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# ANALYSIS OF SEPIC CONVERTER USING PID AND FUZZY LOGIC CONTROLLER

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**Abstract-**This paper explains about the performance of single-ended primary-inductor (SEPIC) converter using PID and FLC(Fuzzy Logic Controller).SEPIC converter consists of power semiconductor devices which are operate as an electronic switches. Operation of SEPIC converter produces harmonics due to the presence of semiconductor device in it. This can be reduced by controlling the converter using PID and FLC.The development of FLC is to generate the control for pulse of required duty cycle to the MOSFET to maintain constant output voltage. The converter is controlled by both PID and Fuzzy Logic Controller. In this paper the performance analysis of both the controller has been done by using the Matlab simulink.By comparing both the results the hardware is implemented for the stable and fast response.

**Introduction-**DC to DC converters plays an important role in electronic devices such as phones and laptop computers, which are supplied with power from batteries. There are three basic types of dc-dc converter circuits termed as buck, boost and buck boost. Buck converters only reduce the voltage, boost converters only boost the voltage level and buck-boost, cuk and SEPIC converter is responsible for both increasing and decreasing the voltage. Buck-boost converter is cheaper because it require a single inductor and a capacitor but it will make the buck-boost converter expensive or inefficient. This problem can be solved by cuk converter by using extra inductor and capacitor. Both cuk and buck-boost converter cause large amount of electrical stress in the components device will result to failure or overheating. The Single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter allowing the voltage at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the

**duty cycle.** The SEPIC converter provides positive regulated output voltage for the given input voltage unlike the buck-boost converter which provides negative regulated output voltage.

**Working of SEPIC converter**

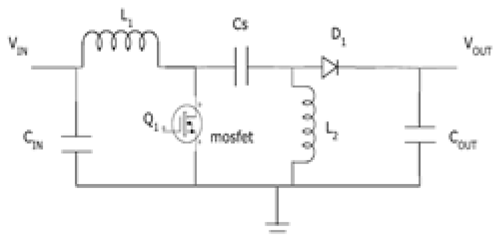


Fig1.circuit diagram of SEPIC converter

The converter is said to be working in continuous-conduction mode if the current through the inductor $L_1$ does not go. In the steady-state operation of the SEPIC converter the average voltage across capacitor $C_s$($VC_s$) is equal to the input voltage $V_{IN}$.Because capacitor $C_s$ blocks direct current hence the average current across $IC_s$ is zero, which making the inductor $L_2$ the only source of load current. Considering the voltages the equation can be written as,

$V_{IN}$=VL1+VCs+VL2

**MOSFET in ON condition:** When the switch $\mathbf{Q_1}$ is turned on, current in inductor $L_1$ and in the inductor $L_2$ increases in the negative direction. The energy to increase the current in inductor $L_1$ is due to the input source. Since $Q_1$ is closed the instantaneous voltage VCs is approximately equal to the input voltage (VIN), the voltage across inductor $L_2$ is equal to – VIN.

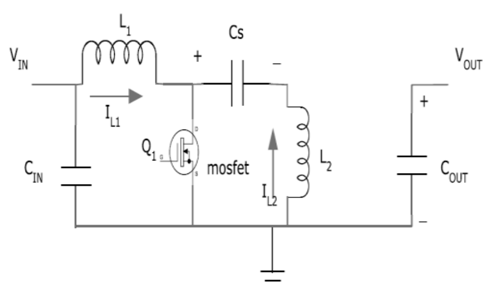


Fig2.Sepic in continuous conduction mode

**MOSFET in OFF condition:**

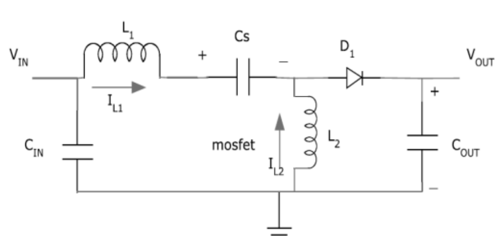


Fig3.Sepic in OFF state

When the switch $Q_1$ is turned off, the current $IC_s$ become same as the current in the inductor $L_1$ as the inductors does not allow sudden changes in the current. The power is delivered to the load from both the inductors $L_1$ and $L_2$.Coupling capacitor ($C_s$) is charged by $L_1$ during the off cycle and recharge $L_2$ during the on cycle. The buck and the boost operation of sepic are possible because of the capacitor $C_s$ and inductor $L_2$.

