AENSI Journals
Advances in Natural and Applied Sciences

ISSN:1995-0772 EISSN: 1998-1090

Journal home page: www.aensiweb.com/ANAS

Improved Control Strategy on Buck-Boost Converter Fed DC Motor with Fuzzy Logic Controller

[1]S. Ben John Stephen and [2]T. Ruban Devaprakash

[1]*Assistant Professor, Electrical and Electronics Engineering, Noorul Islam University, Tamil Nadu, India.*
[2]*Professor, Electrical and Electronics Engineering, Noorul Islam University, Tamil Nadu, India.*

ARTICLE INFO
Article history:
Received 3 September 2014
Received in revised form 30 October 2014
Accepted 4 November 2014

Keywords:
buck-boost; ac-dc converter; PAM; dc motor; power electronics controller; fuzzy logic controller

ABSTRACT
This paper presents comparison of the performance of Fuzzy Logic Controller with that of conventional closed loop controller for buck-boost converter fed dc motor based on voltage control method. For ac to dc conversion, diode bridge rectifier-chopper configuration gives higher input power factor than that of thyristor controlled rectifiers. So, one such configuration called ac-dc buck-boost converter feeding a dc drive is taken up for a detailed study in this paper. The performance of the proposed method is investigated using MATLAB simulation models of buck-boost converter fed dc motor.

To Cite This Article: S. Ben John Stephen and T. Ruban Devaprakash., Improved Control Strategy on Buck-Boost Converter Fed DC Motor with Fuzzy Logic Controller. **Adv. in Nat. Appl. Sci.,** *8(20): 79-84, 2014*

INTRODUCTION

Generally, the conversion of ac power to dc power is carried out using a diode bridge and a large dc capacitor connected to the load terminal. Such an conversion has many disadvantages, including high input current harmonic components and an invariable output dc voltage. Many configurations have been presented to minimize the harmonic current components and improve the input power factor (Prasad, A.R., P.D. Ziogas, S. Manias., 1990)

Many attempts have been made using Pulse Width Modulation (PWM) techniques (Mechi, A., S. Funabiki., 1993) to improve the performance of the switching device. The commonly used Proportional-Integral-Derivative (PID) controllers are simple to be realized, but they suffer from poor performance if there are uncertainties and nonlinearities. The Fuzzy Logic Controllers have emerged as a tool for difficult control problems of unknown nonlinear systems.

This paper presents Modeling and MATLAB simulation of ac–dc buck-boost converter fed dc motor with Pulse Area Modulation technique. It also describes the FLC design for ac-dc buck-boost converter fed dc motor which is simulated in MATLAB software and the simulation results are presented. Finally, the last section presents conclusions derived from this work.

Circuit Description and Principles of Operation:

Fig. 1 represents a separately excited dc motor fed from an ac-dc buck-boost converter. This converter comprises of a diode bridge, a switching device (IGBT), reactor in the dc link, a series connection of a diode and a capacitor parallel to the dc reactor. The step-up and step-down characteristics of the output voltage can be easily obtained by appropriately switching IGBT.

Corresponding Author: S. Ben John Stephen, Assistant Professor, Electrical and Electronics Engineering, Noorul Islam University, Tamil Nadu, India.,
E-mail: benjohnstephen@gmail.com., Mobile : +919952262775.

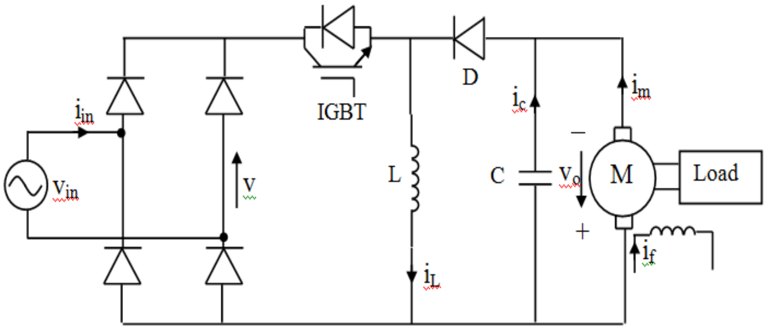

Fig. 1: AC-DC buck-boost converter fed dc motor

Pulse Area Modulation Method:

Principle of Pulse Area Modulation:

Fig. 2 shows the implementation PAM control circuit. The reactor voltage is amplified and fed into the integrating circuit. This integrating circuit is reset at a constant interval, and its output is the saw-tooth wave, which has a gradient that is proportional to the value of inductor current. This saw-tooth wave is compared to the reference wave, thereby obtaining the PWM wave that drives the switching device IGBT.

