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A COMPARATIVE ANALYSIS BETWEEN PI AND FUZZY FOR MODIFIED SEPIC CONVERTER WITH MAGNETIC COUPLING FOR HIGH STATIC GAIN APPLICATIONS

Rahul P Raj , Aparna K G ,Harsha Ravi
Assistant Professors, Dept. of EEE
Sri Vellappally Natesan College of Engineering, KTU, India

Abstract

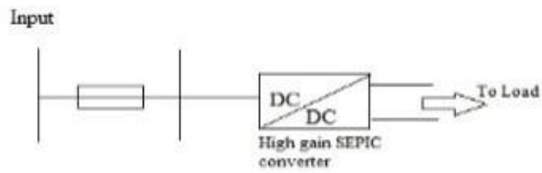
This paper gives a comparative analysis of modified SEPIC converter with magnetic coupling for high static gain applications by using PI and Fuzzy controllers. For high static gain applications without magnetic coupling cannot be essential. By using magnetic coupling high static gain can be achieved without increasing duty cycle and switch voltage with the help of PI or Fuzyy controllers. And also load regulation can be achieved by using both these controllers. From these controllers Fuzzy is the most advanced method than PI for better load regulation. Simulation result for both these controller shows that both are useful for low input high output applications.

Keywords — Magnetic coupling, SEPIC converter, voltage multiplier, very high static gain

Introduction

Conventional sources are the natural gases, coal can be replaced by using the solar energy, wind energy ie, the non conventional energy sources The main attraction of non conventional energy source are its ease of availability and also free of cost. There are research have been done with these non conventional energy source to connection with micro smart grid and also to develop it for various practical applications . Mainly solar cell is to include with boost converter topology. Reduce losses, weight and volume of the overall circuit are the two main challenges dealing with the connection of solar cell. For good performance and characteristics high gain operation is needed . Improvement of the efficiency, reduction of the cost and reliability of the circuit are the challenges dealing with the control circuit consisting of converter. The first aim is to decrease the overall power consumption within the converter. By this tend to lower heat dissipation which lead to minimal thermal management, cooling control and also reliability can be improved. The second goal is pertains to produce the component count simple controller but the voltage stress across the components are high.. The basic topology of the converter part discussed in this preferred paper is the high static gain SEPIC DC-DC converter allowing the voltage at its output to be greater than or less than or equal to that at its input. SEPIC output can be controlled by controlling the duty cycle of control transistor,. A SEPIC is normally a boost converter followed by a buck – boost converter, its basically called as buck – boost converter, but the main advantage of SEPIC is non-inverted output (ie, the out put has the same voltage polarity at its input) by the use of a series capacitor energy transference from the input to output can be achieved, and being a capable of true turned off: Its output drop to 0V,when the switch is turned off, ,following a moderately heavy transient reduction of charge. The use conventional SEPIC converter is the most efficient way to introduce the high static gain converter with reduced cost. The out put power of the circuit can be increased by the use of coupling capacitor.

Due to the is higher coupling cost, a double capacitor multiplier cell is attached across the switch to obtain a high gain converter. This will also increase the efficiency of the switch and reduce the stress the switch.



The above block diagram represents the over all set up of the control circuit which include a converter with a constant DC source. A DC source is the supply input to the high static gain SEPIC converter and the output of the converter is given to the resistive load. The DC voltage produced by the solar cell, which is generally small. To increase the voltage by using the two methods first method is to by multi cascading DC-DC converters and second method is to use high static gain converters

Comparison With Basic Sepic Converter

In the basic SEPIC converter high static gain with low voltage stress cannot be obtained. For a duty cycle close to D=.8 , boost converter is basically a non-isolated step-up converter and which can be generally operate with an adequate static gain and dynamic performance which in turn resulting an output voltage almost around five times that of input voltage), (There are mainly three static ranges are considered in this preferred topology. When a DC-DC converter operate, Static gain q=5 is normally considered as standard gain, when the static gain is greater than q=10 is considered as high gain and also static gain higher than q=20 is considered as very high static gain solution. By eliminating power transformer the efficiency and power density can be increased. Due to the transformer power loss and leakage inductance of the power transformer, which will reduce the efficiency. In order to overcome these disadvantages and to increase the static gain can be achieved by the addition of voltage multiplier cell, switch capacitors and inductor magnetic coupling and also combination of all these three things.

