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DC-DC Buck Converter Using Different Controller

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ABSTRACT: Interleaved power converters can be very beneficial for high performance electrical equipment applications. Reductions in size and electromagnetic emission along with an increase in efficiency, transient response, M and reliability are among the many advantages to using such converters. Fuzzy Logic is a linguistic approach which emerges to design simple, complex and embedded systems with control inputs. A fuzzy logic uses linguistic variables which states IF A AND B THEN C” this rules is used for computation rather than a complex mathematical formula. This paper describes the design of a fuzzy logic controller using voltage output as feedback for significantly improving the dynamic performance of boost dc-dc converter. The fuzzy logic controller has been implemented to the system by developing fuzzy logic control algorithm. The design and calculation of the components especially for the inductor has been done to ensure the converter operates in continuous conduction mode.

KEYWORDS: DC-DC Convertors, DC-DC Buck Convertors, Fuzzy Logic Controller, ANFIS,PID .etc.

I. INTRODUCTION

All electrical equipment require a supply voltage to work, which is typically regarded as constant. An electrical circuit that supports a consistent output voltage is a voltage regulator. The output was regulated using a variety of voltage regulators and control techniques. The dc/dc converter has an unregulated dc converter input and regulated dc outputs. Conversion processes come in a variety of forms, including switched-mode, electronic, magnetic, linear, and capacitive. Every electronic equipment uses a voltage level converter to convert power from one level to another. Extremely important for several applications, ranging in power from low to large, is DC voltage conversion. The structure's objective is to draw attention to and fulfil the system requirement. There are used to traction motor controller in electric automobiles. They transport fast dynamic response, smooth acceleration and more efficiency. The DC converter are used for re-generative braking of DC motor to the comeback energy in to the supply and result save energy in the transport system [1].

Basic forms of DC to DC switch mode converters include boost, buck, and buck-boost converters. To manage the switch-mode dc/dc converter, a variety of control techniques were employed. The greatest engineering applications demanded a low cost and straightforward control structure. Due to the fact that one control approach is considered to be more precise in a given situation than another, they all have some advantages and disadvantages. More people are looking for control technology that performs at its peak under all circumstances. [2].

Fuzzy control and PI control are two examples. Compare the two alternative methods used in this project to design and implement the closed-loop system of the buck converters. Current mode PWM and voltage mode PWM with P, PI, and PID are the control techniques that are most frequently used with dc converters. These traditional control methods cannot operate within the high limit. Consequently, a nonlinear controller is employed to manage dc converters. The benefit of these controllers is their capacity and ability to react quickly in a changeable scenario. Sliding mode control, fuzzy logic control, and other nonlinear controller types are some examples. [4]. [5]. The buck converter is controlled by fuzzy logic because it is easy to use, simple to apply, and has a straightforward architecture, simple design, and not require an exact mathematical model for the system [3].

This converter is also called as step down converter which produces the average output lower than the input DC voltage. Figure1 shows the circuit diagram of buck converter. During the period when the switch is closed (*ton*), the diode

becomes reverse biased. The input voltage is delivered to the load and inductor. The voltage across the inductor, $V_L = V_d - V_O$. During the period when the switch is open (*toff*), the diode becomes forward biased and the input voltage cannot be delivered to the load as well as to the inductor. The stored energy in inductor is transferred to the load i.e. $V_L = -V_O$. The equivalent circuit diagrams are shown in Figure 1.

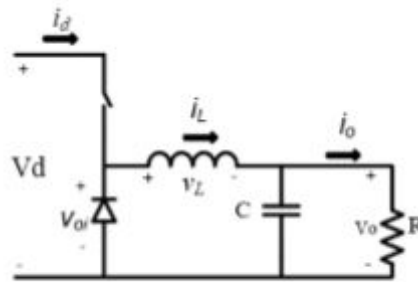


Figure 1-DCDC Buck Converter

Design equations of the buck converter are given below [6, 7].