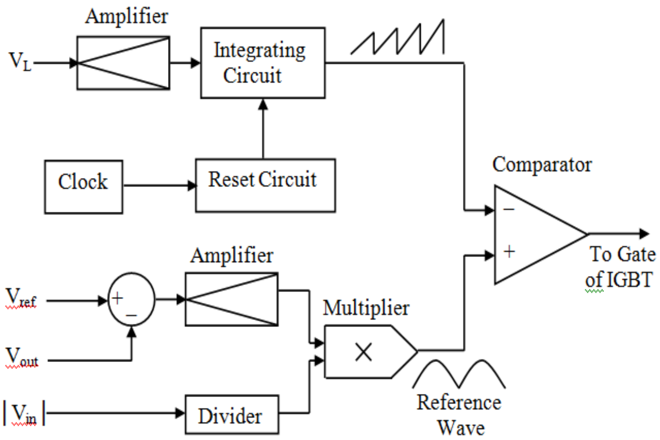

Fig. 2: PAM Control Circuit

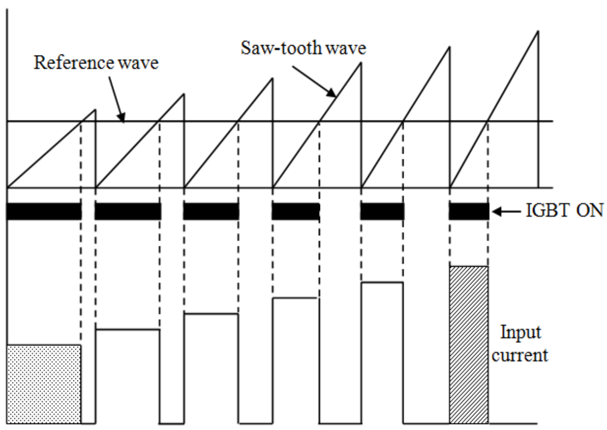

Fig. 3: Gating Signals using PAM technique

Generation of PAM Gating Signals:

Fig. 3 illustrates the generation PAM gating signals which is employed for the control of buck-boost converter. The gradient of saw-tooth wave varies proportionally to reactor current. When reactor current gradually increases, the current becomes a saw-tooth wave whose gradient increases gradually as shown in Fig. 3. If the reference wave has a constant voltage, the duty ratio gradually decreases. So, the input current

Advances in Natural and Applied Sciences, 8(20) Special 2014, Pages: 79-84

waveform becomes square wave in which peak value gradually increases and the pulse width gradually decreases.

The pulse shown with hatched lines has twice the peak value as that shown with dotted area, but it has one-half of pulse width with equal area. If the reference waveform is constant, the areas of these pulses will not change, but if the reference waveform is changed into a sine wave as shown in Fig. 2, the input current will change into sine wave. Thus this controller also improves the input power factor.

Simulation And Results:

For the simulation, a dc motor of rating 180V, 8.5A, 1.5kW, 735rpm having armature resistance R_m=2.80Ω, armature inductance L_m=5.0mH, motor constant K_m=2.11V/(rad/s) and moment of inertia J=0.25 kgm^2 is used. A capacitor C of 330µF, inductor L of 95.8mH and switching frequency of 1.8 kHz have been chosen for this simulation.

Fig. 4 shows the simulated motor speed characteristics using Pulse Area Modulation technique.