**Design of SEPIC converter:**

- Input dc voltage to the converter can be given in the range of 5v<VIN<10v.
- For the duty cycle less than 50% the converter acts in buck mode and the output is given by Vo= D*vin.
- For the duty cycle equal to 50% the converter gives the output same as the input voltage given.
- For the duty cycle greater than 50% the converter acts in boost mode and the output voltage is given by Vo= [D/(1-D)]*Vin
- The design of the SEPIC converter is based upon the following formulae. We take the value of $V_D$=0.5

The maximum duty cycle is given as,

$D_{max} = V_{out} + V_D / V_{in\,(min)} + V_{out} + V_D$

The minimum duty cycle is given as, $D_{min} = V_{out} + V_D / V_{in\,(max)} + V_{out} + V_D$

- The ripple current flowing is equal for both the inductors L1 and L2 is given as,

  $\Delta I_L = I_{out} * V_{out} / V_{(min)} * 40\%$

- The inductor value is calculated as,

  $L1=L2=L= V_{(min)} / (\Delta I_L * f_{sw}) * D_{max}$

- The output capacitor is given as,

  $C2 \geq (I_{out} * D_{max}) / (V_{ripple} * 0.5 * f_{sw})$

**Maximum duty cycle:**

$D_{max} = V_{out} + V_D / V_{in\,(min)} + V_{out} + V_D$

$D_{max}$= (40+0.5)/ (5+40+0.5) =**0.8**

**Minimum duty cycle:**

$D_{min} = V_{out} + V_D / V_{in\,(max)} + V_{out} + V_D$

$D_{min}$= (2+0.5)/ (10+2+0.5) =**0.2**

**Duty cycle less than 50%:**

$V_o = D * V_{in}$

$V_o$= 0.2 * 10 = 2v

**Duty Cycle greater than 50%:**

$V_{o} = [D/(1-D)] * V_{in}$

$V_{o} = [0.8 / (1- 0.8)] * 10 = 40v$

**Inductor value:**

$L1=L2=L= V_{(min)} / (\Delta I_{L} * f_{sw}) * D_{max}$

$L = 5 / (\Delta I_{L} * 50{,}000) * 0.8 = 150$ micro H

**Capacitance value :**

$C2 \geq (I_{out} * D_{max}) / (V_{ripple} * 0.5 * f_{sw})$

$C2 = (3.5 * 0.8) / (V_{ripple} * 0.5 * 50{,}000) = 100$ micro F

**Design Parameters of SEPIC converter:**

| | |
|---|---|
| Input Voltage | : 5v < Vin < 10v |
| Output Voltage | : 2v<Vout<40v |
| Switching Frequency | : 50KHz |
| Duty Cycle Range | : 0.2 to 0.8 |
| Load Resistance | : 10 ohm |
| Inductor L1 | : 150micro H |
| Inductor L2 | : 150micro H |
| Coupling Capacitor | : 100micro F |
| Output Capacitor | : 100micro F |

**Controllers:**

**PID controller**

A proportional-integral-derivative (PID) is a control loop feedback mechanism widely used in industrial control system. A PID controller calculates an error value as the difference between measured process variable and desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Simply put, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change.

**Fuzzy logic controller**

The Concept of Fuzzy Logic was introduced by Lotfi Zadeh (1965), and it's mathematical modelling which are deals with uncertainty. It provides technique which deals with imprecision. 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. 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.

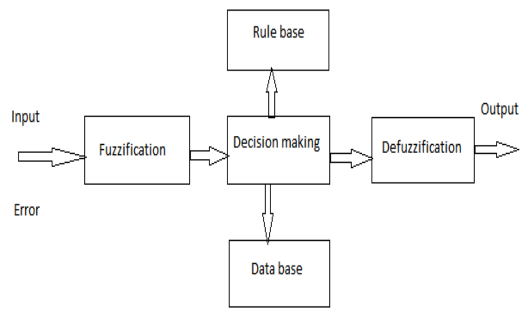


Fig4.Block diagram of FLC

FLC consists of three components namely fuzzification, fuzzy inference system and defuzzification. 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. Membership functions are triangle shaped, trapezoidal shaped. There are two fuzzification methods which are used mostly, Mamdani and Sugeno.

