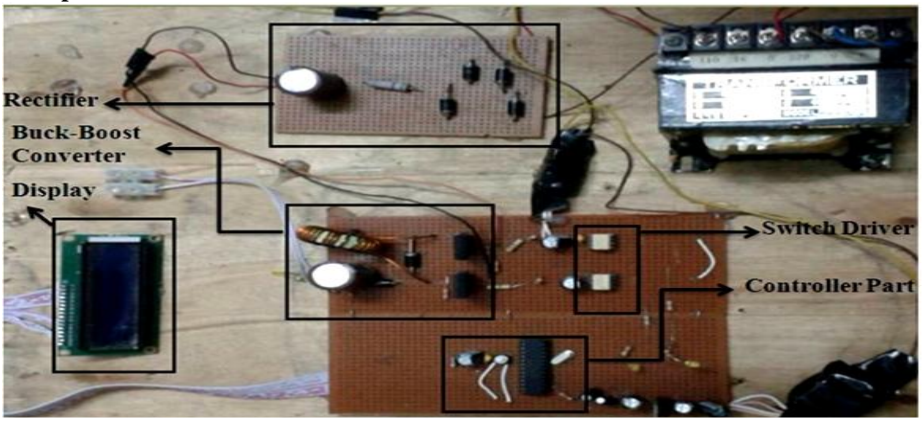

Figure 5: Hardware implementation of the system

The hardware implementation of the total work shows in Fig.5 which is combined with transformer, controller part, switching drive, buck-boost converter, rectifier circuit and the display module to show the output result.

IV. Result Analysis

A. **Simulation result**

The simulation tools help in testing the validity of the design and also save costs by reducing the chances of error. Any defect in design can be easily identified and rectified well before the implementation thus saving cost and time. Proteus 7.5 ISIS (Intelligent Schematic Input System) professional simulation software has been used to simulate the PWM using PIC16F73 controller. This software provides an integrated environment and allows the virtual burning of embedded program coding in the controller and simulates the output for various conditions.

