IPASJ International Journal of Electrical Engineering (IIJEE)
Web Site: http://www.ipasj.org/IIJEE/IIJEE.htm
A Publisher for Research Motivation........
Email: editoriijee@ipasj.org
Volume 2, Issue 5, May 2014
ISSN 2321-600X

Design and Simulation of Fuzzy Logic Controller based Switched-Mode Power Supply

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Abstract

The switch mode power supply(SMPS) has been achieved the high power density and high performance by developing the power semiconductor devices such as IGBT, BJT, MOSFET, and GTO etc. SMPS has the capacity to handle the variable loads and variable input voltage. The efficiency, weight and size of power supplies are a great area of concern for the power supply designers. This article introduces the method of intelligent regulation to control the Buck converter using the pulse width modulation switching by a fuzzy logic controller. In this paper we use the SMPS circuit having power MOSFET as a switch and fuzzy logic controller based PWM gate signals to the switch for controlling purpose. This paper describes the design of a fuzzy logic controller using output voltage of the converter as feedback for significantly improving the dynamic performance of buck dc-dc converter by using MATLAB/ SIMULINK. The SMPS output voltage remains constant irrespective of load and input voltage variations from 140V to 340V.

1. INTRODUCTION

Nowadays, for many Power Electronic appliances the control systems have been increasing widely. Crucial with these demands of the customer, many researchers or designers have been struggling to find the reliable and most economic controller to meet these demands. As compared to open loop system the idea to have a control system in dc-dc converter is to ensure desired voltage level of the output can be produced efficiently. This paper explains the operation of SMPS (switching mode power supply), PWM control, rectifier, fuzzy controller and buck convertor. The block diagram contains the two major circuits, one is power circuit and another one is control circuit, which is used to control the pulse which is provided for the power switch.

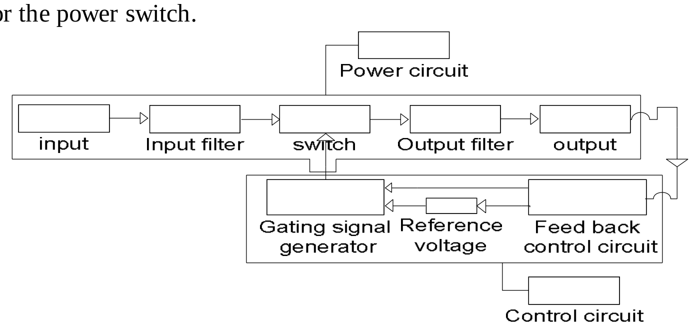

Figure 1 Block Diagram of SMPS

2. DESIGN OF FUZZY LOGIC CONTROLLER

Traditionally, PD, PI and PID controller are most popular controllers and they are widely used in most power electronic closed loop appliances, But in the recent year there are many researchers reported successfully adopted the Fuzzy Logic Controller (FLC) to become one of intelligent controllers. This paper is using fuzzy logic controller with feedback of voltage output respectively. The voltage output in the circuit will be fed to fuzzy controller to give appropriate measure on steady state signal. This technique can be applied to many dc-dc converter topologies such as Buck, Boost and Buck-Boost.

Based on the human knowledge fuzzy logic control is built up by a group of rules of system behavior. For the dynamic behavior of dc-to-dc converter and performance of proposed controllers we use Matlab simulation. the design of fuzzy logic controller can provide desirable both large signal and small signal dynamic performance , which is not possible in linear control technique. Thus, fuzzy logic controller has an ability to improve the robustness of dc-to-dc converters. The basic scheme of the controller consists of four principal components such as: a Fuzzification, which converts input data value into suitable linguistic values; a knowledge base, which consists of control rule set and a data base with the necessary linguistic definitions ; a Decision-Making logic ,which is use to simulating a human decision process and

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infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; And a Defuzzification interface, which yields non fuzzy control action from an inferred fuzzy control action.

An analysis of buck converter circuit revealed that the inductor current plays significant task in dynamic response of buck converter. it also provide the storage energy information in the converter. Thus, any changes in the inductor current may affect output voltage of the converter, output voltage will provide information of steady state condition of converter. However, the three main parameters need to be considered when designing buck converters are power switch, capacitor and inductor.