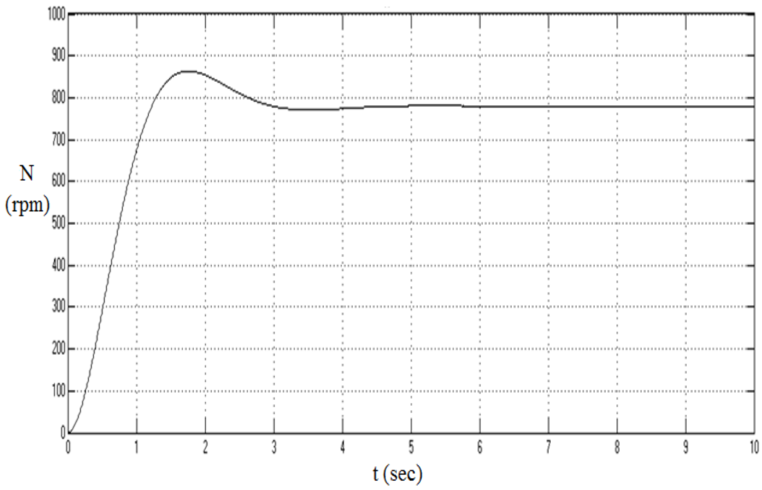

Fig. 4: Simulated motor speed characteristics using PAM technique

Fuzzy Logic Control Method:

Fuzzy Logic Controller:

The basic idea behind Fuzzy Logic Controller is to incorporate the "expert experience" of a human operator in the design of the controller in controlling a process whose input-output relationship is described by collection of fuzzy control rules involving linguistic variables rather than a complicated dynamic model. In Fuzzy Logic System, the linguistic variables are used instead of crisp variables.

The typical architecture of FLC comprises of four stages namely fuzzification, fuzzy rule base, inference engine and defuzzification.

Fuzzification:

Fuzzification is the process of transforming crisp variables into suitable linguistic values. Instead of using mathematical formulas, a FLC uses fuzzy rules to make a decision and generate the control effort. The rules are in the form of IF-THEN statements. Actually, the solutions are based on the experience of a designer or the previous knowledge of the system. In this paper, the knowledge from the PAM controller borrowed first to help to define rules.

In this paper, motor speed is the variable. The inputs to the FLC are error e(k) and change in error Δe(k). The output is the duty cycle d(k). The equation for error and change in error are given in Eq. 1 and Eq. 2.

$$E = e(k) = w_r(k) - w(k). \quad (1)$$

$$CE = \Delta e(k) = e(k) - e(k-1). \quad (2)$$

where k is the time index.

Rule Table and Inference Engine:

Seven fuzzy linguistic variables are used for the input variables e(k) and Δe(k). Those are Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB). The popular shapes are triangular and trapezoidal because these shapes require low calculation time. The initial membership functions are illustrated in Fig. 5.

Advances in Natural and Applied Sciences, 8(20) Special 2014, Pages: 79-84

As observed from the PAM controller, the initial rules are constructed as shown in Table.1.

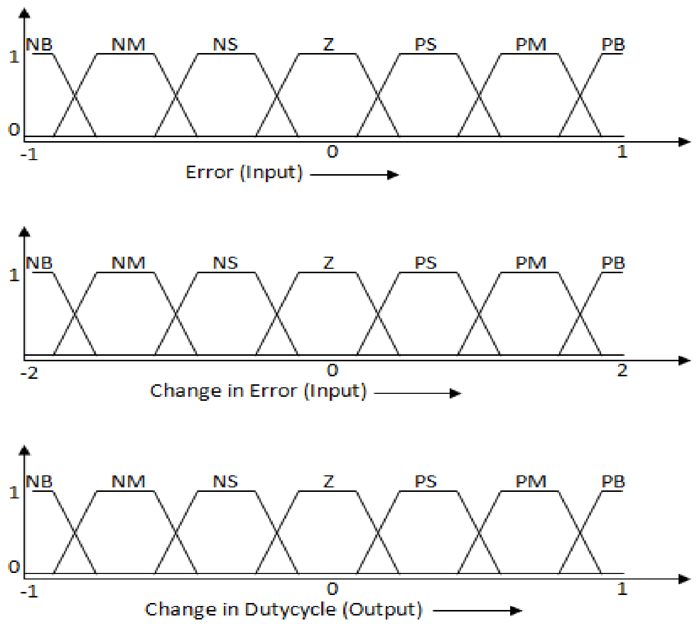

Fig. 5: Initial membership functions

Table 1: Initial Rules

CE \ E	NB	NM	NS	Z	PS	PM	PB
PB	Z	PS	PM	PB	PB	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PS	NM	NS	Z	PS	PM	PB	PB
Z	NB	NM	NS	Z	PS	PM	PB
NS	NB	NB	NM	NS	Z	PS	PM
NM	NB	NB	NB	NM	NS	Z	PS
NB	NB	NB	NB	NB	NM	NS	Z

