

**Conference Paper**

# Implementation of Fuzzy Logic Controller (FLC) for DC-DC Boost Converter Using Matlab/Simulink

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**Abstract:** Nowadays, DC-DC converters circuits are widely used in electronics systems in order to obtain a stabilized output voltage from a given input DC Voltage. Performance of DC-DC converters is dependent on the choice of control methods. Consequently, controlling of DC-DC converter represents essential task in power conversion. The research problem addressed in this paper is to model a controlling system for Boost DC-DC converter. In this way a logic fuzzy controller is used and simulated using MATLAB/SIMULINK to increase converter efficiency and power efficiency.

**Keywords:** DC/DC Boostconverter, Fuzzy Logic Controller, Matlab/Simulink, Controlled Converter

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## 1. Introduction

DC-DC converters are nonlinear system in nature due to their switching property. Static and dynamic characteristics of these converters have been widely discussed in the literature. In many industrial applications there is a need for the transformation of a constant dc voltage source to a variable dc voltage source, and like a transformer, the converter can be employed for stepwise increase or reduction of dc source voltage [1]. In this way, Boost converter is a dc-dc converter in which the output voltage is always greater than the input voltage which depends on switching frequency [2]. Output voltage regulation in the dc-dc converter is achieved by constantly adjusting the amount of energy absorbed from the source and that injected into the load, which is in turn controlled by the relative durations of the absorption and injection intervals. These two basic processes of energy absorption and injection constitute a switching cycle [3]. In this context, Many control methods are used for control of switch mode DC-DC converters and the simple and low cost controller structure is always in demand for most industrial and high performance applications [4]. Several control strategies and mathematical models have been developed by

researches. Tobias Geyer, Georgios Papafotiou, and Roberto Frasca [4] have proposed a modeling and control approach for fixed frequency switch mode DC-DC converters by formulating a constrained optimal control problem using hybrid systems methodologies [4]. Ned Mohan, W.P. Robbins, M. Undeland, R. Nilssen and Olive Mo [5] were among the first to present means of simulating Power Electronics and Motion Control systems [5]. The Concept of Fuzzy Logic system was introduced by Lotfi Zadeh (1965) and its mathematical modeling which is deals with uncertainty [6]. The Fuzzy control represents a practical alternative for a variety of challenging control applications. FLC is nonlinear and adaptive in nature that gives it a robust performance under parameter variation and load disturbances. Fuzzy logic is suited to low-cost implementations and systems of fuzzy can be easily upgraded by adding new rules to improve performance or add new features. In this paper, a brief overview of the operation of a DC-DC boost Converter is provided, then, an implementation of boost converter using Fuzzy control is illustrated by the tool Matlab/Simulink.

## 2. DC-DC Boost Converter Circuit Model

In many industrial applications, it is required to convert a fixed-voltage DC source into a variable voltage DC source. A DC –DC converter converts directly from DC to DC and is

simply known as a DC converter. A boost converter provides an output voltage greater than the input voltage. The circuit arrangement of a boost converter is shown in figure 1; it consists of four essential components: Inductor, switch, diode and output capacitor.

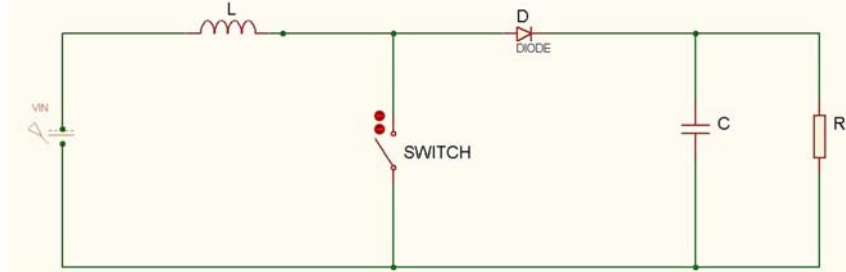


Figure 1. Basic configuration of boost converter.

Boost converter can operate into two modes. The first mode starts when switch is on at  $t = 0$ . The input current rises and flows through inductor and switch while second mode begins at  $t = t_{on}$ , the input current flows through inductor, capacitor, and diode, the inductor current falls until next cycle and energy stored in inductor flows through load.