The ratio between output voltages V_O to the input voltage

$$V_d \text{ is } \frac{V_O}{V_d} = D \quad (1)$$

where D is the duty ratio

By assuming no power loss occurs in the converter, the current ratio is

$$\frac{I_O}{I_d} = \frac{1}{D} \quad (2)$$

the inductor current ripple,

$$\Delta I_L = \frac{V_O}{L} (1 - D) T_s \quad (3)$$

the peak - peak output voltage ripple ΔV_O is given by,

$$\Delta V_O = \frac{\Delta Q}{C} = \frac{T_s}{8C} \frac{V_O}{L} (1 - D) T_s \quad (4)$$

II. LITRATURE REVIEW

Muhammad H. Rashid studied in 2014 It is necessary to change a fixed-voltage DC source into a variable-voltage DC source in many industrial applications. A dc-dc converter, also referred to as a dc converter, converts directly from dc to dc. A DC converter can be thought of as the DC counterpart of an transformer for ac power with constantly changeable turns ratio. It can be used to step up or down a dc voltage source, just like a transformer[6].

For traction motors in electric cars, trolleys, marine hoists, and forklift trucks, dc converters are frequently utilised. Muhammad H. Rashid studied in 2018 They offer efficient acceleration control, quick dynamic response, and smooth acceleration control. A dc converter can be used to regeneratively brake a dc motor, which allows energy to be baked back into the supply. Savings for stop-and-go transportation systems and dc voltage regulation are both utilised. There are several different types of DC-DC converters, including buck (step down), boost (step up), and buck-boost (step up-step down)[7].

W. Yang studied that DC conversion is of great importance in many applications, starting from low power applications to high power applications. The goal of any system is to emphasize and achieve the efficiency to meet the system needs

and requirements. Several topologies have been developed in this area, but all these topologies can be considered as apart or a combination of the basic topologies which are buck, boost and flyback For low power levels, linear regulators can provide a very high-quality output voltage. For higher power levels, switching regulators are used. Switching regulators use power electronic semiconductor switches in On and Off states. Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high efficiency energy conversion [9].

III. FUNCTIONS OF DC-DC CONVERTERS

The DC-DC converter has some functions. These are:

- i. Convert a DC input voltage V_s into a DC output voltage V_o .
- ii. Regulate the DC output voltage against load and line variations.
- iii. Reduce the AC voltage ripple on the DC output voltage below the required level.
- iv. Provide isolation between the input source and the load (if required).
- v. Protect the supplied system and the input source from electromagnetic interference 6.
- vi. The DC-DC converter is considered as the heart of the power supply, thus it will affect the overall performance of the power supply system. The converter accepts DC and produces a controlled DC output.

IV. DC-DC BUCK CONVERTERS USING DIFFERENT

4.1 OPEN LOOP DC-DC BUCK CONVERTER

In open loop boost converter, there is no feedback from output to input contrary to the closed loop which has a feedback circuit. So, the output of an open loop boost converter is not regulated. Open loop control of Buck and Boost Converter is used to obtain a required DC output voltage. The switching frequency and duty cycle decides the output voltage. During ON time the switch is closed and the current flows through switching device, inductor and it close the path with DC source.