**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.

**Defuzzification:** To obtain suitable output various defuzzification methods can be used.

**Simulation Results:**

**1. PID controller**

To demonstrate the performance of proposed SEPIC converter in MATLAB/simulink with the design parameters mentioned above. A constant voltage source of 10 V is given as input to the converter.

**Closed loop control of SEPIC converter:**

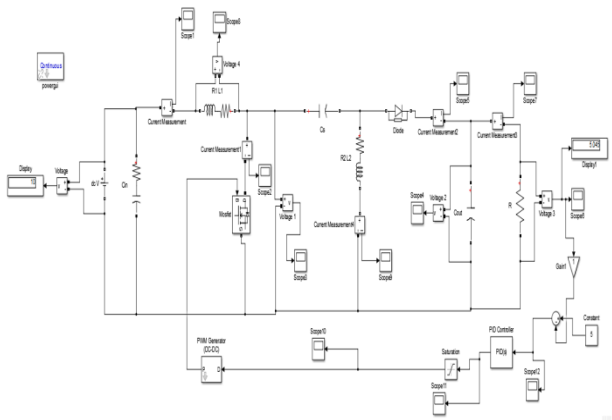

Fig5.closed loop control of SEPIC converter using PID controller in buck mode

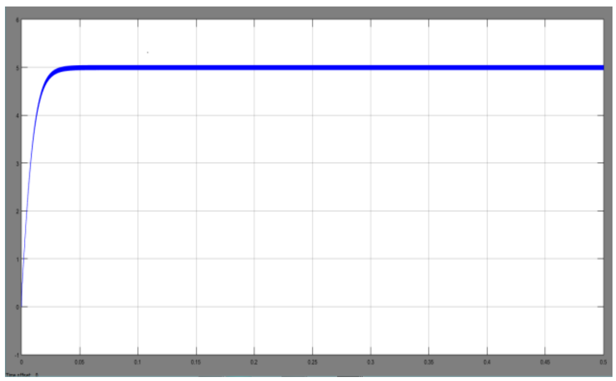

Fig6.output voltage in buck mode

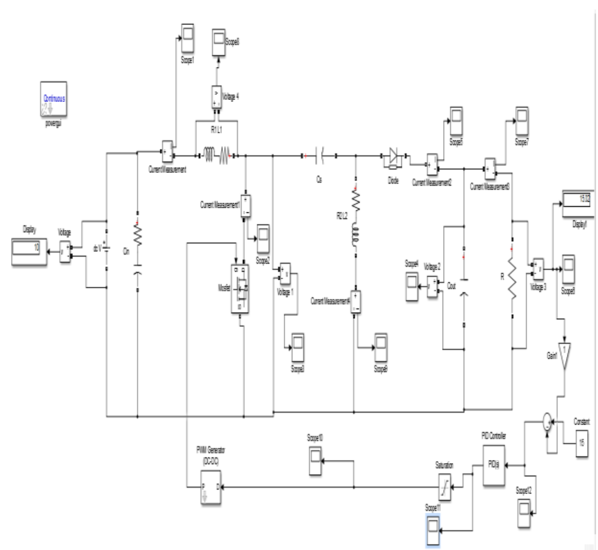

Fig7.closed loop control of SEPIC converter using PID controller in boost mode

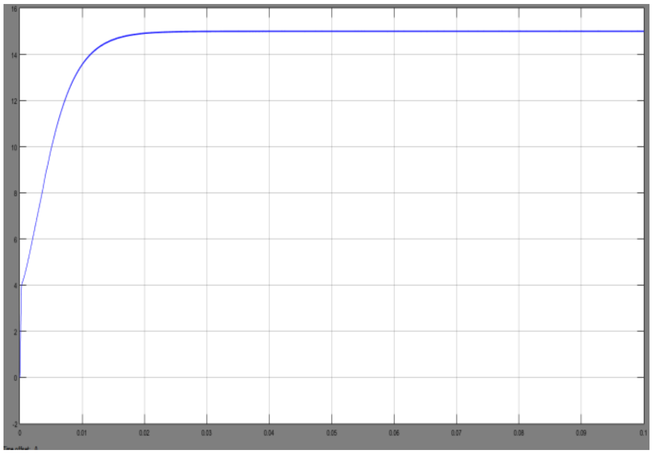

Fig8.output voltage in boost mode

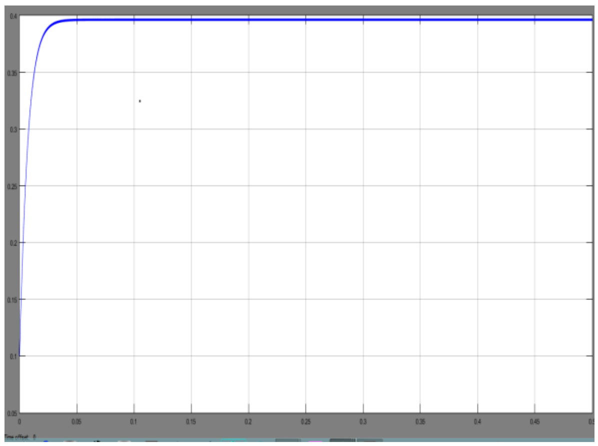

Fig9.controller output

## 2. Fuzzy logic controller

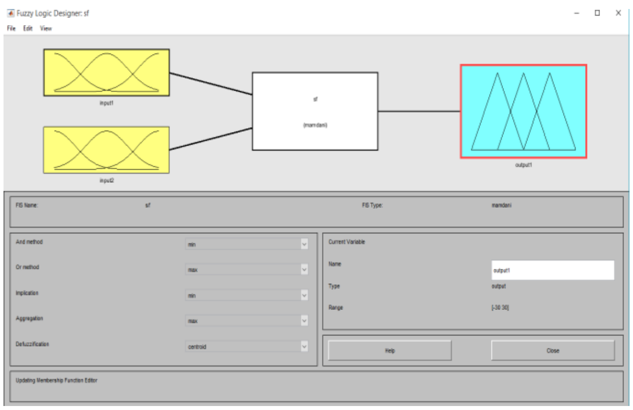

Fig10. Membership function editor window of FIS file used in simulation

