ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

Comparative study of Hybrid Fuzzy Controllers for Buck-Boost Converter in Solar Energy-Battery Systems

Shyma H[1], Prof. Elizabeth Sebastian[2], Prof. Acy M Kottalil[3]

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

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

ABSTRACT: Fuzzy logic controller (FLC) is the most widely used applications of fuzzy set theory. A Fuzzy Logic Controlled (FLC) buck-boost converter for solar energy-battery systems is analyzed. Solar Photovoltaic system has been increasingly playing a significant role in new energy systems. PV system has some disadvantages including low conversion efficiency and inconsistent values of output voltage due to irregular solar power which is caused by weather changes and shading effects. To address these disadvantages, DC-DC converters have been used to control PV output voltage and output power. Fuzzy logic controllers are non linear controllers which do not require exact information of mathematical model. Hybridization of the two controllers can be done to use the positive sides of both controllers to obtain better performance. The comparison of result obtained from fuzzy logic controller, fuzzy - PI hybrid controller, fuzzy - PID hybrid controller for DC-DC converter shows the benefit of the hybrid algorithm in terms of transient response. General design of a fuzzy logic controller based on MATLAB/Simulink is performed. The control system has been developed, analyzed, and validated by simulation study.

KEYWORDS: Fuzzy Logic Controller, Fuzzy PI system, Fuzzy PID system, Membership function, Proportional Integrator, Proportional Integrator Derivative.

I.INTRODUCTION

Photovoltaic (PV) systems will have more significance in the future of energy systems if not the center spot among all. In fact, solar energy systems offer the advantages of low cost fuel and lower maintenance. However, PV systems have some disadvantages like relatively low conversion efficiency, and inconsistent output voltage because of irregular sun power due to weather changes that makes PV systems nonlinear[2]. These disadvantages can be eliminated by using DC-DC converters. DC-DC converters are used to convert unregulated input voltage into regulated output voltage .Switched mode DC-DC converters are used for this purpose.

A controller is a device which maintains the operating conditions of a dynamic system. Main application is to maintain temperature, speed and pressure. It is used to adjust the output voltage with the help of a feedback loop. This feedback loop fed back the output voltage to calculate the difference between reference voltage and output voltage and hence controlling is done to obtain the required output voltage. Proportional controller is a type of controller in which output voltage is proportional to the error voltage. PI controller helps in elimination of forced oscillations and reduction of steady state error[5]. The disadvantage of integral mode is that it has an adverse effect on speed of response and hence overall stability reduces. A controller obtained by combining the three modes proportional P, integral I, derivative D control is named as PID controller. It provides better transient and steady state response for the unit step input and hence gives better performance.

Fuzzy logic is a form of knowledge representation suitable for notions that cannot be defined precisely. It depends upon on a system of non-digital set theory and rules. It uses linguistic variables. Fuzzy logic is much closer to human thinking and natural language than the traditional logical systems. A hybrid controller helps to use the advantages of classical and fuzzy logic controller.

In this paper hybrid controllers can be used to obtain improved closed-loop performance and to avoid variation from the output voltage by reducing steady state error.

II. HYBRID FUZZY PID CONTROLLER FOR BUCK-BOOST CONVERTER

A hybrid fuzzy logic is proposed for PI, PD and PID controllers. . Fuzzy logic is much closer in spirit to human thinking and natural language than the traditional logical systems. Hybrid controller seeks to achieve multiple performance objectives in locally adaptive sense by switching between members of a specified family of feedback functions. In this the hybrid fuzzy logic controller can be used to avoid the variation in the output voltage.

1.Buck-Boost Converter

A buck-boost converter is also known as an inverting regulator. It provides an output voltage which may be less than or greater than the input voltage. It is a circuit that combines a buck converter topology with a boost converter topology in cascade. The polarity of output voltage is opposite to the polarity of the input voltage[11]. There are two modes for the circuit operation. The first mode appears when the transistor is turned on, and diode is reversed biased. During this mode, the input current flows through the transistor and inductor L. The second mode appears when the switch is turned off, and the current flows from L through C, the diode, and the load. The transistor is switched on again in the next cycle when the energy that stored in inductor L would be transferred to the load and inductor current.

