A Comparative Study Of Fuzzy Logic Controller And Proportional Integral Derivative On Buck DC/DC Converter

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Abstract – The switching power supply market is shows potential quickly in today's modern world. Design engineers are not always supplied with the desired amount of voltage they need in order to make their design work. As a solution, controller is added to the system to achieve a simple digital control circuit for regulating the output of the dc-dc converter. This thesis presents a comparative study of Fuzzy Logic Controller and Proportional Integral Derivative Controller on Buck DC/DC Converter. The objective of this thesis is to compare the performance between Fuzzy Logic Controller and Proportional Integral Derivative Controller to improve the performance of DC/DC Converters. The evaluation of the output has been carried out and compared by software simulation using MATLAB. Fuzzy logic controller has been implemented to the system by developing fuzzy logic control algorithm The signals will be processed based on the fuzzy logic rules-based and produce the output. The output will update the duty cycle of the system. This process will continue until it reached the steady-state condition.

. The evaluation of the output has been carried out by software simulation using MATLAB.

Keyword – FLC, PIDC, Buck DC/DC Converter,MATLAB, Simulink

I. INTRODUCTION

Assignment of power electronics is to process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited for user load.

Figure 1 shows a power electronic system block diagram. The output of the power processor is as desired by load. In general, feedback controller compares the output of the power processor unit with a reference value, and the error between the two is minimized by the controller.

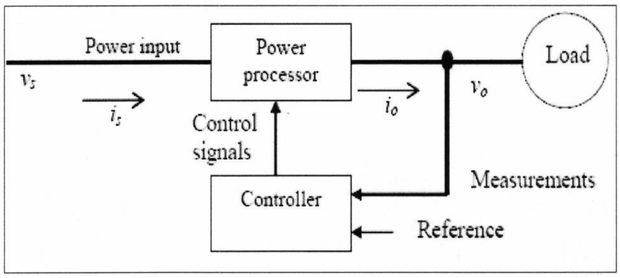

Figure 1: Block Diagram of Power Electronic System

Conventionally, PI, PD and PID controller is most popular controller and widely used in most power electronic appliances but disadvantage of PID is required complex mathematical model of the control process or may be expensive in terms of computer processing power and memory, and a system based on rules based likes FLC may be more effective.

DC/DC converters have been dominating controlled by analogue integrated circuit technology and linear system control design techniques. In recent years, with rapidly development of advanced high-speed digital circuits, digital control will slowly replace the currently used analogue controller in high frequency switching converters. The intelligent power supplies are expected to play an important role in aerospace, communication and automobile industries in the near future [1].