In this paper, magnetic coupling based on modified SEPIC converter employed. Static gain can be equal to or greater than 20 times can be obtained without increase the switch voltage. Conventional SEPIC converter is shown in fig.1. In the basic l topology hard switching operation is used. The major problems dealing with the hard switching operation is that the extreme switching as well as conduction loss will become higher, in order to overcome these disadvantage soft switching operation is used in this scheme. Small leakage inductance is necessary for reduce the diode reverse recovery current and ZCS turn on commutation . By using these three things overall performance and losses can be decreased. Better load regulation can be achieved by using fuzzy controlled method and PI controlled method modified SEPIC converter with magnetic coupling. During load disturbance and parameter variations Fuzzy can provide good performance and also which can be operate with noise and other disturbance of different nature

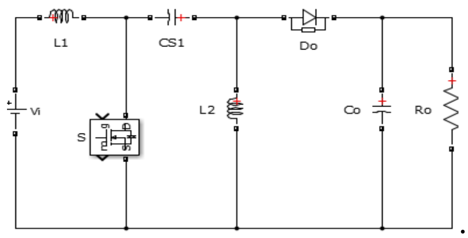


Fig.2. Conventional SEPIC converter

Modified Sepic Converter With Magnetic Coupling Analysis And Different Operating Stages

The block diagram of complete setup preferred topology shown in fig.3. DC supply from a PV cell given to the high static gain SEPIC converter. The DC-DC converter gives an output gain greater than or equal to 20. The output of the converter given to the resistive load, the out put voltage sensed by the voltage sensor.

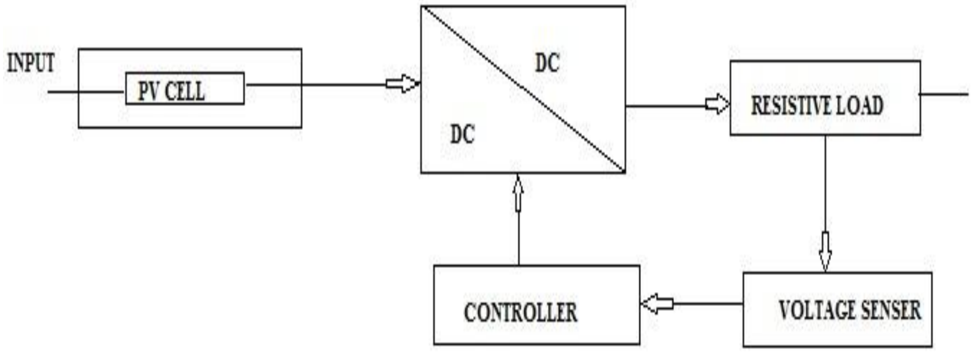


Fig.3 Block diagram of complete setup

The voltage sensor which is actually a voltage multiplier. In the case of Fuzzy control method Fuzzy control take the control of the output voltage based on Fuzzy rules. These rules tune the circuit whenever there is any change in the load in order to make the output voltage constant. . In the case of PI control method PI control take the control of the output voltage based on PI values. These values tune the circuit whenever there is any change in the load in order to make the output voltage constant. In both these method whenever there is change in the load, the controller (PI or Fuzzy) adjust the duty cycle based on the requirement. The controlled DC supply is given through a fixed switching frequency