2.Fuzzy Logic Controller

FLC is widely used in many fields, including the development of household materials such as dishwashers, TVs, and in industry applications. The reason for increasing use of FLC is because of its ability to use a linguistic form instead of mathematical form to manipulate knowledge. FLCs are designed to fit any model, and are not dependent on mathematical models. FLCs also have other advantages such as low cost and simplicity of control, which makes FLC more applicable than other classical controllers in many control systems.

FLC is the most important control method for nonlinear systems. The two input of fuzzy logic are the error and the change in error. The error was calculated by comparing the output voltage with reference voltage. The change in error was calculated by the present error with previous error. The output voltage of a buck-boost converter is controlled by the fuzzy logic control. The FLC uses linguistic variables as input instead of numerical variables.

There are three principal elements to a fuzzy logic controller. These elements are:

1) Fuzzification module (fuzzifier)
2) Rule base
3) Defuzzification module (defuzzifier)

The fuzzifier converts the crisp values of the input into fuzzy values to send to the rule base and is named as fuzzification process. The rule base is expressed as a set of if-then rules, based on predetermined expert knowledge. The defuzzifier converts the output values of rule base to the crisp values and is named as defuzzification process. Fuzzy rule base transfers the fuzzy values to if and then rules. Decision making logic is used to decide the output value. Membership function is the type of function that is used in fuzzy control, such as triangular MF and Gaussian MF. Rule base of fuzzy logic controller is shown in table 1.

In table 1, 25 fuzzy control rules are used according to the practical operating experience. Here triangle membership functions were used for each error (e (k)) and the change in error (e(k)) and duty cycle of fuzzy variable. Figure 1 and 2 shows the membership function for error and change in error. The input space data of the FLC for the error vary between -10 and 10, while the data for the error variation vary between -1 and 1. The output space data vary between -0.8 and 0.8 (which was decided by trial and error). Due to the 5 linguistic input variables, there are 25 rules in total.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

Table1: Rule Base Decision Map

	de					
e		NB	NS	Z	PS	PB
	PB	Z	PS	PS	PB	PB
	PS	NS	Z	PS	PS	PB
	Z	NS	NS	Z	PS	PS
	NS	NB	NS	NS	Z	PS
	NB	NB	NB	NS	NS	Z

3. Classical Controller

The PI controller has been used in many industrial applications due to its ability to compensate most practical industrial processes. Most processes of low to medium order are controlled by using PI and PID controllers. A PD controller is a proportional-derivative controller that responds to the rate of change in process error. A PD controller can affect a control system by improving the damping, decreasing the maximum overshoot, decreasing the rise time and setting time and show noise at higher frequencies. The PID controller is the main building block of these control strategies. It consists of a proportional element, an integral element, and a derivative element. K_p, K_i, and K_d are the gains of P, I, and D elements respectively. The error signal is considered as the input of a PID controller.

