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PID - Fuzzy Logic Hybrid Controller for a Buck Converter

Aqulin Ouseph[1]*, Prof. Babu Thomas [2], Prof. Thomas P Rajan[3]

PG Student [PE], Dept. of EEE, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[1]

Assistant Professor, Dept. of EEE, Mar Athanasius College of Engineering, Kothamangalam, Kerala, India[2,3]

ABSTRACT: PID fuzzy logic hybrid controller can be used to improve the dynamic response of digitally controlled DC-DC converter. Classical linear techniques have stability limitation around the operating points. Fuzzy PID hybrid controller is an important control methodology to control power systems. The aim is to improve the dynamic response of a digital controlled DC-DC converter under load variation. The fuzzy controller is implemented as gain scheduler that computes proportional, integral and derivative constants values for PID controller. To illustrate the effect of each controller type on the converter performance, the buck regulator topology is selected. Comparison between conventional PID controller, fuzzy logic controller and fuzzy PID hybrid controller, are presented. The comparison of result obtained from PID controller, fuzzy logic controller, fuzzy - PID hybrid controller for DC-DC converter shows the benefit of the hybrid algorithm in terms of transient response under load variation conditions. Simulations were carried out using MATLAB/SIMULINK.

KEYWORDS: Buck converter, FLC (Fuzzy Logic Controller), Hybrid fuzzy PID Controller, MATLAB/SIMULINK, PID Controller.

I.INTRODUCTION

A good control system requires the use of efficient techniques that provide simple and practical solutions despite the system disturbances and uncertainties in order to fulfill the performance requirements. Analysis and control of DC-DC power converters is difficult due to the presence of nonlinear phenomena. Classical linear techniques have stability limitations. Conventional control techniques used for DC-DC converters are PID controllers which tend to give linear characteristics. It is continuously desirable for buck converters with constant output voltage that the output voltage remains constant in both steady and transient operations whenever the supply voltage and/or load current is disturbed.

Fuzzy logic is a form of knowledge representation in a specific way suitable for notions that cannot be defined precisely but which depend upon their context based on a system of non-digital set theory and rules. This technique has advantage like ability to deal with vague systems and its use of linguistic variables. Fuzzy control has also been applied to control DC-DC converters because of its simplicity, ease of design and ease of implementation. Fuzzy controllers do not need an exact mathematical model for the system being controlled and are suited to nonlinear time-variant systems. They are designed on the basis of expert knowledge of the converters not on the rigorous theories.

Proportional-integral-derivative (PID) control provides a generic and efficient solution to real world control problems. The combination of PID and flexible fuzzy logic controller makes the control of nonlinear objects, such as the electricity grid, more feasible [1]. In order to prevent the overshoot and the variation in the output voltage of the buck converter, hybrid fuzzy controller plus PI are used [2]. From the literature review it can be analyzed that Fuzzy PID controller reduces overshoot as compare to classical PID controller.

II.HYBRID CONTROLLER FOR CONVERTERS

DC converters are extensively used in control of electrical drives, one such application is regenerative braking of DC drives, where energy is returned back into the supply. DC-Dc converter has two stages namely, power stage which is the buck converter and the controller stage. Output which should be a constant value is changed whenever there is a change in input or load. Controller is a loop which should be designed in such a way that it makes changes in power

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stage to make the output to quickly settle to the desired value. Fuzzy logic controller provides fast rise time and less percentage of overshoot. PID controller provides low steady state error i.e. better accuracy [3]. Therefore a hybrid model is designed using the two controllers which improve the Performance of DC-DC Buck converter. Block diagram of hybrid model can depicted as figure 1.