Analysis of Modified SEPIC converter with magnetic coupling Circuit

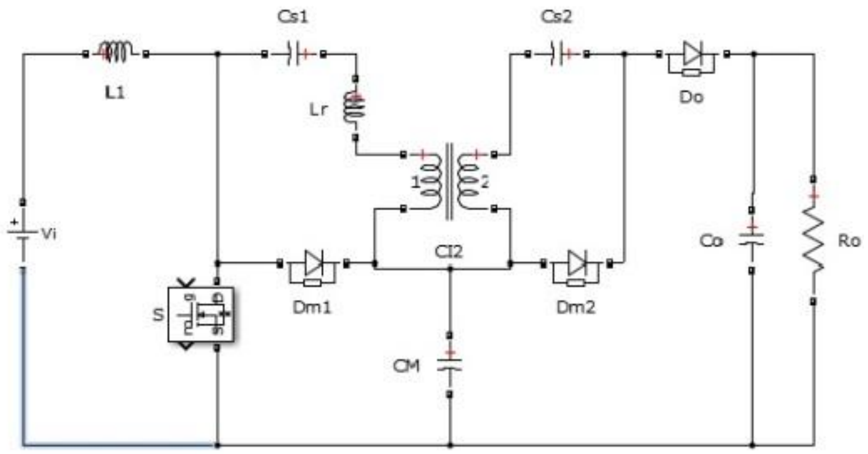


Fig 4.Proposed system

Fig 4.shows that the proposed system, in this system magnetic coupling and voltage clamping circuit are added to the conventional circuit. Overvoltage across the diode can be decreased by adding a voltage multiplier circuit at the secondary side. The multiplier consist of diodeD_{M2} and capacitor C_{s2}, which will act as non dissipative clamping circuit for the output diode. The main advantages by the inclusion of voltage multiplier circuit to increase the static gain as well as reduce the voltage across the diode D_0 than the output voltage. And thus the energy transference from the inductor to the output easily. For decreasing the switching losses, switch become turn on only at zero current. Due to the existence of coupling leakage inductance the current variation ratio($\frac{d_i}{d_t}$) presented by all diode is limited.Switch over voltage produced in isolated DC-DC converters due to the leakage inductance. The stored energy in the leakage inductance must be transferred to the clamping circuit. In this proposed topology leakage inductance is necessary for obtaining ZCS turn–on commutation and reduce diode reverse recovery problem. By providing magnetic coupling at the input side and voltage multiplier at the secondary side very high static gain and better performance can be obtained. Ripple current at the input side increased due to the presence of input inductor winding turns ratio when the magnetic coupling is included with the input inductor. For achieving higher efficiency mainly isolated active clamp SEPIC fly back converter are illustrated. However, converter complexity increases due to the presence pulsating current and the active clamp technique with an additional switch. In this preferred topology, by considering the same transformer ratio very high static gain can be obtained by commutation losses and switch voltage can be decreased and also ZCS switch turn on obtained at the resonant stage. These are the main advantages over the previous topology

Sepic Converter With Magnetic Coupling Modes Of Operation

The main objective of this preferred topology to increase the converter static gain double than that of the conventional topology by the reduction of the switch voltage. For obtaining this converter can be operate in CCM mode at a duty cycle greater than d=.8. There are has five operational stages in Modified SEPIC converter in CCM. These are the assumptions made for theoretical analysis 1)All capacitors are taken as voltage source 2) All semiconductors can be considered as ideal.

1) Stage 1$[t_o - t_1]$: Switch S is start to conducting and thus the energy stored in the input inductorL_1. Capacitor C_{S2} charged through the secondary winding L_{2S} and diodeD_{M2}. The leakage inductance reduces the current and the energy transference occur in a resonant way. The output diode is blocked and the maximum diode voltage is equal to ($V_O - V_{CM}$) and the energy transference to the capacitor C_{S2} is finished and diode D_{M2} is become blocking stage, at the instant t_1.

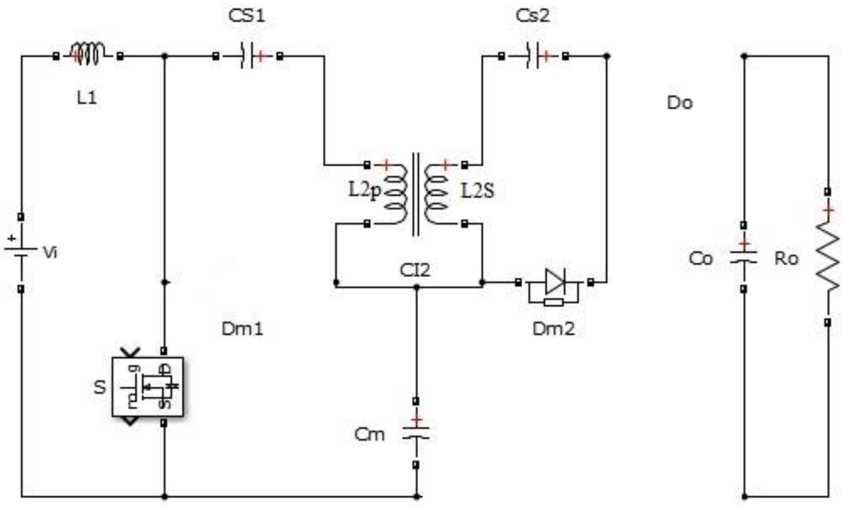


Fig 5: First operation stag
e

2) Stage 2 $[t_1 - t_2]$(fig.6): at the instant t_1,the energy transference to the capacitor is finished $C_{S2}$and diode D_{M2} is blocked. Switch is tend to turned off at the instant t_2 and both the inductors L1 and L2 store energy and thus current linearly increase.

