ANALYSIS OF FUZZY BASED INTERLEAVED CUK CONVERTER

T Sravya[1], K Venkata Sai Prakash[1], B Dileep kumar[1], B Venkataramana [1],G Venkatarao[1]
[1]Lendi Institute of Engineering and Technology(LIET), Vizianagaram
Email: hidiszsravya@gmail.com, saiprakash1818@gmail.com

***Abstract*: Conventional DC-DC converters are widely used in non-conventional power conversions namely in solar and wind power generation systems. Since there is no filter inductor on output side, output current of cuk converter is pulsed, which is not desirable, so it is required to improve the quality of power when DC-DC converters are employed for transferring requisite amount of power. The objective of this paper is to analyze , simulate and examine the operation of interleaved cuk converter. The unwanted ripple content is diminished and reduction in settling time by implementing interleaved structure to cuk converter topology with current and voltage feedback control loop by using fuzzy logic controller. In this paper the proposal model gives high efficiency and gain with limited duty cycle and wide load variation range. The performance of this system is observed in MATLAB/SIMULINK SOFTWARE.**

***Keywords*— DC-DC converter, cuk configuration, interleaving technique, reduced current and voltage ripple, voltage feedback, fuzzy logic controller.**

INTRODUCTION

Cuk converter is one of the most versatile Buck -Boost converter topologies that is output voltage from converter can be both lower and higher than input voltage. The advantages of using cuk converter over the conventional Buck-Boost topology are continuous current at both input and output and low output voltage ripple with properly designed filter. The major disadvantage in the cuk converter is input current is high due to this inductor losses are maximum and by using the single switch throughout the operation so temperature and switching losses are also high. So to overcome these disadvantages ,we may place the two cuk converters in parallel i.e.. called INTERLEAVED TECHNIQUE.This topology possesses the advantages of both Buck and Boost converter. The main advantages of this Interleaved cuk converter are the high input current is divided into two halves due to the parallel connection and Temperature losses are reduced by using the two switches during the total time period of operation. The applications of interleaved cuk converter are in renewable power applications like in solar and wind power applications as voltage regulator in hybrid solar-wind energy system where input voltage depends on speed of wind and sun, it is used in self regulating power supplies, consumer electronics, battery power systems, adaptive control applications and also used in power amplifier applications. In literature many researches has been done on conventional solutions for controller design of different DC-DC converters based on classical and modern control theory. Widely used classical control theory based controllers are PID controllers. These controllers require precise linear mathematical models and also fail to perform satisfactorily under parameter variation, non-linearity and load disturbance. In certain applications like finding operating point of a system, Fuzzy logic controller

(FLC) have proven to be a good choice. The advantages of the Fuzzy logic controllers over PI, PID controllers are:

- Non linearities can be smoothly handled in a much better way
- There is nothing requirement of input to be precised.
- Cover a wider range of operating conditions

CUK CONFIGURATION:

Main advantage of behind usage of Cuk Converter is to produce purely regulate DC output voltage over the buck-boost converter and other DC-DC topologies. It reduce ripple content at input as well as at output side with an improvement in settling time period.

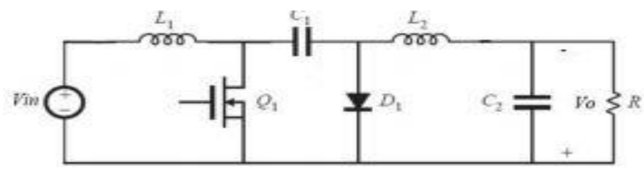


Fig-1: Cuk Converter

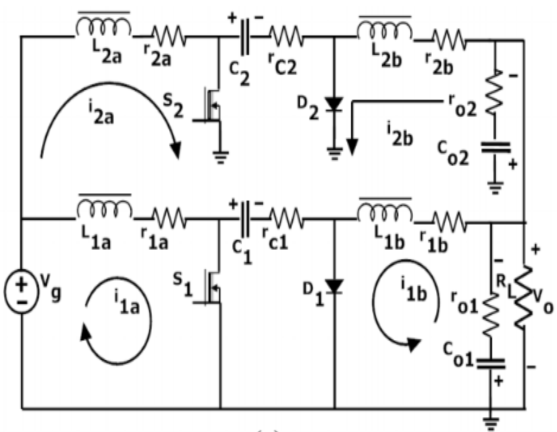
Fig-1 shows the circuit diagram of a cuk converter where Vin is the input voltage and Vo is the average Output voltage. The output voltage equation of the converter is as follows