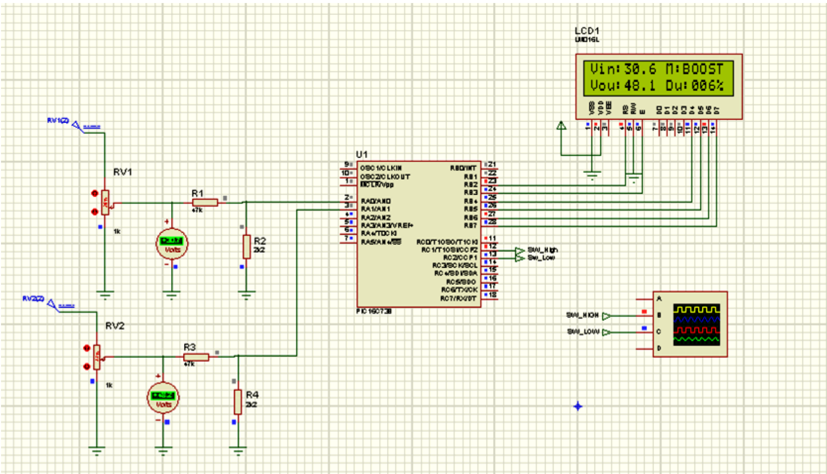

Figure 6: Simulation output in Boost mode

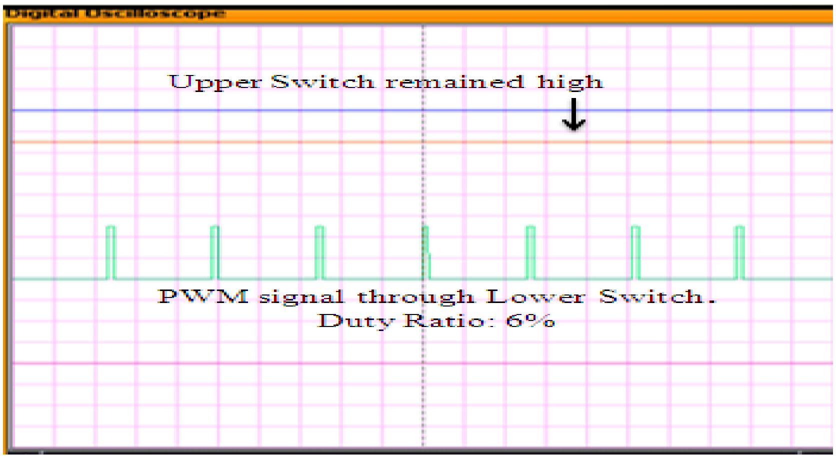

Figure 7: Duty cycle in Boost mode

The simulation result shows that the control program on microcontroller worked well in boost mode. In Fig. 6 the result is illustrated. Here input voltage is 30.6 V and output voltage is 48.1V which is around the nominal battery charging voltage (48V). In Fig.7 output shows that the duty is 6%. In boost mode the higher side switch (Q1) is remained on and switching mode is applicable for lower side switch (Q2). So PWM signal goes to low side switch and virtual scope shows that the duty is around 6%.

In Fig. 8 the result is illustrated for buck mode. Here input voltage is 57.8V and output voltage is 48.1V which is around the nominal battery charging voltage (48V).In the Fig. 9 it is shown that the duty cycle is 45%. In buck mode the lower side switch (Q2) is remained off and switching mode is applicable for higher side switch (Q1). So PWM signal goes to higher side switch (Q1) and virtual scope shows that the duty is around 45%.

