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Using Fuzzy Control System Develop Boost DC-to-DC Converter

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Abstract

The main motive of this study is to use MATLAB Simulation to design a FLC (fuzzy logical controller) for a boost DC-DC converter. By creating an FLC algorithm, the FLC was integrated into the system. This implies that the controller bases its control decisions on the concepts of fuzzy logic. The inductor has undergone extensive design and calculation work to guarantee that the transformer runs in mode of continuous conduction. This suggests that the appropriate functioning of a converter depends on the careful design and selection of its components. Through software simulation with MATLAB software, the system's output has been assessed and compared. The circuits that are closed-loop (with feedback control) and open-loop (without it) are compared. The simulation results show that this methodology is utilized for managing the voltage output of the boost DC-DC converter in a steady-state condition. This implies that the performance of the converter is effectively enhanced by FLC. Overall, the goal of the study is to enhance the adaptable implementation of a DC-DC boost converter by presenting a methodology for designing and implementing a FLC. The simulation-based evaluation demonstrates encouraging outcomes in reaching the targeted control goals.

Keywords: MATLAB-Simulink, boost converter, DC to DC converter, fuzzy controller

INTRODUCTION

The most common circuits in power electronics appliances are DC-DC converters. These days, you can find them in practically every electronic device because DC sources power all semiconductor components. The direct current converters maintain a given voltage to the necessary level. Usually, this is accomplished by utilizing appropriate switching action to chop and filter input voltage; this is typically accomplished through pulse width modulation. FUZZY logic control (FLC) has been effectively utilized in addressing a diverse range of engineering issues, such as DC-DC converters. Investigations have revealed that fuzzy control outperforms linear controllers in terms of performance and can save development costs. Control schemes like fuzzy logic for power converters are becoming possible to implement thanks to advancements in electronic devices and electronic monitoring technologies. This facilitates the integration of method analyzing about a system controller by the designer [1].

When a system is hard for modelling because of its intricate, irregularities, or imprecise nature, fuzzy control is a very useful tool. DC-DC converters are included in this category due to their time-varying structure, nonlinear components, and parasitic parts.

The method of execution is presented in this study of a PD FLC for Boost dc to dc converters. The converter state space model and control methods can be used to evaluate its adaptability and flexible limited execution. By enhancing control,

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the P-D controller is intended to raise the system's stability because it has the capacity to forecast system response errors in the future. Instead of taking the derivative from error signal, the final response of the system is used to mitigate the effects of the abrupt change in the error signal's value. To avoid abrupt changes in the control output that could arise, mode-D is therefore hence meant to be commensurate with the shift in the outcome parameter. To stop rapid shifts in the signal that indicates an error from causing shifting in the control system outcome. Thus, mode-D is meant to be proportionate to the alteration in the element of output [2–5].

Power electronic systems that relied on traditional control techniques typically did not function well when there is a nonlinearity, load disturbances, parameter variations, etc. To enhance the controller's performance in power converters, numerous attempts have been made. Power electronic systems were controlled using adaptive controllers, among other methods. However, these controllers are parameter-sensitive because they also require precise mathematical models. For the direct current Buck converter, FLC can perform better than the traditional PI controller. The high starting current of these controlled converters is one of their main issues [6–10].

PROPOSED METHOD

The fuzzy logical controller-based buck-boost Converters are depicted in Figure 1. It provides an explanation about each element and illustrates the fundamental interactions between the accessories. For example, the analog to digital converter, Pulse width modulation generator, and Direct to Direct converter, load, and FLC. Buck-boost converters is very much useful when a particular output voltage is needed at that moment. The output of a Buck Boost Converter can be adjusted to rise or fall in accordance with the duty cycle variation. An error value is the difference between the measured voltage and reference voltage from the Buck Boost converter. The FLC gathers the e(t) error signal and generates a variable duty cycle. which can produce the necessary duty cycle for the buck-boost converter's MOSFET to be switched, controlling the output voltage.