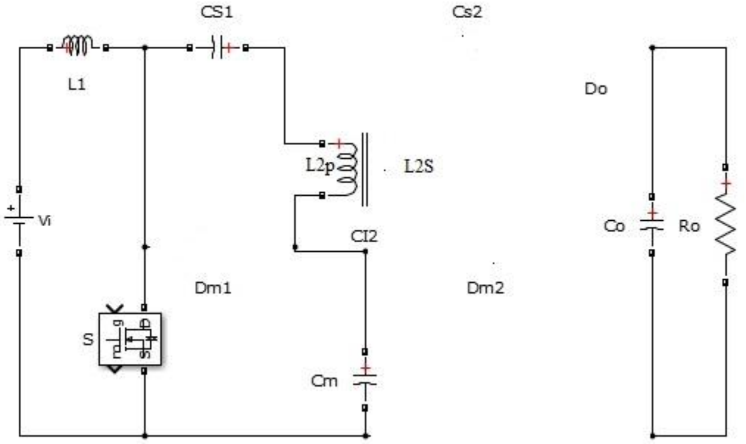


Fig 6. Second operation stage

1) Stage 3 [$\mathbf{t_2} - \mathbf{t_3}$](fig.7) : at the instant t2 Switch is remain in turned off condition . Stored energy in the L1 inductor transferred to the capacitor CM. And also energy transference to the output through the capacitors cs1,cs2 inductor L2 and output diode d0

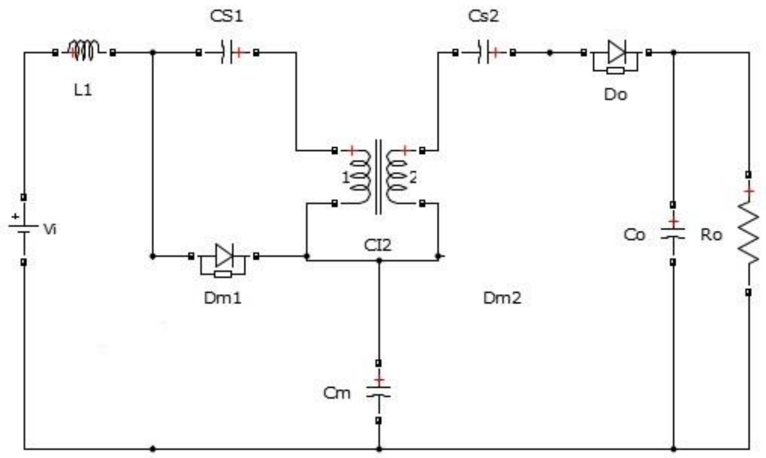


Fig 7.Third operation stage

3) Stage 4[$\mathbf{t_3} - \mathbf{t_4}$](fig.8): During the instant $\mathbf{t_3}$.energy transference to the capacitor CM is completed and the diode DM1 is blocked. The energy transferred to the output is maintained until the instant the instant *t*4, when the power switch is turned ON

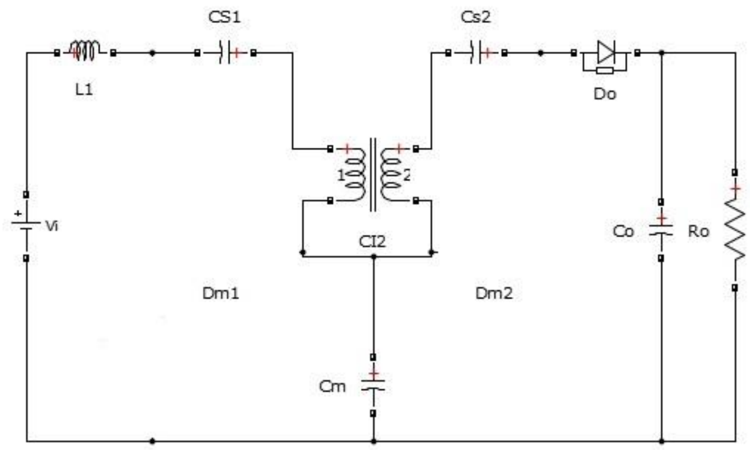


Fig 8.Fourth operation stage

4) Stage 5[$t_4 - t_5$](Fig.9): At the instant $t_4$power switch is turned on, due to the presence of leakage inductance the current at the output diode D0 linearly decreases and change in current is limited, and also reducing the diode reverse recovery problems. The converter back to first operational stage when the output diode blocked.