In steady state time integral of the inductor voltage over one time period must be equal to zero as shown in equation 1

$$V_{IN} * t_{on} + (V_{IN} - V_{OUT}) * t_{off} = 0 \tag{1}$$

Where:

$V_{IN}$  : Input voltage

$V_{OUT}$  : Average output voltage

$t_{on}$  : Switching on time

$t_{off}$  : Switching off time

Dividing both sides by  $T_s$  and rearranging terms we obtain:

$$\frac{V_{OUT}}{V_{IN}} = \frac{T_s}{t_{off}} = \frac{1}{1-D} \tag{2}$$

Where:

$T_s$  : Switching cycle

D: Duty cycle

When switch turns on, current is passing through switch. Consequently, current increases in the inductor. When switch turns off, current stored into inductor is  $I_L$ , So:

$$V_{IN} = L \frac{di_L}{dt} \tag{3}$$

Applying Laplace transformation to equation (3) we obtain:

$$V_{IN}(s) = L * s * I_L(s) \tag{4}$$

On other hand:

$$V_{OUT} = R * I_L(s) \tag{5}$$

From equation (4) we obtain:

$$\frac{V_{OUT}}{V_{IN}} = \frac{R}{L * s} \tag{6}$$

Which represents transfer function of boost converter.

## 3. Fuzzy Logic Controller

Fuzzy controllers fulfill the same tasks like a classic controller. Fuzzy controller differs from the classic one in that it manages the control complex space in a heuristic manner. However, the fuzzy controller can approximate, with any precision level, linear and non-linear control functions. In many situations is easier to obtain a fuzzy controller with high performance than a classic controller with same performances [7]. The most important specifications of fuzzy control method are their fuzzy logical ability in the quality perception of system dynamics and the application of these quality ideas simultaneously for power systems [8].

Four major units are fuzzification block, a fuzzy knowledge-base block, a fuzzy inference engine and a defuzzification block [9] as shown in Figure 2.

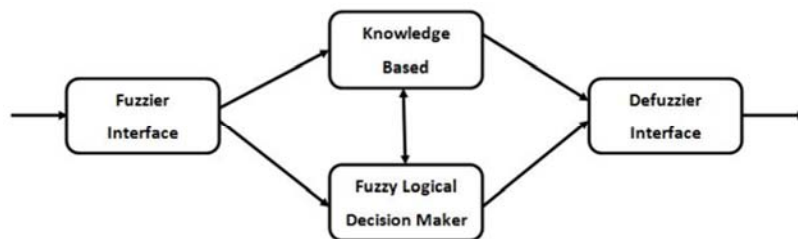


Figure 2. Fuzzy logic controller system.

The functions of the blocks of the fuzzy system are briefly summarized in below:

The fuzzifier interface is a block which classify input data into suitable linguistic values or sets ; it measures values of input variables in order to convert them into suitable values that may be viewed as labels of fuzzy. The knowledge base is comprised of two components namely called fuzzy sets (data base) and fuzzy control rule base. The concepts associated with fuzzy sets are used to characterize fuzzy control rules and fuzzy data manipulation in an FLC. These concepts are subjectively defined and based on experience. So, it should be noted that the correct choice of the membership functions of a term set plays an essential role in the success of an application [10]. While fuzzy decision maker represents the kernel of a fuzzy logic controller, it has capability of simulating human decisionmaking based on fuzzy concepts and of inferring fuzzy control actions using fuzzy implication (fuzzy relation) and the rules of inference in fuzzy logic. This means that the

fuzzy decision maker handles rule inference where human experience can easily be injected through linguistic rules. Finally, defuzzifier interface converts the conclusion from the fuzzy logical decision maker into the control input to the plant.

### 4. Modeling of Fuzzy Logic Controller for BOOST Converter Using Matlab/Simulink

The intend of this part is to model DC-DC boost converter and fuzzy logic controller (FLC) which improve efficiency and performance of the converter. Modelling and simulation are performed on Matlab/Simulink.

#### A. Boost converter modeling using Matlab/Simulink

Referring to the equation (6), the boost converter can be modelled as a transfer function to permit automatic tuning as shown in Figure 3.