3. Fuzzy Logic Membership Function

The buck dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of buck converters. In Fuzzy controllers mathematical model is not require. Instead, they are designed based on general knowledge of the plant(converter). The Fuzzy controllers are designed to adopt the varying operating points. Fuzzy Logic Controller is designed to control the output of buck dc-dc converter. In the fuzzy logic system two input variables, error (e) and change of error (de) and one output variable (u) is duty cycle of PWM output are used.

For each input and output variable fuzzy sets must be defined. As shown in Fig. 2. The five fuzzy subsets PS (Positive Small), PB(Positive Big), ZE (Zero), NS (Negative Small), NB (Negative Big) have been chosen for input variables error (e) and change of error (de). The Triangular shape has been adopted for the membership functions; the value of each input and output variable is normalized in the range[-1,1] by using suitable scale factors.

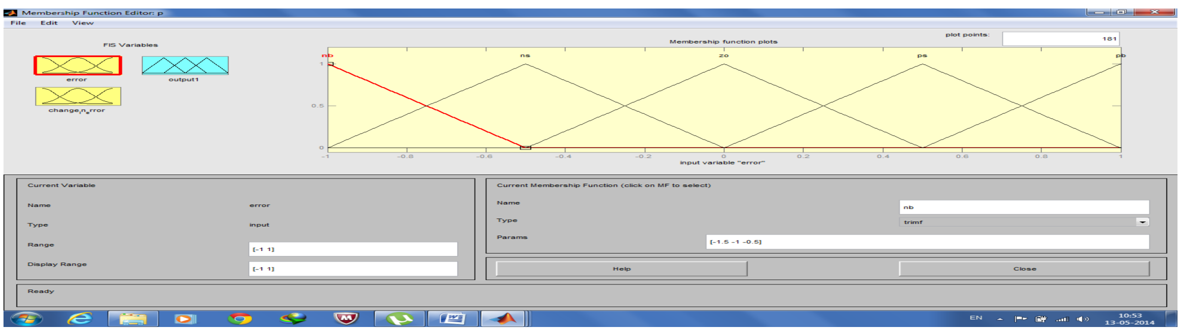

Figure 2 The Membership Function plots of error.

