

Comparison of load resistor and battery on controlling buck boost converter using fuzzy-pi method

Maryanto Massarang^{1*}, Jumiyatun Jumiyatun¹, Yulius Salu Pirade¹, Mahwada Mahwada¹, and Andi Fatmwati¹

¹Department of Electrical Engineering, Tadulako University, Palu, Indonesia.

Abstract. This paper discusses about controlling the buck boost converter output voltage remains constant by comparing of loads resistor and battery. Buck boost converter output voltage tends to be unstable when given a disturbance with a variety of loads, for that it needs proper control to adjust the duty cycle. The controls that will be used are a combination of conventional control methods, i.e. Proportional Integral (PI) and intelligent control, i.e. Fuzzy logic. The results show that the combination of PI control and Fuzzy Logic can improve performance, i.e. small errors close to zero and the buck boost converter output voltage remains constant even though the load is varied, i.e. resistors and battery.

1 Introduction

Based on the range and usefulness of the DC-DC converter there are various kinds, i.e. Buck Converter, Boost Converter, Buck boost converter, Cuk Converter, Sepic Converter and Zetta Converter that works with switching systems. The power supply with this switching system is better than linear systems. In linear power supply the efficiency is very low due to power losses in the transistor, while the switching system if it is assumed is ideal then the converter efficiency can reach up to 100% [1]

This paper will discuss the control of the output voltage of DC-DC buck boost converter which serves to decrease and increase the voltage to remain constant when given of loads a resistance or battery. Buck boost converter is a switching converter that can decrease and increase the output voltage by adjusting the duty cycle provided to switching devices such as: Mosfet, Thyristor, IGBT, GTO. To be able to control the converter output voltage, a control method is needed that can increase efficiency, eliminate offset and produce large initial changes. To overcome this problem, a method is used, which is a combination of PI control and Fuzzy Logic that will regulate the duty cycle. The PI method is a conventional control that has been widely used both for research and for applications in industry. While Fuzzy like Proportional Derivatives (PD) is a fuzzy intelligent control whose behavior resembles a PD.

The converter consists of a DC input voltage source (V_s), a controlled switch (S), inductor (L), diode (D) capacitor filter (C) and resistance load (R). The Buck boost converter produces an output voltage greater than or smaller than the input voltage, depending on switching duty (D). When the switch is ON, the diode is reverse biased, the input voltage goes through the inductor so that the inductor voltage (V_L) equals the input voltage (V_s) and the inductor current rises linearly so that the energy in the inductor goes up too.

* Corresponding author : jum.elektro@gmail.com

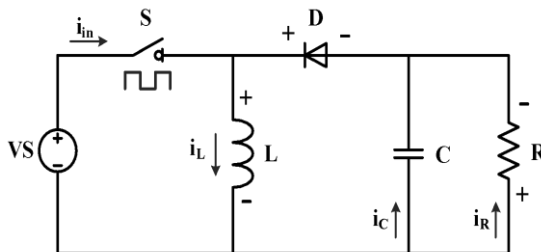


Fig.1. Buck boost converter

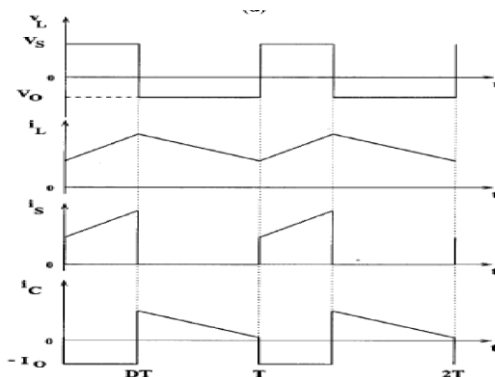


Fig. 2. Waveforms of buck boost converter

Several research that have been carried out related to control buck boost converter are research conducted by Dedy Siddik Sidabutar, et al with the title "Design and Development of Buck boost converter on Solar Panels Using PI and PID Control Methods Based on Atmega 8535 Microcontroller" discussing how to maximize the use of solar panels with electronic circuit buck boost converter that can increase and decrease the output voltage. In this study using PI and PID control methods to improve system performance that can be seen from the response speed and steady state error. By using trial and error, the efficiency gained from buck boost with PI control is 9.5% and from PID control is 8.7%, but PID Control is better than the maximum overshoot (MP) and Settling Time (TS) values smaller from PI control[2].