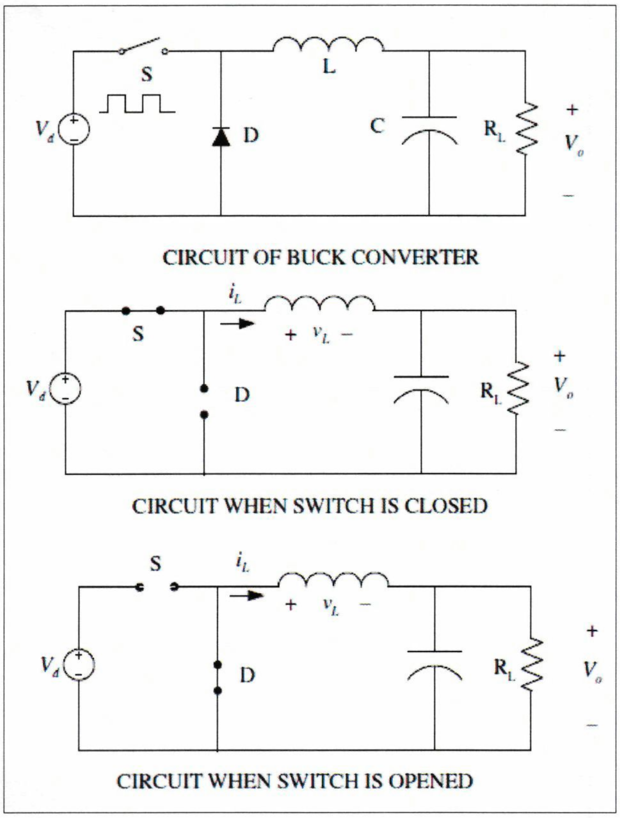

Figure 2: Step Down or Buck Converter

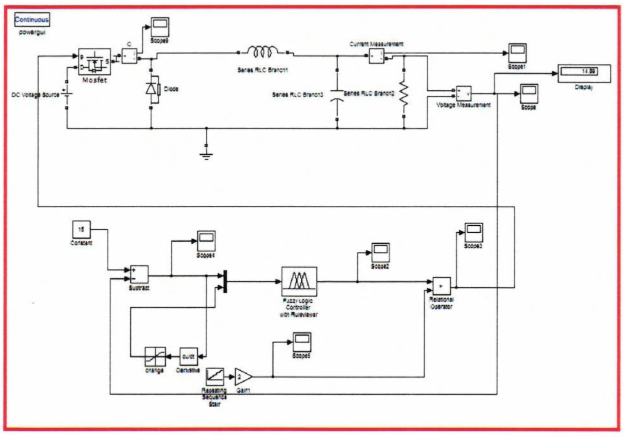

Figure 3: Buck circuit diagram of closed loop fuzzy logic controller.

CIRCUIT DESCRIPTION

Figure 3 mostly used a pair of switches, usually one controlled (e.g. MOSFET) and one uncontrolled (e.g. diode), to achieve unidirectional power flow from input to output and also use one capacitor and one inductor to store and transfer energy from input to output. They also filter or smooth voltage and current.

The DC/DC converters can operate in two distinct modes either in Continuous conduction mode (CCM) or discontinuous conduction mode (DCM). The term continuous and discontinuous is referred to inductor current. Continuous means the inductor current does not go to zero at the end of the off period and the current goes to zero in discontinuous mode. In practice, a converter may operate in both modes. Therefore, a converter and its control should be designed based on both modes of operation [4]. However, for this purposed we only consider the dc-dc converters operated in CCM.

CIRCUIT OPERATION

During the interval when the switch is on, the diode reverse biased and the input provides energy to the load as well as to the inductor.[8] The results is in positive inductor voltage, $V_L = V_d - V_o$. It causes linear increase in the inductor current

$$v_L = L\frac{di_L}{dt}$$

$$\Rightarrow i_L = \frac{1}{L}\int v_L dt$$

When the switch is turned off, because of the inductive energy storage, i_L continues to flow. This current now flows through the diode, and $v_L = -V_o$ for a time duration (1-D) T until the switch is turned on again [8].

Derivation of Fuzzy Logic Controller for DC/DC Converter

The block diagram of the fuzzy control scheme of dc/dc converters is shown in Figure 3 The fuzzy logic controller is divided into five modules: fuzzifier, data base, rule base, decision maker, and defuzzifier. The inputs of the fuzzy logic controller are the error e and the change of error ce, which are defined as

$$e = V_O - V_{ref}$$

$$ce = e_k - e_{k-1}$$

where V_O is the present output voltage, *Vref* is the reference output voltage, and subscript k denotes values taken at the beginning of the kth switching cycle. The output of the fuzzy controller is the duty cycle and is defined as

$$d_k = d_{k-1} + \eta \cdot \delta d_k$$

where *.dk* is the inferred change of duty cycle by the fuzzy controller at the kth sampling time, and . is the gain factor of the fuzzy controller. Adjusting . can change the effective gain of the controller. Each universe of discourse is divided into five fuzzy subsets: PB (Positive Big), PS (Positive Small), ZO (Zero), NS (Negative Small), and NB (Negative Big). The partition of fuzzy subsets and the shape of the membership function are shown in Figure 8 The values of e and ce are normalized. The triangular shape of the membership function of this arrangement presumes that for any particular input there is only one dominant fuzzy subset. Also for any combination of e and ce, a maximum of four rules are adopted. The derivation of the fuzzy control rules is heuristic in nature and based on the following criteria:

1) When the output of the converter is far from the set point, the change of duty cycle must be large so as to bring the output to the set point quickly.

2) When the output of the converter is approaching the set point, a small change of duty cycle is necessary.

3) When the output of the converter is near the set point and is approaching it rapidly, the duty cycle must be kept constant so as to prevent overshoot.

4) When the set point is reached and the output is still changing, the duty cycle must be changed a little bit to prevent the output from moving away.

5) When the set point is reached and the output is steady, the duty cycle remains unchanged.

6) When the output is above the set point, the sign of the change of duty cycle must be negative, and vice versa [4].

The rules for the buck converter are formulated in Table I. The fuzzy rule base is composed of following 25 rules as shown in Table I. The 25 rules can be plotted in a surface shown in Figure 8 which is a plot of output surface for output verses error and change in error.