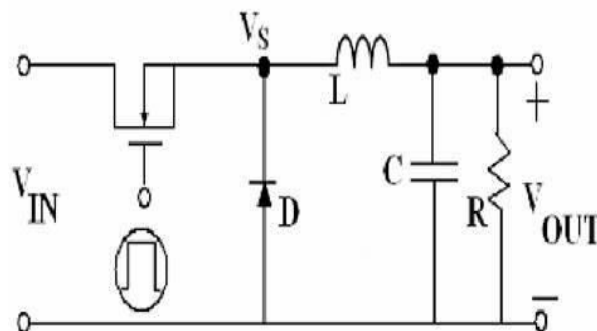


Figure 4- Open loop control of Boost Converter

4.2 CLOSED LOOP CONTROL OF BUCK CONVERTER USING FUZZY LOGIC CONTROLLER

Fuzzy logic, proposed by Lofti Zadeh in 1965, emerged as a tool to deal with uncertain, imprecise, or qualitative decision making control problems. Controllers that combine intelligent and conventional techniques are commonly used in the intelligent control of complex dynamic systems. Therefore, embedded fuzzy controllers automate what has traditionally been a human control activity. So FLC is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. FLC doesn't need any difficult mathematical calculation like the other control systems. So it is one of the available answers today for a broad class of challenging controls. FLC controller has three principal components: 1. Fuzzifier: A fuzzyfication interface that converts input data into suitable linguistic values. 2. Rule Base and Data Base: Both are known as knowledge base that consists of a data base with the necessary linguistic definition and control rule set 3. Decision Making: A decision making logic, which is simulating a human. To design a fuzzy controller, fuzzy input shape and fuzzy output shape must be constructed, then rules that control the relation between the input and output of the fuzzy controller must be determined to make the surface of the fuzzy controller change as shown in Figure 3. In this figure, input1 reflects the negative error, which represents the higher value of the required output and input2 represents the positive error, which represents less than the desired output, while output1 represents the value of the duty cycle that controls in the firing of the MOSFET. Then a closed-loop buck converter using an FLC is constructed in MATLAB/Simulink as shown in Figure 3. Finally, a

simulation program for the circuit in Figure 3 is run to get the shape of the output voltage with respect to the reference voltage as shown in Figure 3. As shown on Figure 3, the fuzzy controlled buck converter exhibits the following answers:

- A. The output voltage (blur) follows the reference voltage (red).
- B. Rise time equals 0.007 s.
- C. Steady state error equals (+/- 0.05) v.

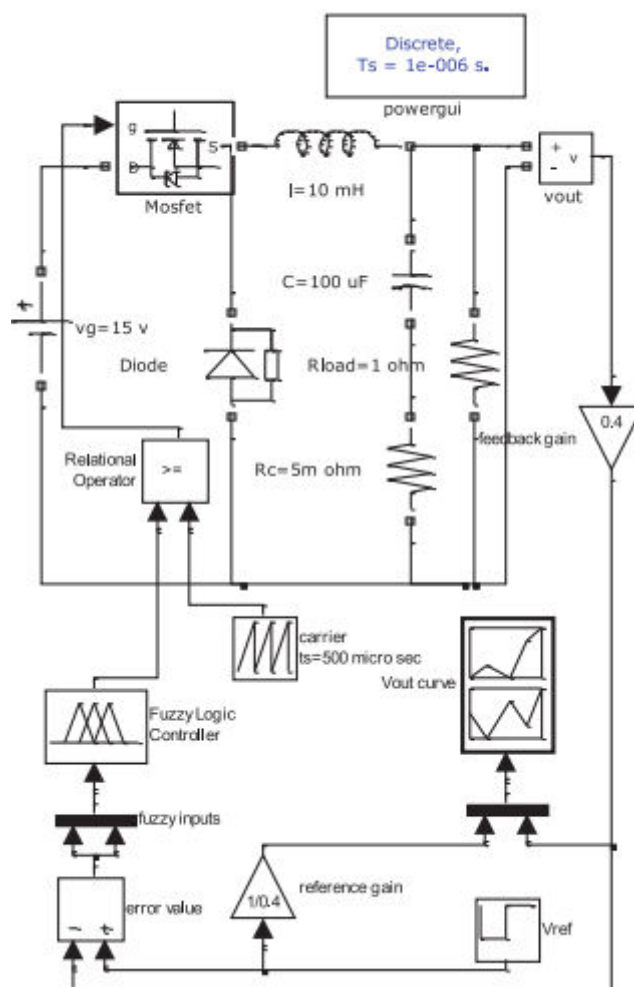


Figure 3: General structure of the fuzzy logic controller on closed-loop system

4.2.1 Structure of Fuzzy Logic

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model [5]. Simulation is performed in boost converter to verify the proposed fuzzy logic controllers.

