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# Comparison of Buck-Boost and CUK Converter Control Using Fuzzy Logic Controller

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***ABSTRACT*—** DC-DC converters are used in many application such solar battery system, dc motor drives etc. DC-DC converters are used to convert the unregulated dc voltage into regulated dc voltage .The performance of these types of converters are best choice of control methods. Traditional methods require a mathematical model for a system but the fuzzy logic controller doesn't require any mathematical model and very simple to implement .The main objective of this work to reduce the overshoot of these types of converters. This work concentrates on buck-boost and cuk converter. The buck-boost and cuk converter is simulated for different R-Loads and their output voltage is settle at desired voltage .The performance of buck-boost and cuk converter are simulated using Matlab/Simulink and comparison study is performed.

**KEYWORDS**— Buck-boost converter,*Cuk converter, PWM , FLC, Matlab/Simulink.*

## I. INTRODUCTION

In recent year there has been an increasing in the development of DC-DC converter to improve the dynamic behavior [1-2]. The performance of power converters is the choice of control methods. Frequency domain analog methods predominantly used are based on an equivalent linear small signal model of the converter and this model has restricted validity especially for systems with strong non-linearity.

FLC is mostly used in industrial application and the main tool of FLC operation is membership function .It doesn't require any mathematical model for a system. The FLC provides a faster transient response[3-4].

The fuzzy control theory gives an alternative approach for collecting human knowledge and dealing with nonlinearities. The fuzzy modeling and control methods have succeeded in controlling uncertain systems that cannot be easily handled by a conventional control methods[5-6] **.**The popularity of Fuzzy Logic Controllers was its logical resemblance to a human operator. It operates on the foundation of knowledge base which in turn rely upon the various if then rules, similar to the human operator.

In this paper the proposed converter is simulated in Matlab/Simulink with simple block. The converter is control with FLC .

## II. BLOCK DIAGRAM

The input voltage is given to converter here the converter used are buck-boost and cuk converter. Then the converter output was given to load [7-8].The output voltage is varied depending upon load whenever load change, gate pulse width is varied and given input signal to converter. Based on the ON- OFF time of converter switch, output voltage is varied and settles down for reference voltage. The Fig. 1. shows the block diagram of converter.

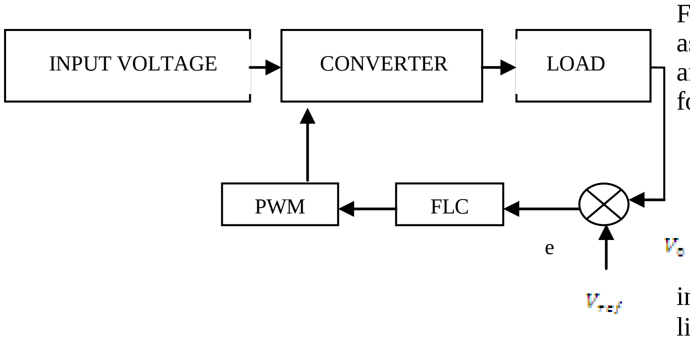


Figure 1. Block diagram of converters

The equation (1) shows a output voltage equation

$$V_o = -V_s \frac{k}{1-k} \quad (1)$$

Where $V_o$= output voltage, $V_s$ = supply voltage, k= duty cycle

The equation (2) and (3) shows the inductor and capacitor

$$L = \frac{(1-k)R}{2f} \quad (2)$$

Where L= inductance, R= resistance, f= switching frequency

$$C = \frac{k}{2fR} \quad (3)$$

where C=capacitance

*A.Buck-boost converter*

Buck-Boost converter can be obtained by the cascade connection of the two basic converters are the step-down converter and the step- up converter. In steady state, the output to input voltage conversion ratio was the product of the two converters in cascade

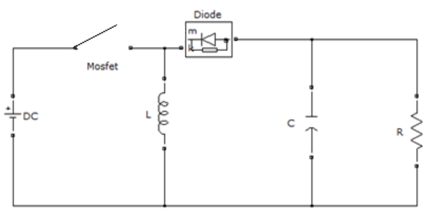


Fig. 2 Circuit diagram of buck-boost converter

The circuit arrangement of buck-boost converter is shown in Fig .2

*B.Cuk converter*

Cuk converter has several advantages over buck-boost converter .One of the advantage is the input current of cuk converter is continuous.