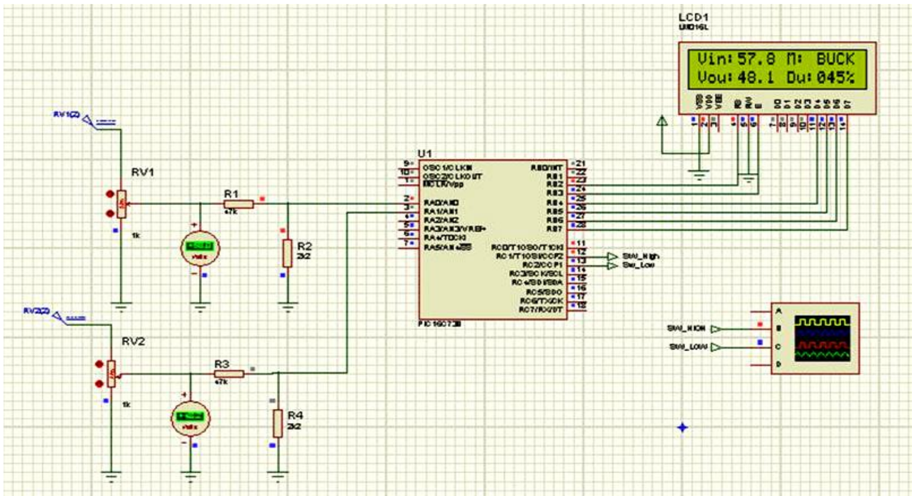

Figure 8: Simulation output in Buck mode

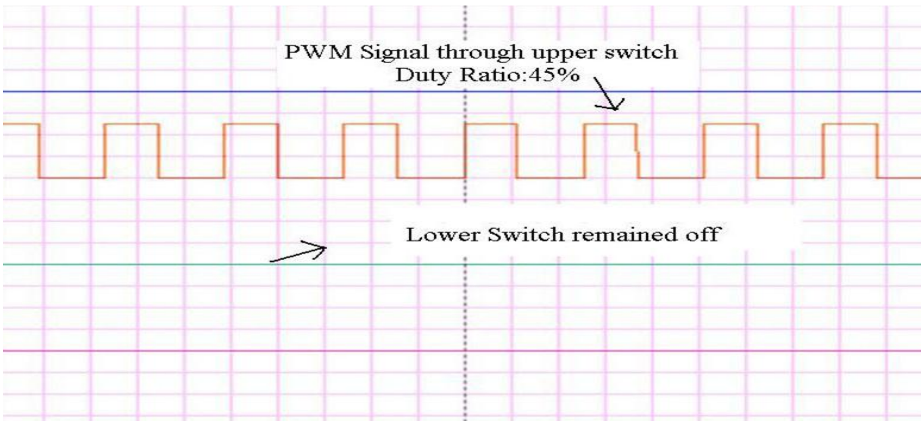

Figure 9: Duty cycle in Buck mode

B. Calculation result

According to the simulation result, when input voltage is Vs = 30.6 then Duty cycle is D=6%.
So, Vo = -DVs/1-D = (0.6× 30.6) / (1-0.6) = 46V, which is close to 48V. So it works as Boost mode.
Again, According to the simulation result, when input voltage is Vs = 57.8 then Duty cycle is D= 45%.
So, Vo = -DVs/1-D = (0.45× 57.8) / (1-0.45) = 47.3V, which is close to 48V. So it works as Buck mode.

C. Hardware result

Figure 10: Hardware output in Boost mode

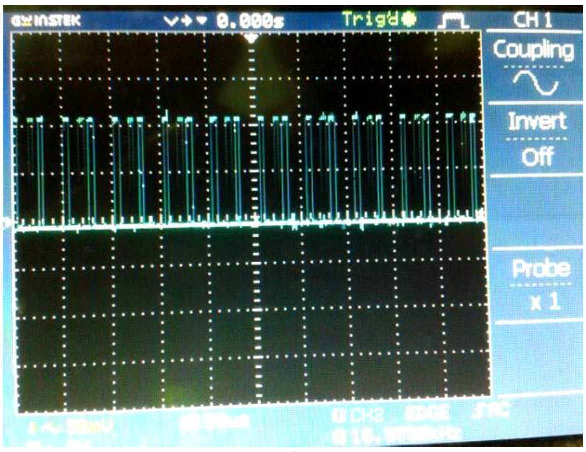

Figure 11: Wave shape of duty cycle in Boost mode

In Fig. 10, there are showing hardware result for boost mode. Here input voltage is 10.8 V and output voltage is 48.4V which is around the nominal battery charging voltage (48V). Display shows that the duty is 11%. We also found the duty cycle from oscilloscope which shown in Fig. 11.

Figure 12: Hardware output in Buck mode

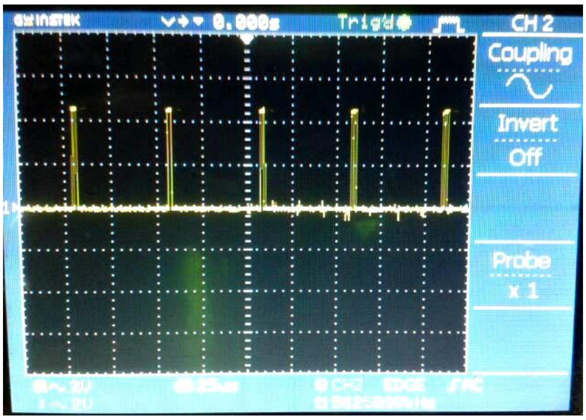

Figure 13: Wave shape of duty cycle in Buck mode

In Fig. 12 there are showing hardware result for buck mode. Here input voltage is 60.6 V and output voltage is 48.0V which is around the nominal battery charging voltage (48V). Display shows that the duty is 3%. We also found the duty cycle from oscilloscope which shown in Fig.13.