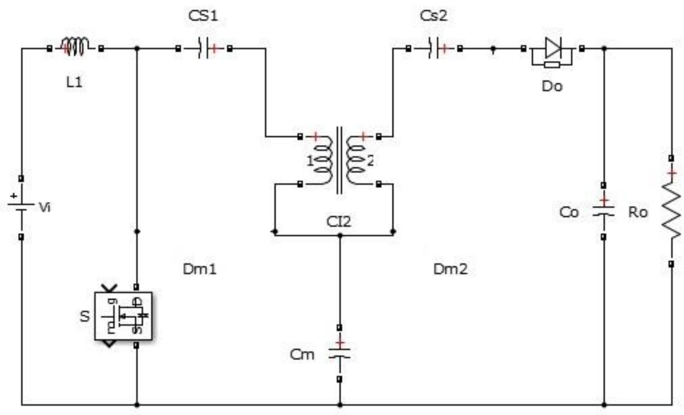


Fig 9:Fifth operation stage

In this proposed topology static gain calculated by (1), by increasing the winding turns ratio (n) static gain is increased without increasing the switch voltage.

$$\frac{V_0}{V_1} = \frac{1}{1-D}\times(1+n) \qquad (1)$$

n represents the inductor winding turns ratio,

$$n = \frac{N_{L2s}}{N_{L2P}} \qquad (2)$$

at duty cycle D=.8 switch voltage become five times the input voltage for all the three cases ie, where n=1,static gain q=10,n=2 static gain q=15 and n=3 static gain q=20,.

Maximum switch voltage is produced during the third operation stage an which is equal to the capacitor voltage CM. capacitor switch voltage VCM,

$$\frac{V_{CM}}{V_I} = \frac{1}{1-D} \qquad (3)$$

B) Design of proposed converter

Input Voltage =15V;
Switching frequency=24KHZ;
Output voltage=300V
Power output P_0 =100w;
Using these specification, modified SEPIC converter with magnetic coupling and voltage multiplier design can be obtained as :

1)Dutycycle,D: Duty cycle is calculated by using the equation (1), static gain q=20 and winding turns ratio n=2.6 ie

$$D = 1 - \frac{V_i}{V_O}\times(1+n)$$

$$=(1\text{-}15/300)\times(1+2.6)$$

$$=.819 \qquad (4)$$

*2) Diode voltage vdo and switch vs:*capacitor voltage equal to the diode and switch voltage, which is obtained from the equation

$$V_s = V_{DM1} = \frac{V_i}{1-D} \qquad (5)$$

$$= \frac{15}{1-.819} = 82.9 \text{ V}$$

Voltage across the output diode VDO and voltage at the diode DM2 are equal, which are calculated by

$$\mathbf{V_{Do}} = \mathbf{V_{DM2}} = \mathbf{V_0} - \mathbf{V_{CM}} = \frac{n \times V_i}{1-D} \quad (6)$$

$$= \frac{2.6 \times 15}{1-.819} = 215.5 \text{ V}$$

3) Inductance $\mathbf{L_1}$ and $\mathbf{L_{2P}}$- $\mathbf{L_{2s}}$: for current ripple at the input side i_L = 5A, the inductance values are calculated by

$$\mathbf{L_1} = \mathbf{L_{2P}} = \frac{V_i \times D}{i_L \times f} \quad (7)$$

From equation (4)D=.819 and f is the switching frequency=24KHZ,

$$\mathbf{L_1} = \mathbf{L_{2P}} = \frac{V_i \times D}{i_L \times f} = 15 \times .812/5 \times (24 \times \mathbf{10^3})$$

$$= 102 \mu\text{H} \quad (8)$$

The average current values at the Inductance $\mathbf{L_1}$and inductance $\mathbf{L_2}$ equal to the input and output current.