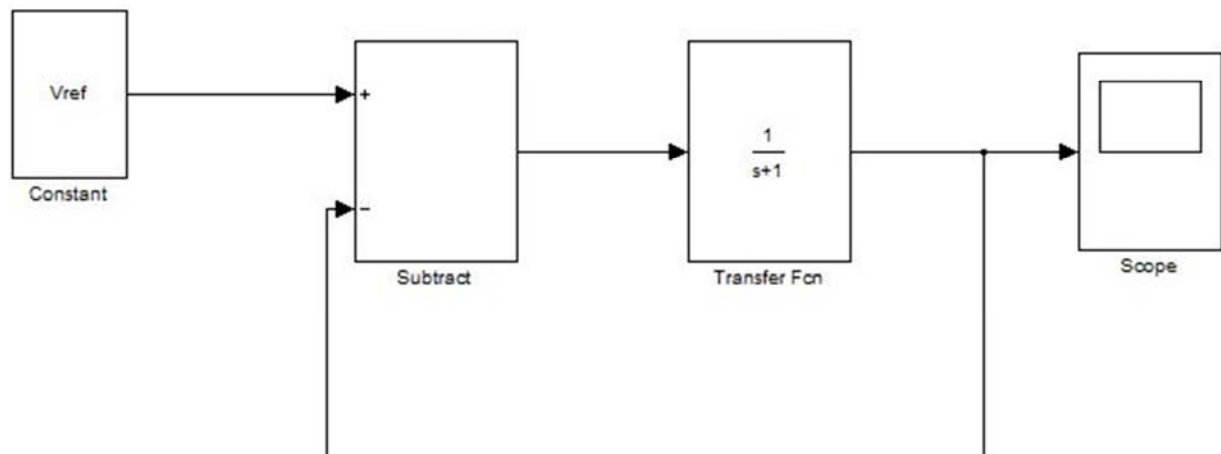


Figure 3. Transfer function model of boost converter.

#### B. Fuzzy logic controller modeling using Matlab/Simulink

The boost 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 boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying

operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.[11] Then, it is necessary to determine membership functions assigned to inputs and outputs as shown in Table 1.

Table 1. Fuzzy control rules.

Change In Error \ Error	PS	PB	NS	NB	ZO
PS	PB	PB	ZO	NS	PS
PB	PB	PB	PS	ZO	PB
NS	ZO	PS	NB	NB	NS
NB	NS	ZO	NB	NB	NB
ZO	PS	PB	NS	NB	ZO

The role of fuzzy logic controller is to control the output voltage of the boost converter. Fuzzy logic controller has two inputs which are error and change in error. These inputs are divided into five groups; (NB) Negative Big, (NS) Negative Small, (PS) Positive Small, (PB) Positive Big, (ZO) Zero Area, as shown in Table-1.

### 5. Simulation Results

A Matlab/Simulink model of DC-DC boost converter controlled with a fuzzy logic controller is shown in Figure 4.

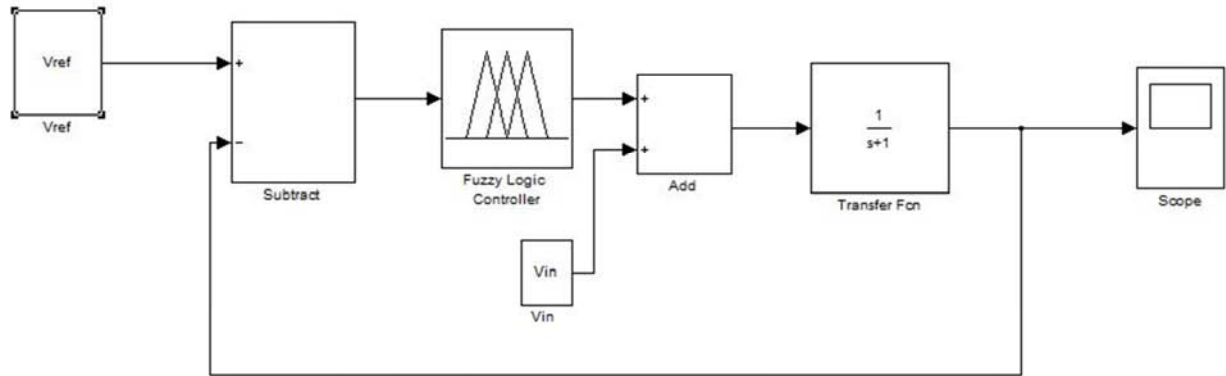


Figure 4. Simulink model of boost converter with fuzzy logic controller.

A simulation run for the Boost Converter is carried out whose design parameters are specified in Table 2.

Table 2. Design parameters.

Parameters	Values
Input voltage	5 V
Output voltage	12 V
Load resistance	500Ω
Frequence	50 KHZ
Inductance	200 μH
Capacitance	200μF

Waveforms of boostconverter output voltage in open loop mode are shown in Figure 5.