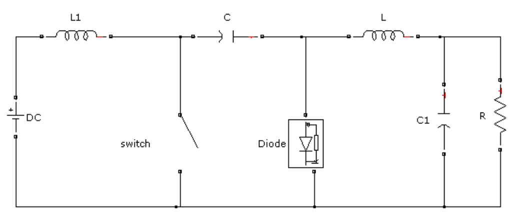


Fig. 3 Circuit diagram of cuk converter

The circuit arrangement of cuk converter is shown in the Fig. 3, the MOSFET use as a switch, the capacitor is uses as main energy storage .When input voltage is turned on and the MOSFET switch is turn off, diode is become forward bias and capacitor is charged.

## III. Design of Fuzzy logic controller

The FLC consist of three blocks they are fuzzifier, uzzifier and inference system. Fig. 4. shows the block gram of Fuzzy Logic Controller. The input of FLC are in the form of numerical variables are converted into a linguistic variables are done by fuzzifier [9]. The inference system consists of if-then rules. The defuzzification is conversion linguistic variable into a numerical values.

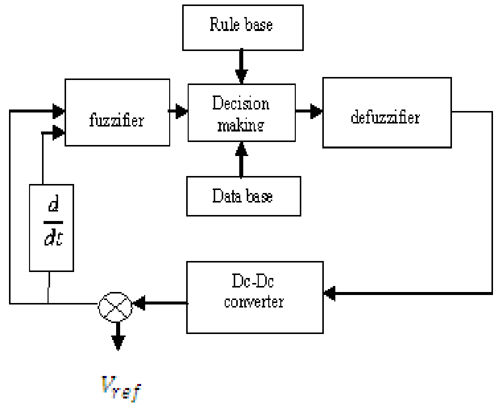


Fig. 4 Block diagram of fuzzy logic controller

The fuzzy logic controller consist of two input are error and change in error. For the system, $V_0$ is the actual output voltage of dc-dc converter, $V_{ref}$ is the reference voltage then error is calculated.

$$E(k) = V_{ref} - V_0 \quad (4)$$

The change in error equation is given in below

$$\Delta E(k) = e(k) - e(k-1) \quad (5)$$

The membership function for error and change in error are shown in the Fig 5 and 6

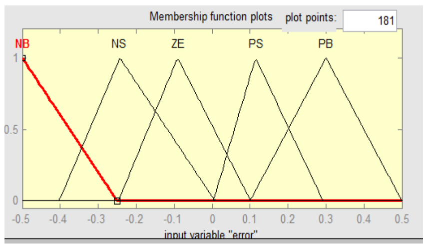


Fig. 5 Membership function of error

In the Fig NB stands for(Negative Big),NS stands for (Negative Small),ZE stands for (Zero),PS stands for (Postive Big) and PBstands for(Postive Big).

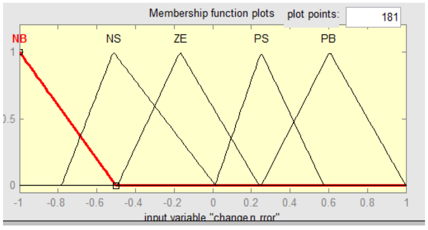


Fig. 6 Membership function of error

The rules of fuzzy are listed below

(1) IF E (error) is NB (Negative Big) AND ΔE (Change in error) is Negative Big (NB) THEN Output is Negative Big (NB)

(2) IF E (error) is Zero AND ΔE (Change in error) is Negative Big (NB) THEN Output is Negative Big (NB)

