International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 4 Issue 6, June 2015

Design of Fuzzy Based Controlling System for Buck Converter

Ms. Bhagyashri U. Patil
Department of Electronics and Telecommunication,
Rajarambapu Institute of Technology, Islampur, Sangli
Shivaji University, Kolhapur. Maharashtra, India.

Prof. S. R. Jagtap
Department of Electronics and Telecommunication,
Rajarambapu Institute of Technology, Islampur, Sangli
Shivaji University, Kolhapur. Maharashtra, India.

Abstract— **Controlling of DC-DC converter is vital task in power conversion. DC-DC converters are used in many applications like solar charger, computer power supplies, switching mode regulators, aircrafts etc. Focus of this paper is to model a controlling system for buck converter which controls output of buck converter constant instead of changing load and input supply to buck converter. Controlling method used to control buck converter is fuzzy controlling. In this paper a adaptive fuzzy controller is used for buck converter which is simulated in MATLAB/SIMULINK using fuzzy logic. Fuzzy controlling gives less overshoots in output of buck converter. This control system increases converter efficiency and power efficiency.**

Keywords—buck converter, fuzzy control, MATLAB (SIMULINK).

I. INTRODUCTION

The buck converter is a DC-DC converter that is used to convert high voltage level to low voltage level. Like in our mobile charger a small amount of DC voltage is required which is obtained by using buck converter. But in industry non-linear loads are there which may change output of buck converter that means there may be undesired output voltage received at load. Because of this power and converter efficiency reduces. There are various linear control methods available but these methods have limitations. So there is need of non-linear control method to control buck converter in variant load and variant input supply condition.

Pulse width modulation (PWM), voltage mode control, current mode control, proportional (P), proportional integral (PI), proportional integral derivative (PID) control these are control methods. As all these methods have advantages, have also some disadvantages. But these methods give desired result at large load variation condition.

Fuzzy based control system is simple non-linear method to control buck converter. This system requires only understanding of whole process which is to be controlled. It does not require any mathematical model like other control methods. Overshoot percentage and settling time of output is low by using fuzzy controlling of buck converter.

II. PROPOSED SYSTEM ARCHITECTURE

This is proposed system architecture.

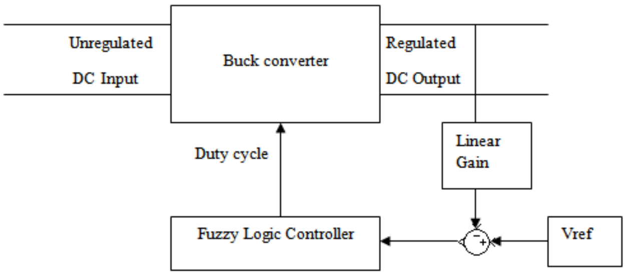

Fig. 1 Fuzzy controlled buck converter

Main goal of proposed system is to obtain constant output voltage of buck converter at variant load and variant supply condition. In this proposed system output voltage of buck converter will be first scaled by linear gain and then will be subtracted from desired voltage. This subtraction gives error. This result will be applied to fuzzy logic controller. Fuzzy logic controller picks changing data and gives adaptive PWM pulses, which are given to power switch of buck converter so that with these proper PWM pulses a desired output voltage will be obtained.

A. Buck converter circuit

A buck converter circuit is as shown in Fig.2 [6] where power electronic switch is controlled by duty ratio as dictated by output voltage requirement.

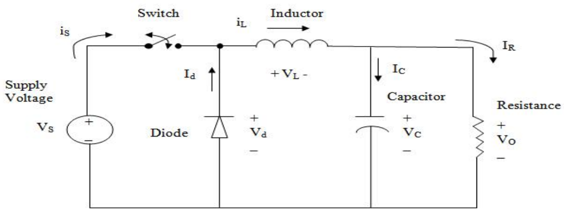

Fig. 2 Buck converter

ISSN: 2278 – 1323

Where V_S= Supply voltage, V_d =Voltage across diode, V_L= voltage across inductor, V_C= Voltage across capacitor, V_o= Output voltage of buck converter.