Maula Nurul Khakam et al in her research entitled "Design and Implementation of Battery Charging Management Systems and Loads on Independent Power Plants Using Synchronous Non-Inverting Buck Boost DC-DC Converter discusses the design, simulation and implementation of synchronous non-inverting buck boost (SNIBB) using four H-bridge switches to adjust the current and multi-stage voltage charging the lead-acid battery, using two modes ie constant current (CC) and constant voltage (CV). When the CC and CV modes of the SNIBB circuit are able to maintain the charging voltage and current according to the set point with the change in input voltage. The battery management test with loads can regulate the charging process and discharging the battery to the load [3]

Jumiyatun et.al in his paper discussed the comparison of two methods, i.e. the PI conventional method with Fuzzy Logic - PI to control the buck converter output voltage remains constant. Control using Fuzzy-PI controllers is better for performance and faster response than conventional methods, i.e. PI is shown from the graph of the output voltage response with large rise time difference [4]

Jumiyatun et al, in his research entitled " Controlling DC-DC Buck Converter Using Fuzzy-PID with DC motor load" discusses the DC-DC buck converter which functions to

decrease the voltage by using switching MOSFET to control the buck converter output voltage constant with the motor load DC. The method used is a combination of conventional control methods, namely Proportional Integral Derivatives (PID) and intelligent controls i.e. Fuzzy logic to improve performance so that a small error approaches zero and the buck converter output voltage remains constant even though the motor load is altered. [5]

2 Research Method

In designing the buck boost converter in this research, the first step is to determine the appropriate parameter values of the inductor (L), capacitor (C), and duty cycle components which will then be compared when testing using R and battery loads. The method used is a combination of Fuzzy logic and PI controller, so it is expected to improve performance.

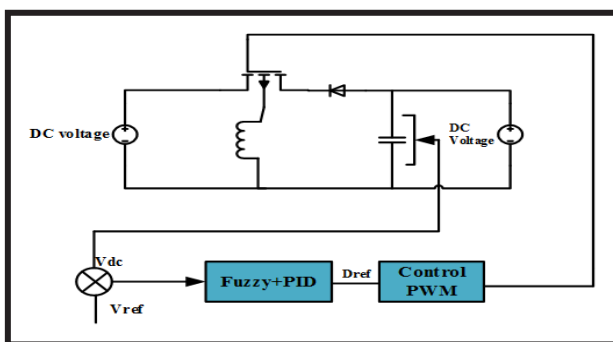


Fig.3. Block diagram for the control of the Buck Boost Converter

In Figure.3. shows the diagram system of a dc-dc buck boost converter, input voltage and current from a DC source, where the input voltage is designed higher or lower than the output voltage that will be increased or lowered according to load requirements. The output voltage will be set according to the specified set point and then feed backed and the error obtained is controlled using the fuzzy-PI combined method.

2.1 Design of DC-DC Buck Boost Converter [8]

To design a buck boost converter as a first step is to calculate and determine the value of the appropriate component parameters so that the whole system runs well.

Table 1. Parameters of buck boost Converter

Parameter	Score
Input Voltage (V_{in})	24 Volt
Output Voltage (V_o)	14Volt
Ripple Voltage (ΔV)	5%
Output Current (I_o)	2,16 A
Ripple Current (ΔI)	3%
Frequency Switching	10 KHz

- Determine of duty cycle values

$$V_0 = -V_s \left[\frac{D}{1-D} \right] \tag{1}$$

$$D = 0,3684$$

- Determine of resistance

$$R = \frac{V_0}{I_0} = \frac{-14}{2,16} = -6,4814815\Omega \tag{2}$$

- Determine of inductor

Based on equation (2) the IL value is obtained as follows.

$$IL(avg) = \frac{V_0 D}{R(1-D)^2} = \frac{24 \times 0,3684}{6,4814815 (1-0,3684)} = \frac{8,8421}{2,58544} = 3,42A \tag{3}$$

$$\Delta IL = 3\% \times IL(Avg) = 0,03 \times 3,42 = 0,1026A \tag{4}$$

$$L = \frac{V_{in} \times D}{\Delta IL \times f} \tag{5}$$

$$L = \frac{24 \times 0,3684}{0,1026 \times 10,000} = 0,002285714H \tag{6}$$

- Determine of capacitor values

$$\Delta V_0 = 5\% \times V_0 = 0,03 \times 14V = 0,7V$$

$$\Delta V_0 = \frac{V_0 \times D}{RCf} \tag{7}$$

$$C = \frac{V_0 \times D}{R \Delta V_0 f} = \frac{14 \times 0,3684}{6,4814814815 \times (10 \times 10^3)} = 1337\mu F \tag{8}$$