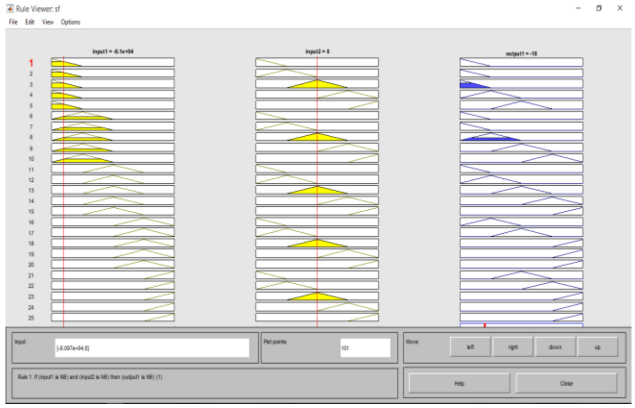

Fig11. Rule viewer window of FIS file

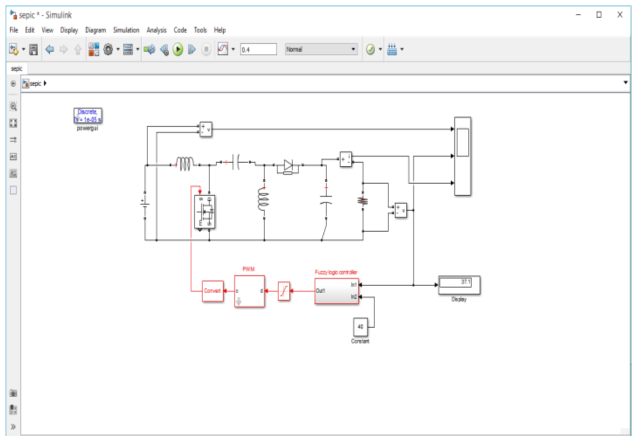

Fig12.Simulink model of fuzzy controlled SEPIC converter

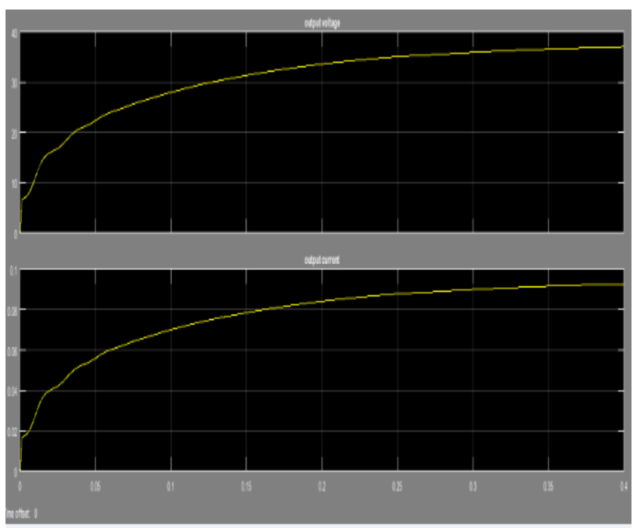

Fig13.Simulink result of fuzzy controlled SEPIC converter

## SIMULATION RESULTS OF SEPIC CONVERTER WITH DUTY CYCLE

**Expected output by calculation:**

| INPUT VOLTAGE | DUTY CYCLE | OUTPUT VOLTAGE |
|---|---|---|
| 10 | 0.5 | 10v |
| 10 | 0.2 | 2v |
| 10 | 0.8 | 40v |

Table1.output voltage by calculation

**Output by simulation:**

| INPUT VOLTAGE | DUTY CYCLE | OUTPUT VOLTAGE |
|---|---|---|
| 10 | 0.5 | 9.09v |
| 10 | 0.2 | 1.9v |
| 10 | 0.8 | 36.2v |

Table2.output voltage by simulation of PID controller

| INPUT VOLTAGE | OUTPUT VOLTAGE |
|---|---|
| 10 | 2.03v (in buck mode) |
| 10 | 37.1v (in boost mode) |

Table3.Output voltage by simulation of fuzzy controller.

