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PERFORMANCE ANALYSIS OF CUK CONVERTER USING FUZZY LOGIC CONTROLLER

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ABSTRACT

In this paper the performance comparison of CUK converter using Fuzzy logic controller with PI controller is discussed. The CUK converter is a special type of DC-DC converter. The advantage of CUK converter is continuous input and output current. The design of the PI controller is based on root locus method and the designing of fuzzy logic controller is based on general knowledge of the plant (dc-dc converter). Fuzzy logic controller (FLC)is cheaper to develop a wider range of operating conditions and they are adjustable in terms of natural language. In this paper the modelling of CUK converter with PI controller and Fuzzy logic controller are developed and all the results are tested by MATLAB/Simulink software.

Keywords: *CUK Converter,- State Space Averaging Technique,- PI Controller,- Fun::y Logic Controllers.*

I. INTRODUCTION

Switch Mode Power Supply topologies follow a set of rules. A very large number of converters have been proposed, which however can be seen to be minor variations of a group of basic DC-DC converters – built on a set of rules. Many consider the basic group to consist of the three: BUCK, BOOST and BUCK-BOOST converters. The CUK converter, is a BOOST-BUCK converter. The CUK converter is a special type of DC-DC converter where a negative polarity output may be desired with respect to the common terminals of the input voltage and the average output is either higher or lower than the dc input voltage. It is generally a boost converter followed by a buck converter with a capacitor to couple the energy. In this paper the non- isolated CUK converter is analyzed. It uses a capacitor as its main energy-storage element, where other converters use an inductor. The CUK converter uses capacitive energy transfer and the analysis is based on current balance of the capacitor. The capacitor is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the MOSFET and the diode [1].It will be desirable to combine the advantages of these basic converters into one converter.CUK converter is one such converter. It has the following advantages.

- Continuous input current.
- Continuous output current.
- Output voltage can be either greater or less than input voltage.

A. Operating Principle of CUK converter

Switch ON/ Diode OFF:CUK converter is actually the cascade combination of a boost and a buck converter.

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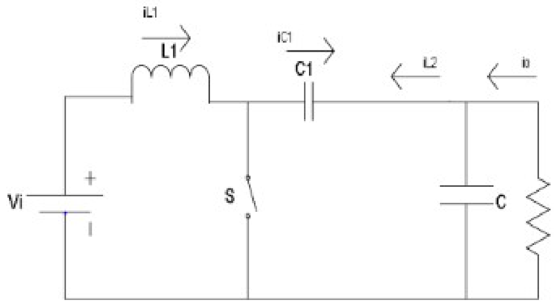

Fig. 1: Circuit Scheme of CUK Converter during ON State

Here Fig. l shows the circuit scheme of the converter when switch S is ON. The current $i_L$builds the magnetic field of the inductor in the input stage. Current in both the inductors i_L1 and i_{L2}increases, at the same time the voltage of capacitor C_t reverse biases diode D and turns it off. The capacitor Ct discharges its energy to the circuit formed by C $_t$, Lt. C and the load and energy dissipates from the storage elements in the output stage.

The basic non-isolated CUK converter is a switch mode power supply with two inductors, two capacitors, a diode, and a switch. The two inductors Lt and La are used to convert the input voltage source (V,) and the output voltage source (C) into current sources respectively. At short time duration an inductor can be considered as a current source as it maintains a constant current. The voltage source, the current would be limited only by the parasitic resistance, resulting in high energy Charging a capacitor with a current source prevents resistive current limiting and its associated energy loss.

Figure 1 show the circuit scheme of the converter when the switch S is off. At the same time the input voltage is turned on and the diode D is forward biased and capacitor C_l is charged through L_t, D and the input supply V,. Current in both the inductors i_L t and iLincreases [2]. The energy which is stored in the inductor La is transferred to the load. The diode D and the switch S provide asynchronous switching action[3].

II. CONTROLLERS

Control system comprises of controllers which manages, commands, directs or regulates the behavior of devices or systems using control loops. Controller is a device, historically using mechanical, hydraulic, pneumatic or electronic techniques often in combination, but more recently in the form of a microprocessor or computer, which monitors and physically alters the operating conditions of a given dynamic system. The objective is to develop a control model for controlling such systems using a control action in an optimum manner without delay or overshoot and ensuring control stability. Typical applications of controllers are to hold settings for temperature, pressure, flow or speed. For continuously modulated control, a feedback controller is used to automatically control a process or operation. The control system compares the value or status of the process variable(PV) being controlled with the desired value or set point(SP), and applies the difference as a control signal to bring the process variable output of the plant to the same value at the set point [4]. The basic control loop can be simplified for a single-input-single-output (SISO) system.

