# DC/DC Buck Converter Using Fuzzy Logic Controller

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# DC/DC Buck Converter Using Fuzzy Logic Controller

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***Abstract*— DC/DC converter is an electronic gadget that converts DC power from one level to another level. There are three types of converters, they are boost converter, buck converter, and buck-boost converter. This project focuses on the dc/dc Buck converter by using PI control and fuzzy logic control with input 24V and output 12V. The dc/dc buck converter called as a step-down converter, PI control, and fuzzy logic control are applying for the control of switching device in buck converter then output voltage can be controlling 12V. PI control is generally used for deploying a feedback control. The output voltage can be obtained by tuning the P and I gains. Fuzzy logic control is the simple method, reasonable and easy in design. The Fuzzy controller can attain the fast-transient response, little overshoot, reducing voltage and current ripples, the term PI is defined as P for proportional and I for integral. The whole converter circuit is designed and implemented in MATLAB Simulink. The analysis is carried out by making a comparison of both the controllers' output voltage.**

***Keywords*— *DC/DC buck converter, PI control, fuzzy logic control, simulation.***

## I. Introduction

All electronic devices are operated some supply voltages which is generally assumed constant. The voltage regulator is an electronic circuit that supporting to the constant output voltage. Various types of voltage regulators and many control methods were used to regulate output. In the dc/dc converter, the converter input is unregulated dc, and outputs are regulated dc. There are several types of conversion procedures such as switched-mode, electronic, magnetic, linear, and capacitive.

Every electronic device is used to change the power from one level to another voltage level is required. DC voltage conversion extreme importance of some applications start from lower to higher power application. The goal of the structure is to highlight and complete the system requirement. There are used to traction motor controller in electric automobiles. They transport fast dynamic response, smooth acceleration and more efficiency. The DC converter are used for re-generative braking of DC motor to the comeback energy in to the supply and result save energy in the transport system [1].

DC to DC switch mode converter basic types, boost converter, buck converter, and buck-boost converter. Various control procedures were used to control the switch-mode dc-dc converter, low cost, and simple control structure are demanded the highest engineering application. All control technique has some advantage and disadvantage due to their particular control technique considers of accurate control technique under particular situations compare to other technique. The control technology that gives the best performance under all conditions is more demanded. [2]. For example Fuzzy control and PI Control.

In this project, compare these two different procedures for the design implementation of the closed-loop system of the buck converters are takeout. The generally using control technics to the dc converter are current mode PWM and voltage mode PWM with P, PI, and PID. These conventional control systems are incapable of performs under the large limit. Therefore, a nonlinear controller is used for controlling dc converters. The advantages are this type of controllers is the fast response in the transient situation and their ability. The various types of nonlinear controllers are sliding mode control, fuzzy logic control, etc. [4]. [5].

Fuzzy logic control is working the control of buck converter because of easiness, simple to apply, simple design, and not require an exact mathematical model for the system. [3].

## II. Methodology

### *A. PI Controller*

PI control is used in the last few years. Their performance fulfilled in transient below the partial working series and the steady-state performance are better. But the linear method poor large-signal disturbance. Fig.1. shows the closed-loop system using PI control. [7].

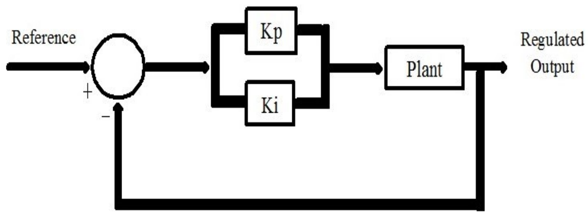


Fig.1. The closed-loop system using the PI controller

Proportional Integral control is the special type of PID control, but not used Derivative (D) part of the error.
Control indication U for PI controller is,

$$U = K_p + K_i \int \Delta dt$$

Kp = proportional gain
Ki = integration gain
Δ = error

PI control transfer function C(s) is,

$$C(s) = K_p + \frac{K_i}{S}$$

**The general approach of PI tuning:**

1. Set integration gain is zero
2. Rise KP till acceptable answer are found
3. Adding integration gain and tune KI until the error of steady-state was removed. [6].