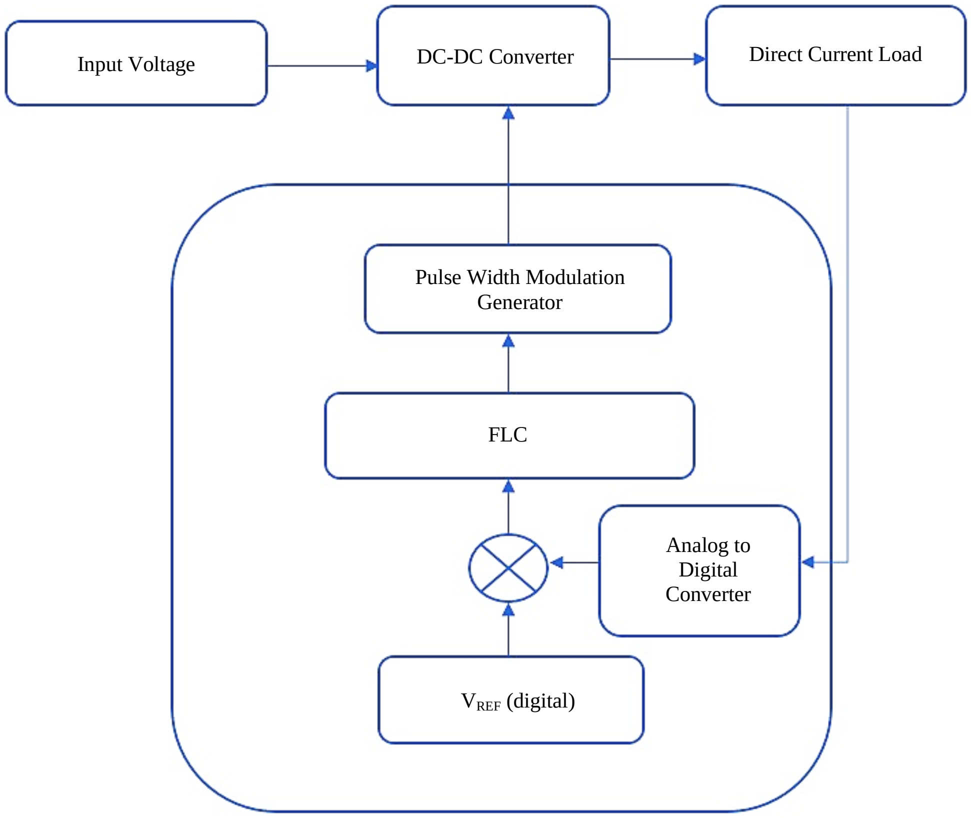

Figure 1. Buck-boost converter using FLC.

A step-up transformer, sometimes referred to as a boost converter, increases the value of DC input voltage and produces an output. Essentially, converters include a transistor for switching, a diode, and at least one energy storage component. To minimize output voltage ripple, capacitors are typically added to the output and are sometimes combined with inductors. It primarily operates in two different states:

The switch is made to close its contacts during the ON phase, which causes the inductor current to increase. The fly-back "D" and capacitor which are connected in parallel, and a load are the only paths via which flows the inductor current when the switch is in closed position. It allows the capacitor to transfer the energy it has stored during its on time. The configuration and specifications of the Boost converter model circuit are displayed in Figure 1.

DC-DC Boost Converter Using FLC

Figure 2 shows the Boost DC to DC Converter. An analysis of the circuit for the boost converter demonstrated that an inducer current is crucial to the Boost Converter's dynamic response. Furthermore, it can offer converter storage energy information. Therefore, any changes in the inductor current may have an impact on the produced voltage, and this produced voltage will provide more details regarding the steady state condition of the converter. However, the power switch, inductor, and capacitor are the three primary parameters that must be considered when designing boost converters. The power switch is designed with the goal of achieving the desired output voltage and stability [11–13].

LITERATURE REVIEW

Dukare *et al*. introduced fuzzy logic as a potent problem-solving methodology in the 1965s. Fuzzy logic's capacity to generate exact solutions from approximate data makes it similar to human decision-making. These days, a wide range of industries, including the automotive industry, dishwashers, automatic focus cameras, and home goods, successfully use FLC applications [1].

Salve *et al*. made a significant improvement in the dynamism in execution of the direct boost converter by incorporating a FLC. The results indicate that without direct boost converter the FLC had a substantial overshoot of 80%, which can be considered quite high. Overshoot is a measure of how much a system's response exceeds its steady-state value in response to a sudden change in input. High overshoot can lead to instability or damage to the system [2].

Shamim-Ul-Alam *et al*. recommended designing a moving model controller for a direct boost converter using fuzzy logic. All changes are guaranteed by the shifting system, and fuzzy logic boosts productivity and reduces mistake, electricity, and rippled current by reducing the chattering phenomenon caused by sliding controllers [3].

