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DC-DC Converter Using Fuzzy Logic Controller

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Abstract - *This paper presents an approach for DC-DC converter generally consists of power semiconductor devices which are operate as an electronic switches. Operation of these switching devices causes inherently nonlinear characteristic to the DC-DC Converters include buck-boost converter. Proposed system consists of development of fuzzy logic controller for generating control PWM pulses of required duty cycle for MOSFET of the buck-boost converter to maintain the constant output voltage. Duty cycle of the converter is adjusted continuously to obtain required output voltage. However, implementations of this control method to nonlinear system like buck-boost converters will suffer from dynamic response for the converter output. To achieve a stable and fast response, nonlinear controller were applied to control buck-boost converters. In this Paper, performance analysis of FLC has been done by using of MATLAB-Simulink.*

Key Words: DC-DC Converter, Buck-Boost Converter, Fuzzy Logic Controller, MATLAB-Simulink.

1. INTRODUCTION

DC-DC converters are the mostly used circuits in power electronics appliances. They can be found in almost every electronic appliance nowadays, since all semiconductor components are powered by DC sources. DC-DC converters are basically used for stabilizing a given dc voltage to a desired value. This is generally achieve by using chopping and filtering of input voltage through suitable switching action, generally implemented by using pulse width modulation. The buck-boost is a popular non-isolated, inverting power stage topology, sometimes called a step-up/down converter. Power supply designers choose the buck-boost converter because the output voltage is inverted from the input voltage, and the output voltage can be either higher or lower than the input voltage. The topology gets its name from producing an output voltage that can be higher or lower in magnitude than the input voltage [4].

Buck-boost converter is an intriguing subject from the control point of view, due to its intrinsic non-linearity. DC-DC converter consists of power semiconductor devices which operate as electronic switch. Operation of various switching device causes the inherently nonlinear characteristic to DC-DC converters such as buck-boost converter. Consequently, converter requires controller with high degree of dynamic response. PID controllers are generally used with converters because of its simplicity. However, implementation of this control method to nonlinear system like power converters will suffer from dynamic response of the converter output. One of the design targets for electronic engineers is to improve the efficiency of power conversion. For PWM (pulse-width modulation) converters, switching loss is an important performance measure. Fuzzy logic control has been applied successfully to a wide variety of engineering problems, including dc to dc converters. Fuzzy control is an attractive control method because its structure, consisting of fuzzy sets that allow partial membership and "if-then" rules, resembles the way human intuitively approaches a control problem. This makes it easy for a designer to incorporate heuristic knowledge of a system into the controller. Fuzzy control is obviously a great value for problems where the system is difficult to model due to complexity, non-linearity and imprecision. DC-DC converters fall into this category because they have a time-varying structure and contain elements that are non-linear and have parasitic components [5]. Buck-boost converter is used where constant output voltage required for a specific application. Buck-boost converter operate in buck as well as boost mode this is most effective advantage of the buck-boost converter. In this paper, MATLAB simulink is used as a platform in designing the buck-boost converter using fuzzy logic controller in order to study the dynamic behavior of DC-DC converter and performance of proposed system.

2. PROPOSED METHODS

Buck-boost converter using fuzzy logic controller is as shown in Fig-1 [3]. It shows the basic connections of the peripherals, along with description of the components such as DC-DC converter, Load, Fuzzy logic controller, PWM generator, Analog to digital converter.

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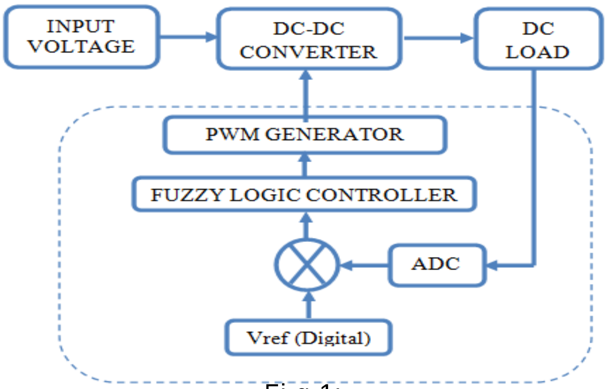

Fi g-1:
Buck-boost converter using fuzzy logic controller

For specific application where specific output voltage is required at that time buck- boost converter is used. In Buck boost converter output voltage can be to step up and step down output voltage according to the variable duty cycle. Difference between the measured voltage from the Buck-boost converter and reference voltage is taken as the error value. The error signal e(t) is fed forward to Fuzzy logic controller generate the variable duty cycle. Which can generates the required duty cycle for switching MOSFET of buck-boost converter thereby regulating the output voltage.

2.1 Buck boost converter

Buck boost converter is the category of DC-DC converter which converts an unregulated DC input voltage to a regulated DC output voltage. It operates by periodically opening and closing an electronic switch, here MOSFET. Buck boost regulator provides an output voltage which may be less than or greater than input voltage hence the name as buck-boost converter. Output voltage has opposite polarity to that of the input voltage. Circuit diagram of buck boost converter is shown in Fig-2.