$Vo = -D \times Vin / (1 - D)$,Where D is the duty cycle of the converter.

INTERLEAVED CUK CONFIGURATION:

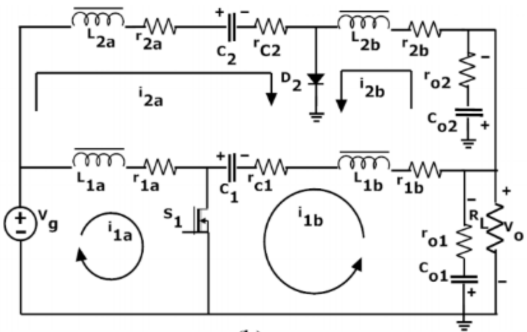
Interleaved technique means connection in parallel. Here connecting two cuk converters in parallel gives interleaved cuk converter. This converter divides the high input current and improves current shape on input side and Temperature losses are reduced by using the two switches during the total time-period of operation ie, during first half of the time-period(Ton/2) one switch(S1) is closed and another switch(S2) is opened. Similarly during second half of the time-period (Ton/2) switch(S2) is closed and switch(S1) is opened. An ICC is developed with improved efficiency and superior and better transient performance and defeat the demerits of cuk converter configuration. This technique provides continuous current on both sides and reduces switching current stress.

Circuit Diagram:

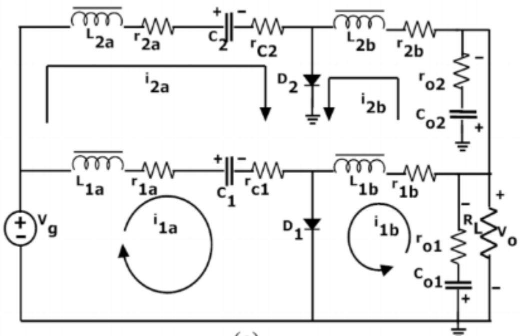


(a)

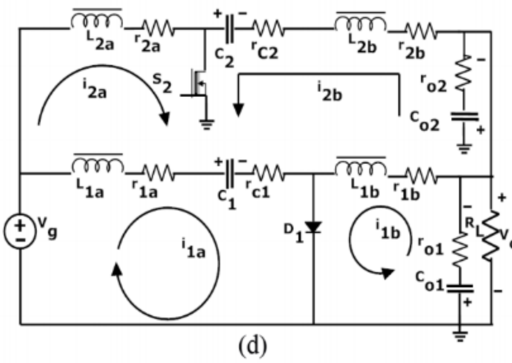
MODES OF OPERATION:



(b)



(c)



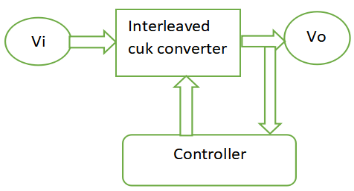
Circuit diagram of interleaved cuk converter with different modes of operation.(a)basic circuit (b)S1 ON and S2 OFF (c)S1 and S2 OFF(d) S1 OFF and S2 ON

Mode 1:S1 ON & S2 OFF:- The circuit diagram when switches S1 ON and S2 OFF as shown in the figure (b).During this period L1a andL2a discharges. The stored energy in L2a transfers toC2 and it charges. Also the capacitor C1 discharges through C1,S1,Co1,L1b,Co2,L2b and RL, hence transfers stored energy in the capacitors to the load. The load current is assumed constant and flows in negative direction.