## Hardware Implementation

In this hardware part a microcontroller of 8 bit PIC16F877A is used.The microcontroller contains 40 pins and its operating voltage is about 2 to 5.5v it also has two 8bit timer circuit and one 16bit timer . Along with this rectifier circuit and step down transformer is also included.

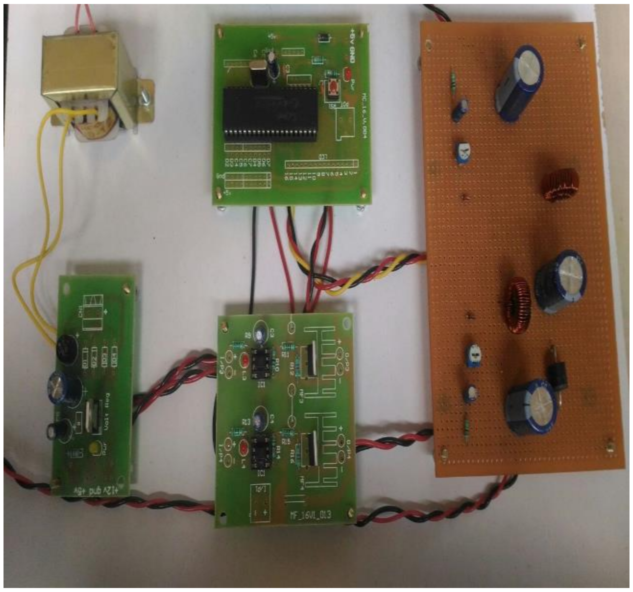

Fig14. Hardware implementation of SEPIC converter using fuzzy logic controller

**Conclusion:**

In this paper, Analysis of SEPIC Converter using PID and fuzzy controller are presented. The output voltage of SEPIC Converter can be stabilized using variable duty cycle generated by the PID controller. By comparing the simulation results of both the controller the settling time is less in fuzzy controller compared to PID.Moreover, the fuzzy controller circuit is simpler and much cheaper compared to other PID control mechanisms where large numbers of components are needed. Thus, closed loop response of the SEPIC converter using the Fuzzy Logic Controller is observed to be superior to the PID Controller.

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