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Implementation of Fuzzy Logic Controller for DC–DC step Down Converter

Shaik Gousia begum, Syed Sarfaraz Nawaz, G. Sai Anjaneyulu

Abstract**: This paper presents the design of a Fuzzy logic controller for a DC-DC step-down converter. Buck converters are step-down regulated converters which convert the DC voltage into a lower level standardized DC voltage. The buck converters are used in solar chargers, battery chargers, quadcopters, industrial and traction motor controllers in automobile industries etc. The major drawback in buck converter is that when input voltage and load change, the output voltage also changes which reduces the overall efficiency of the Buck converter. So here we are using a fuzzy logic controller which responds quickly for perturbations, compared to a linear controllers like P, PI, PID controllers. The Fuzzy logic controllers have become popular in designing control application like washing machine, transmission control, because of their simplicity, low cost and adaptability to complex systems without mathematical modeling So we are implementing a fuzzy logic controller for buck converter which maintains fixed output voltage even when there are fluctuations in supply voltage and load. The fuzzy logic controller for the DC-DC Buck converter is simulated using MATLAB/SIMULINK. The proposed approach is implemented on DC-DC step down converter for an input of 230V and we get the desired output for variations in load or references. This proposed system increases the overall efficiency of the buck converter.

***Keywords**: DC-DC Buck Converter, Fuzzy Logic Controller, Pulse Width Modulation (PWM), MATLAB/SIMULINK.*

I. INTRODUCTION

The design of a buck converter is to keep a constant output voltage under the different load conditions and unregulated input supply voltage. The transient overshoot and recuperation time of the output voltage should be limited for stable operation in numerous electronic applications, which is ensured in the closed loop controllers. Recently, several strategies have been proposed in the to mitigate the disadvantages of the traditional linear controllers for power electronic converters. Fuzzy logic is a type of controller in non-linear technology is used to control the buck and boost converters.

Now a day we are facing situations where we cannot predict the conditions are true or false. Fuzzy refers to something which is non-linear or indefinite. Fuzzy logic is based on the perception that Humans make choices based on uncertain or non numerical information. Classical controllers like PWM control, proportional controller (P), proportional integral controller (PI), proportional integral derivative controllers (PID) only provides results which is either true or false. These controllers don't provide adequate results when there is nonlinearities in parameters or load. So we are using non linear controllers like fuzzy for controlling the non-linearity's in the load because it responds faster to a transient condition, easy to design and implementation. So here the aim of the fuzzy logic controller is used to stabilize the load voltage of the buck converter in transient state conditions.

II. PROPOSED MODEL

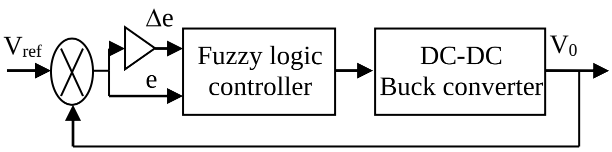

Fig 1. Block diagram of Fuzzy logic controller for buck converter.

The main aim of this model is to maintain constant load voltage when there are fluctuations in the load and input parameters. So the difference between output voltage and desired voltage which is taken as reference voltage (Vref) is referred as error (e) and (Δe) as change in error which is applied to the fuzzy logic controller. Based on variations in the variations in data FLC gives the different duty cycles which are given to the switch in the DC-DC buck converter through a PWM generator [7]

III. BUCK CONVERTER

The DC-DC buck converters are effectively decreases the voltage levels as per our requirement. The basic circuit of the Buck converter is shown in Fig.2. Here the MOSFET is controlled by pulses which are coming through the fuzzy logic controller.

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* Correspondence Author
Shaik Gousia Begum*, EEE (Power Electronics), GRIET (JNTUH), Hyderabad, India. Email: skgousiabegum228@gmail.com
Syed Sarfaraz Nawaz, EEE department, GRIET (JNTUH), Hyderabad, India.. Email: sarfaraz86nawaz@gmail.com
G. Sai Anjaneyulu, EEE (Power Electronics), GRIET (JNTUH), Hyderabad, India. Email: saianjaneyulu71@gmail.com.