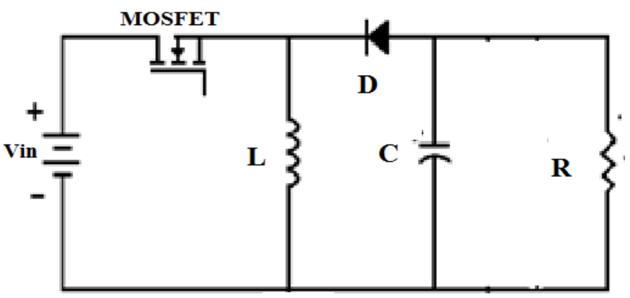

Fig-2: Circuit diagram of buck-boost converter

Operation of buck boost converter circuit can be divided into two modes.

- During mode 1, MOSFET is turned ON and diode D is in reverses biased. The input current which rises and flow through inductor L and MOSFET.
- During mode 2, MOSFET is switched OFF and current flowing through inductor L would now flow through L, C, D and the load. The energy stored in inductor L can be transferred to the load and the inductor current would fall until MOSFET is switched ON again in the next cycle.

3. METHODOLOGY

Input DC voltage is regulated by using DC-DC converter before it is fed to load. As we know the efficiency of conversion is very low, so it is of utmost importance to design DC-DC converter with the appropriate topology to obtain maximum efficiency and also with less cost. A buck-boost converter is designed to step up and step down a variable input voltage to a constant output voltage of 12 volts. To produce a constant output voltage is obtained by applying feedback control loop Fuzzy logic controller.

3.1 FUZZY LOGIC CONTROLLER

The Concept of Fuzzy Logic was introduced by Lotfi Zadeh (1965), and its mathematical modeling which is deals with uncertainty [7]. It offers an important concept of soft computing with words. It provides technique which deals with imprecision. The fuzzy theory provides mechanism for representation of linguistic terms such as “many,” “low,” “medium,” “often,” “few.” In general, the fuzzy logic provide an inference structure that enable appropriate human reasoning capabilities. Fuzzy logic systems are suitable for approximate reasoning. Fuzzy logic systems have faster and smoother response than conventional systems and control complexity is less. The fuzzy inference system combines fuzzy IF–THEN rules for mapping from fuzzy sets in the input space X to the output space Y based on fuzzy logic principle. In fuzzy logic, knowledge representation, fuzzy IF–THEN rule is a technique for capturing knowledge that involve imprecision. The main feature of reasoning using fuzzy rules is its partial matching capability, An inference to be made from fuzzy rule even when the rule’s conditions are partially satisfied [8].Block diagram of fuzzy logic controller is shown in Fig-3.

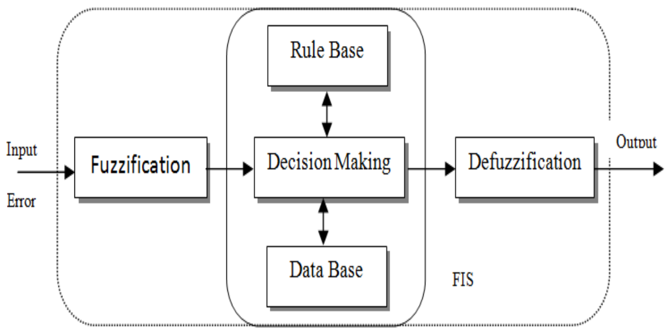

Fig-3: Block diagram fuzzy control system

FLC consists of three components namely fuzzification, fuzzy inference system and defuzzification. In general a fuzzy set issued to express a fuzzy variable which is

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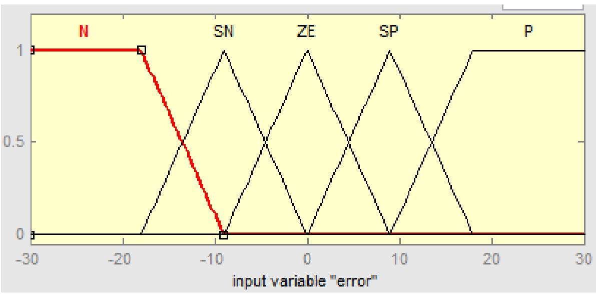
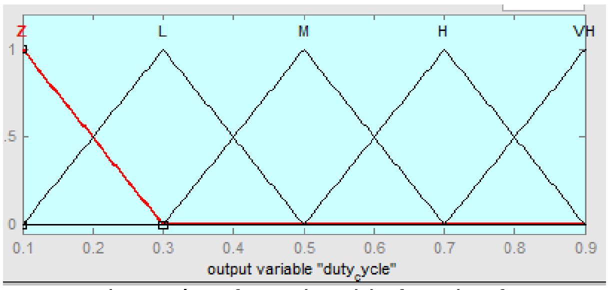
defined by a membership function. The values of membership function vary between 0 and 1. At the heart of the fuzzy rule base are the IF-THEN rules.