Mode 2 -S1 OFF & S2 OFF: -The circuit diagram when both switches S1 and S2 are in OFF condition is shown in figure (b). During this period inductors L1a and L2a are discharging and stored energy transfers to capacitors C1 & C2 respectively. Also, C1 starts charging. At the same time inductors L1b& L2b are discharging as shown in figure (d)transfers its energy to load.

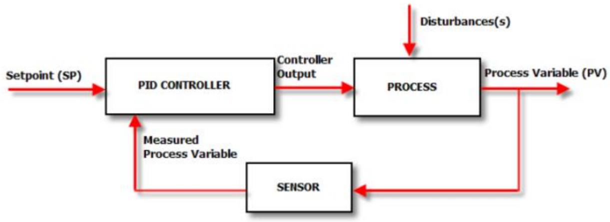
Mode 3- S1 OFF & S2 ON:-The equivalent circuit when the switches S1 OFF and S2 ON is shown in the figure (d).During this period L2a charges and L1a discharges.The stored energy in L1a transfers to C1 and it continuous to charge.Also the capacitor C2 discharges through C2,S2,Co2,L2b and RL.Hence transfers stored energy in the capacitor to the load.

Closed loop control scheme :



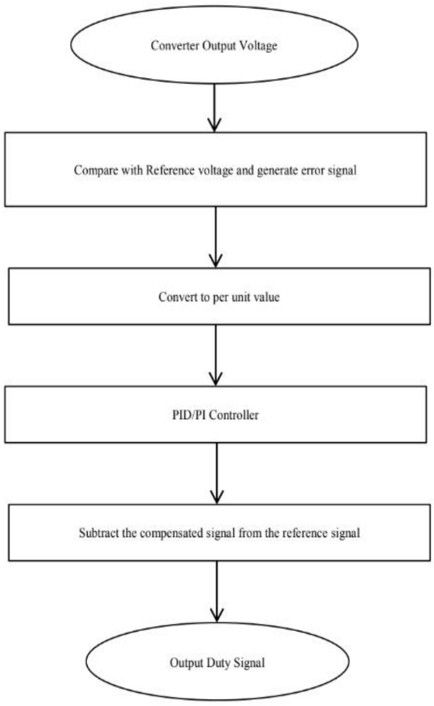
Above figure shows the basic block diagram of the closed loop interleaved cuk converter. Output voltage is first sent to the controller (PI, PID or FLC) and compared with the reference or set voltage. Resultant error signal is then used to compensate the duty signal of the switch and the process continuous till the set value is reached.

PID controller:



A Proportional-integral-derivative controller(PID controller or three-term controller) is a control loop mechanism employing feedback that is widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value e(t) as the difference between a desired setpoint (SP) and a measured process variable(PV) and applies a correction based on proportional,integral and derivative terms(denoted P,I, and D respectively)

PID control scheme:



Closed loop control of interleaved cuk converter:

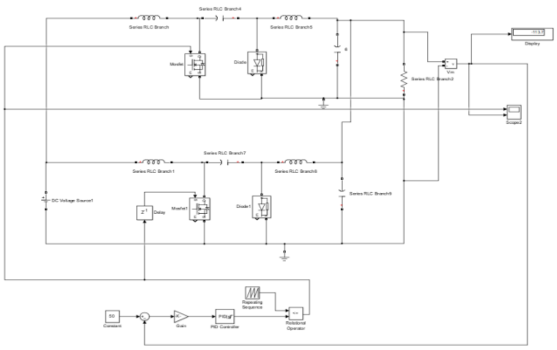
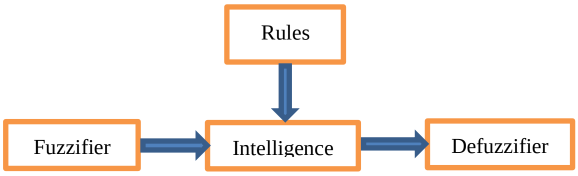