Table I:
Rule for 25 error and change of error

de \ error is	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

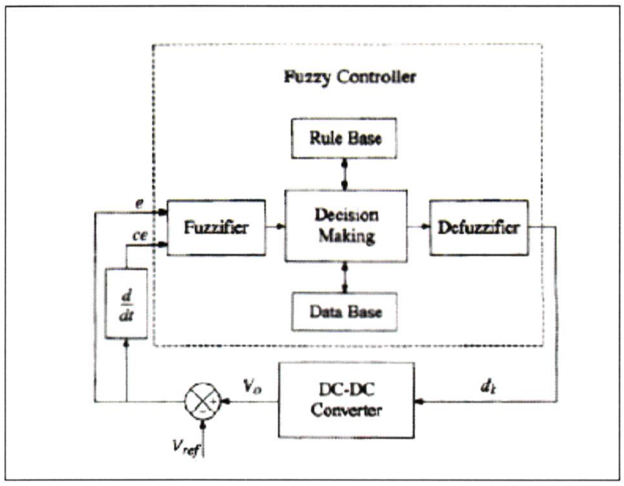

Figure 4: Block diagram of the fuzzy control
(Wing-Chi So, Chi K. Tse, Yim-Shu Lee, 1996).

II. RESULTS AND DISCUSSION

The simulation is run to obtain the numerical results such as the step down output voltage and current. The simulation result based on output voltage deviation, voltage overshoot percentage, rise time, peak time and settling time for FLC and comparison with PID controller**.** The Simulink model used for simulation as illustrated at figure 5 for FLC and PID at figure 6. The step response second order analysis, where;

Rise Time = time until the Point Value (PV) first crosses the set point

Peak Time = time to the first peak

Settling Time = time to when the PV first enters and then remains within a band whose width is computed as a percentage of the total change in PV (or delta PV)

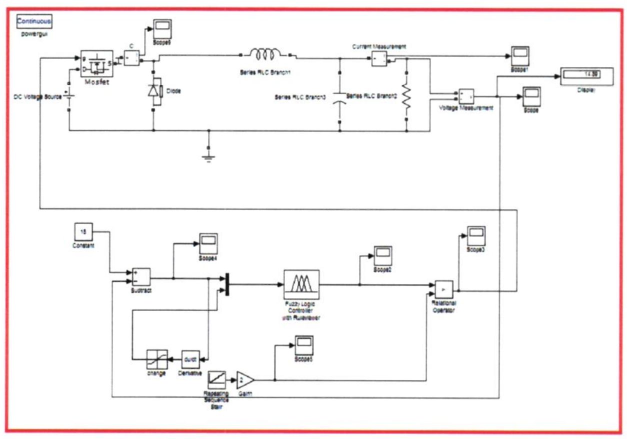

Figure 5: A Simulink model of FLC for Buck Converter

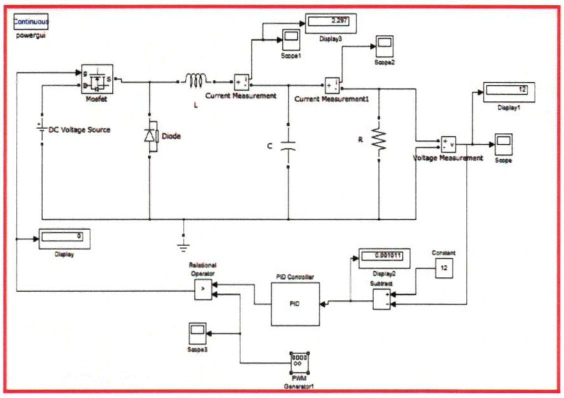

Figure 6: A Simulink model of PID for Buck Converter

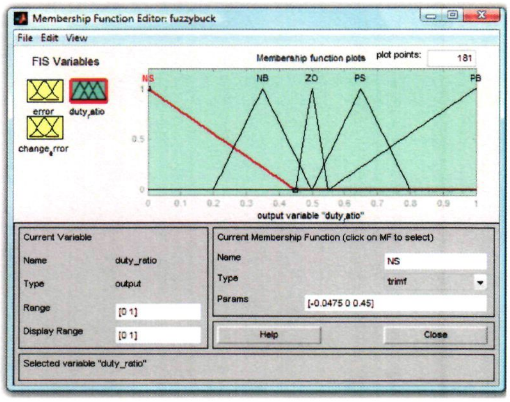

Figure 7: Membership Function used for Inputs and Output for generating the data, which is given to the genetic module