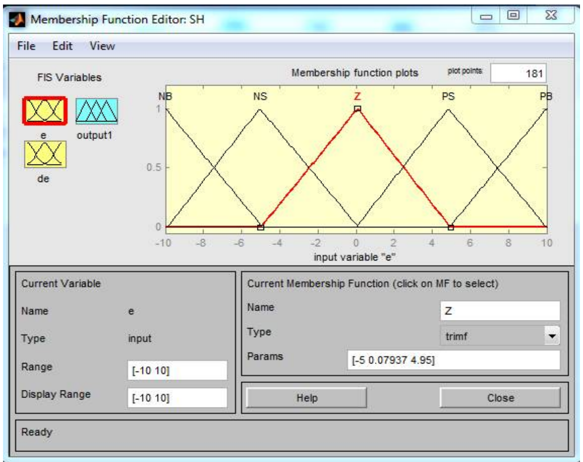

Figure 1: MF for error

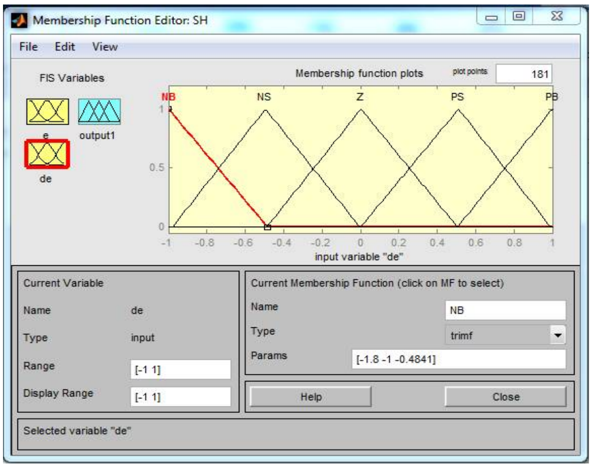

Figure 2: MF for change in error

4. Hybrid Fuzzy PID Controller

The fuzzy logic controller does not need to update information for system variables. But classical controller needs to update precise information for the system and the classical controller cannot eliminate steady-state error. Hybridization helps to control and minimize the steady state error of the system, as the fuzzy logic control alone cannot eliminate steady-state error. Hybridization is one good way to take advantage of fuzzy logic controller and PID controller. Figure 3 shows the block diagram of Hybrid Fuzzy PID Controller. In figure, error signal is the value of the difference between the reference and the output voltage. Fuzzy logic controller in block diagram is the fuzzy based control method while the PID is the classical control to control the output voltage.

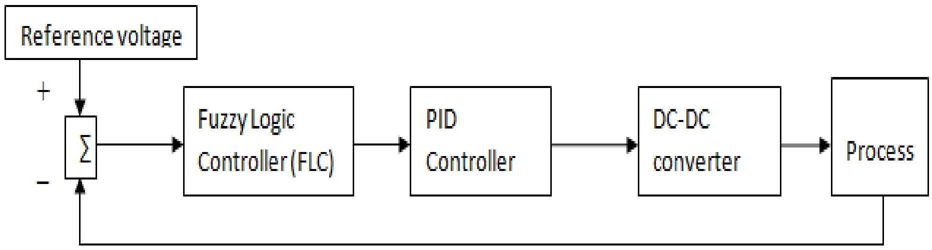

Figure 3: Block diagram of Hybrid Fuzzy PID Controller

III. SIMULATION RESULTS

Figure 4 shows the simulink model of buck-boost converter with FPI and FPID controller. It comprises of a PI or PID controller connected in series with a fuzzy logic controller. The major disadvantage of classical control logic is the presence of steady state error on load. To eliminate this disadvantage it is necessary to combine Fuzzy Logic Controller with classical controller, which is capable of removing the disadvantage existing in Fuzzy Logic control. Therefore, the PI controller helps in eliminating the disadvantage of Fuzzy Logic Controller.

Table 2: Simulation parameters of Buck-Boost converter

Simulation Parameters	Values
Reference Voltage	12V
Input Voltage	8V
Input Inductor	133e-5H
Output Capacitor	100.67e-3F
Load Resistor	10ohm
Switching frequency	600Hz