Different types of controllers

- Proportional Controller
- Integral controller
- Derivative controller
- Proportional integral controller
- Proportional integral derivative controller

III. FUZZY LOGIC CONTROLLER

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The operating principle of a Fuzzy logic controller is similar to a human operator. It performs the same actions as a human operator does by adjusting the input signal looking at the system output show the fuzzy inference system which consists of three sections namely fuzzifier, rule base and defuzzifier [5].

In fuzzifier the input signals are converted into fuzzy number. Then they are used in the rule base to determine the fuzzy number of the controlled output signal. Finally,the controller output is converted to the crisp value. There are two inputs to the fuzzy inference system. One is the control error which is the difference between the reference signal and the output signal and the other one is the change in the error. They are first fuzzified and converted to fuzzy membership values and are used in the rule base in order to execute the related rules to generate an output.

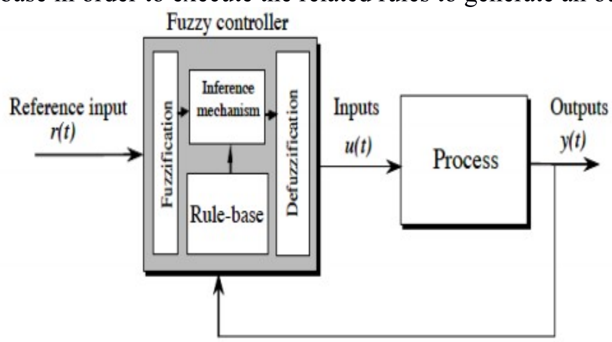

Fig 2: Fuzzy controller architecture

The fuzzy rule base or the fuzzy decision table is the unit mapping of two crisp inputs to the fuzzy output space defined on the universe of output signal[6].

It is necessary to observe the behavior of the error signal and its change on different operating regions, as shown by the Roman numbers .

It can be observed that the output from the fuzzy logic controller is the change that is required to increase or decrease the overall control action to the de fuzzification method called the centre of area is widely used in fuzzy logic control applications fuzzy Inference system (FIS) maps crisp inputs to crisp outputs. An FIS consists of four components: the fuzzifier, inference engine, rule base, and defuzzifier. The fuzzifier maps input numbers into corresponding fuzzy membership values. The inference engine defines mapping from input fuzzy sets to output fuzzy sets. It determines the degree to which the antecedent (predecessor) part is satisfied for each rule. If the antecedent part of the rule has more than one clause, fuzzy operators are applied to get a number that represents the result of the antecedent part for that rule. Outputs of all rules are then aggregated[7]. The defuzzifier maps the output fuzzy sets into a crisp number. The generally used defuzzification method is the centroid method.

A. Fuzzification

Fuzzification is the first step in the fuzzy inferencing process. This involves a domain transformation where crisp inputs are transformed into fuzzy inputs. Crisp inputs are exact inputs measured by sensors and passed into the control system for processing, such as temperature, pressure, rpm's, etc... Each crisp input that is to be processed by the FIU has its
own group of membership functions or sets to which they are transformed. This group of membership functions exists within a universe of discourse that holds all relevant values that the crisp input can possess.

B. Rule evaluation

Rule evaluation consists of a series of IF-Zadeh Operator-THEN rules. A decision structure to determine the rules require familiarity with the system and its desired operation. This knowledge often requires the assistance of

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interviewing operators and experts. For this thesis this involved getting information on tremor from medical practitioners in the field of rehabilitation medicine.

C. Defuzzification

Defuzzification involves the process of transposing the fuzzy outputs to crisp outputs. There are a variety of methods to achieve this, however this discussion is limited to the process used in this thesis design. A method of averaging is utilized here, and is known as the Centre of Gravity method or COG, it is a method of calculating centroids of sets. The output membership functions to which the fuzzy outputs are transposed are restricted to being singletons. This is so to limit the degree of calculation intensity in the microcontroller[8]. The fuzzy outputs are transposed to their membership functions similarly as in fuzzification[9]. With COG the singleton values of outputs are calculated using a weighted average, illustrated in the next figure. The crisp output is the result and is passed out of the fuzzy inferencing system for processing else where.