*A. Fuzzy Logic Control*

Fuzzy Control method completes the same work as the PID controller, it is introduced by L. A. Zadeh in 1965, also its mathematical model deals with uncertainty. It offers the system is an agreement with fuzziness. The fuzzy logic offers an inference structure that allows suitable human mental capacities. Fuzzy structures appropriate near to the logic. The fuzzy method is a fast and smooth reply than other systems and less controller difficulty. The inference system is the IF-THEN rule for plotting fuzzy set in input to output created on the fuzzy opinion. In fuzzy, data presentation, IF-THEN rules are methods for taking data are includes the fuzziness. The key feature of logic is using fuzzy rules of fractional matching ability, the inference is completed after fuzzy rules even rule conditions are partially fulfilled. [2]. [3]. [9].

The Fuzzy control with 2 inputs and 1 output. The output voltage obtained from the buck converter is compared with the reference voltage. The difference between these two values is called error and the change in error. The output of fuzzy control is the duty cycle and given to the PWM Generator that generates a signal to the MOSFET of the dc/dc buck converter. MOSFET gets ON/OFF according to the signal of the PWM generator, producing a required output voltage. [8]. [9]. [10]. as shown in fig.2.

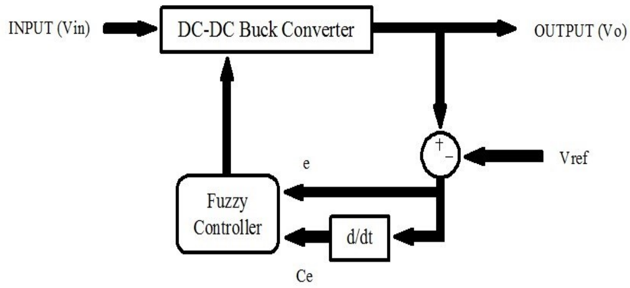


Fig.2. DC/DC Buck Converter using Fuzzy Control

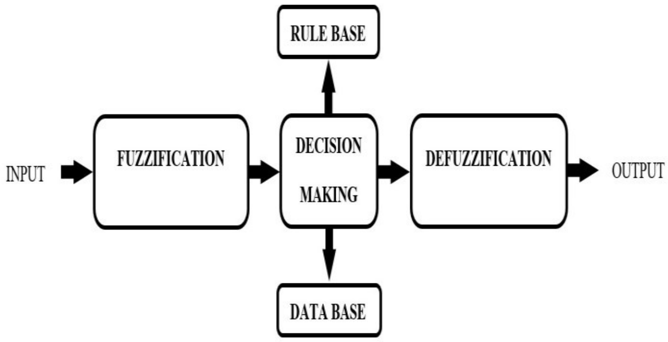


Fig.3. fuzzy logic control

Fuzzy control contains three parameters that are fuzzification, fuzzy inference system, and defuzzification. Overall the system fuzzy-sets distributed to the represents fuzzy variables called membership function. The value changes of membership function between 0 and 1.

- Fuzzification:

Fuzzification is a process that converts input data into the appropriate linguistic value. Membership functions expressed are trapezoidal-shaped, triangle-shaped.

- Fuzzy Inference System:

Fuzzy inference scheme which expressed to combine membership function with controlling rules to drive fuzzy output.

- Defuzzification:

Get the compact output by using several defuzzification methods. The use of other methods to estimate every related output in the table.

## III. Simulation Studies

### *B. MATLAB-Simulink design of DC/DC Buck converter using PI controller:*

PI controller tested simulation by using MATLAB software. Simulation is done for output voltage and load variation for the buck converter.