- Fuzzification: Fuzzification is the process of convert input data into suitable linguistic values. i.e. convert crisp facts into fuzzy sets described by linguistic expressions. Membership functions are triangle shaped, trapezoidal shaped. There are two fuzzification methods which are used mostly, Mamdani and Sugeno. Plot of membership function for input error and output shown in Fig-4 and Fig-5 respectively.



Fi g-4: Plot of membership function for error



F ig-5: Plot of membership function for output

- Fuzzy Inference System: The fuzzy IF-THEN rule expresses a fuzzy implication relation between the fuzzy sets of the premise and the fuzzy sets of the conclusion. The rules IF part describes situation for which rules are designed and THEN part describes the response of fuzzy system. For example. IF the Error is N THEN Duty Cycle is Z.

- Defuzzification: To obtain crisp output various defuzzification methods can be used e.g., center of gravity, bisector of area, mean of maximum, Adaptive integration, Fuzzy clustering defuzzification, First of maximum, Last of maximum, Semi-linear Defuzzification, Quality method, Middle of maximum. To obtain a crisp numerical output value.

4. SIMULATION RESULTS

To demonstrate the performance of proposed DC-DC buck boost converter, in MATLAB/Simulink with the parameters given in table. A constant voltage source of 20 V is input to converter with R load having value R= 20. The complete model consists of voltage source, linear load, voltage source PWM converter.

Table 1: Parameters used in buck-boost converter

Sr. No	Parameter	Value
1.	Switching	Fs = 3kHz
2.	Input Voltage	Vin = 20
3.	Inductance	L = 560mH
4.	Capacitance	C = 1 uF
5.	Load Resistance	R= 20 Ohms

4.1 Buck-Boost Converter Using Feedback Loop

The Simulink model of designed system is shown in Fig-6.

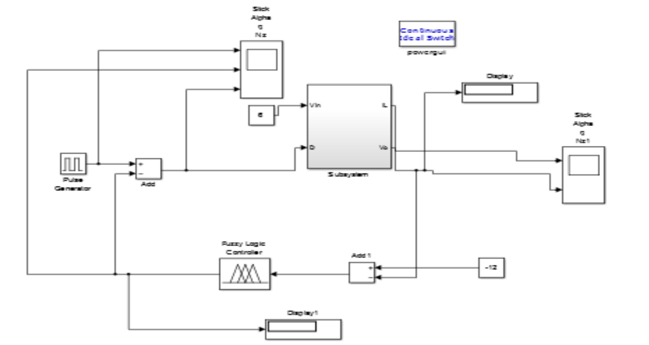


Fig-6: Simulink model of buck-boost converter in closed loop mode

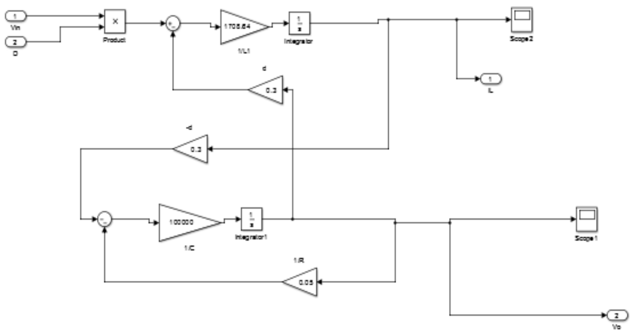


Fig-7: Subsystem buck-boost converter in close loop mode

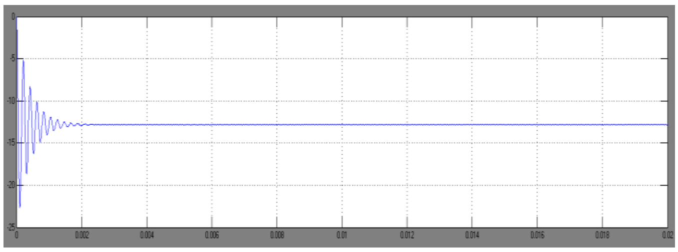


Fig-8: Output voltage of buck-boost with fuzzy logic controller

The pid_out calculated by PID settles down as slowly error converges to zero as output voltage approaches the desired set point as can be seen in Fig-8.

6. CONCLUSIONS

In this paper, Analysis of Buck-Boost Converter with fuzzy logic converter is presented. The output voltage of Buck-Boost Converter can be stabilized using variable duty cycle generated by the fuzzy logic controller. Buck-Boost converter with closed loop fuzzy logic controller precisely improved the dynamic response of the system during load as well as source variation with reduced voltage and current ripple. Moreover, the circuit is simpler and much cheaper compared to other control mechanisms where large numbers of components are needed. Finally performance analysis of Buck-Boost Converter with fuzzy logic controller has been done by using of MATLAB-Simulink.

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