It has DC input voltage, a power switch, inductor, filter capacitor and load resistance R. Buck converter operates in two modes:

Mode 1 (Switched closed) and Mode 2 (Switch open)

Mode 1: This is switch on state where power switch is closed, diode gets reverse biased and does not conduct.. Voltage across inductor is $V_S - V_{o.}$ Using the inductor equations, the current in the inductor will rise at a rate of $(V_S - V_o)/L$.

Mode 2 : When the switch opens, current must still flow as the inductor works to keep the same current flowing. As a result current still flows through the inductor and into the load. Diode gets forward biased. Inductor current discharges and there is negative voltage drop across inductor, which will be target output voltage and current through the inductor decreases with a slope equal to $-V_o/L$ [1].

B. Fuzzy logic controller

In fuzzy controller controlling is determined from a set of simple linguistic rules. The development of rules requires only understanding of the process to be controlled and doesn't require any mathematical model.

A simple block diagram of fuzzy controller is shown in Fig. 3.

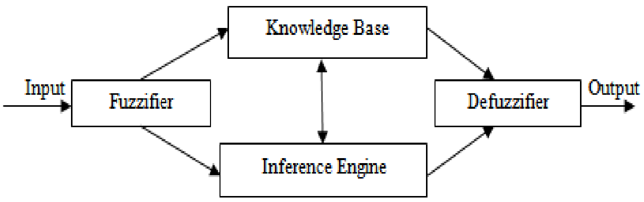

Fig. 3 Fuzzy control system

Four major units of fuzzy controller are: Fuzzifier block, knowledge base, inference engine, defuzzifier block etc [6].

- Fuzzification: In this block classification of input data is done into suitable linguistic values or sets.
- Knowledge base: In this block fuzzy rules are written in the form of IF….THEN statements.
- Inference engine: In this block decision making is done.
- Defuzzification: In this block fuzzy control action is converted into crisp signal.

The derivation of the fuzzy control rules is based on human knowledge about what to do if system output get increase or decrease and based on the following criteria [7].

- When the converter output is not reference value and it far from reference point, duty cycle should be large to bring the output to the reference point rapidly.
- When the converter output is less than desired output voltage then duty cycle should be increased to get target output.
- When converter output is greater than desired output voltage then duty cycle should be decreased to get target output.

In proposed system fuzzification has inputs error and change in error. Output voltage of buck converter and desired voltage are subtracted so result obtained is error.

$$e[n] = \text{Reference voltage} - V_0[n]$$

$$ce[n] = e[n] - e[n-1]$$

The n is time at which values are sampled. e[n] is error resulting from subtraction of output voltage of buck converter form reference voltage sampled at n time.$V_0[n]$ is output voltage of buck converter sampled at n time. ce[n] is change in error resulting from subtraction of current error and previous error.

These two values are multiplied by gain and fed to fuzzy logic controller. The fuzzy controller output gives change in duty cycle. This change in duty cycle and previous duty cycle are added together and final output i.e. duty cycle given to the gate of power switch, which is MOSFET.

In fuzzification [6], first step is to decide membership functions for inputs and outputs. Membership functions assigned to input and outputs are PB, PS, ZE, NS, NB. Where NB = Negative big, NS = Negative small, ZE = Zero equal, PS = Positive small, PB = Positive big. Following is rule tableI given which is used for change in duty cycle values of our buck converter system.

TABLE I
FUZZY CONTROL RULES

Error / Change in error	NB	NS	ZE	PS	PB
PB	ZE	PS	PB	PB	PB
PS	NS	ZE	PS	PB	PB
ZE	NB	NS	ZE	PS	PB
NS	NB	NB	NS	ZE	PS
NB	NB	NB	NB	NS	ZE

Using fuzzy toolbox in SIMULINK two inputs to fuzzy controller tool box are mapped in universe (-1 to 1). FIS file in SIMULINK is obtained as shown in Fig.4. and in Fig.5 rule viewer is shown which shows change in duty cycle value for particular error and change in error values given to the fuzzy toolbox. It shows that for error = 0.183, change in error = 0, change in duty cycle = 0.196.