For the magnetic coupling inductor L2S can be obtained from L1 inductance, for n=2.6

$$\mathbf{L_{2S} = 2.6^2 \times (102 \times 10^{-6})}$$

$$= 689.52 \mu\text{H} \quad (9)$$

4)Leakage inductance L: Leakage inductance not represented in this proposed fig 3 and also during the operation stages 1-5. Leakage inductance is necessary to decrease the reverse recovery current at the output diode and also to obtain ZCS turn-on commutation. Leakage inductance can be inserted in series with L2P inductor or which is included in series with L2S inductor. For these, small value of leakage inductance is essential

When the switch is turned on during the fifth stage of operation, , the commutation losses will increases because very high change in current di/dt at the output diode and also reverse recovery current will occur ,. This can be overcome by inserting a leakage inductance at the primary side. Change in current at the output diode taken as 25$A/\mu s$. Leakage inductance value obtained by

$$L_r = \frac{V_i}{(1-D)\, n \frac{d_i}{d_t}}$$

$$= \frac{15}{(1-.819)\ 25 \times 10^6 \times 2.6} = 1.27 \mu\text{H} \quad (10)$$

1) *Output current:* The average current value of all diode equal to the output current.

$$I_{Do} = I_{DM1} = I_{DM2} = I_o = \frac{P_o}{V_o}$$

$$= 100/300 = .333 \text{ A} \quad (11)$$

7)CapacitorsC_s *and* C_M*:* capacitor voltage ripple factor ΔV_C equal to 15% of capacitor voltage CM ie,

$$\Delta V_C = \frac{V_i}{1-D} \times \frac{V_i}{P_o}$$

$$= \frac{15}{1-.819} \times \frac{15}{100} = 12.4\text{V} \quad (12)$$

Voltage across the capacitor CS1 and CM can be calculated as

$$C_{s1} = C_M = \frac{I_o\, n}{\Delta v_C \cdot f}$$

$$= \frac{.333 \times 2.6}{12.4 \times (24 \times 10^5)} = 2.9\mu F \qquad (13)$$

V .Load Regulation Obtained By Using Fuzzy Control

Based on the system behavior Fuzzy logic controller is made up by a group of rule based on the human knowledge. For the applications to dc-dc converter system Fuzzy set theory is largely used in the control area. Difference in the reference voltage and sensed voltage from the output of the converter Fuzzy logic controller generate corresponding error signal. This resultant voltage error signal is amplified and compared with a saw tooth carrier wave of fixed frequency (f) to generate the PWM pulses. Which is used for controlling switch of the converter.

B) Fuzzy controller design: Error (E) and change in error(CE) are the Input for the fuzzy controller. Change in duty cycle is the controller output. Error is defined as the difference between the set reference voltage and sensed voltage from the voltage of the converter output, and the change in error is defined as the present error and previous error. To determine the new duty cycle by varying the duty cycle in which could be either positive or negative is added with the existing duty cycle. The error and change in error are the Input to the fuzzy logic controller. These error input are divided into seven group : LN: Large negative, SN: Small negative, ZE: Zero error, LP: Large positive, SP: Small positive, VLN: Very large negative, VSN: Very small negative.

The Fuzzy uses the linguistic variable by converting the numerical variable into linguistic variable which is known as the Fuzzyfication. The controller performance can be improved by varying membership function and rules. By using 25 rules the fuzzy operation is implemented. Finally the fuzzy output is converted into real output value by the process is called defuzzification

VI . Pi Controller for Load Regulations

Proportional –integral controller is a control loop feedback system. The PI controller continuously calculate set reference voltage and sensed output voltage to generate an error signal. This resultant voltage error signal is amplified and compared with a saw tooth carrier wave of fixed frequency (f) to generate the PWM pulses. Which is used for controlling the switch.

PI Design: Proportional account for present value of the error.ie the error will be large and positive the controller output will also large and positive. Integral account for the past value of the error, ie if the error will be too small, error will accumulate overtime and the controller will respond by applying stronger action.K_p,K_d are proportional and derivative gain constant. By generating suitable values for gain eroor can be minimized.