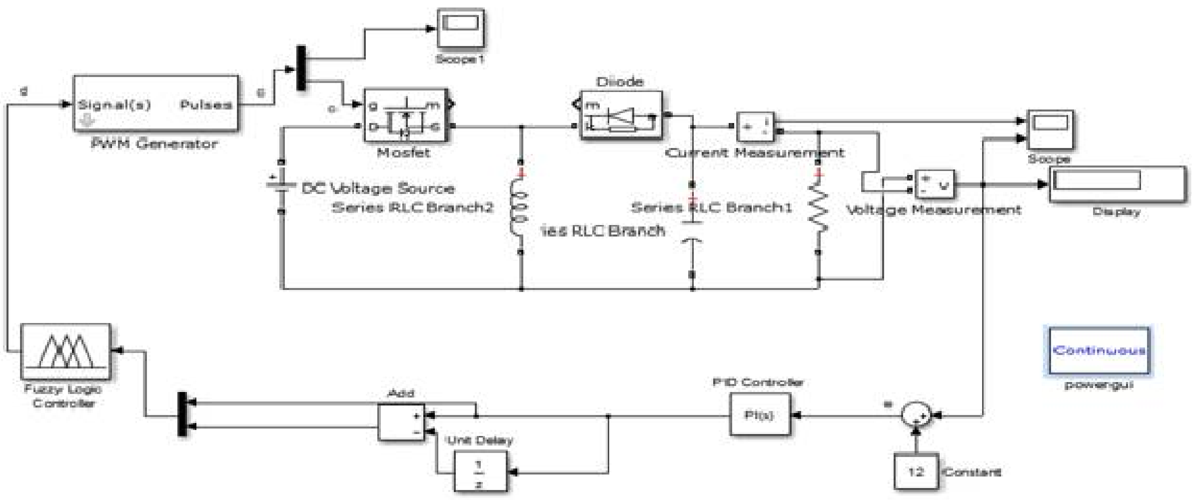

Figure 4: Simulink model of buck-boost converter with Hybrid Fuzzy Controller

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

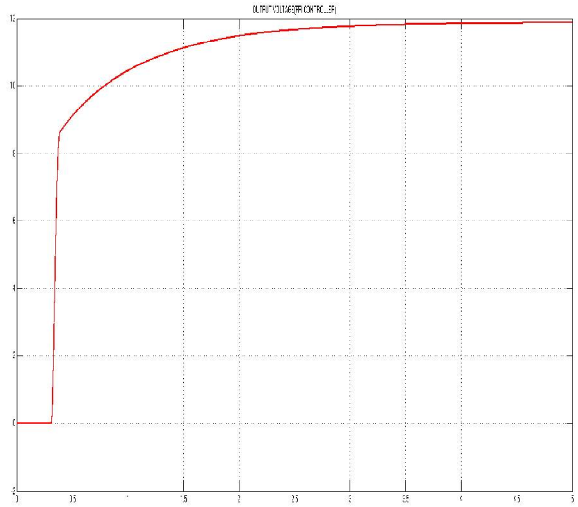

Figure 5: Output voltage of FPI controller

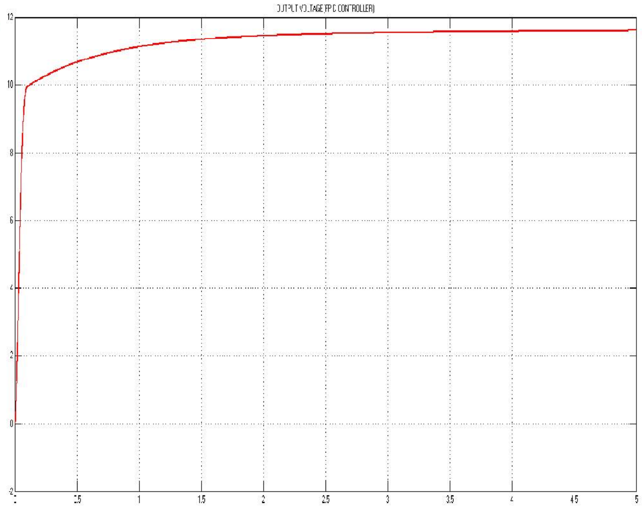

Figure 6: Output voltage of FPID controller

IV. COMPARATIVE STUDY

The FPI and FPID control results are as shown in table 3. The output voltage of FPI has zero overshoot , the rise time is 1.032 sec, and settling time 3.1318 sec. The output voltage at steady state is equal 11.8761V after 4.9996sec. The output voltage of FPID has zero overshoot, the rise time is 0.5686 sec, and settling time 3 sec. The output voltage at steady state is equal 11.8481V after 4.9997sec.