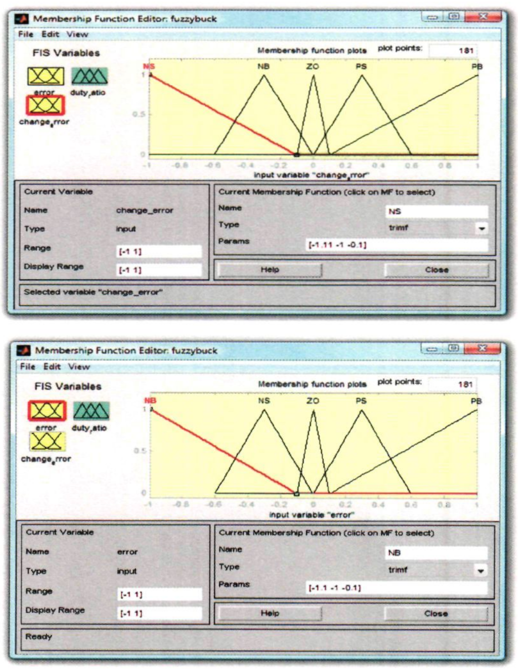

Figure 8: *Membership Function for error and de*

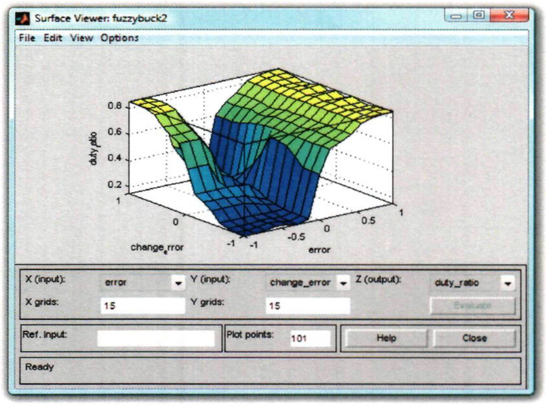

Figure 9: Output MF and surface plot for inputs and output

Table III

Peak Overshoot Ratio, Rise Time, Peak Time and Settling Time From FLC Buck Converter.

Voltage Input (V)	**Voltage Reference (V)**	**Peak Overshoot Ratio (%)**	**Rise Time (sec)**	**Peak Time (sec)**	**Settling Time (sec)**
25	25	0.0089	0.00829	0.008334	0.008
25	20	0.0079	0.00739	0.0074	0.008
25	15	0.0014	0.006	0.0064	0.0065
25	10	0.0144	0.00523	0.0053	0.0053
25	5	0.0146	0.00399	0.0041	0.0042

Table IV

Peak Overshoot Ratio, Rise Time, Peak Time and Settling Time From PIDC Buck Converter.

Voltage Input (V)	**Voltage Reference (V)**	**Peak Overshoot Ratio (%)**	**Rise Time (sec)**	**Peak Time (sec)**	**Settling Time (sec)**
25	25	0.065	0.008	0.008	0.05
25	20	0.045	0.007	0.01	0.065
25	15	0.043	0.008	0.01	0.14
25	10	0.065	0.006	0.012	0.07
25	5	0.058	0.005	0.058	0.12

Table V

The deviations of voltage resulted from FLC Buck Converter

Voltage Input (V)	**Voltage Reference (V)**	**Output Voltage (V)**	**Deviation (V)**	**Deviation(%)**
25	25	24.93	-0.07	0.28
25	20	19.95	-0.05	0.03
25	15	15.01	0.01	0.06
25	10	9.999	0.001	0.01
25	5	4.958	-0.042	0.85

Table VI

The deviations of voltage resulted from PIDC Buck Converter

Voltage Input (V)	Voltage Reference (V)	Output Voltage (V)	Deviation (V)	Deviation(%)
25	25	24.59	-0.41	1.66
25	20	19.98	-0.02	0.1
25	15	15.02	0.02	0.13
25	10	9.995	0.005	0.05
25	5	5.067	0.067	1.32