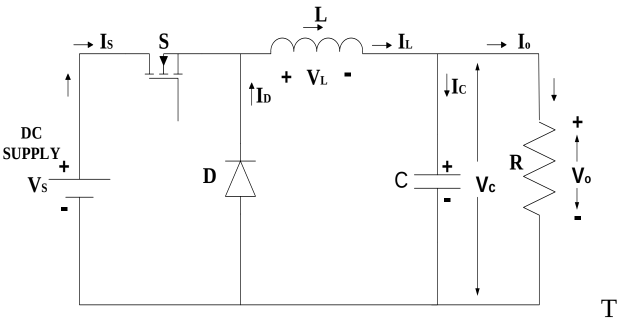

Fig 2. Circuit Diagram of DC-DC Buck Converter

The modes of operation of DC-DC buck converter are explained below

Mode 1: When MOSFET is closed, the current in the load and the charge of a capacitor is increase gradually because the energy also being stored in inductor. Throughout this the diode gets reverse biased because there will be a positive voltage across the cathode.

So the voltage across inductor is $V_L = V_S - V_0$

Mode 2**:** When switch is opened, the polarity of the inductor voltage changes so the diode gets forward biased but current flows in the same direction. Once the inductor is fully discharged, the capacitor starts to discharge and becomes the source of current flowing in the circuit till the switch is turned ON again.

The voltage across inductor is $V_L = -Vo$

So, the output voltage is,

$$V_0 = DV_S$$

Where, $D = T_{ON}/T$

IV. CONTROLLER DESIGN

Fuzzy logic is a mathematical logic based on "degree of truth" unlike the "true or false". Instead of operating at only 0 and 1, it takes different states in between them (i.e., all cases in between truth and false). It handles with imprecise or uncertain data. Fuzzy logic controller [8] is easy develop and design and can operate at wider operating conditions. Fuzzy logic controller is utilized in different industrial automation and household appliances.

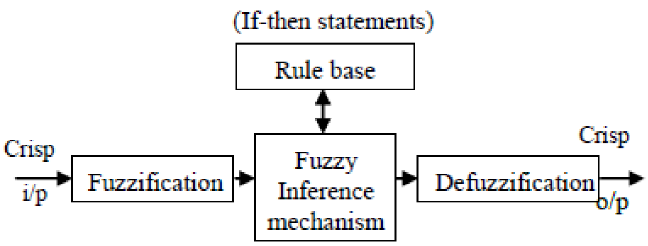

Fig.3. Block diagram of Fuzzy Logic Controller

A. ***Input:*** These are the measured plant output values .

B. ***Fuzzification:*** Each input data i.e., different values of error

(e) and change in error (Δe) are mapped into a membership value in between 0 and 1 by comparing plant output value with the reference.

C. ***Rule base*****:** Rule base is a combination of different types of rules. The rules used in fuzzy logic algorithm are normally "if and then" statements. In this "if" means the condition and "then" means conclusion. Based upon the obtained inputs values i.e., error (e) and change in error (Δe) controller implement these rules and give a proper signal to the plant.

When the load voltage of converter is higher than the required voltage then duty cycle should be minimized.

- When the load voltage of converter is less than the **V**$_{\mathbf{ref}}$ then the duty cycle should be increased.

The AND operator used in this operation and following are the seven variables used for error (e) andchange in error (Δe).

- NB (Negatively Big)
- NM (Negatively Medium)
- NS (Negatively Small)
- Z (Zero)
- PB (Positively Big)
- PM (Positively Medium)
- PS (Positively Small)

Table- I: Rule base for Fuzzy logic controller

(Δe) \ (e)	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

The membership functions like triangular and trapezoidal functions are used to reduce the calculations. Fig. 4 to 6 shows the membership functions of error and change in error and output.