Next to design the value of the new buck boost converter for component

Table 2. Parameters of comparison buck boost Converter

Parameter	Score
Input Voltage (Vin)	6 Volt
Output Voltage (Vo)	14Volt
Ripple Voltage (ΔV)	5%
Output Current (Io)	2,16 A
Ripple Current (ΔI)	2%
Frequency Switching	10 kHz

Table 3. Parameters of Battery

Unit	Score (SI)
Nominal Capacity	7,2 Ah
Nominal Voltage	12 V
Weight	2kg
Max & Min Voltage	14,5 V-11,5V
Max Charging Voltage	14V
Standard Current	2,16 A
Operation Temperature	0°C - 45°C

2.2 Designing Controller Method [9]

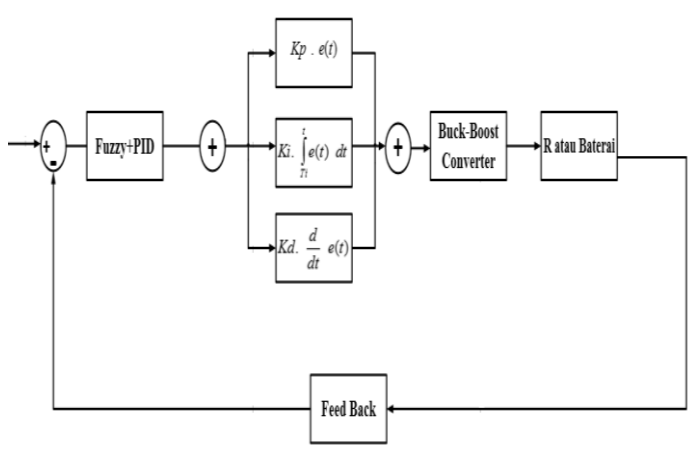


Fig 4. Block diagram of combination Fuzzy- PI controller

2.2.1 PI Controller (Proportional Integral) [10]

Proportional plus integral (PI) controller is a controller whose control action has proportional and integral properties to error signals.

For proportional plus integral controller, the form of the equation is

$$u(t) = K_p \left\{ e(t) + \frac{1}{\tau_i} \int_0^1 e(t) dt \right\} \tag{8}$$

or in the Laplace transformation magnitude

$$U(s) = K_p \left\{ 1 + \frac{1}{\tau_i s} \right\} E(s) \tag{9}$$

where K_p is proportional reinforcement and τ_i is integral time. The parameters K_p and τ_i can be determined.

So that the proportional plus integral controller transfer function is

$$\frac{U(s)}{E(s)} = K_p \left\{ 1 + \frac{1}{\tau_i s} \right\} \tag{10}$$

The proportional plus integral controller block diagram is as follows:

$$E(s) \rightarrow K_p \left\{ 1 + \frac{1}{\tau_i s} \right\} \rightarrow U(s) \tag{11}$$

Where:

K_p = Proportional Strengthening

τ_i = Integral Time

The functions of the PI component are as follows:

1. Proportional Control serves to speed up the rise time.
2. Integral Control functions to eliminate steady state errors.

2.2.2 Fuzzy Logic Controller [11]

Fuzzy logic controller is a fuzzy system that is applied as a controller where in this research will be combined with a PI controller to produce better performance. Variable inputs on fuzzy controllers are generally in the form of a difference between the output reference value and the actual output value called error value. Whereas fuzzy logic controller output is command

control given to actuator or drive. Fuzzy controller structure consists of fuzzifier, fuzzy rule base, inference engine and defuzzified.