ISSN: 2278 – 1323

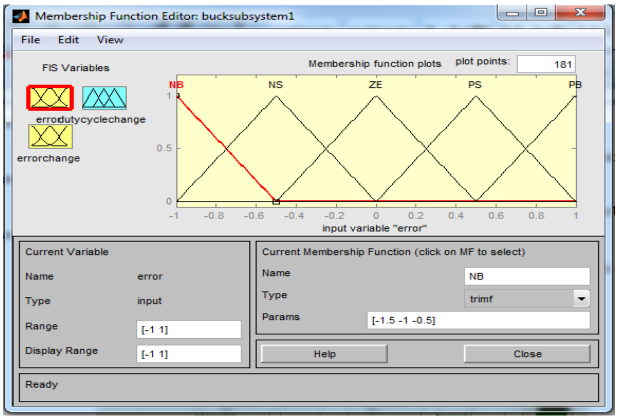

Fig.4 Membership function editor window of FIS file used in simulation

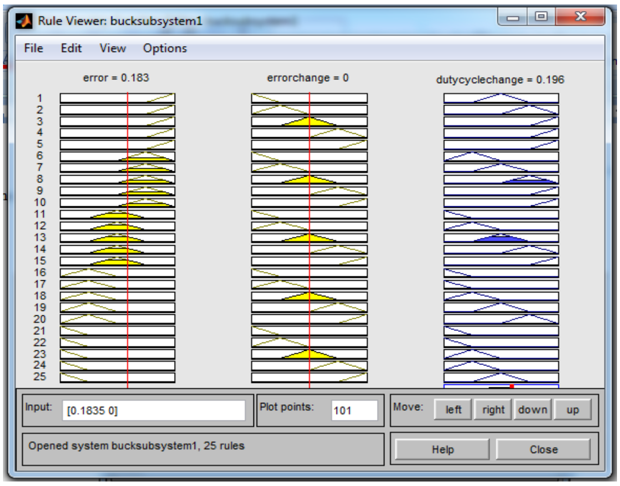

Fig.5 Rule viewer window of FIS file

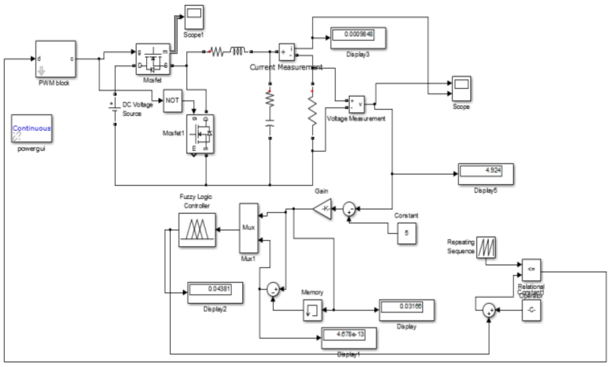

Fig. 6 Simulink model of fuzzy controlled buck converter

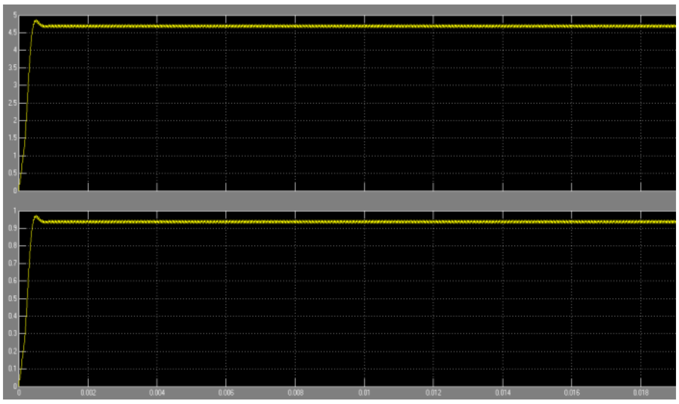

Fig. 7 Simulink result of fuzzy controlled buck converter for 5 ohm load

III. SIMULATION RESULTS

Fuzzy controlled buck converter is simulated using MATLAB 2010.