Fig2: PID controlled interleaved cuk converter

FUZZY LOGIC CONTROLLER DESIGN:



A fuzzy control system is a control system based on fuzzy logic , a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0(true or false)respectively. One of the most successful implementation of fuzzy set theory is fuzzy logic control as introduced. As mentioned in introduction part it doesn't require any complex control scheme or mathematical modeling rather it uses human understanding on the particular system to be controlled in the form of lingual variables like short, big etc. and is represented in simple logic forms that is AND, OR and NOT. The advantage of using FLC over PID controller is reduction in settling time and output voltage ripple is reduced.

Fuzzification: It is the process of transforming a crisp value to a fuzzy set.

Rules: It stores IF-THEN rules provided by experts.

Intelligence: It simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.

Defuzzification: It is the process of transforming a fuzzy set to a crisp value.

FLC Membership function:

Interleaved cuk converter output voltage function shows non linearity because of its small signal model. Due to no requirement of exact mathematical model FLCs can be easily adapted for varying operating points.An FLC is designed in mamdani style matlab fuzzy interface system. The input variables are 'error' and 'dE'(error change) and the output is 'duty' signal. Reference show that each input need to be divided into seven groups for DC-DC converters but prove that five groups are enough to control the converter accurately. Following figures show the membership function plots of inputs and output.

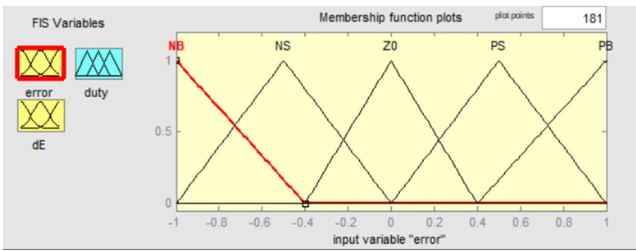


Fig3 Membership function plot for input 'error'

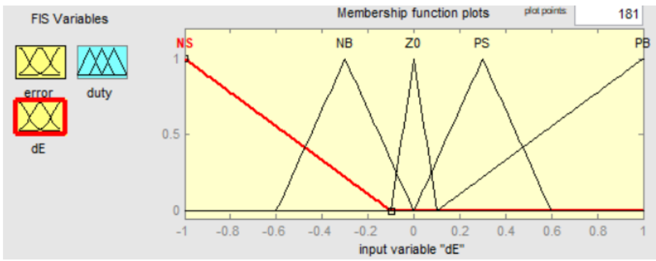


Fig4: Membership function plot for input 'dE'

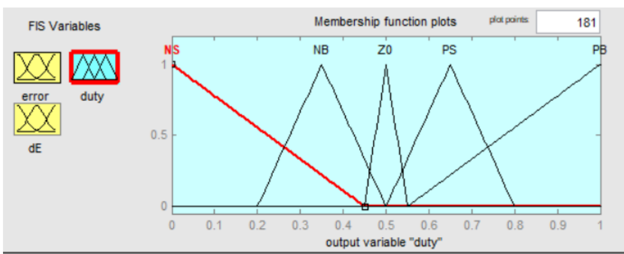


Fig5: Membership function plot for output 'duty'

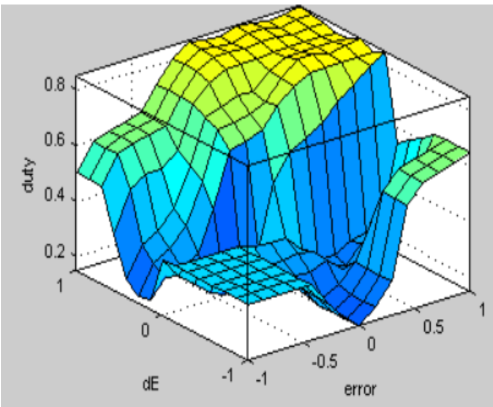


Fig6 Graphical representation of rule base

FLC rule base:

The two inputs of the fuzzy logic controller ('error' and 'dE') are divided into five groups which are N.B: Negative Big, N.S: Negative small, Z0: Zero area, P.s: Positive small and P.B: positive Big with properly scaled parameters as shown in following table.