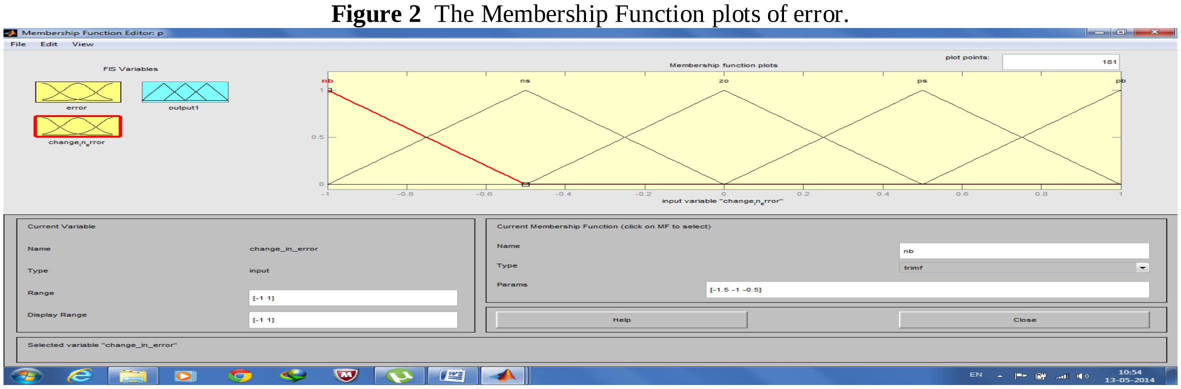

Figure 3 The Membership Function plots of change error

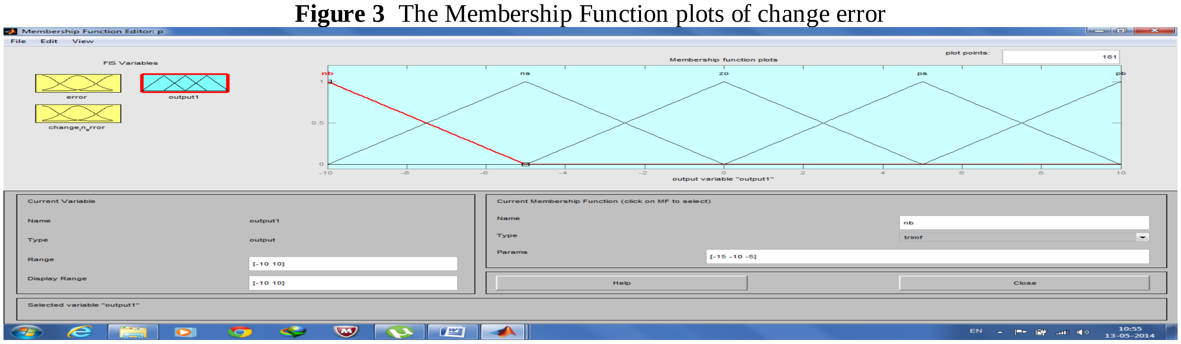

Figure 4 The Membership Function plots of duty ratio

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4. Fuzzy Logic Table Rules

Fuzzy controller rules which are play a very important role for controller simulation are obtained from the analysis of the system behavior. In their formulation it must be considered that, By using this controller we improve the converter performances in terms of dynamic response and robustness. when the output voltage is far from the set point i.e error (e) is NB or PB, the controller must be do the strong corrective action i.e duty cycle close to zero or have the dynamic response as fast as possible, obviously taking into account current limit specifications of the system.

Table 1: Rules for error and change of error

(e) / (de)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

Second, when output voltage error of the system approaches to zero i.e error (e) is ZE, NS, PS then in order to ensure stability around the working point, the current error should be properly taken into account. when the current value approaches the limit value, suitable rules must be introduced to preventing the large overshoots. The rules of fuzzy control for error and change of error can be referred in the table 1:

5. Simulation Results

The simulink model of buck converter with fuzzy logic controller is shown in Figure 5 and simulation is carried out in MATLAB/SIMULINK.

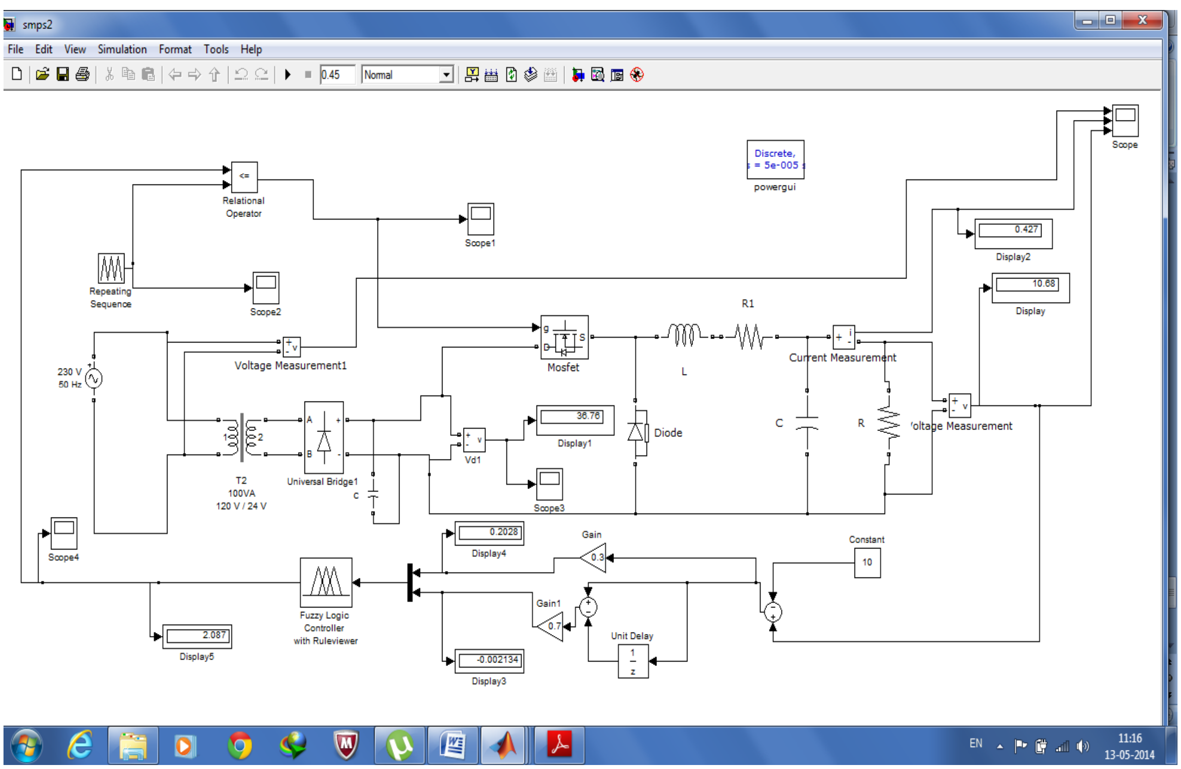

Figure 5 Closed loop simulink model of Buck converter using Fuzzy logic Controller

Simulation is done with the variation in input voltage from 140 volt to 340 volt at different loads maintaining output voltage constant at 10 volt The simulation results are shown in Figs 5-8 and tabulated in Table 2 .