D. Simulation & Hardware result comparison

Table 1: Comparison between Simulation and Hardware output

Input Voltage (V)	Output Voltage(V)	
	Simulation output voltage (V)	**Hardware output voltage (V)**
10	48.1	48.4
20	48.1	48.0
30	48.1	47.9
40	48.1	48.6
50	48.1	48.9
60	48.1	48.0
70	48.1	47.8

In table-1 it is seen that output voltage is changed through the input voltage. The output voltage of the simulation result and hardware result almost same.

In Fig. 14, shows that output voltage is exactly 48.1V for any given input voltage which ranges between 10V to 70V. Intersecting points make a straight line which is perpendicular to the Y axis lies around 48V point. The result indicates that the system will be effective enough to obtain nominal battery charging voltage. In Fig. 15 output curve obtained from practical data of the hardware. Intersect points make a line which shows a little fluctuation around 48V. Overall hardware output is very appreciable as output voltage in every case tends to nominal battery charging voltage.

It is seen that the output voltage of both graphs are almost same in simulation and hardware result. So this result indicates that the system will be effective enough to obtain nominal battery charging voltage.

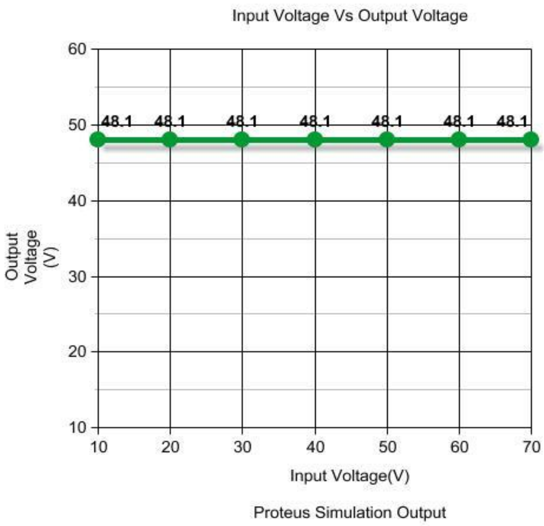

Figure 14: Graphical view of Simulation output

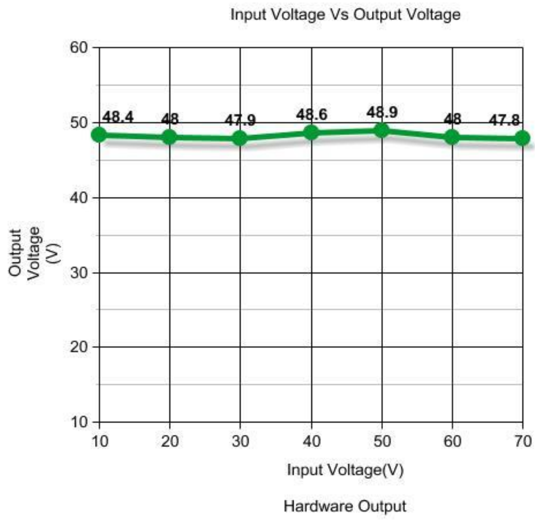

Figure 15: Graphical view of Hardware output

V. Conclusion

DC-DC converters are new control schemes to achieve better regulation and fast response in alternative energy systems like Wind machine. Switching regulators are the backbone of power electronic equipments. Challenge to design switching regulators for wind machine is to maintain almost constant output voltage. The proposed system of controller based Buck Boost converter is found to be more compact, user friendly and more efficient. The inbuilt ADC and PWM channels in the PIC16F73 Microcontroller make the control module of the converter very compact. The Buck Boost controller with PIC16F73 as its integral part senses the output voltage and varies the PWM duty ratio so that the output voltage at lower wind speeds is also maintained above the battery charging voltage (48V). As a result the voltage produced at lower wind speeds is also effectively utilized and the efficiency of the proposed system is higher than the existing system. Most importantly MOSFET switches are used in the buck-boost part to draw their low power consumption and high switching frequency characteristics. The implemented converter almost provides around 48V (Nominal Battery Charging Voltage) regardless of input voltage is higher or lower than 48V.

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