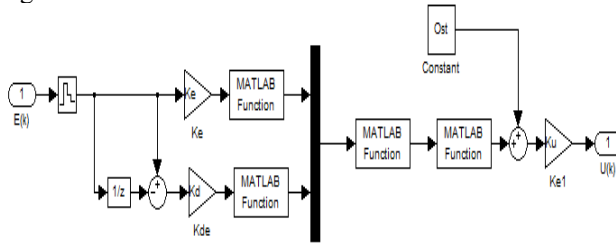


Fig 5. Block diagram of Logic Fuzzy control on buck boost converter

Figure 6. Shows the membership degree function that defines E, ΔE with triangular normalization supported by 7 sets.

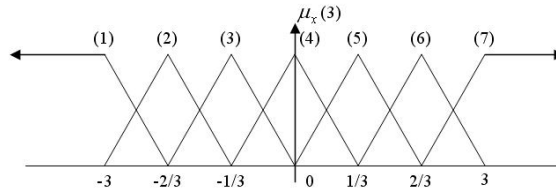


Fig 6. Triangle function

Arrangement of fuzzy rules by using inference assistance to determine the control signal, by using a membership set of seven pieces for each input shown in Table 4.

Table 4. Preparation of Fuzzy Rules

E/dE	1	2	3	4	5	6	7
1	1	1	2	2	3	3	4
2	1	2	2	3	3	4	5
3	2	2	3	3	4	5	5
4	2	3	3	4	5	5	6
5	3	3	4	5	5	6	6
6	3	4	5	5	6	6	7
7	4	5	5	6	6	7	7

In the design of the inference used is the Mamdani method which has the Equations:

$$\mu_y(k) = \max[\min\{\mu_u(k), \mu_r(E(i), \Delta E(j))\}] \quad (12)$$

Next to get the control action value (u) a defuzzification process will be carried out, the COA (Center of Area) method.

3 Result and Discussion

Data retrieval and testing on research of buck boost is done during open loop and close loop, that is, before and after the combined control of Fuzzy logic and PI control is installed. The load used is the resistance and battery.

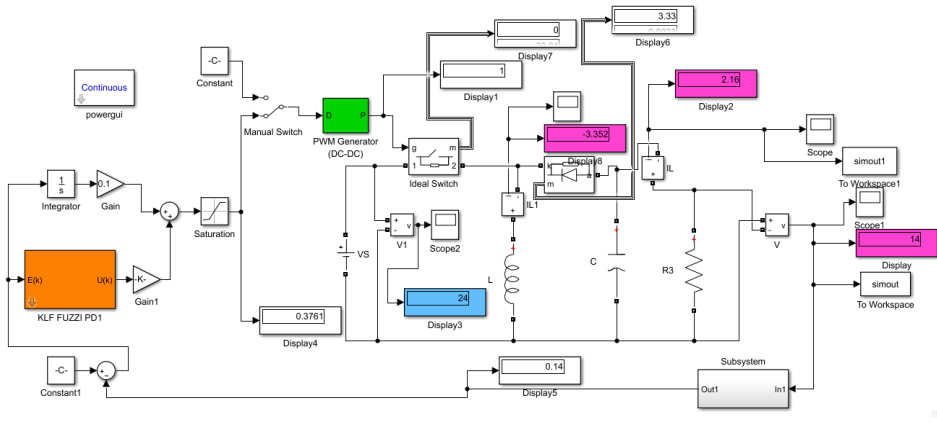


Fig.7. Image Simulation of whole Buck boost converter with resistance load.

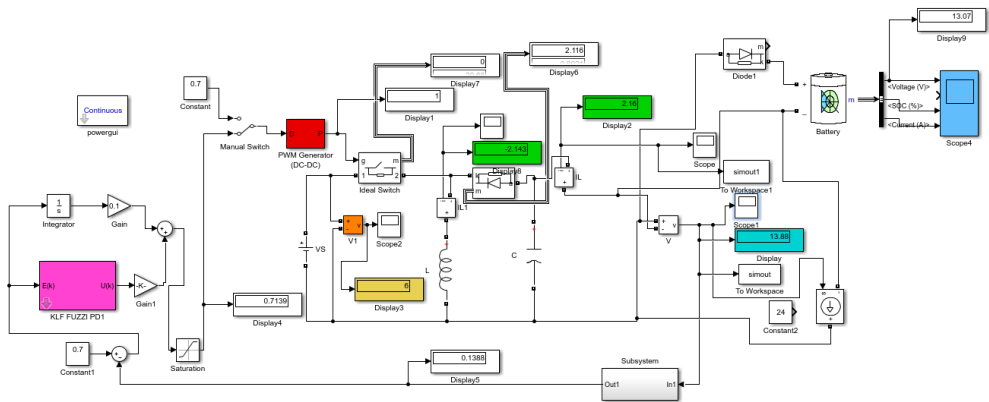


Fig.8. Image Simulation of whole Buck boost converter with battery load.