Rubaai and Chouikha [4]: The authors' main motive was to design controllers of direct current converter. Using suitable scaling factors connected to the fuzzy controller's input variables, simulation results have been obtained. Simulation findings indicate that the Fuzzy control can applied to dc/dc converters with ease, offering an intriguing substitute for more traditional methods [4].

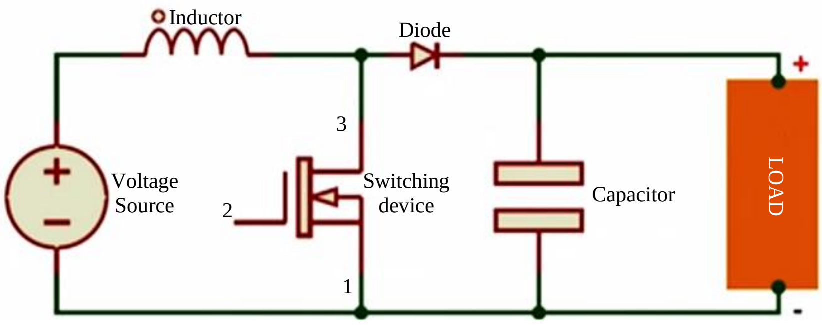

Figure 2. Boost DC to DC converter.

PROBLEM STATEMENT

Power semiconductor devices serve as electronic switches that form a DC-DC converter. Direct current converters are inherently nonlinear due to the operation of switching devices. Consequently, high levels of dynamic control are required for this converter. Due to their simple structure, proportional-integral-derivative (PID) controllers are commonly used in conjunction with converters. However, the primary drawback of PID controllers is their inability to achieve optimal efficiency in nonlinear systems. They often exhibit poor dynamic response, overshoot, longer rise and settling times, and other issues that affect the Boost converter's output voltage regulation. When the output voltage overshoots, PID controllers typically lead to a prolonged settling period. Therefore, it is essential to investigate the implementation of a suitable Fuzzy Logic Controller (FLC) to address these challenges. Due to its nonlinear nature and adaptability, Fuzzy Logic Control (FLC) offers robust performance under varying parameters and load disturbances, making it a valuable alternative for managing complex control scenarios. Unlike PID controllers, which are limited in their performance under diverse conditions, Fuzzy Logic Control demonstrates increased resilience as it can function effectively across a wider range of operating conditions and with various types of noise and disturbances. Moreover, developing a fuzzy controller is not more expensive than creating a model-based controller or another type of device performing a similar function. Low-cost implementations are well-suited for fuzzy logic, and fuzzy systems can be easily updated by integrating new inputs to enhance functionality or boost performance. Figures 3–5 show the flowchart, simulation, and output voltage waveform of the converter, respectively.