5.1 Results with load variation:-

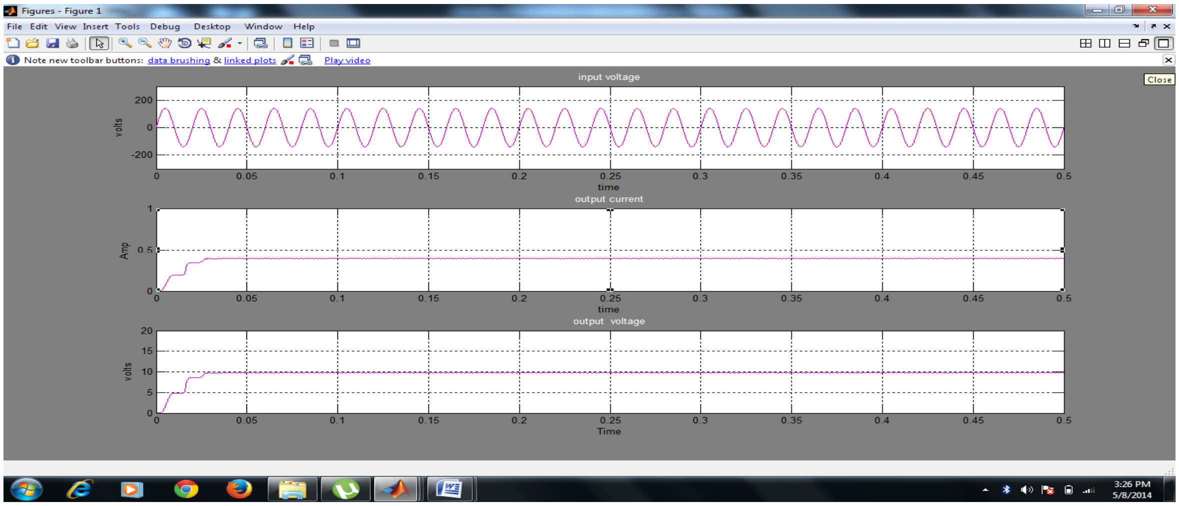

Figure 6. Output Voltage and current with 140 V input voltage at load resistance 25Ω

Figure 7. Output Voltage and current with 140 V input voltage at load resistance 50Ω