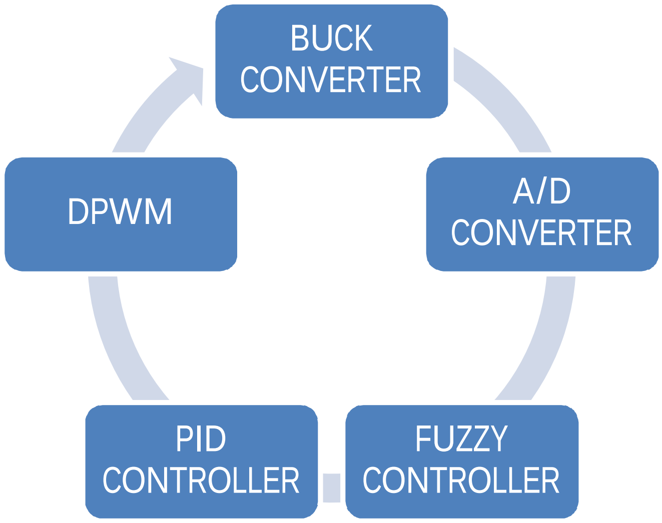

Fig .1 Block diagram of hybrid controller

Fuzzy associative matrices are expressed in the form of IF....THEN which totally have 25 rules. These rules are used to control DC-DC converter such that output voltage is tuned with respect to the reference output voltage. The membership function plot for error, change in error and output are shown in figures 2, 3 respectively. The error signal and change in error signal have five Gaussian membership functions i.e. ce(t)/e(t)={NB,NS,ZE,PS,PB} and their values ranges from (-1,1) as shown in figures 2, 3. Advantage of Gaussian over other membership functions includes smoothness and nonzero at all points. Triangular membership function can also selected as the membership function. There is no large variation in result with the change of membership function. Importance is to the logic. There will be small variation in results. The output signals K_p, K_i, K_d have the same degrees with five Gaussian membership functions each. Fuzzy associative matrices are shown in table 1, 2, 3.

Table 1: Associative matrices for K_p

K_p			Error(e)			
		NB	NS	ZE	PS	PB
Change in	NB	VL	VL	MB	MB	ME
Error(CE)	NS	VL	MB	MB	ME	MS
	ZE	MB	MB	ME	MS	MS
	PS	MB	ME	MS	MS	ZE
	PB	ME	MS	MS	MS	ZE

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Table 2: Associative matrices for K_i

K_I			Error(e)			
		NB	NS	ZE	PS	PB
Change in	NB	ZE	ZE	MS	MS	ME
Error(CE)	NS	ZE	MS	MS	ME	MB
	ZE	MS	MS	ME	MB	MB
	PS	MS	ME	MB	MB	VL
	PB	ME	MB	MB	VL	VL

Table 3: Associative matrices for K_d

K_d			Error(e)			
		NB	NS	ZE	PS	PB
Change in	NB	MB	ZE	ZE	ZE	MB
Error(CE)	NS	ME	ZE	MS	MS	ME
	ZE	ME	MS	MS	MS	ME
	PS	ME	ME	ME	ME	ME
	PB	VL	MB	MB	MB	VL

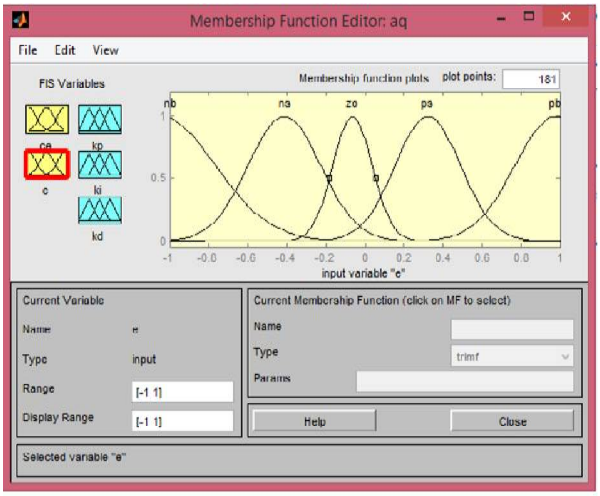

Fig .2 Membership function for e

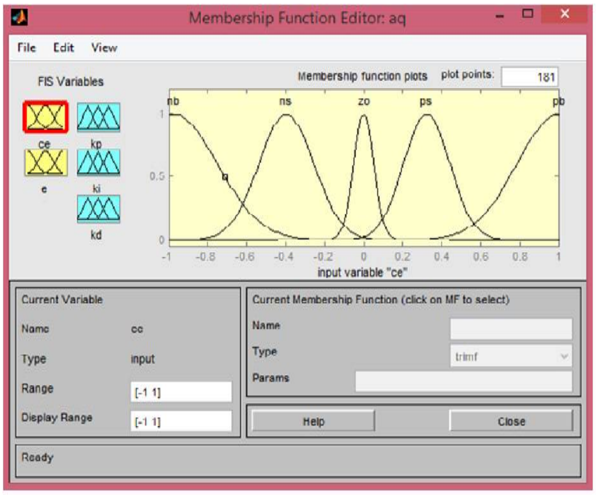

Fig .3 Membership function for ce

III.SIMULATION RESULTS

Figure 4 indicates the simulated model of hybrid PID fuzzy logic controller. At first the output voltage is compared with the reference voltage thereby error and change in error are obtained. The error and change in error are fed as two inputs to fuzzy controller which computes K_p , K_i, and K_d. The obtained K_p , K_i, and K_d values are fed to PID controller and the corresponding duty ratio command is obtained. The signal generated from PWM block as per the duty command from PID module is fed to the gate of MOSFET of buck converter. Figure 5, 6, 7 shows output current, voltages of conventional PID, Fuzzy, and hybrid controller respectively. Figure 8 shows gate pulse of hybrid controller and automatic tuning of PID coefficients by fuzzy module in hybrid controller.