Testing Buck Boost Converter with R load

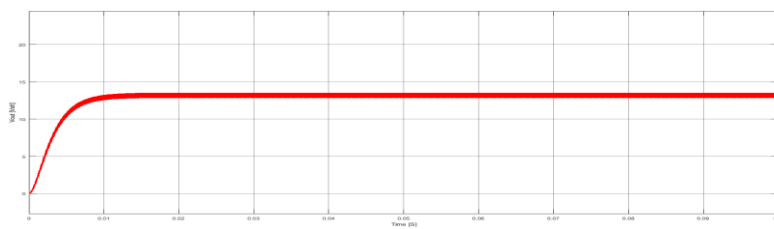


Fig.9. Respond of resistor load on open loop buck boost converter

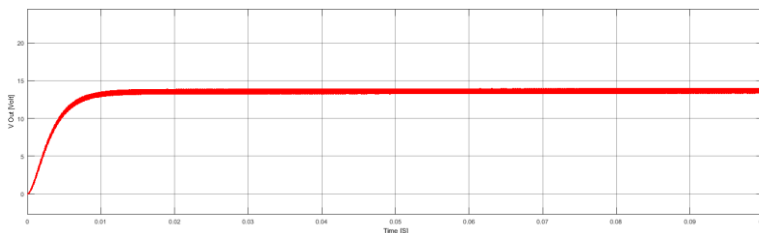


Fig.10. Respond of resistor load on close loop buckboost converter

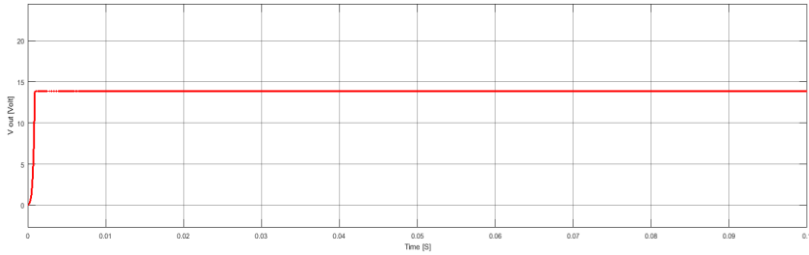


Fig.11. Responds of battery load on open loop buck boost converter

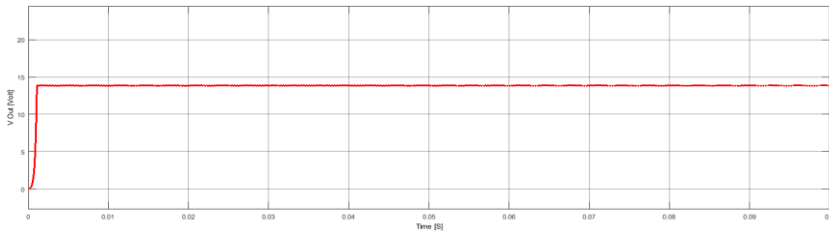


Fig.12. Respond of battery load on close loop buck boost converter

Table 5. Comparison of Resistor and Battery Loads in Open Loop Testing

Parameters			Value			
			Resistor		Battery	
Input Voltage (V_{in})	24	6				
Output Voltage (V_{out})	14	14	13.52	13.51	13.84	13.84
Output Current (I_o)			2.086	2.084	0.012	0.04

Table 6. Comparison of Resistor and Battery Loads in Close Loop Testing

Parameters			Value			
			Resistor		Battery	
Input Voltage (V_{in})	24	6				
Output Voltage (V_{out})	14	14	14	14	13.89	13.88
Output Current (I_o)			2.16	2.16	13.89	13.88

4 Conclusion

The results comparison of load the resistor and battery for controlling the output voltage of DC-DC buck boost converter by using a combination of Fuzzy-PI method shows that when open loop and close loop, resistor load performance is better than using a battery load. This can be seen from the graph of the output voltage response where the load resistor is more stable with zero error.

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