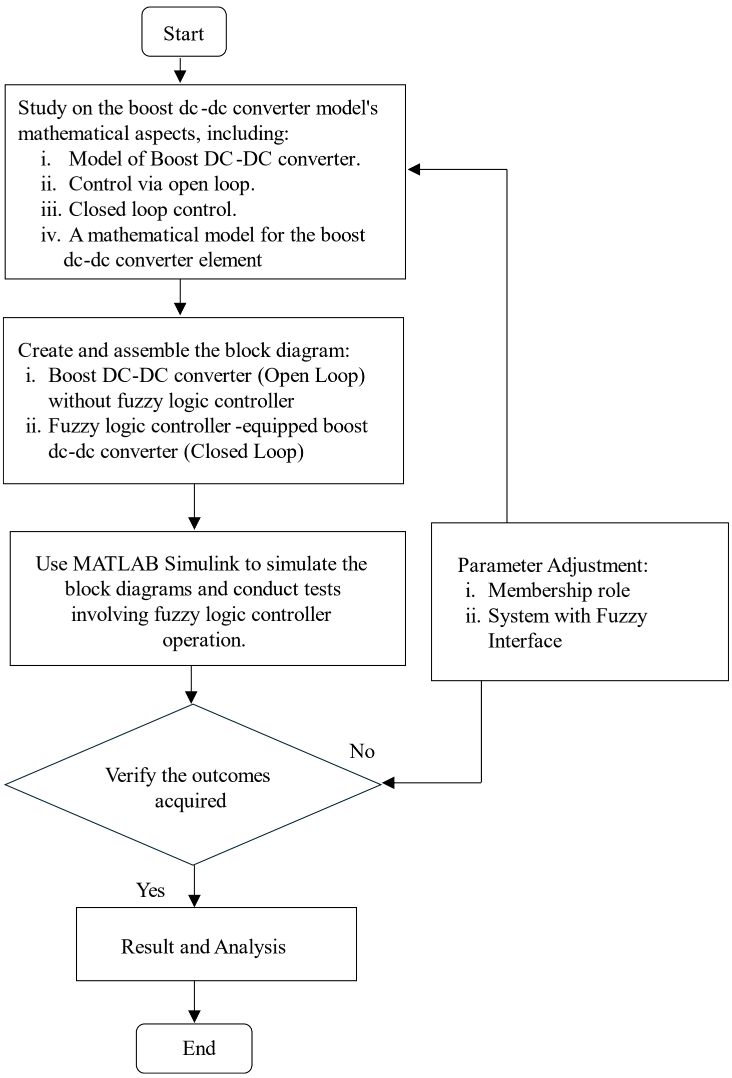

Figure 3. Flowchart of a boost DC-DC converter model.

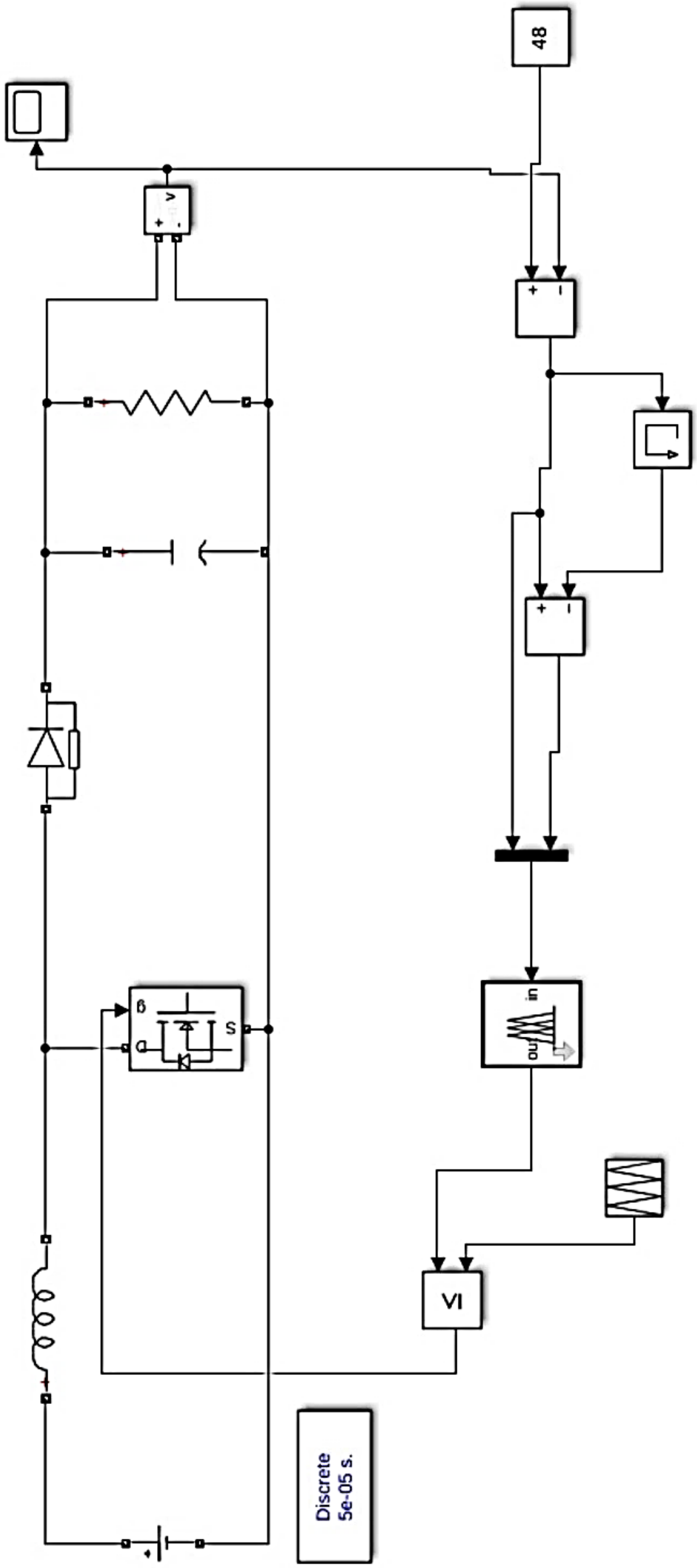

Figure 4. Simulation of boost converter using fuzzy logic controller.