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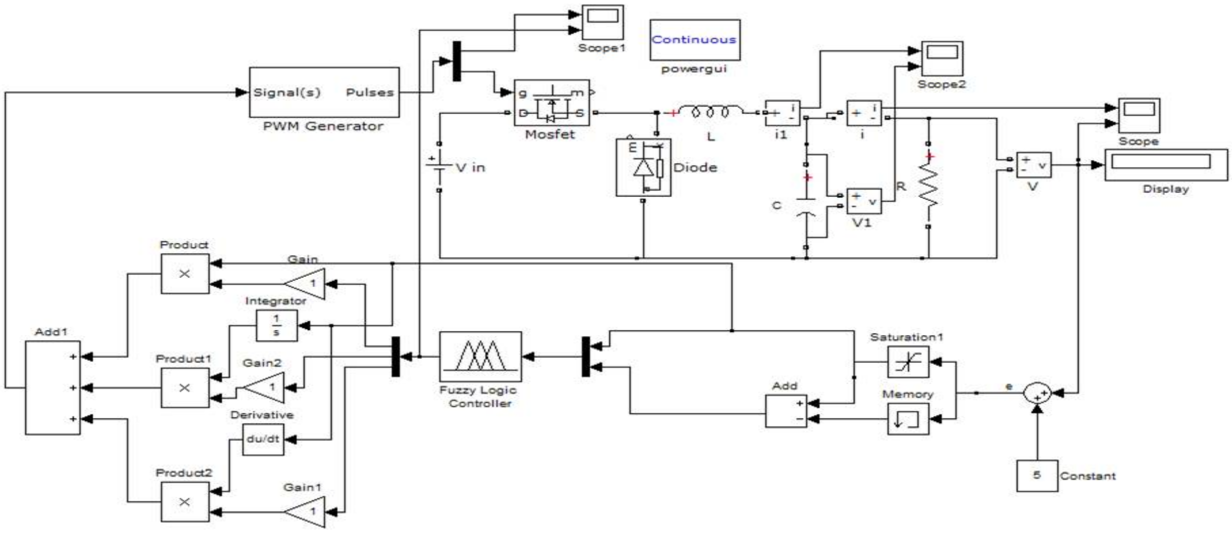

