Design Of Controller Based Buck & Boost Converter

Sainath Shinde[1], Ulhas Bhandekar[2], Kaushik Avhad[3]
Students, Electrical Engineering Department, K.D.K.College of Engineering, Nagpur, India

ABSTRACT
A controller based buck and boost converter is proposed in this study where if the input voltage is low, output can be made constant by the use of boost converter which boost it to desired output voltage level, also the dc output voltage will increase. Whenever the input voltage is high then for this condition the converter bucks this high voltage to desired output voltage. This controller based buck-boost converter, enables the converter output voltage to remains constant although there is variation in input voltage. The output voltage can be set according to requirement by use of keypad.

Keyword:- Buck and Boost converter, keypad, controller.

I. INTRODUCTION

In power electronics, there are three basic topologies: the buck, the boost, and the buck and boost. Variations of these three topologies solved most power conversion problems and continue to do so today. DC-DC power converters are employed in order to transform an unregulated DC voltage input (i.e. a voltage that possibly contains disturbances) in a regulated output voltage. From the buck-boost converter we can get voltage which is less or more than input voltage based upon the duty cycle, the. A buck-boost converter circuit is a combination of the buck converter as well as boost converter. The output to input conversion ratio is also a product of ratios in buck converter and the boost converter. The output voltage is controlled by controlling the switch-duty cycle. This study is proposed a plan on controller based buck-boost converter for the variation of output voltage as per user requirement. As usually known, the conventional buck-buck converter is widely used in the industry. DC–DC converters have been effectively controlled for many years using analog integrated circuit technology and linear system design techniques. The analog control circuits present some drawbacks as follows: monitor a reduced number of signals to save costs, solve only specific task, requires auxiliary active and passive electronic devices, use pulse amplifier as interface for the electronic power Switches, shown reduced noise immunity and difficulty to assure further developments or new more complex control functions. Digital control in power electronics has been intensively used during the last decade. The improved performances and price reduction of digital controller has enable their application in power electronic control. The primary advantages of digital control over analog control are higher increased flexibility by changing the software, more advanced control techniques and reduced number of components. The implementation of complex control function with analog circuits is difficult but using digital programmable device the implementation becomes easier. Digital technology has been considered to replace the analog technology. This project will investigate the ability of digital control of the buck converter using microcontroller to control the operation of the DC-DC converter.

II. MODELING OF BUCK-BOOST CONVERTER

The circuit action can be divided into two modes. During Mode 1, switch S is turned on and diode D is reversed biased. The input current, which increases, flows through Inductor L and switch S. During Mode 2, switch S is switched off and the current, which moves through Inductor flow, is L-C-D and the load R.

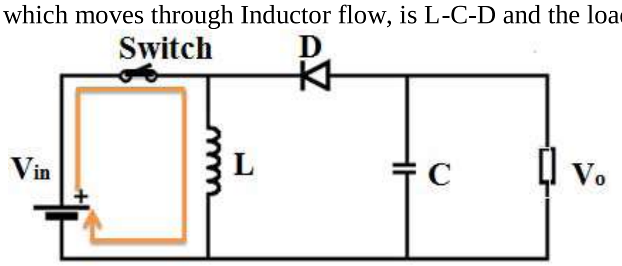


Fig. 1. Buck-Boost Converter (1st mode)

The energy stored in the Inductor L would be moves to the load Ro and the Inductor current would fall until switch S is on again in the next cycle.in this Mode Inductor was demagnetized.

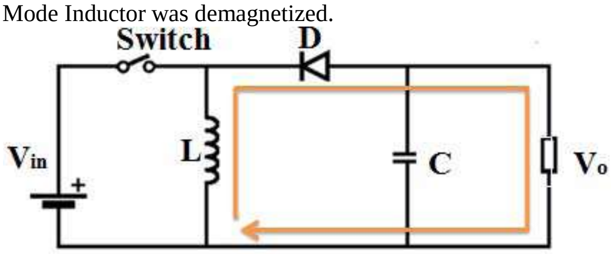


Fig. 2. Buck-Boost Converter (2nd mode)