Because the FLC uses the knowledge from the PAM controller, the performance obtaining from the FLC is similar to the PAM controller. The efficiency can be improved by adjusting the membership functions and rules. The membership functions are adjusted by making the area of membership function near zero region narrower to produce finer control resolution. After adjusting the membership functions and rules, the final membership functions and rules are obtained as shown in Fig. 6 and Table.2 respectively.

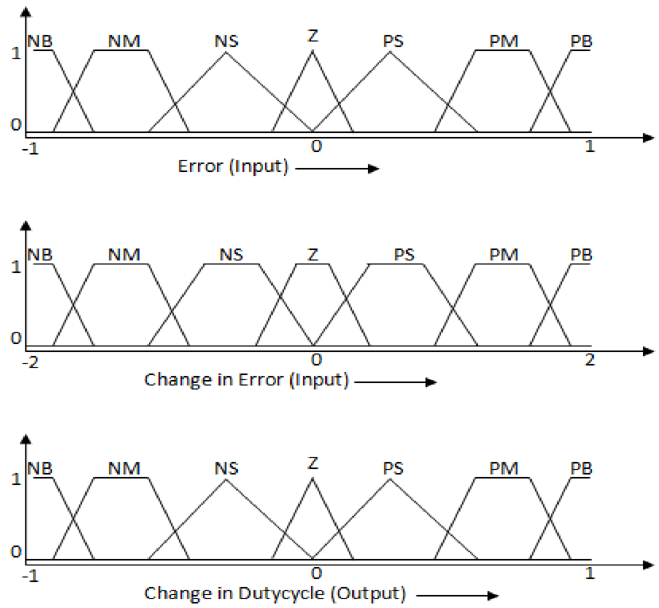

Fig. 6: Final membership functions

Advances in Natural and Applied Sciences, 8(20) Special 2014, Pages: 79-84

Table 2: Final Rules

CE \ E	NB	NM	NS	Z	PS	PM	PB
PB	NM	NS	NS	NB	PB	PB	PB
PM	NM	NM	NS	NB	PB	PB	PB
PS	NB	NM	NM	Z	PB	PB	PB
Z	NB	NB	NM	Z	PM	PB	PB
NS	NB	NB	NB	Z	PM	PM	PB
NM	NB	NB	NB	NB	PS	PM	PM
NB	NB	NB	NB	NB	PS	PS	PM

Defuzzification:

In defuzzification process, the linguistic variables are converted into crisp variables (Yousef, H.A., H.M. Khalil., 1995). As the center of gravity method is considered to be the best well-known defuzzification method, it is utilized in this paper. The formula of this method is

$$U = \frac{\sum_{i=1}^{n} S_i F_i}{\sum_{i=1}^{n} F_i}. \quad (3)$$

where U is the output from defuzzification, S_i is the specific position at i^{th} fuzzy set, and F_i is the membership degree at that position. The defuzzified output is the duty cycle d(k). The change in duty cycle Δd(k) can be obtained from d(k) and previous duty cycle d(k-1) which is given in Eq. 4.

$$\Delta d(k) = d(k) - d(k-1). \quad (4)$$

Simulation and Results:

The simulation of Buck-Boost Converter fed DC motor with Fuzzy Logic Controller is done using MATLAB/Simulink toolbox. Simulation result is shown in Fig. 7.