Fig .4 Simulink model of hybrid controller

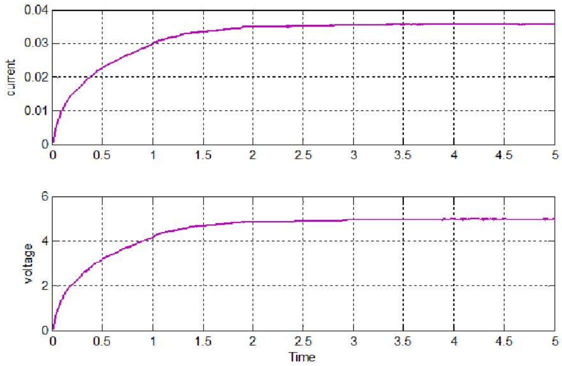

Fig .5 Output plots of PID controller

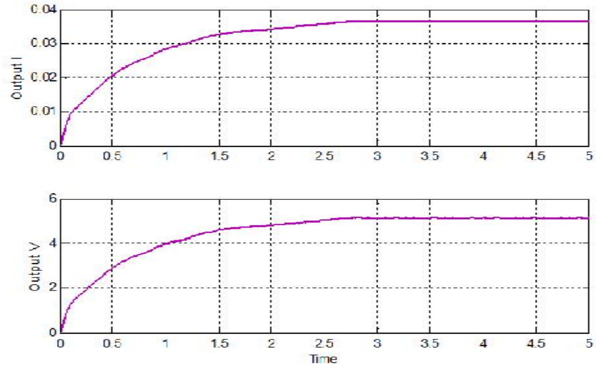

Fig .6 Output plots of Fuzzy controller

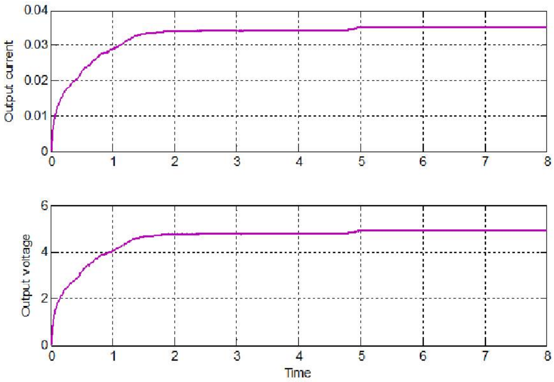

Fig .7 Output plots of Hybrid controller

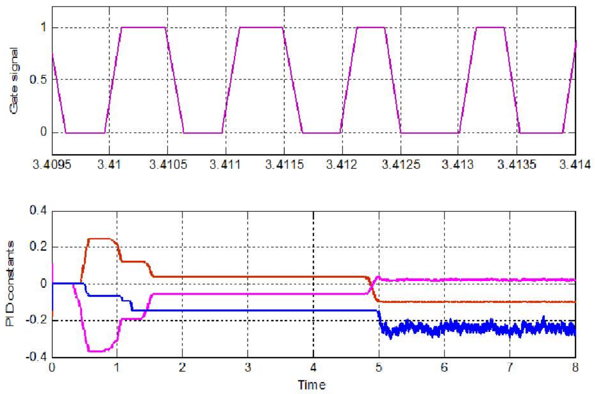

Fig .8 Gate pulse & automatic tuning of K_p, K_i, and K_d

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Table 4: Comparative study

Controller	PID	Fuzzy	Hybrid
Rise Time	1.2047	1.3823	0.0108
Settling Time	3.5	3	3.8153
Steady State Error	0.9930	0.1254	0.1090
Overshoot	5.01	2.5077	1.023

For demonstrating the performance of the hybrid controller it is compared with conventional PID controller and fuzzy controller as shown in table 4. Rise time is decreased by 1.2S compared to PID controller. Steady state error is reduced by 13% compared to Fuzzy controller. Overshoot is reduced to 59% of that of Fuzzy controller.

IV.CONCLUSION

PID controllers are the most commonly used controllers in industrial process control because of their advantages. The purpose of a Fuzzy-PID hybrid controller is to achieve the improvement in the transient response for change in load conditions. Hybridization of these two controller structures exploits the beneficial sides of both categories. The fuzzy controller is implemented as gain scheduler for PID controller. The fuzzy gain scheduler automatically tunes coefficients K_p, K_i, and K_d thereby, improving the transient response for load conditions. The comparative study Results point out that FLC tuned by PID Controller is superior to the other control strategies because of fast transient response, minimum steady state error and low rise time etc. Hence, It achieves the most closely output voltage regulation.

REFERENCES

[1] Nguyen Gia, Mai Tuan, Tran Cong, Nguyen Huu, "PID-Fuzzy Logic Hybrid Controller For Grid-Connected Photovoltaic Inverters" , IFOST IEEE Proceedings, 2010.
[2] Reshmi R, Sumi Babu, "Design and Control of DC-DC Converter using Hybrid Fuzzy PI Controller" , IJREAT, Volume 1, Issue 3, June-July, 2013.
[3] Deepak Renwal, Mahendra Kumar, "Hybrid Pi-fuzzy Logic Controller Based Dc-Dc Converter" , IEEE International Conference on Green Computing and Internet of Things,2015.
[4] Priyanka Srivastava, Shri S.k. Singh, Shri. Nishant Tripathi, "Hybrid PID-fuzzy Controller in buck-boost Converter", IJAERT 30th -31st August 2014.
[5] Vimala Vindhya, Venkat Reddy, "PID-Fuzzy Logic Hybrid Controller For A Digitally Controlled DC-DC Converter" , ICGCE, International Conference 12-14 Dec. 2013 .
[6] Bouchafaa, F., Hamzaoui, I. and Hadjammar, A. (2011): Fuzzy Logic Control for the tracking of maximum power point of a PV system, Energy Procedia, Vol. 6, pp. 633-642.
[7] Cheng, C. (2011): Design of output filter for inverters using fuzzy logic, Expert Systems with Applications, Vol. 38(7), pp. 8639-8647.
[8] Control Tutorials for Matlab, PID Tutorial. http://www.engin.umich.edu/group/ctm/PID/PID.html
[9] Corcau, J. I. and Stoenescu, E.(2007): Fuzzy logic controller as a power system stabilizer, International Journal Of Circuits, Systems And Signal Processing, Vol. 1(3), pp 266-273.
[10] Dereli, T., Bayasoglu, A., Altun, K., Durmusoglu, A. and Türksen, I. B. (2011): Industrial applications of type-2 fuzzy sets and systems: A concise review, Computers in Industry, Vol. 62(2), pp. 125-137.
[11] Dixon, L. (2001): Control loop design, Unitrode Corporation. http://focus.ti.com/lit/ml/slup098/slup098.pdf
[12] Eker, I. and Torun, Y. (2006): Fuzzy logic control to be conventional method, Energy Conversion and Management, Vol. 47(4), pp.377-394.
[13] Elmas, C., Deperlioglu, O. and Sayan, H. H. (2009): Adaptive fuzzy logic controller for DC–DC converters, Expert Systems with Applications, No. 36, pp. 1540–1548.