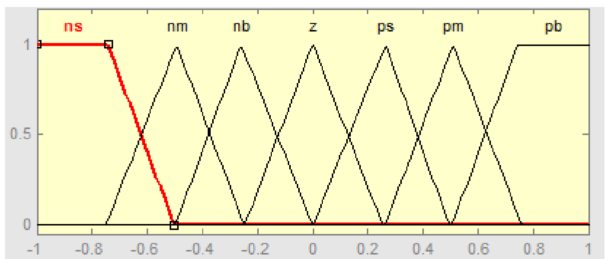

Fig.5. Input error membership function

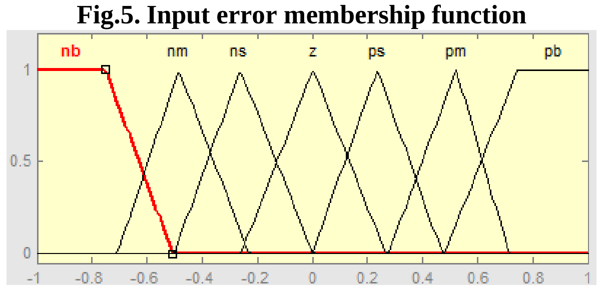

Fig.6. Change in error membership function

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D. ***Inference mechanism:*** In this the decisions is made for different situations and generate a control signal which is given to the plant.

E. ***Defuzzification:*** This is opposite process of fuzzification. It aggregates all the decisions (which are been taken) into a single crisp value which is given to the buck converter through PWM **generator [11].**

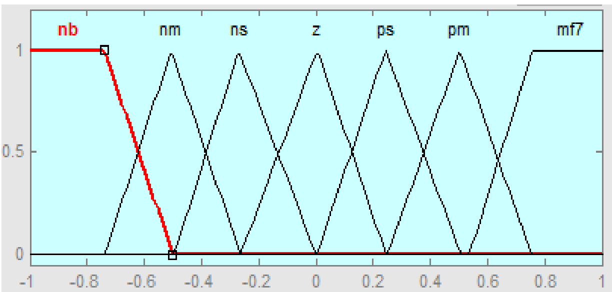

Fig.7. Change in output membership function.

V. SIMULATION RESULTS

The designed Fuzzy logic controller for Buck Converter is implemented in Simulink. The circuit parameters are shown in below table

TABLE II: DC-DC BUCK CONVERTER PARAMETERS

Parameters	Values
Output Power	300W
Inductor	56mH
Capacitor	13uF
Input Voltage	230V
Output Voltage	120V
PWM Frequency	2KHz

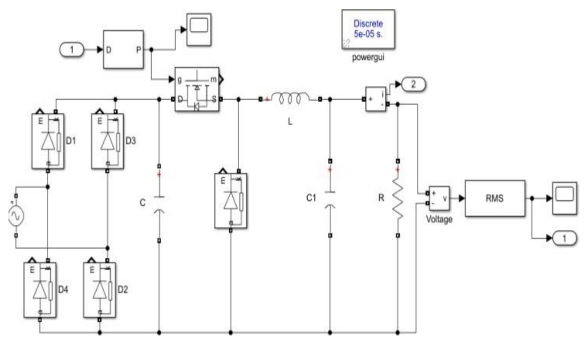

Fig.8. Simulation diagram of DC-DC Buck Converter

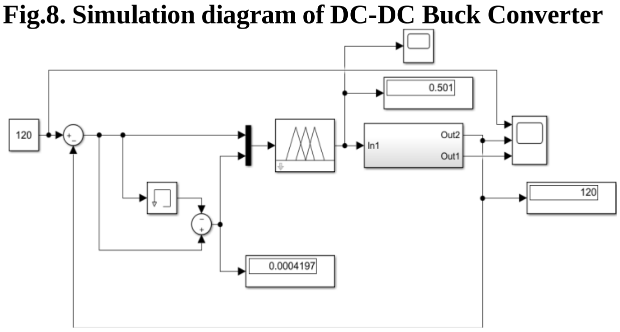

Fig.9. Proposed simulation diagram of fuzzy logic controller for DC-DC Buck Converter