Assuming that the inductor current rises linearly from I_1 to I_2 in time t_1,

$$V_S = L\frac{I_2 - I_1}{t_1} = L\frac{\Delta I}{t_1} \qquad (1)$$

$$t_1 = \frac{\Delta IL}{V_S} \qquad (2)$$

And inductor current falls linearly from I_1 to I_2 in time t_2,

$$V_a = -L\frac{\Delta I}{t_2} \qquad (3)$$

$$t_2 = \frac{-\Delta IL}{V_a} \qquad (4)$$

Where $\Delta I = I_2 - I_1$ the peak-to-peak is ripple of inductor L. From equation

$$\Delta I = \frac{V_S t_1}{L} = \frac{-V_a t_2}{L} \qquad (5)$$

Substituting $t_1 = kT$ and $t_2 = (1-k)T$, the average output voltage is

$$V_a = -\frac{V_s k}{1-k} \qquad (6)$$

Substituting $t_1 = kT$ and $t_2 = (1-k)T$ into equation (6) yields

$$(1-k) = \frac{-V_s}{V_a - V_s} \qquad (7)$$

Substituting $t_2 = (1-k)T$, and $(1-k)$ from equation (6) into equation (7) yields

$$t_1 = \frac{V_s}{(V_a - V_s)f} \qquad (8)$$

Assuming a lossless circuit,

$$V_s I_s = -V_a I_{a=} V_s I_a k/(1-k)$$

$$I_s = \frac{I_a k}{1-k} \qquad (9)$$

The switching period T can be found from

$$T = \frac{1}{f} = t_1 + t_2 = \frac{\Delta IL}{V_s} + \frac{\Delta IL}{V_a} = \frac{\Delta IL(V_a - V_s)}{V_s V_a} \qquad (10)$$

And this gives the peak- to-peak ripple current,

$$\Delta I = \frac{V_s V_a}{fL(V_a - V_s)} \qquad (11)$$

$$\Delta I = \frac{V_s k}{fL} \qquad (12)$$

When transistor Q_1 is on, the filter capacitor supplies the load current for t = t_1. The average discharging current of the capacitor is $I_c = I_a$ and the peak-to-peak ripple voltage of capacitor is

$$\Delta V_c = \frac{1}{C}\int_0^{t_1} I_C dt = \frac{1}{C}\int_0^{t_1} I_a dt = \frac{I_a t_1}{C} \tag{13}$$

Substituting $t_1 = V_a/[(V_a - V_s)]$ from equation (9) becomes

$$\Delta V_c = \frac{I_a V_a}{(V_a - V_s) f C} \tag{14}$$

$$\Delta V_c = \frac{I_a k}{f C} \tag{15}$$

In condition for continuous current and capacitor voltage, if I_L is the average inductor current, the inductor ripples current $\Delta I = 2I_L$.Using equation (6) and (12), we get

$$\frac{kV_s}{fL} = 2I_L = 2I_a = \frac{2kV_s}{(1-k)R}$$

This gives the critical value of the inductor L_c as

$$L_c = L = \frac{(1-k)R}{2f}$$

If V_c is the average capacitor voltage, the capacitor voltage, the capacitor ripple voltage $\Delta V_c = 2V_a$.Using equation (15), we get

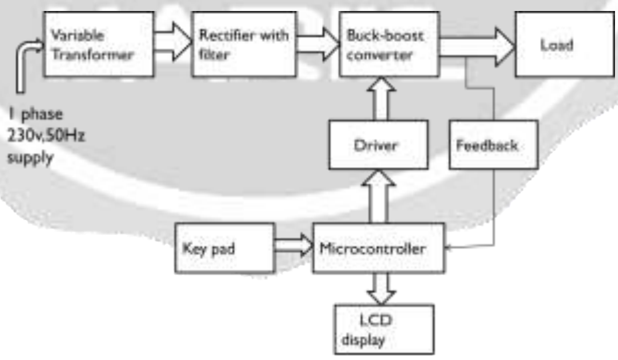
$$\frac{I_a k}{Cf} = 2V_a = 2I_a R$$

This gives the critical value of capacitor C_c as

$$C_c = C = \frac{k}{2fR}$$

III. DESIGN OF CONTROLLER BASED BUCK-BOOST CONVERTER

A. System block diagram



Fi 3: Methodology of the system

From the above Fig. we are using internal AC supply as input to our system. Here a autotransformer is used to vary the supplied ac power. It is 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. The ATmega328 is a single-chip microcontroller created by Atmel in the mega AVR family. It requires separate auxiliary supply of 5 volts which is supplied by means of external supply source. 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 output voltage is 100V. The main purpose of DC-DC buck-boost converter is to provide fixed 100V DC output regardless of input voltage is lower or higher than 100V. Microcontroller takes decision whether to buck or boost. According to the decision converter provides the desired output voltage. This output voltage value is then displayed on LCD.

***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 100V from input voltage(>100V). 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 100V in buck mode. On the other hand when the voltage is less than 100V, 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 100V 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 100V. If the input voltage is greater than 100V then the converter will be worked as buck mode and the input voltage is less than 100V then the converter worked as boost mode and maintain 100V all the time to charge the battery.