Table 3: Comparison between FPI and FPID

Parameters	FLC	FPI	FPID
Rise time	0.4355	0.3032	0.15686
Settling time	3.1189	3.1318	3
Steady state value	11.80	11.821	11.87
Steady state error	0.199	0.172	0.135

V.CONCLUSION

The buck-boost converters are designed and performance is analyzed using hybrid fuzzy controller. A fuzzy logic based hybrid approach is presented for PI and PID controllers. The fuzzy logic controller reaches at the desired voltage after a long rise time. In fuzzy PI control, the system had a very short rise time with a very small overshoot compared to FLC. In fuzzy PID control, the system had a very short rise time without overshoot, and the system had less voltage oscillations than the fuzzy PI. The rise time of FPI and FPID is reduced by 30% and 63% compared to FLC and settling time of FPID is reduced by 3.8%. The hybrid fuzzy PID control system was also very stable showing a good performance and outperforming all the other classical controllers at the same system conditions.

REFERENCES

[1] Karime Farhood Hussein, Ikhlas Abdel-Qader, "Hybrid Fuzzy PID Controller for Buck- Boost Converter in Solar Energy-Battery Systems ", IEEE Transaction, Dec. 2015.

[2] Mustafa E. Sahin, Halil. Okumus, "Fuzzy Logic Controlled Buck-Boost DC-DC Converter for Solar Energy-Battery System", IEEE Transaction, Dec. 2011.

[3] Abhinav Dogra, and Kanchan Pal, "Design of Buck-Boost Converter for Constant Voltage Applications and Its Transient Response Due To Parametric Variation of PI Controller", IJIRSET Vol. 3, Issue 6, June 2014.

[4] Sumi Babu , Reshmi R, "Design Control of DC-DC Converter using Hybrid Fuzzy PI Controller", IJREAT, Volume 1, Issue 3, June-July, 2013 .

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

[5] Ms. R. J. Deshpande, Prof. K. N. Kasat, "A Review on Performance of Dc- Dc Buck Converter Using Conventional and Self Tuning Fuzzy PID Controller", IJARCSSE, Volume 4, Issue 4, April 2014.
[6] Priyanka Srivastava, Shri S.k. Singh, "Hybrid Fuzzy PID Controller for Buck-Boost Converter ", JAERT, August 2014
[7] Ned Mohan, Tore M Undeland, William P Robbins, "Power Electronics Converters, Applications and Design", Singapore, Media Enhanced 3rd ed; John Wiley sons Inc, 2003.
[8] Priyanka Srivastava, Sh. S.K.Singh, "Study Of Fuzzy Logic And Pid Controller In Buck-Boost Converter", IJSRET, Volume 3, Issue 6, September 2014.
[9] Babita Panda, Akashdeep Sarkar, "Comparative Study of PI and Fuzzy Controllers for Solar powered DC-DC Boost Converter", IEEE Transaction, Dec. 2015.
[10] Bhagyashri U. Patil, Satyawan R. Jagtap, "Adaptive Fuzzy Logic Controller for Buck Converter", ", IEEE Transaction, Dec. 2015.
[11] s. Vijayalakshmil, E.Arthika, "Modeling and Simulation of Interleaved BuckBoost Converter with PID Controller", IEEE Transaction, Dec. 2015.
[12] Abhinav Dogra, Kanchan Pal , " Design of Buck-Boost Converter for Constant Voltage Applications and Its Transient Response Due To Parametric Variation of PI Controller", IJIRSCT, Vol. 3, Issue 6, June 2014.