(3) IF E (error) is PB (Positive Big) AND ΔE (Change in error) is Positive Big (PB) THEN Output is Positive Big (PB)

TABLE 1. Rule base table

| E \ ΔE | NB | NS | ZE | PS | PB |
|---|---|---|---|---|---|
| NB | NB | NB | NB | NS | ZE |
| NS | NB | NB | NS | ZE | PS |
| ZE | NB | NS | ZE | PS | PB |
| PS | NS | ZE | PS | PB | PB |
| PB | ZE | PS | PB | PB | PB |

## IV. SIMULINK MODEL

### *A. Simulink model of buck-boost converter*

The buck-boost converter is simulated in open loop are shown in Fig. 7 .The output voltage is measured in scope

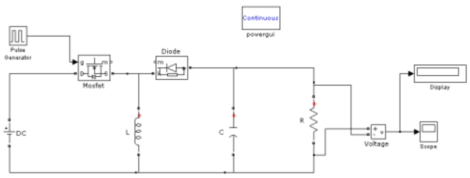

Fig. 7 Simulink model of buck-boost converter

The actual output voltage is compared with a reference voltage generate an error signal is given as input to FLC.The output of FLC is compared with saw tooth generator it generates a pulse and given as input to MOSFET.

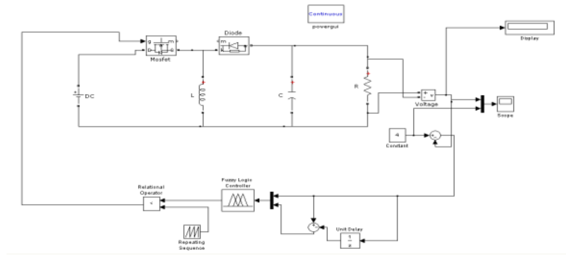

Fig. 8 Simulink model of buck-boost converter with FLC

### *B. Simulink model ofcuk converter*

The simulink model of cuk converter are shown in the Fig.9

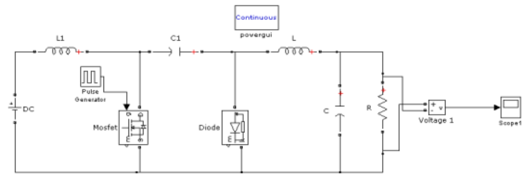

Fig. 9 Simulink model of cuk converter

Voltage(V)

The simulink model of cuk converter with FLC are shown in the Fig.10

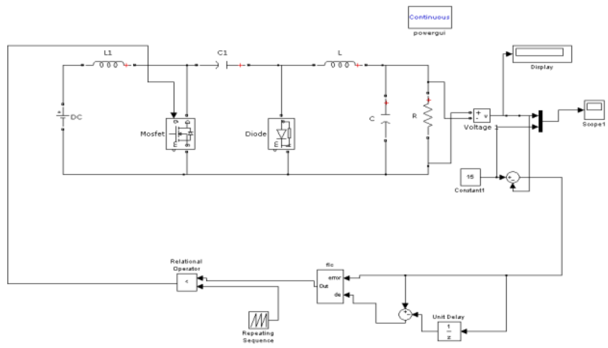

Fig. 10 Simulink model of cuk converter with FLC

## V. SIMULATION RESULT

### *A. Simulink resultof buck-boost converter*

The buck-boost converter is simulated in MATLAB 2012 .The output voltage is measured for different R-Loads are shown in Fig.11,12,13 and 14. The output voltage are measured by varying input voltage with constant duty cycle are shown in Table .2 and 3 . In Table. 4 the buck-boost converter with different R-Loads its settling time is shown.