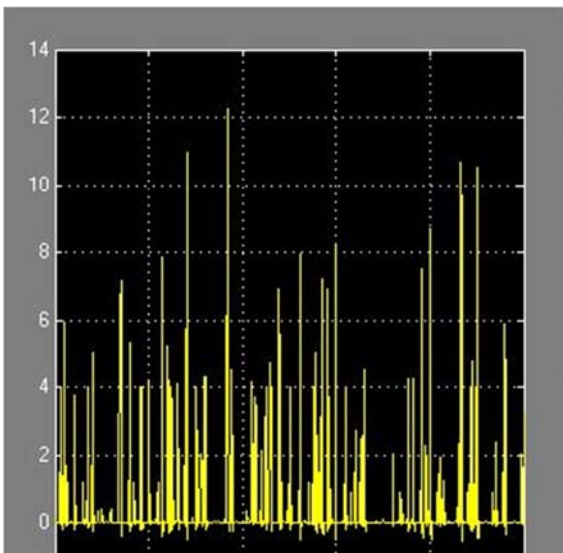


Figure 5. Output voltage in open loop mode.

The simulation results of output voltage for boost converter with fuzzy logic controller are shown in following figures, the value of output voltage is getting about 12V. Figure 6 and Figure 7 show results of fuzzy controlled boostconverter for supply voltage 12V and load variant conditions. Figure 8 and Figure 9 show results for 500 ohm load and input supply variant voltage.

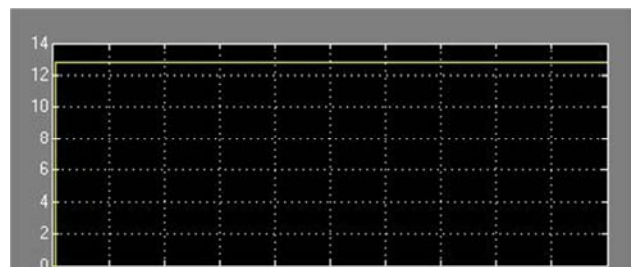


Figure 6. Output voltage of fuzzy controlled buckConverter for 5 ohm load.

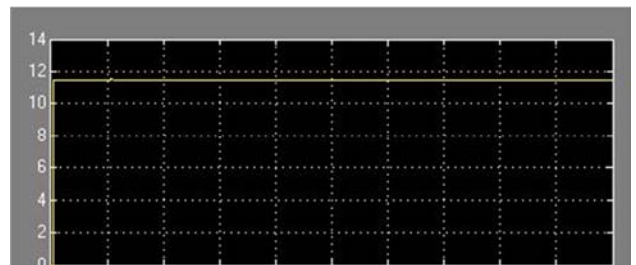


Figure 7. Output voltage of fuzzy controlled buckConverter for 500 ohm load.

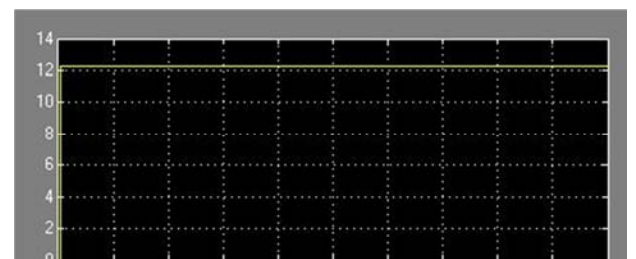


Figure 8. Output voltage of fuzzy controlled buck converter for 5V supply voltage.

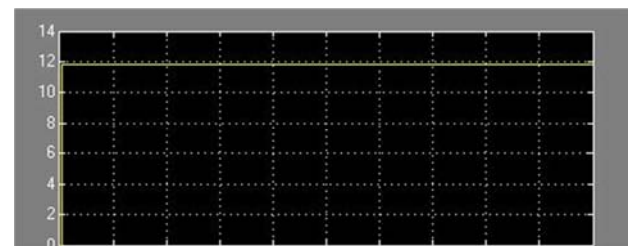


Figure 9. Output voltage of fuzzy controlled buck converter for 20 supply voltage.

In open loop mode, output voltage is sensitive to parameters variations (Figure 5). Results of fuzzy controlled boost converter for 5V supply voltage and load variant conditions show that output voltage is 12.8 V for 5 Ohm load (Figure 6) and is 11.5 V for 500 Ohm load (Figure 7). While results of fuzzy controlled buck converter for 500 Ohm load and variant supply voltage show 12.3V for 5 V supply voltage (Figure 8) and 11.8V for 20V supply voltage (Figure 9).

## 6. Conclusion

In this paper, we provided a brief overview of DC-DC boost converter and fuzzy logic controller, and proceeded to illustrate a model of fuzzy logic controlled boost converter using Matlab/Simulink. This paper demonstrated the effectiveness of fuzzy controller applied to DC-DC boost converter. Good behavior of the boost converter proves the robustness of the controller especially it shows good stabilization quality.

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