Buck converter parameters are as given in Table II

TABLE II
BUCK CONVERTER PARAMETERS

Parameter	Value
Input voltage	12 V
Output voltage	5V
Inductor value	145.83 uH
Capacitor value	200 uF
PWM frequency	25 kHz

In Fig. 7 waveforms of buck converter output voltage (upper part) and output current (lower part) is shown.

In Table III, output voltage for different load (resistor) values resulted in MATLAB simulation is given.

TABLE III
MATLAB SIMULATION RESULT OF FUZZY CONTROLLED BUCK CONVERTER FOR SUPPLY VOLTAGE 12 V AND LOAD VARIANT CONDITION

Load (Resistor) value in ohm	Output voltage in Volt
5	4.9
500	5
1000	5.1
2	4.8

In Table IV, output voltage for different input supply values resulted in MATLAB simulation is given.

TABLE IV
MATLAB SIMULATION RESULT OF FUZZY CONTROLLED BUCK CONVERTER FOR 500 OHM LOAD AND INPUT SUPPLY VARIANT CONDITION

Supply voltage in Volt	Output voltage in Volt
12	5
20	5.11
30	5.3

ISSN: 2278 – 1323

From above Table III and Table IV load values changed from 2 ohm to 1000 ohm we have get constant output voltage of buck converter. Also for changing supply voltage condition output voltage of buck converter is constant. Overshoots are also very small. Thus fuzzy controlled buck converter is efficient method to control buck converter.

IV. CONCLUSION AND FUTURE IMPROVEMENT

The proposed system is designed to control buck converter. Fuzzy logic controller is simple method and it doesn't require any mathematical model. Only thorough understanding of plant which is to be controlled is necessary. From the simulated result, fuzzy controlling is adaptive controlling method to control constant output voltage at buck converter output at variant load and variant supply voltage conditions. Settling time to obtain desired output voltage of buck converter is very low.

Currently we are working on hardware implementation of fuzzy controller for buck converter.

REFERENCES

[1] Muhammad H. Rashid, "Power Electronics Circuits, Devices and Application",3rd ed,2006,Pearson,ch.5, pp.186-190

[2] Liping, Guo, J.Y. Hung, R.M. Nelms, ''Evaluation of DSP-Based PID and Fuzzy Controllers for DC--DC Converters'', IEEE Trans. on Industrial Electronics, June 2009,Vol. 56, No. 6, pp.2237- 2248..

[3] S. M. Muyeen, R. Takahashi, J. Tamura, "Operation and Control of HVDC-Connected Offshore Wind Farm", IEEE Trans. on sustainable energy , April 2010,Vol. 1, No. 1, pp.30-37.

[4] S. M. Muyeen, A. Al-Durra, "Modeling and Control Strategies of Fuzzy Logic controlled Inverter System for Grid Interconnected Variable Speed Wind Generator", IEEE systems journal, December 2013, Vol. 7, No. 4, pp.817-824.

[5] N. S K Sastry, Dr. S. Pattnaik,, "Reduction of Ripple in a single phase buck converter by Fuzzy logic control", International Journal of Engineering Research and Applications (IJERA) , May-Jun 2012,Vol. 2, Issue 3, pp.2202-2204.

[6] R. Ganesan , S. Vignesh, "Design and Simulation of a Fuzzy Non Linear PI Controller for Dc-Dc Buck Converter for Low Steady State Deviations and Its Performance Comparison with PI Controller", International Journal of Innovative Research in Science, Engineering and Technology, May 2014, Vol. 3, Issue 5, pp.12695-12701.

[7] K.V.H. Prasad, CH.U. M. Rao, A.S. Hari, "Design and simulation of a fuzzy Logic Controller for Buck & Boost Converters", International Journal of Advanced Technology & Engineering Research (IJATER) , May 2012,Vol. 2, Issue3, pp.218-224.

[8] M.S. R. Krishna, Dr. S. Satyanarayana, "Design and Analysis of PI like Fuzzy Logic Controlled Buck Converter", International Journal of Electronics and Computer Science Engineering,vol.2, No.3, pp.1050-1058**.**

[9] Shamik Bandyopadhyay1, "Advance Control techniques for DC/DC Buck Converter with Improved Performance", January 2015,Vol. 4, Issue 1, pp. 201-208.

ISSN: 2278 – 1323