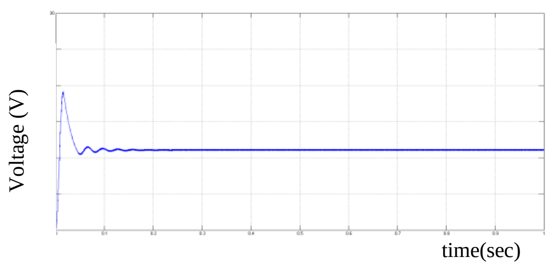


Fig. 11 Output of buck-boost converter for R- Load 50Ω

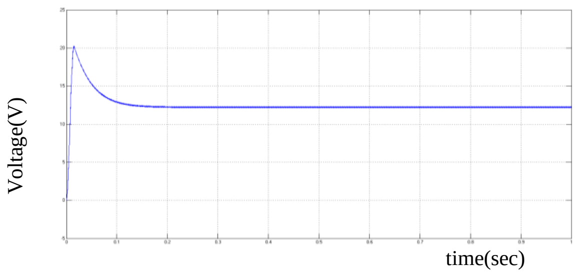


Fig. 12 Output of buck-boost converter for R- Load 100Ω

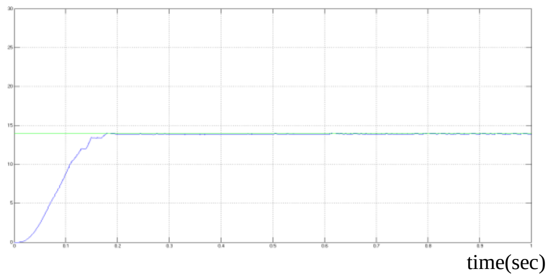


Fig. 13 Output of buck-boost converter with FLC at R- Load 50 Ω

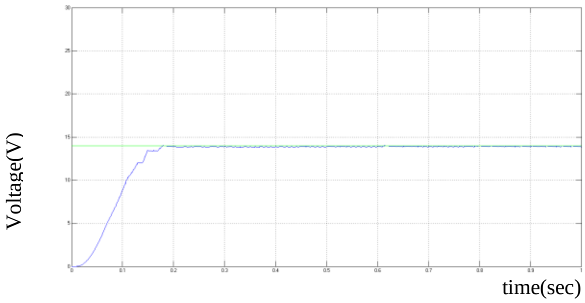


Fig. 14 Output of buck-boost converter with FLC at R- Load 100 Ω

TABLE 2. Buck-boost converter at duty cycle k=0.5

| Input Voltage(V) | Output Voltage(V) | |
|---|---|---|
| | Theory | Practical |
| 5 | 5 | 4.92 |
| 7 | 7 | 7.037 |
| 10 | 10 | 10.22 |
| 12 | 12 | 12.34 |

Table 2. shows the comparison of theoretical and practical output voltage for different input

TABLE 3. Buck-boost converter at duty cycle k=0.3

| Input Voltage(V) | Output Voltage(V) | |
|---|---|---|
| | Theory | Practical |
| 5 | 2.83 | 2.14 |
| 7 | 4.12 | 2.996 |
| 10 | 6.05 | 4.28 |
| 12 | 7.34 | 5.13 |

Table 3. shows the comparison of theoretical and practical output voltage for different input

TABLE 4. Settling time of buck-boost converter

| R-Load | Buck-boost converter without FLC | Buck-boost converter with FLC |
|---|---|---|
| 50 | 0.5 | 0.475 |
| 100 | 0.45 | 0.4 |
| 150 | 0.39 | 0.37 |
| 200 | 0.4 | 0.3 |

Table 3. shows the comparison of buck-boost converter with and without FLC at different R-Load

### *A. Simulink result of cuk converter*

The cuk converter is stimulated for different R-Load and their waveform are shown in Fig 15 and 16.