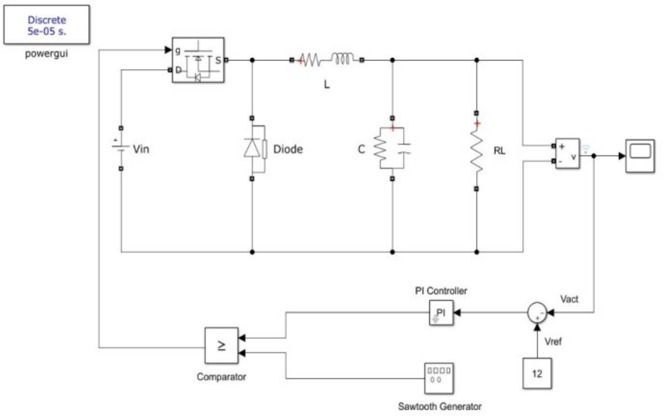


Fig.4. DC/DC Buck Converter using PI Control

Above fig. shows the DC/DC Buck converter using PI control, the simple buck converter is used in this model, the output voltage and reference voltage are compared then form the error signal. This error signal is fed to PI control and the PI control is produce control indication based to error indication for differing the on and off time to controller switch of buck converter, and output of PI control is compared to saw tooth generator indication to generate PWM indication which is drive switching the MOSFET.

TABLE I Ratings of Elements Employed in Simulation

| | |
|---|---|
| Input voltage | 24 V |
| Output voltage | 12 V |
| Inductor | 250 mH |
| Capacitor | 100 µF |
| Proportional gain | 10 |
| Integral gain | 100 |

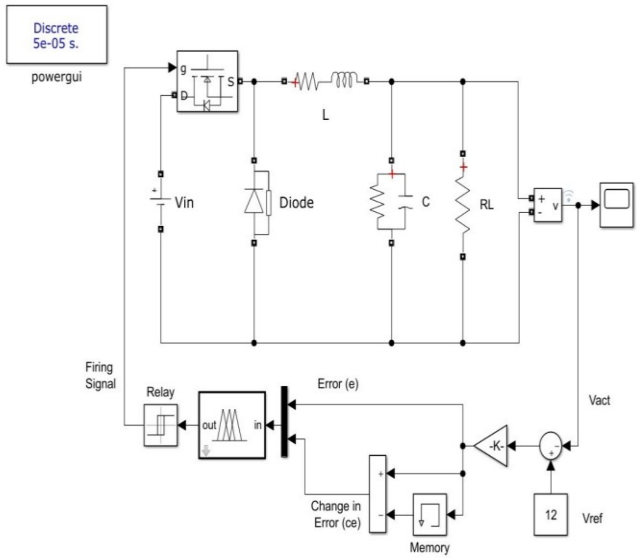


Fig.5. DC /DC Buck Converter using Fuzzy Logic control

### *C. MATLAB-Simulink design of Dc/DC Buck convertor using Fuzzy logic control:*

Above fig. shows DC/DC Buck converter using Fuzzy control, the simple buck converter is used in this model the output voltage and reference voltage are compared then form the error signal. Gain block reproduces input by constant values. Memory is used for applying the one integration step delay, the output is the previous input value. The sum of this form changes in error. This error signal and change in the error signal is fed to fuzzy control. The output of the fuzzy controller is specified 'on' or 'off' value by comparing the input to the specified thresholds.

TABLE II Ratings of Elements Employed in Simulation

| | |
|---|---|
| Input voltage | 24 V |
| Output voltage | 12 V |
| Inductor | 250 mH |
| Capacitor | 100 µF |
| Proportional gain | 10 |
| Integral gain | 100 |

MATLAB equivalent Fuzzy designer shown fig.6.

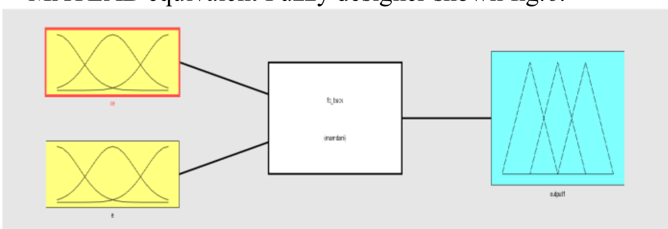

Fig.6. Fuzzy Designer

The fuzzy logic controller performs in 3 functions is Fuzzification, fuzzy inference system, and defuzzification. The fuzzification process means where membership function applied and the degree of the membership function is determined.