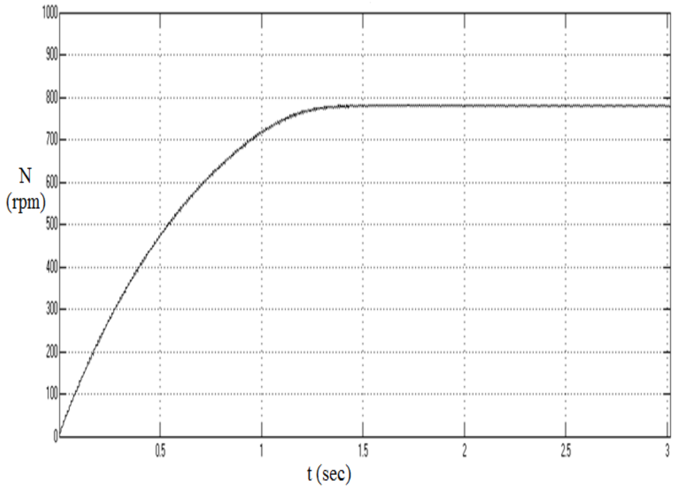

Fig. 7: Simulated motor speed characteristics using Fuzzy Logic Controller

Advantages of Fuzzy Logic Control:

Comparing the motor speed characteristics shown in Fig.4 and Fig.7, it is evident that the settling time of speed is 1.3 seconds in Fuzzy Logic Control method and 3 seconds in PAM control method for the same dc motor and load conditions. So, the settling time is less in model using Fuzzy Logic Controller.

Conclusion:

AC-DC Buck-Boost converter employing a single switching device such as IGBT together with a single-phase diode bridge rectifier is suitable for the control of small capacity dc drives.

The proposed converter contributes to a reduced number of power switching devices. This may result in advantages such as small installation size and less energy loss. One-switch converter is very convenient for an economical variable dc voltage supply since the number of switches does not highly affect the characteristics of the ac-dc converters.

The settling time of the speed of motor is less in model using Fuzzy Logic Controller when compared to other model using Pulse Area Modulation technique. Thus, the performance of the Fuzzy Logic Controller is superior to the conventional control techniques.

Advances in Natural and Applied Sciences, 8(20) Special 2014, Pages: 79-84

REFERENCES

Busse, A., J. Holtz., 1982. Multiloop control of a unity power factor fast switching ac to dc converter. IEEE Pow. Elec. Special. Conf., pp: 171-179.

Chen, J., D. Maksimovic, R. Erickson, 2001. Buck-Boost PWM Converters having two independently controlled switches. Proc. IEEE PESC, pp: 736-741.

Itoh, R., K. Isshizaka, 1989. Single-phase sinusoidal converter using mosfets. IEE Proc., pp.237-242.

Lee, Y.J., K.Y. Suh, D.W. Chung, 1987. Optimal PAM strategy for variable-speed drive of three-phase induction motor. Trans. Korean Inst. Elect. Eng., pp: 616.

Liu, K.H., Y.L. Lin., 1989. Current waveform distortion in power factor correction circuits employing discontinuous-mode boost converters. Proc. IEEE PESC'89, pp: 825-829.

Mechi, A., S. Funabiki, 1993. Step-up/down voltage PWM ac-dc converter with one switching device. IEE Proc., pp: 35-43.

Prasad, A.R., P.D. Ziogas, S. Manias, 1990. A novel passive wave shaping method for single-phase diode rectifiers. IEEE Trans. Ind. Electron, pp: 521.

Salmon, J.C., 1992. Circuit topologies for single-phase voltage doupler boost rectifiers. Conference Proceedings of the IEEE Apec'92, Boston, USA, pp: 549-556.

Senthil Kumar, N., V. Sadasivam, K. Prema, 2004. Design and simulation of fuzzy controller for cloesd loop control of chopper fed embedded DC drives. Proc. IEEE International Conference, POWERCON, Singapore.

Stihi, O., B.T. Ooi., 1988. A Single-phase controlled current PWM rectifier. IEEE Trans. Power Electron., pp: 453.

Takahashi, I., W. Ikeshita., 1985. Improvement of input current waveforms of a single-phase rectifier circuit. IEE J.Proc., pp: 174.

Yousef, H.A., H.M. Khalil, 1995. A fuzzy logic-based control of series DC motor drives. Proc. IEEE International Symposium, pp: 517-522.