Comparison Results Between FLC and PID

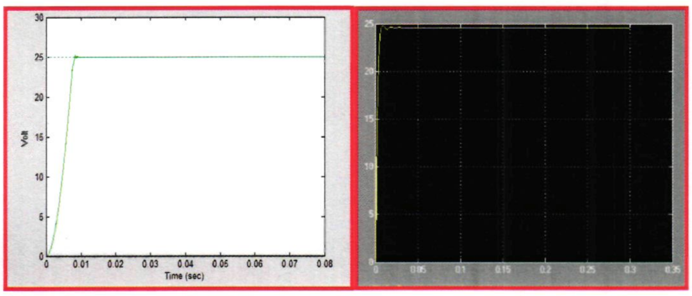

Figure 10 (a): FLC Figure 10 (b): PIDC

Figure 10: Output Voltage Vi = 25V and Vref = 25V

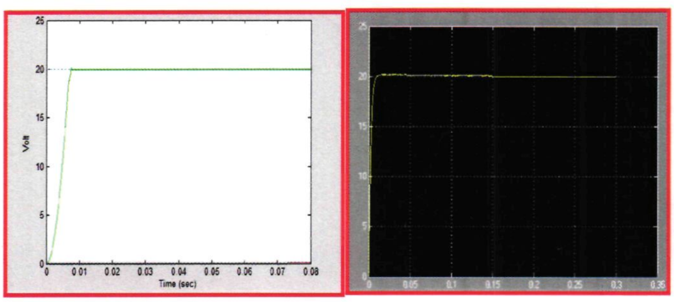

Figure 11 (a): FLC Figure 11 (b): PIDC

Figure 11: Output Voltage Vi = 25V and Vref = 20V

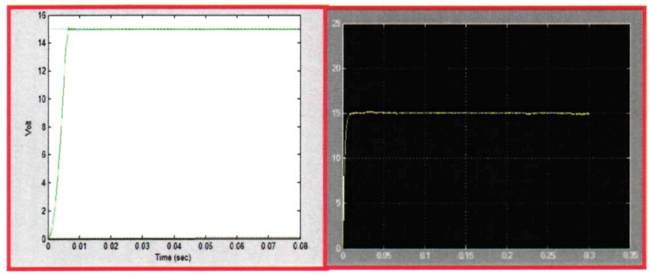

Figure 12 (a): FLC Figure 12 (b): PIDC

Figure 12: Output Voltage Vi = 25V and Vref = 15V

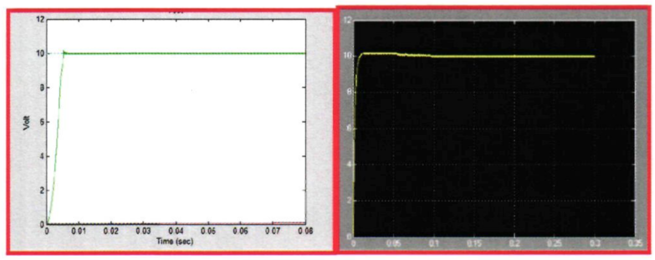

Figure 13 (a): FLC Figure 13 (b): PIDC

Figure 13: Output Voltage Vi = 25V and Vref = 10V

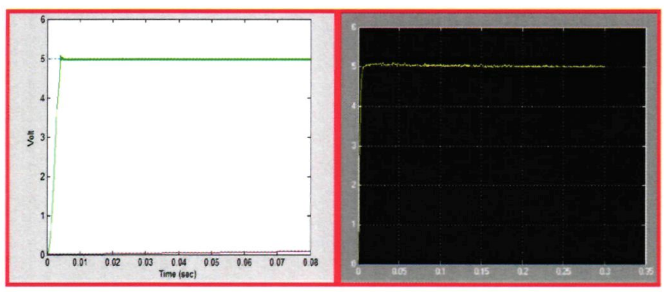

Figure 14 (a): FLC Figure 14 (b): PIDC

Figure 14: Output Voltage Vi = 25V and Vref = 5V

Design of prototype dc-dc buck converter controlled by using fuzzy logic controller has been successful achieved. The 25V voltage input is applied to the circuit and the output parameters for closed loop circuit was tested and measured. Testing of the FLC and PIDC simulation results has been compared and both of them show that there are no significant differences of the output results.

For the 25V input the output voltage for Fuzzy Logic Controller with 0% overshoot and rise time 8.29ms shows the better performance compared PIDC whereby it has 0.1% overshoot and rise time is 80ms.The FLC achieved the desired output voltage compared to the PIDC circuit. Thus, increasing of the output performance. The value of the output current also improving corresponds to the value for the output power.

For the 25V input the result of the output voltage shows the fuzzy logic controller managed to control the desired output voltage even though the input is increasing.

III. CONCLUSION

The results confirmed that the FLC achieved much better in term of fasters in rise time, peak time, settling time and robustness as compared to PIDC. The FLC also produced less voltage deviation from variation of voltage reference setting. It also presented better dynamic performance, such as small overshoot, more damping and sensitive to parameters variations for Buck Converter. Thus, FLC has been potential ability to improve the robustness of DC/DC converters.

This FLC can be applied to many converter topologies other than Buck such as Buck-Boost and Boost. Since the result shown FLC is the fast response controller with higher accuracy the future development plan is to develop machinery for semiconductor that use FLC as controller instead of Programmable Logic Controller (PLC). Thus, will minimise the cost of the machine due to simplicity of controller and size of machine also can be reduce.

V. REFERENCES

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