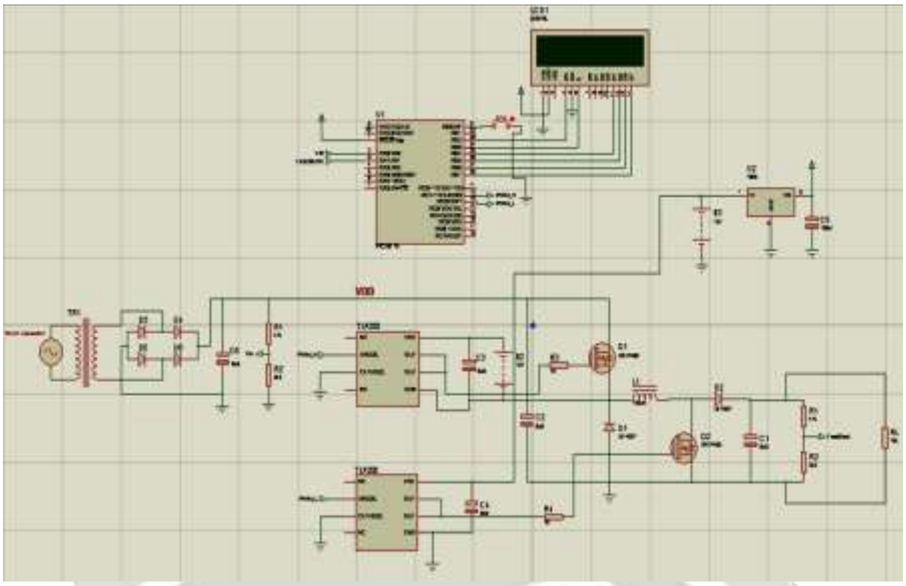


Fig 4 Schematic diagram of controller based buck-boost converter

IV. Result Analysis

Fig 5: Wave shape of duty cycle in Boost mode

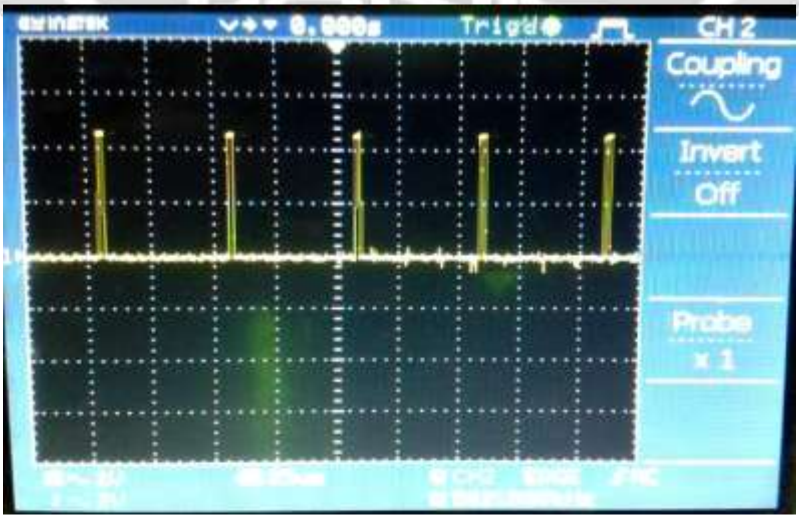


Fig 6: Wave shape of duty cycle in Buck mode

V. Conclusion

DC-DC converters are new control schemes to achieve better regulation and fast response. The proposed system of controller based buck and boost converter is found to be more compact, user friendly and more efficient. The inbuilt ADC and PWM channels in the ATmega328 microcontroller make the control module of the converter very compact. The buck and boost converter with controller Atmega328 as its integral part senses the output voltage and varies the PWM duty ratio. Most importantly MOSFET switches are used in the buck and boost part to draw their low power consumption and high switching frequency characteristics. The implemented converter almost provides around 100 volts (nominal 100 watt dc loads) regardless of input voltage higher or lower than 100 volts i.e. (70v<100v<130v).

References

[1] Shafait Ahmed, Khandakar Abdulla Al Mamun, Abhishek Barua , Jewel Sikder Joy ,Rocky Chakma "Design & Implementation of Controller Based Buck-Boost Converter for Small Wind Turbine". *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e- ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 6 Ver. I (Nov – Dec. 2015), PP 44-50.*

[2] B. Ram Kiran, G. A. Ezhilarasi, "Design and Analysis of Soft-Switched Buck-Boost Converter for PV Applications". *IEEE INDICON 2015* J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.

[3] Anagha Mudki Asst. Prof. Sangeeta Deshmukh."Microcontroller Based MPPT Buck-Boost Converter Using 555 Timer**".** *International Journal of Engineering Research & Technology (IJERT)Vol. 2 Issue 7, July - 2013ISSN: 2278- 0181*K.

[4] Sumit K Rathor, Ankit Patel, Sejal Patel, Jugnu Patel, "Closed Loop Buck-Boost Converter using RTW" Dept. of Electrical Engg.GCET Gujarat, India,IEEE,pp.978-1-4673-9939-5/16,2016.