RULE BASE FOR 'ERROR' AND 'DE'

dE \ error	N.B	N.S	Z0	P.S	P.B
N.B	N.B	N.B	N.B	N.S	Z0
N.S	N.B	N.B	N.S	Z0	P.S
Z0	N.B	N.S	Z0	P.S	P.B
P.S	N.S	Z0	P.S	P.B	P.B
P.B	Z0	P.S	P.B	P.B	P.B

MATLAB IMPLEMENTATION

A interleaved cuk converter is modeled in Matlab using sim power system components. The specifications of the converter are as follows

Input voltage(Vin)=30 V

Controlled output voltage(Vo)=40V

Load resistance(R)=10 ohm

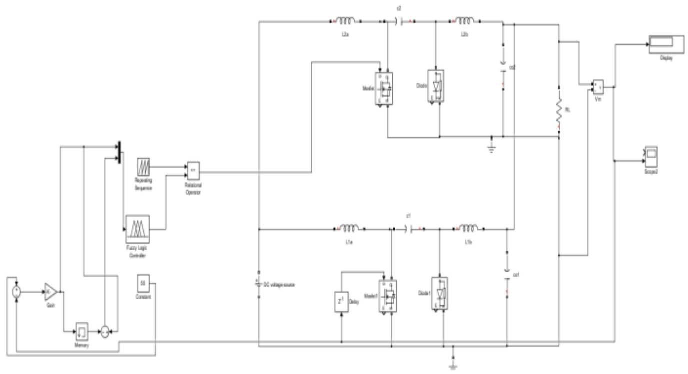
L1a=L2a=3.94*10^-3 H

L1b=L2b=2.64*10^-3 H

C1=C2=16*10^-3 F

Co1=Co2=10*10^-3 F

SIMULATION DIAGRAM:



RESULTS

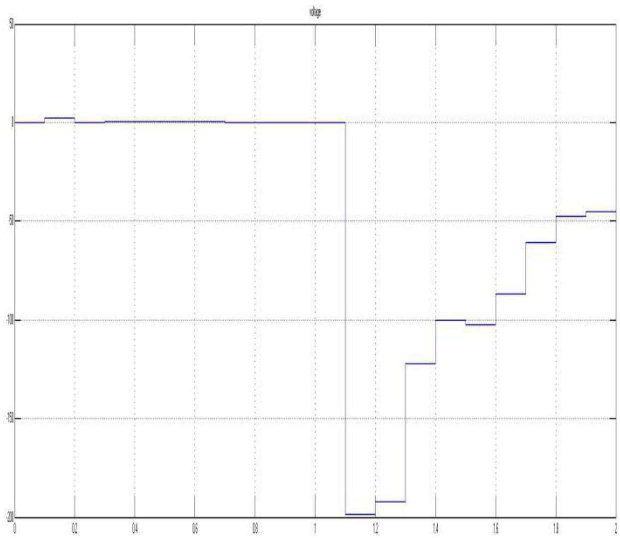


Fig:8 output voltage waveform using PID

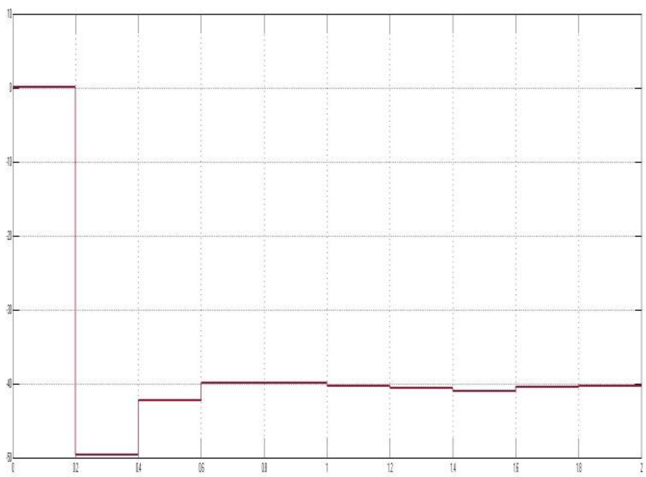


Fig:9 output voltage waveform using FLC

In this study a matlab Simulink model is developed inorder to validate and compare the performance of Fuzzy logic controlled interleaved cuk converter with PID controlled counterpart with exact same parameters.From the fig-8 and fig-9, It is clearly show that the settling time by using Fuzzy logic controller is very small when compared to PID controller. Similarly the output voltage ripple of a converter by using FLC is negligible compared to PID controller.

COMPARISON CHART

Controller	settling time(second)	output voltage ripple
PID	1.2	comparatively high
FLC	0.4	low

CONCLUSION

In this paper a Fuzzy logic controlled interleaved cuk converter is designed and compared with conventional control method like PID controller. Results show that, though PID controller gives higher settling time and gives higher output voltage ripple, accordingly the PID controller output voltage is significantly low. But for FLC the settling time is very low and output voltage ripple is completely negligible. So it can be concluded that for controlling a interleaved cuk converter Fuzzy logic controller is the ideal choice. Future works may take hardware implementation and real world system performance into consideration.

REFERENCES

1) Saptarshi Rakshit and Jayabrata Maity " fuzzy logic controlled cuk converter"International conference on communication and signal processing, April 3-5,2018, India.

2)N.F Nik Ismail,I Musirin, R. Baharom, "Fuzzy Logic Controller on DC/DC Boost Converter",2010 IEEE International conference on power and Energy(PECon2010),10.1109/PECON.2010.5697663,January 2016

3)Beena B.Tuvar and M H Ayalani "Analysis of a modified interleaved Non-isolated cuk converter"Third International Conference on Trends in electronics and Informatics (ICOEI 2019) explore part number:CFP19J32-ART;ISBN:978-1-5386-9439-8

4)K. Viswanathan, d. Srinivasan and R. Oruganti, "A Universal FuzzyController for a Non-linear Power Electronic Converter", IEEEInternational Conference on Fuzzy systems, doi10.1109/FUZZ.2015.1004957, 2015

5)Mohamed Boutouba, Abdelghani EI Ougli, Sabah Miqoi and BelkassemTifhaf, "Assymetric Fuzzy Logic Controlled DC-DC Converter for SolarEnergy System", Journal of Renewable Energy and Sustainable Development(RESD), Vol- 2, Issue 1, pp. 52-59 June 2016

6)W. C. So, C. K. Tse, and Y. S. Lee, "A fuzzy controller for DC–DCconverters", IEEE PESC Conference Record, pp. 315–320,2008

7) L. A Zadeh, "Outline of a New Approach to the Analysis of Complexsystem and Decision Process", IEEE Transaction on System, Man andCybernatics, Vol.SMC- 3, No. 1, pp. 28-44, 2011

8) C. C. Lee, "Fuzzy Logic in Control System: Fuzzy Logic Controller-Part I", IEEE Transaction on System, Man and Cybernatics, Vol- 1.20,No. 2, pp. 404-418, 2012

9) C. C. Lee, "Fuzzy Logic in Control System: Fuzzy Logic Controller-Part II", IEEE Transaction on System, Man and Cybernatics, Vol- 1.20,No. 2, pp. 404-418, 2012

10) F.Ueno, T. Inoue, I. Oota, M. Sasaki, "Regulation of Ćuk Convertersusing Fuzzy Controllers", IEEE 13th International Conference onTelecommunication and Energy (INTELEC'91), pp. 261-267, 2013