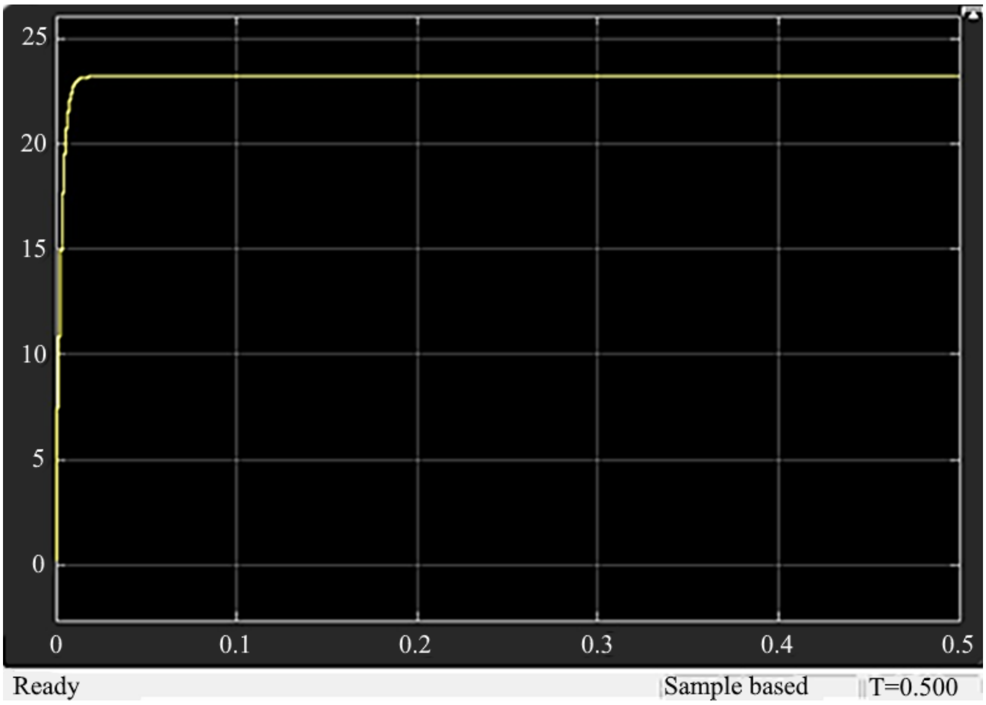

Figure 5. Output voltage waveform of converter.

METHODOLOGY

Boost Converter Topology

This circuit consists of a capacitor, switch (MOSFET), diode, and inductor. By regulating the duty cycle of the switch, the input voltage is increased. Traditional controllers are replaced with fuzzy logic controllers, or FLCs, which control the output voltage of the converter using a set of linguistic rules. The FLC takes into account two inputs: the error (the discrepancy between the desired and actual output voltage) and the change in error. Using membership functions, input variables are transformed into fuzzy language phrases such as "Positive Large," "Zero," and "Negative Small." To link these inputs to the output (duty cycle adjustment), a set of if-then statements is developed as a rule base.

SIMULATION AND RESULT

According to the simulation results, the fuzzy-controlled Boost DC-DC Converter achieves the following: Under various load conditions, the output voltage remains within 1% of the desired value. Compared to a PID controller, the fuzzy controller reduces overshoot and settling time. The system adapts well to nonlinearities and variations in input voltage. The advantages of the proposed method are demonstrated by comparing performance indicators, such as transient responsiveness, steady-state error, and efficiency, with traditional PID-based controllers.

CONCLUSION

This study successfully accomplished to design a FLC boost DC-DC converter using Matlab simulation. It is proving that a straight forward algorithm utilizing the fuzzy rules parameter in conjunction with FLC prediction is more practical in terms of a circuit without FLC. Without FLC it has 80% overshoot and with FLC it performs better with a 20 V input on the output voltage and 0% overshoot. Additionally, as the final power increases according to the protocol, it stabilizes to produce a fixed output current of 0.5 A.

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