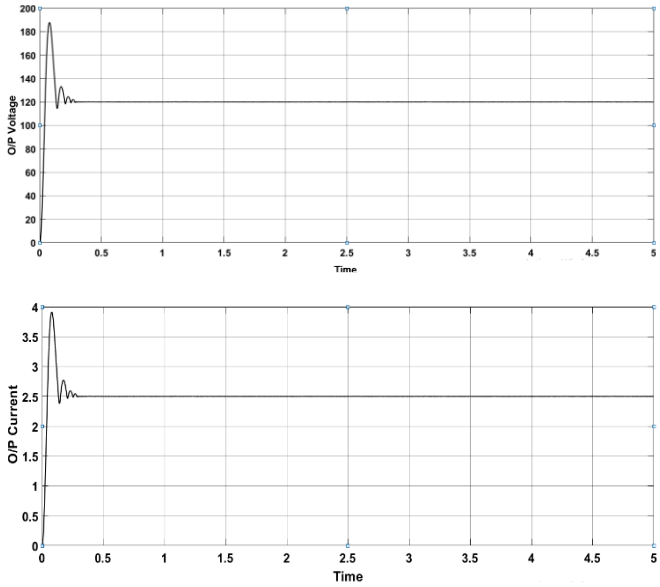

Fig.10. The waveforms output load voltage and inductor current of the DC-DC Buck Converter using Fuzzy Logic Controller for 120V

Table- III: Reference voltage variant conditions

Reference Voltage	Output Voltage
100V	99.3V
130V	129V
140V	139.4V

From the above table when reference voltage of the system changes, the output load voltage of converter is linearly tracking the reference point.

TABLE IV: DIFFERENT LOAD CONDITONS

Load	Output Voltage
10Ω	119.5V
48Ω	120V
50Ω	120.1V

From the above table we can conclude that, when the load resistance value changes, the output voltage of converter is almost constant

TABLE V: INPUT VOLTAGE VARIENT CONDITIONS

Input Voltage	Output Voltage
150V	118.9V
180V	119.3V
250V	120.4V

From the above table, we can observe that the load voltage is constant (approximately) for DC-DC Buck Converter, even though the input voltage changes rapidly.

VI. CONCLUSION

In this paper, the simulation of fuzzy logic controller (FLC) for DC-DC buck converter is implemented. The proposed circuit has been implemented with Matlab/Simulink. The simulation results proves that the Fuzzy logic control method is the suitable controlling method for the DC-DC Buck converter and gives the desired dynamic responses like settling time, delay time, steady state error, maximum overshoot compared to the linear controllers which are unable to cope up with the non-linearity's in the system. Therefore, the fuzzy logic controllers are able to handle the non-linearity in the system effectively, and which increases the overall performance and efficiency thus reduces the cost and time of operation.

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AUTHORS PROFILE

Shaik Gousia Begum, is pursuing Master's degree in Gokaraju Rangaraju institute of engineering and technology (GRIET), Power Electronics branch. Her Master's was about different soft computing techniques for buck converter. She studied different soft computing techniques like Fuzzy logic controller and neural networks algorithms. Her main research interest are power electronics, machine learning and deep leaning.

Syed Sarfaraz Nawaz, is pursuing PhD from JNTUH. He had done his M.Tech with DISTINCTION in 2010 from GRIET Hyderabad and his B.Tech FIRST CLASS in 2007 from SSITS affiliated to JNTUH. He had overall experience of 12 years. He is familiar with software's like MATLAB, LABVIEW, EAGLE, KEIL, E-Tap Software, Proteus, Multisim, VISIM, PSIM etc and worked on DSPACE1104,F28086/7 DSP Control boards, PCI6221 Control Card and TI control boards. His areas of interest are Power Electronics, Power Systems, and Machines

G. Sai Anjaneyulu, is pursuing Master's degree in Gokaraju Rangaraju institute of engineering and technology (GRIET), Power Electronics branch. His Master's was about different soft computing techniques for BLDC motor. he studied different soft computing techniques like Fuzzy logic controller and neural networks algorithms. His main research interest are power electronics, machine learning and deep leaning

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