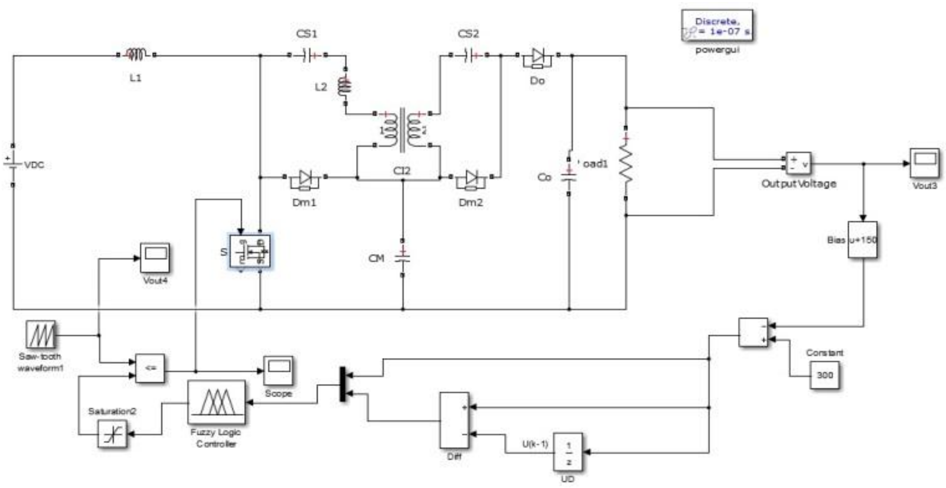


Fig 10 Simulation diagram of Fuzzy controller method

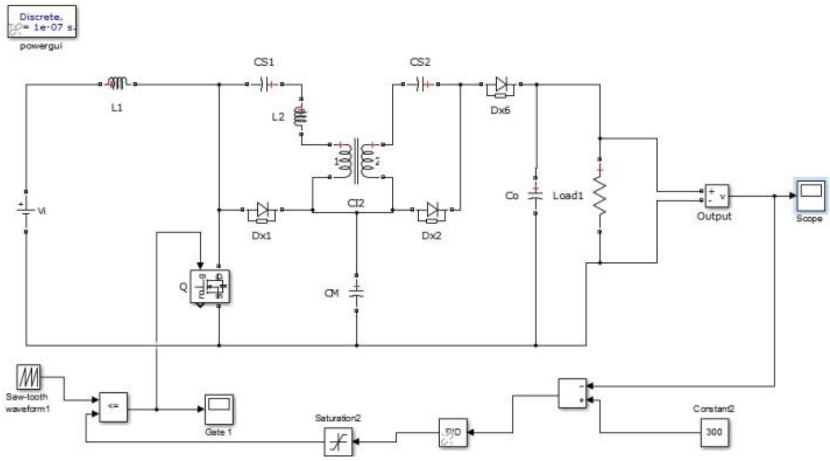


Fig 11. Simulation diagram of PI controlled method

VI Simulation Results

For analyzing the regulated out putfor Fuzzy controlled and PI controlled modified SEPIC converter with magnetic coupling and voltage multiplier are simulated by using MATLAB/SIMULINK , model. Here input voltage equal to 15 and correspondingly the out put voltage will be generated 300 for the variation of load

TABLE I
SIMULATION PARAMETERS

Parameter	value
Input Voltage	15V
Switching frequency	24KHz
Output voltage	300V
Duty cycle	.85
Static gain	20
Output power	105W
Efficiency	94%

The whole system is simulated in MATLAB/SIMULINK tool . In the following graphs, which is clear that for any variation in the load beyond a particular limit Fuzzy will more suitable than PI.

A) Fuzzy controlled modified SEPIC controller simulation results

1)

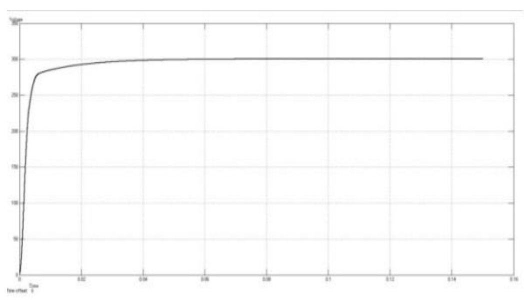


Fig 12:Output voltage with load equal to 900Ω

2)

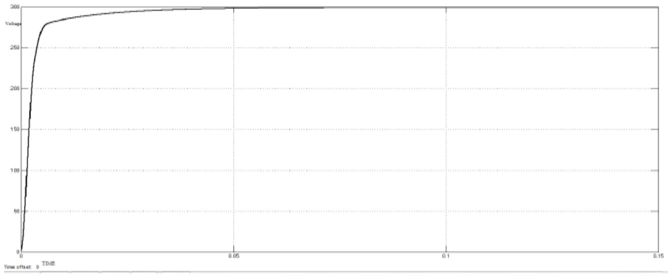


Fig 13:Output voltage Load equal to 875Ω

3)