IV. SIMULINK MODEL

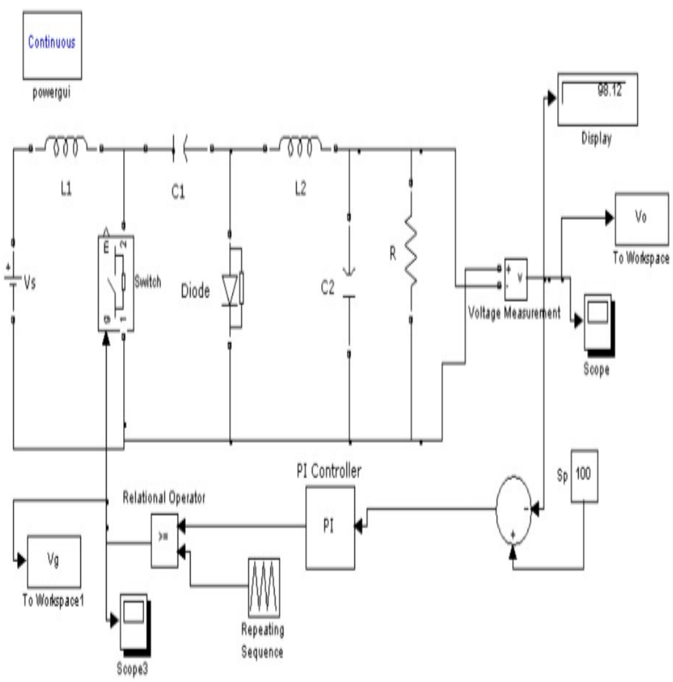

Fig 3: Simulink model of CUK converter with PI controller

The figure 3 shows the closed loop Simulink model where output voltage of the power converter is matched with a set point and the steady state error produced is passed through PI controller.

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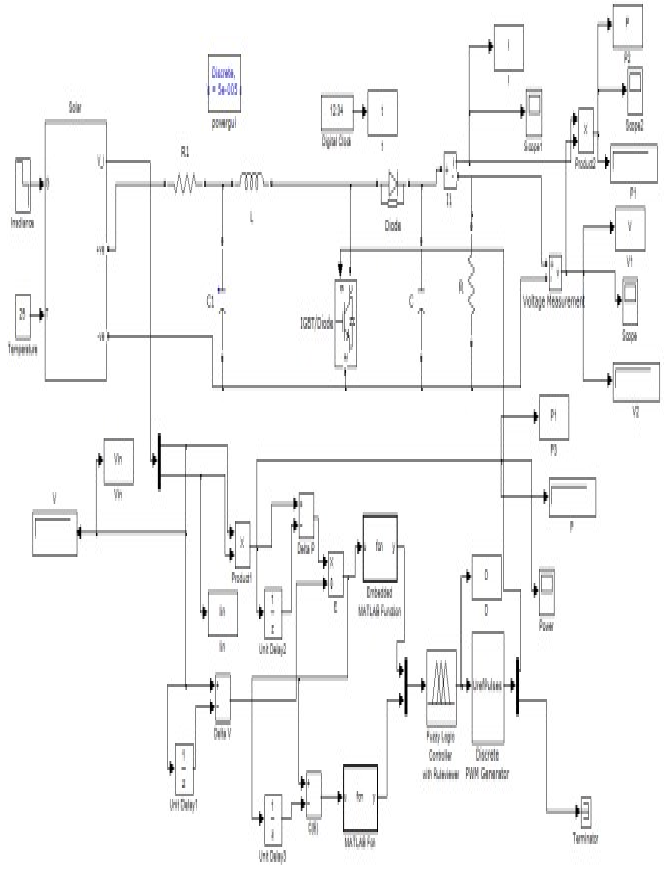

Fig 4: Simulink Model of CUK Converter with Fuzzy Logic Controller

The figure 4 shows the closed loop Simulink model where output voltage of the power converter is matched with a set point and the steady state error produced is passed through Fuzzy controller. The output of Fuzzy controller is compared with saw tooth waveform using PWM technique to generate the pulse which is fed to the gate of the converter switch.

V. RESULTS

The simulink model of CUK converter using fuzzy logic controller. The input to the fuzzy logic controller is the error and derivative of error and output of the fuzzy logic controller is compared with fuzzy logic controller rather than using PI controller. controller is Hence the performance of the system is improved using fuzzy logic controller.