This project the Membership functions are used like

1. Negative Big (NB)
2. Negative Medium (NM)
3. Negative Small(NS)
4. Zero (ZE)
5. Positive Small (PS)
6. Positive Medium (PM)
7. Positive Big (PB)

The input-1 error it has 7 membership functions-
NB, NM, NS, ZE, PS, PM, PB
Input-1 with 7 membership functions as shown in fig.7.
Input-2 is changed in error it has 7 membership functions-
NB, NM, NS, ZE, PS, PM, PB
Input-2 with 7 membership functions as shown in fig.8.
The input-1 and input-2 are fed to the Fuzzy control.
Output block also takes 7 membership functions-
NB, NM, NS, ZE, PS, PM, PB
Output with 7 membership functions as shown in Fig.9.

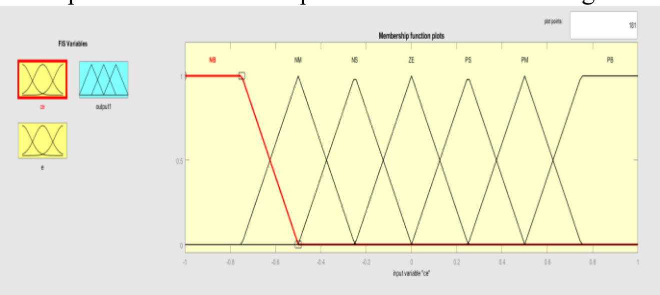

Fig.7. Input-1 with 7 Membership Functions

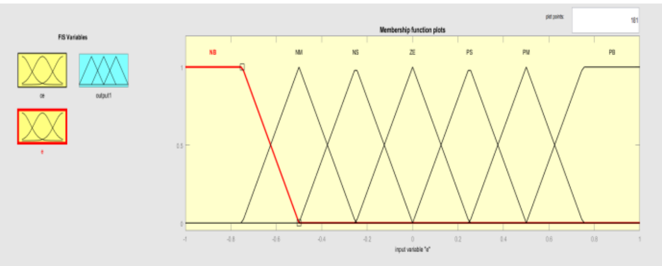

Fig.8. Input-2 with 7 Membership Functions

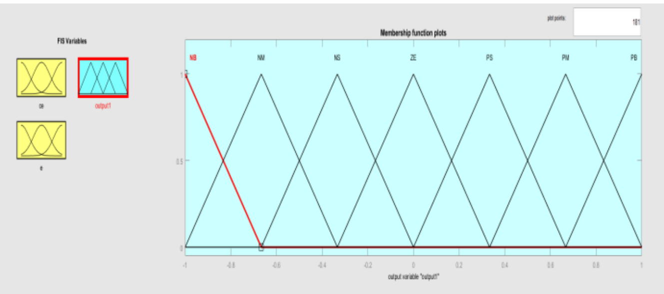

Fig.9. Output with 7 Membership Functions

Fuzzy inference scheme which expressed to combine membership function with controlling rules to drive fuzzy output. The process contains Logical Operations. Fuzzy logic plotting input to output with the If-Then Rules called a fuzzy rule. The rules are used in this project are shown in Table. III.

De-fuzzification completed by the centroid method to give the fine value at the output of the Fuzzy control.

TABLE III FUZZY RULE

| Ce \ e | NB | NM | NS | ZE | PS | PM | PB |
|---|---|---|---|---|---|---|---|
| **NB** | *NB* | *NB* | *NB* | *NB* | *NM* | *NS* | *ZE* |
| **NM** | *NB* | *NB* | *NB* | *NM* | *NS* | *ZE* | *PS* |
| **NS** | *NB* | *NB* | *NM* | *NS* | *ZE* | *PS* | *PM* |
| **ZE** | *NB* | *NM* | *NS* | *ZE* | *PS* | *PM* | *PB* |
| **PS** | *NM* | *NS* | *ZE* | *PS* | *PM* | *PB* | *PB* |
| **PM** | *NS* | *ZE* | *PS* | *PM* | *PB* | *PB* | *PB* |
| **PB** | *ZE* | *PS* | *PM* | *PB* | *PB* | *PB* | *PB* |

## IV. SIMULATION RESULTS

### A. *PI controller:*

The simulation results on output voltage by using PI control are shown in fig.10.