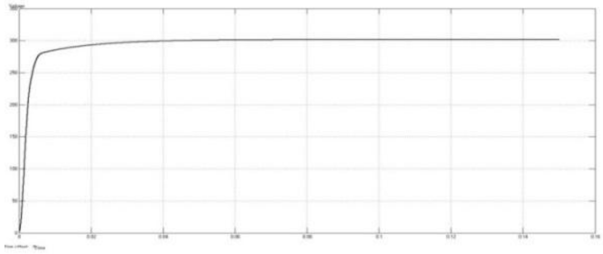


Fig 14:Output voltage load equal to 925 Ω

Fig.12 to Fig 14 shows that for any variation in the load we can obtain the constant output voltage, ie regulated output voltage.

A) PI controlled modified SEPIC converter simulation results

1)

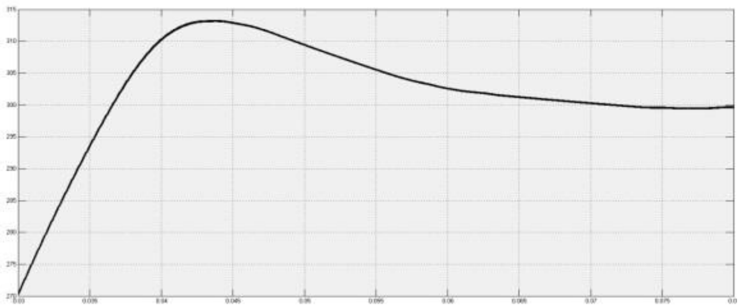


Fig 15:Output voltage with load equal to 900Ω

2)

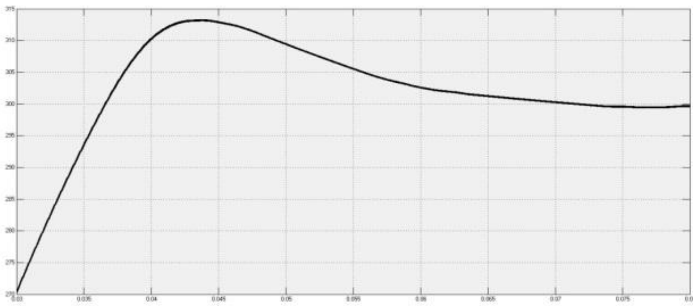


Fig 16:Output voltage Load equal to 875Ω

3)

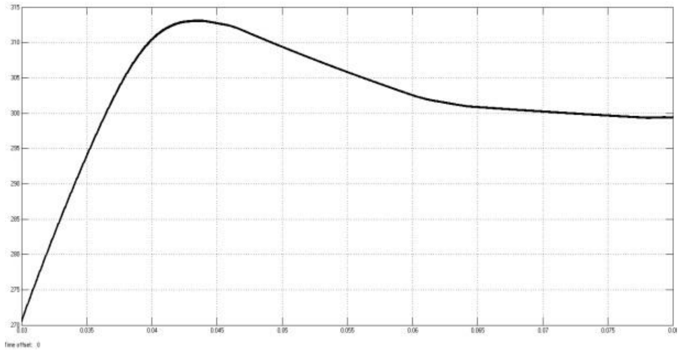


Fig 17:Output voltage load equal to 925 Ω

Fig.14 to Fig 17 shows that beyond a particular limit PI controller has variation in its output voltage.

TABLE II.

COMPARISON BETWEEN PI AND FUZZY

	FUZZY	PI
Input voltage	15	15
Load	875-925	875-925
Output voltage	300-300	300-290

VI. Conclusion

This paper investigated the performance of Fuzzy controller over PI for modified SEPIC converter for high static gain applications. The simulation results shows that the Fuzzy can be employed effectively for load regulation than PI. Furthermore the Fuzzy can provides a robust performance under parameter variation and load disturbances. The simulation results substantiated the Fuzzy goals.

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A. TOMASZUK_ and A. KRUPA Faculty of Electrical Engineering, Department of Automatic Control Engineering and Electronics, Bialystok University of Technology, 45d Wiejska St. 15-351 Bialystok, Poland.

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