- **Input-** The inputs are most often hard or crisp measurement from some measuring equipment is converted into fuzzy values for each input fuzzy set with the fuzzification block. (Jan Jantzen 1998)
- **Fuzzification-** The first block inside the controller is fuzzification which converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block matches the input data with the conditions of the rules to determine. There is degree of membership for each linguistic term that applies to the input variable. (Jan Jantzen 1998)
- **Rule Base** -The collection of rules is called a rule base. The rules are in “If Then” format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error.(dE). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is

easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques. (Jan Jantzen 1998)

- **Defuzzification**-Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. 14 The output levels are depending on the rules that the systems have and the positions depending on the non-linearities existing to the systems. To achieve the result, develop the control curve of the system representing the I/O relation of the systems and based on the information; define the output degree of the membership function with the aim to minimize the effect of the non-linearity (Jan Jantzen 1998)
- **Output**- The output is output gain that can be tuned and also become as an integrator .The output crisp value can be calculated by the centre of gravity or the weighted average [7].

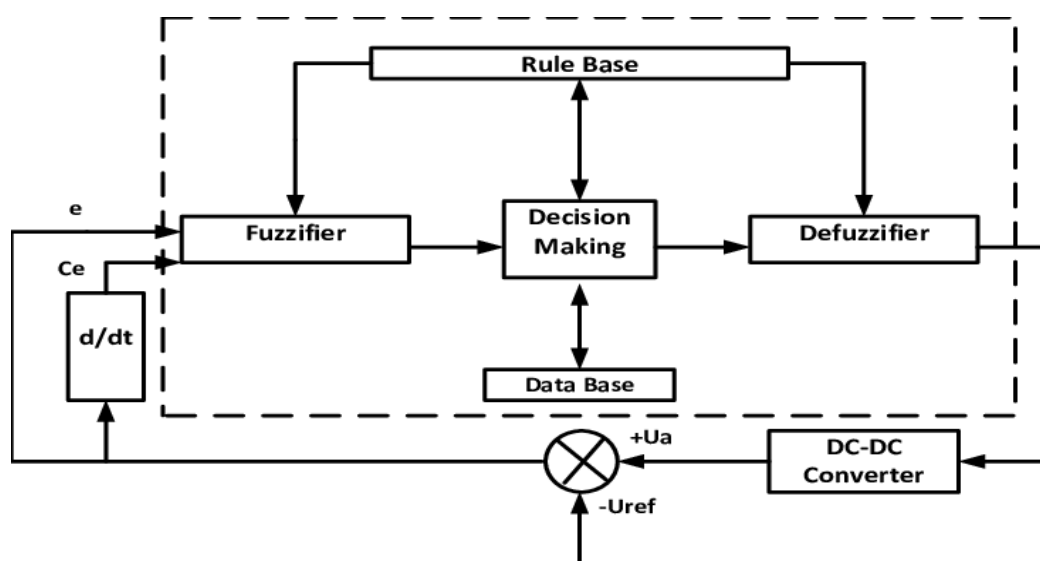


Figure 4: Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

V. CLOSED LOOP CONTROL OF BUCKCONVERTER USING PID CONTROLLER