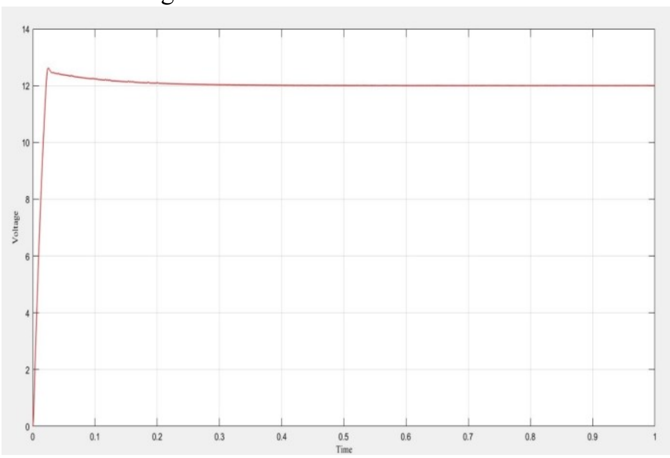

Fig.10. PI Controller Output voltage

Fig.11. show results of PI control for load variable condition. The load can be varying 50-ohm, 70-ohm, and 30-ohm.

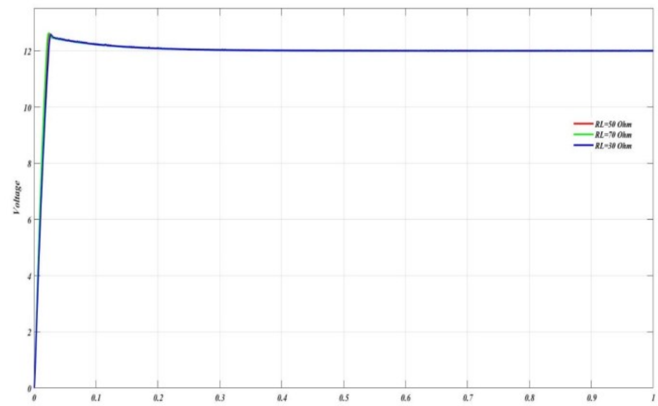

Fig.11. PI controller Output for Load Variation

### B. *Fuzzy logic controller:*

The simulation results on the output voltage of a buck converter with fuzzy control are shown in fig.12.

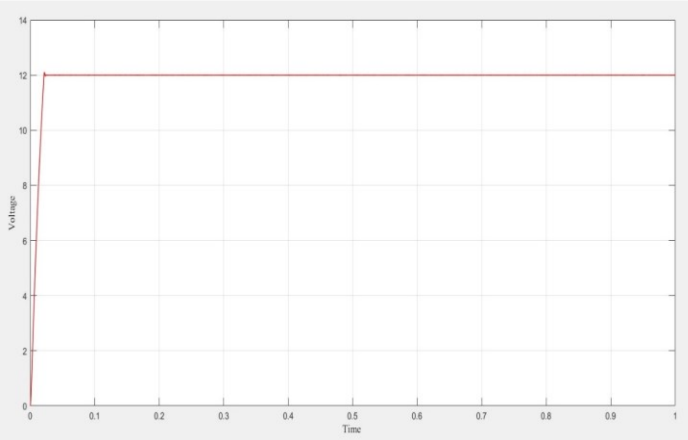


Fig.12. Fuzzy Controller Output voltage

Fig.13. show results of fuzzy control for load variable conditions. The load can be varying 50-ohm, 70-ohm, and 30-ohm.