5.3 Results with input voltage variation

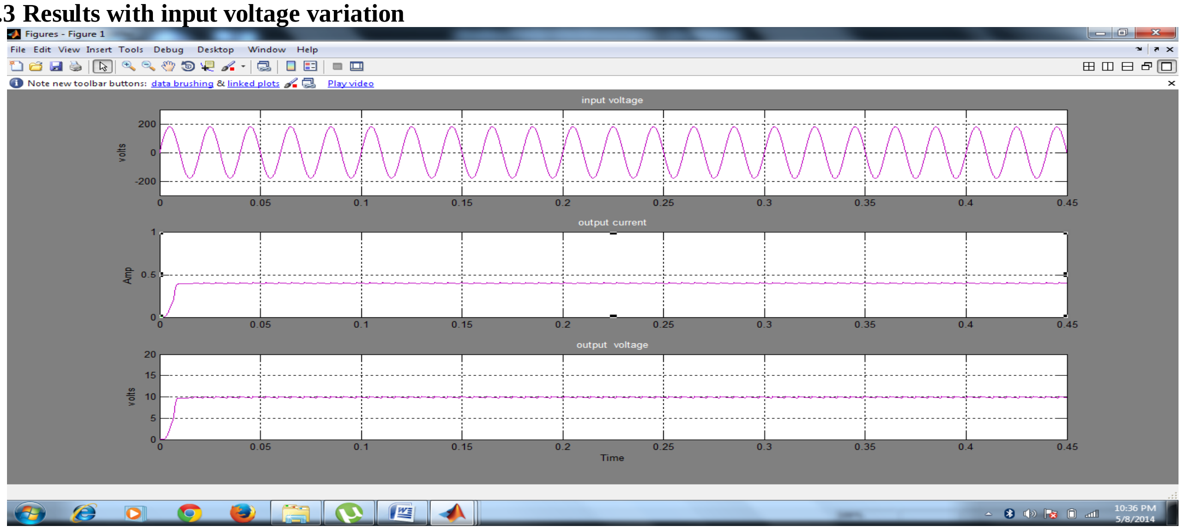

Figure 8. Output Voltage and current with 180 V input voltage at load resistance 25Ω

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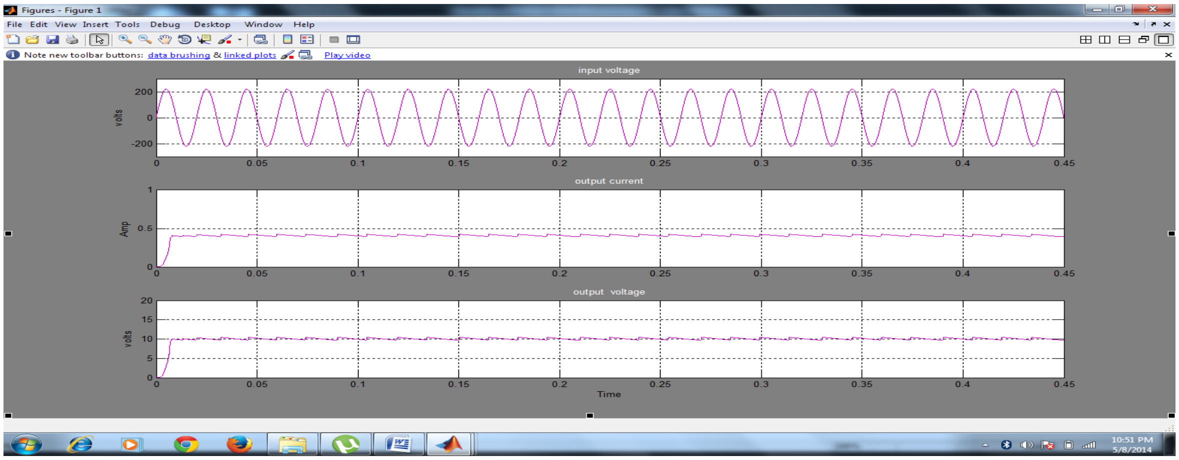

Figure 9. Output Voltage and current with 220 V input voltage at load resistance 25Ω

Table 2:- Results with load and input voltage variation

	Input voltage(v)	Load resistance(Ω)	Output voltage(v)	Output current(mA)
1	140	25	9.749	0.390
		50	9.747	0.1949
		75	9.785	0.1305
		100	9.841	0.0984
2	180	25	9.853	0.3941
		50	9.972	0.1994
		75	10.03	0.1337
		100	9.889	0.0988
3	220	25	9.736	0.3895
		50	9.880	0.1976
		75	9.948	0.1326
		100	9.987	0.0998
4	260	25	10.30	0.4120
		50	10.38	0.2076
		75	10.44	0.1392
		100	10.39	0.1039
5	300	25	10.63	0.4251
		50	10.48	0.2097
		75	10.53	0.1405
		100	10.36	0.1036
6	340	25	10.30	0.4121
		50	10.55	0.2109
		75	10.72	0.1429
		100	10.69	0.1069

6. CONCLUSION

Design of the fuzzy logic controller on control buck dc-dc converter by using MATLAB simulink has been successfully achieved. A algorithm based on the prediction of fuzzy logic controller, using the fuzzy rules parameter, is showing to be more convenient than the other circuit. As the closed loop circuit with fuzzy logic controller with 0% overshoot shows the better performance compared to the open loop circuit without using fuzzy logic controller whereby it has

80% overshoot.SMPS operating in a Buck converter is an step down DC-DC converter used in many electronics devices. The same has been simulated by Using the MATLAB, an output voltage of 10V was obtained with an input range of 140V-340V DC supply. the waveforms across various points were obtained, studied and compared with the theoretical waveforms. The waveforms were found to be same to the desired waveforms. Hence, the circuit of buck dc-dc converter controlled by fuzzy logic controller confirmed the requirement of the proposed approach.

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