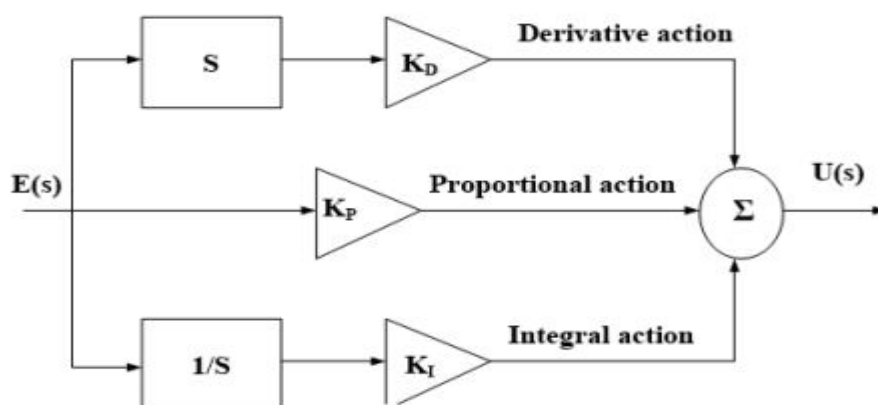


Figure 5- Buck Converter Using PID Controllers

The buck converter is designed using the equations 1-4 as given in section 1 and are shown in the Table 1. Design Values of PID controller are shown in the Table 2. The converter output voltage is regulated with lesser settling and rise time using FOPID controller compared with PID controller. The output voltage ripple is drastically reduced with FOPID controller. The overshoot is reduced considerably from a higher value to a negligible value with the use of FOPID controller. The under shoot and the slew rates are also improved with the used FOPID over PID controllers.

The performance comparison of buck converter with conventional PID and FOPID are given in Table 3. The comparison of response of the converter under these two controllers are shown in Figure 6.

Table 1. Design parameters of the buck converter

Parameter	Value
Input Voltage, V_d	24 V
Inductance, L	0.1 H
Capacitance, C	47 μ F
Load Resistance, R	25 Ω
Switching frequency	5000 Hz
Duty cycle, D	0.4

Table 2. Design Values of controllers

Controller	K_p	K_i	K_d	λ	μ
FOPID	0.702	0.6	0.45	0.885	1.2
PID	0.94	0.45	0.5847	-	-

Table 3. The performance comparison of buck converter with conventional PID and FOPID controllers

Controller	Vd (V)	Vo (V)	Rise Time (ms)	Slew rate (mv/s)	Ripple (V)	Overshoot %	Under-Shoot %	Settling Time
PID	24	9.933	92.687	85.735	0.02	15.698	2.000	19.98ms
FOPID	24	9.99	40.614	105.223	0	0.505	2.060	0.003ms

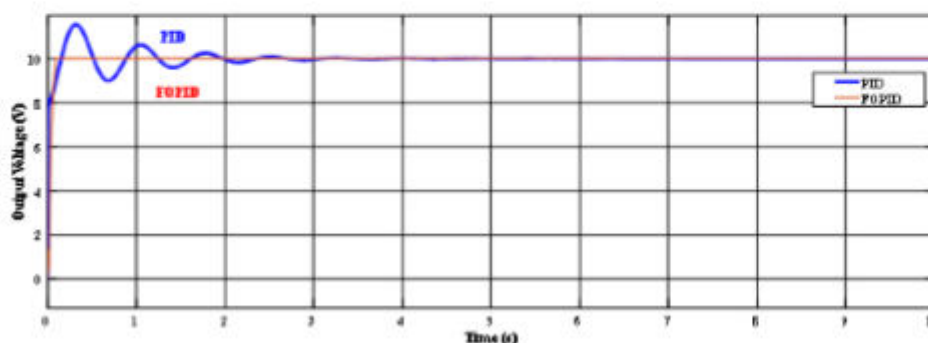


Figure 6 Comparison of output voltage of buck converters using PID and FOPID controllers