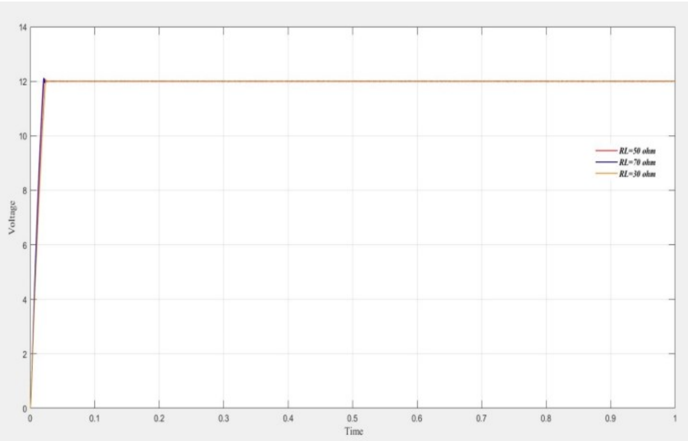


Fig.13 Fuzzy Controller Output for Load Variation

*C. Compare Result of PI Control and Fuzzy control:*

The simulation results compare to output voltage are shown in fig.14.

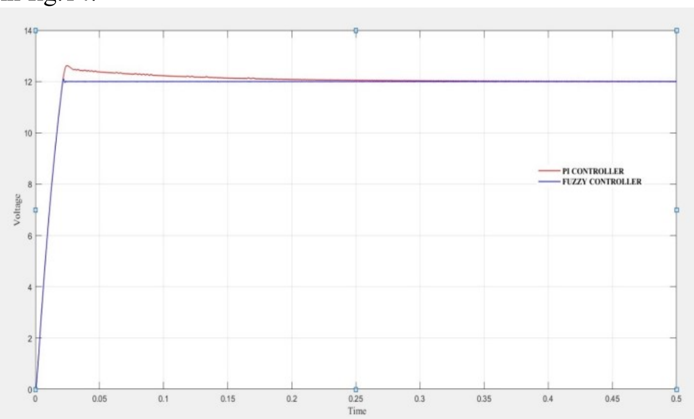


Fig.14. Result of PI Control and Fuzzy Control

Table IV. show comparative results of fuzzy and PI controller buck converter for load variable condition. the load can be varying 50-ohm, 70-ohm, 30-ohm.

TABLE IV MATHEMATICAL RESULTS OF FUZZY AND PI

| RL=50Ω | | | | |
|---|---|---|---|---|
| *Controller* | $V_{in}$ | $V_{out}$ | *Rise Time* | *Overshoot* |
| ***PI*** | **24** v | **12** v | **16.181** *ms* | **4.737** % |
| ***FUZZY*** | **24** v | **12** v | **16.164** *ms* | **0.505** % |
| **RL=70Ω** | | | | |
| *Controller* | $V_{in}$ *(V)* | $V_{out}$ | *Rise Time* | *Overshoot* |
| ***PI*** | **24** v | **12** v | **15.388** *ms* | **4.737** % |
| ***FUZZY*** | **24** v | **12** v | **15.374** *ms* | **0.505** % |
| **RL=30Ω** | | | | |
| *Controller* | $V_{in}$ | $V_{out}$ | *Rise Time* | *Overshoot* |
| ***PI*** | **24** v | **12** v | **17.998** *ms* | **4.737** % |
| FUZZY | 24 v | 12 v | 17.983 ms | 0.505 % |

From Table- IV the values of raise time and peak overshoot of buck converter PI controller and Fuzzy controller can be seen. It can be noticed that with the use of Fuzzy and PI controller,

## V. CONCLUSION

Simulation results of PI control and fuzzy control are simulated using MATLAB/Simulink. The same parameter values of the dc/dc buck converter are used. PI control technique is more complicated due to the employed mathematical models, and the PI controller gives more overshoot and rises time. Primary control constraints using the tuning requirements to adjusted many times to complete the simulation and to get satisfactory performances. Fuzzy control gives no overshoot and minor rise time equated to the PI controller. Hence, it has been concluded that the fuzzy control is the simplest method, it gives good performance when compared with PI control.

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