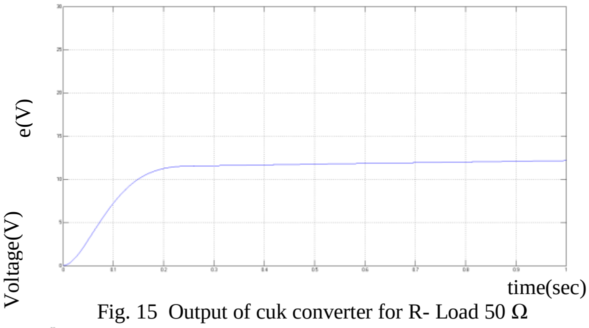


Fig. 15 Output of cuk converter for R- Load 50 Ω

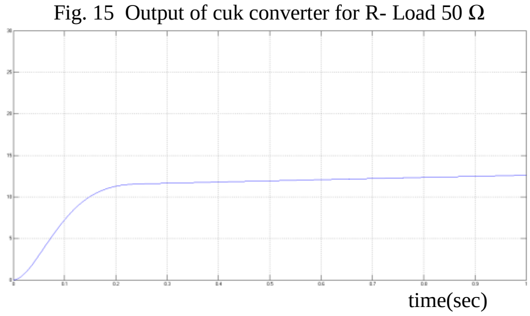


Fig. 16 Output of cuk converter for R- Load 100 Ω

The cuk converter converter with FLC used to improve the performance of cuk converter as well as it reduces the overshoot of an converter and settling time. The Fig 17 and 18 shows cuk converter with FLC for load R-50Ω and R-100 Ω and their settling time shown are shown in Table 7.

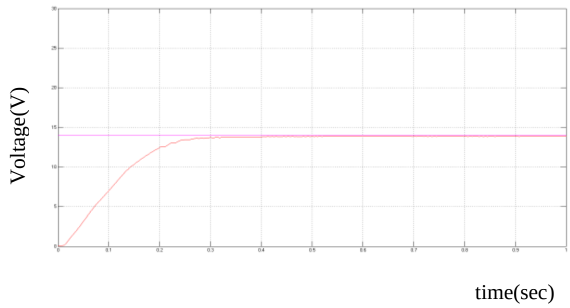


Fig. 17 Output of cuk converter with FLC at R- Load 50 Ω

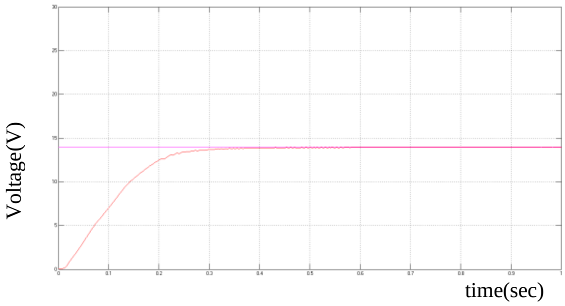


Fig. 18 Output of cuk converter with FLC at R- Load 100 Ω

TABLE 5. Cuk converter at duty cycle k=0.5

| **Input Voltage(V)** | **Output Voltage(V)** | |
|---|---|---|
| | **Theory** | **Practical** |
| 5 | 5 | 3.881 |
| 7 | 7 | 5.73 |
| 10 | 10 | 8.54 |
| 12 | 12 | 10.4 |

Table 5. shows the comparison of theoretical and practical output voltage for different input

TABLE 6. Cuk converter at duty cycle k=0.3

| **Input Voltage(V)** | **Output Voltage(V)** | |
|---|---|---|
| | **Theory** | **Practical** |
| 5 | 2.14 | 1.282 |
| 7 | 2.996 | 2.101 |
| 10 | 4.28 | 3.331 |
| 12 | 5.13 | 4.151 |

Table 6. shows the comparison of theoretical and practical output voltage for different input

TABLE 7. Settling time of cuk converter

| **R-Load** | **Cuk converter without FLC** | **Cuk converter with FLC** |
|---|---|---|
| 50 | 0.8 | 0.5 |
| 100 | 0.55 | 0.4 |
| 150 | 0.5 | 0.38 |
| 200 | 0.48 | 0.43 |

The stimulation result of buck-boost converter is compared with cuk converter. The buck-boost converter settles time is low.

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