A. Cuk converter design specifications

The specifications of the system are listed below

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Table 1: Design parameters of CUK converter

V_g	25V
L1	1mH
L2	1mH
C1	100µF
C2	450 µF
R	100Ω
$V_{O(desired)}$	100V
d	0.8

The output voltage of CUK converter with fuzzy logic controller rather than using PI controller. controller is 100V as shown in Fig. 5 and 6. Hence the performance of the system is improved using fuzzy logic controller.

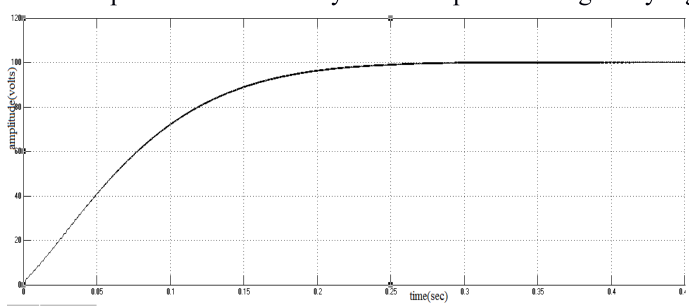

Fig 5:Output waveform of Cuk converter using PI controller with constant voltage

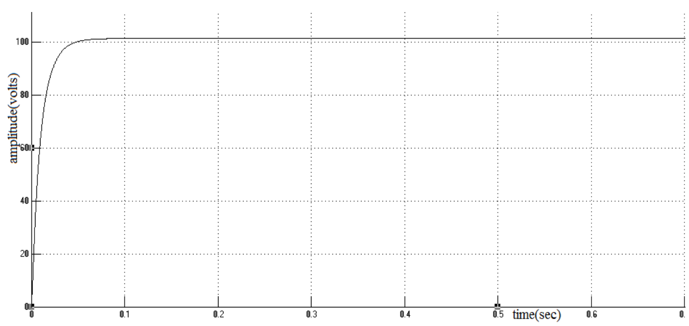

Fig 6:Output waveform of Cuk converter using Fuzzy controller with constant voltage

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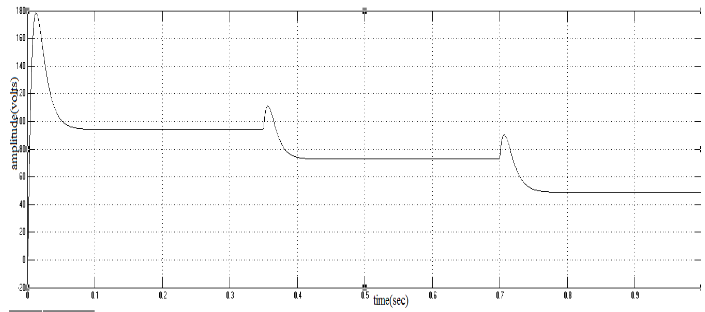

Fig7:Output waveform of Cuk converter using PI controller with varible voltage

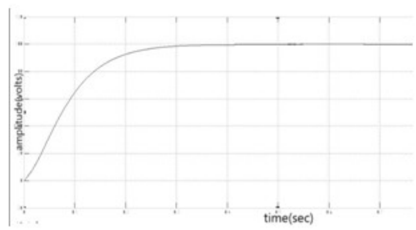

Fig 8:Output waveform of Cuk converter using Fuzzy controller with varible voltage

B. Comparison between Pi Controller And Fuzzy Logic Controller

Table 2: Performance Comparison

PI Controller				**Fuzzy Logic Controller**		
I/P vol.	**Mt**	**t, (sec)**	**V, (v)**	**Mt**	**t, (sec)**	**V, (v)**
25	**25%**	**0.23**	**98.83**	**3%**	**0.04**	**100**
20	**10%**	**0.22**	**98.73**	**1%**	**0.03**	**99.ó8**
15	**0%**	**0.20**	**98.ó 1**	**0%**	**0.05**	**98.37**

From the above table it can be observed that settling time and peak overshoot is reduced more using fuzzy logic controller rather than using PI controller. Hence the performance of the system is improved using fuzzy logic controller.

VI. CONCLUSION

This paper presents analysis of CUK converter with closed loop control by using both conventional PI controller and a fuzzy logic controller and the unique features in this paper is comparison of time response specification among two controllers for different input voltage. The linearized model of CUK converter is obtained by using state space

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averaging technique. The values of time domain specifications have improved more in fuzzy logic controller rather in PI controller.

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