VI. CLOSED LOOP BUCK CONVERTER ANFIS

The neural network controllers are devices that require detail data about the converter, especially the number of inputs neurons which is equal to the input signals, also the output neurons which are equals to the output signals respectively, they have the ability of training with the help of known examples to obtain knowledge about a problem. The ANFIS is the combination of Fuzzy Logic technique and neural network technique to improve the quality of the output voltage of the converter, the structure of ANFIS consists of two inputs namely x and y and one output Z, a number of rules and five distinct layers (architecture of an ANFIS) as in figure 7. The ANFIS derives its name from adaptive neuro-fuzzy inference system. ANFIS method is based on the combination of artificial neural network and Fuzzy logic control. It combines the advantages of ANN and capability in learning from process and fuzzy logic control capability in handling uncertain information. This makes ANFIS capable of approximating nonlinear and uncertainties system without requiring pure mathematical. Fuzzy logic controller has the limitation that is not expert by itself. In fact, it needs and expert and provide the best performance. Therefore if expert assigns the wrong rule, then Fuzzy Logic controller may be provide poor performance even than the PID controller. Furthermore, most of the times we don't have sufficient knowledge about the behaviour of the system. Therefore, while the implementation of Fuzzy Logic controller, we are not sure about its correct rules. so, In order to overcome the limitation of fuzzy logical controller, artificial neural network can be used a make the fuzzy logic controller expert by itself. As we know that artificial neural network requires Input and output data only for it training. Therefore all we need is the input and output data of the system only. Based upon this system Input and output data, ANN learns the system behaviour, applies the correct rules and assign the correct membership function value to obtain the best performance. Among the ANN, Fuzzy, and ANFIZ is the most easiest and accurate technique to get the best results.

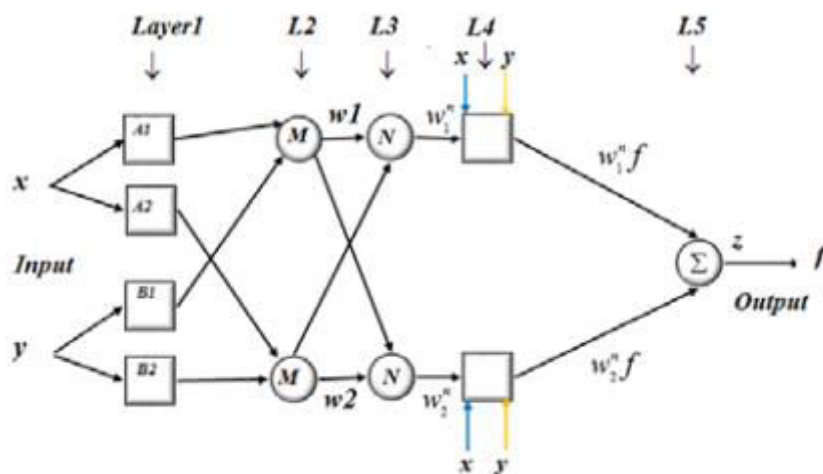


Figure7-ANFIS structure

VII. CONCLUSION

A simple algorithm based on the prediction of fuzzy logic controller, possibly using the fuzzy rules parameter, is showing to be more convenient than the circuit without fuzzy. As the 20 V input on the output voltage for the closed loop circuit (with fuzzy logic controller) with 0% overshoot shows the better performance compared to the open loop circuit (without fuzzy logic controller) whereby it has 80% overshoot. Moreover, the value of the output current also improving corresponds to the system and produce a constant value for the output current as 0.5 A. This scenario would not happen to the output current of the open loop circuit. Using a closed loop circuit with fuzzy logic controller, it is confirmed that the buck dc-dc converter gives a value of output voltage exactly as circuit requirement. Hence, the closed loop circuit of buck dc-dc converter controlled that by fuzzy logic controller confirmed the methodology and requirement of the proposed approach. These studies could solve many types of problems regardless on stability because as we know that fuzzy logic controller is an intelligent controller to their appliances. The closed loop control of buck converters are carried out with conventional PID controller. The performance were evaluated in terms of various time domain specifications such as rise time, settling time, output voltage ripple, overshoot, undershoot etc. For all types of converters, the performance of FOPID controller gave far better result as compared with conventional PID controllers. Adaptive Neuro-Fuzzy System (ANFIS) controller is better than the PID controller regarding performance and efficiency. The fuzzy controller has the main disadvantage with selecting the rules, membership functions, and scaling factors, this drawback can be modified using Neural Network to obtain satisfactory results. Finally, the ANFIS controlling method is an easy method and can obtain good results over the unbalanced voltage at the input and parameters variation leading to improved voltage regulation in the converter circuit, which enables us to implement this approach to different Dc/Dc converters topologies as future work.

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