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Evaluation of Time Response Analysis using Fuzzy PI Controller for Luo Converter

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ABSTRACT

A comparative evaluation of the Proportional-Integral, Fuzzy Logic Controllersfor applications to Positive Output Elementary Luo Converter. The mismatch between the characteristics which lead to varying performance is outlined. Sensitivity of these controllers to supply voltage disturbances, load disturbances and servo response are studied and results are presented**.** The proposed FPIC performance is evaluated in terms of Integral Square Error (ISE), Integral Absolute Error (IAE) and Integral Time Absolute Error. The FPIC capable of providing good static and dynamic performance with reduced error over PIC and FLC.Dynamic equations describing POELC are derived by using state space average method. The simulation model of the Luo converter with its control circuit is implemented in MATLAB/SIMULINK.

Keywords: Fuzzy logic controller (FLC), Fuzzy Proportional Integral controller (FPIC)Positive Output Elementary Luo Converter (POELC), Proportional – Integral Control (PLC), State Space Modeling, Fuzzy Controller.

I. INTRODUCTION

DC-DC converters are widely used in industrial applications are dc motor drives, computer systems and communication equipment's. Henry Shu-hung Chung, presents an investigation into the use of a current control scheme (CCS) and a comparison with classical switching for switched-capacitor (SC) step-down dc/dc converters. A CCS specially designed for a SC step-down dc/dc converter [1]. On-cheongMak and Adrian Ioinovici, the magnetic devices are played by a switched-capacitor (SC) circuit, formed by two sub circuits. The SC dc–ac inverter exhibits a good regulation capability with respect to large changes in line and load, good efficiency, and a clean sinusoidal output [2]. Fang Lin Luo and Hong Ye, A new series of dc/dc converters—negative output super-lift converters have been successfully created. It largely increases the voltage transfer gain in power series. Very high output voltage is easily obtained. [3].

S. Kannan, SheshaJayaram and M. M. A. Salama, real and reactive power coordination controller for a unified power flow controller (UPFC). To avoid instability/loss of the DC link capacitor voltage during transient conditions for a real power coordination controller has been designed [4].Miao Zhu, Fang Lin Luo and Yi He, the canonical explanation, existence conditions for the solving principles which simplify the derivation process of steady-state performance of the complex dc–dc converter. A fifth order self-lift Luo converter is seventh order re-lift SEPIC converter is performed and the corresponding simulation results are shown and validate the theoretical analysis [5].

Fang Lin Luo and Hong Ye, EF and the sub sequential parameters can be illustrated into the unit-step response and interference recovery. Luo-converters are analyzed to the following applications are EF, pumping energy, stored energy (SE), capacitor/inductor SE ratio, energy losses [6]. Voltage lift technique is popular method to apply in electronic circuit design. A new series dc/dc converters for positive output multiple-lift push–pull switched-capacitor dc/dc Luo-converters [7].The Luo converter is a new series of

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DC-DC converters. The output voltage of the pulse width modulation (PWM) based on DC-DC converters are changed by changing the duty cycle [8]. For thepurpose of optimize the stability of positive output triple lift converter dynamics while ensuring correct operation in any working condition, a PI control is a more feasible approach. The PI control are presented alternative to the control of switching power converters [9]-[10].

A fuzzy controller for controlling voltage level of a Luo with positive output is in continues current mode (CCM) is used to control the speed of a DC motor [11]. The good stability of the large signal model obtained with reducing width that it is a main reason of slow dynamic response. Two ways proposed by "Tseetal" for acquisition rapid frequency response.One way is todevelop a accurate non-linear model of the convertersbased on which the controller is designed [12].

All DC/DC converters, the output voltage and power transfer efficiency is limited with parasitic of power electronic elements. The Luo converters are new DC/DC converters that they are developed [13].

The time variations and switching nature of power converters their static and dynamic behavior becomes highly non-linear.If adding additional filter components are inductor and capacitor to reduce the harmonic levels of the output voltage [14].The PI control technique offers advantages compared to FLC control methods: stability, even for large line and load are reduce steady error, robustness, good dynamic response implementation [15]. The Fuzzy like PI control technique advantages compared FLC control methods: stability, it offers good servo and regulatory response for line and load disturbance[16].For high-frequency power converter applications such asmajority-carrier device, voltage controller and switching MOSFET is used perpetually. High on-state drain-tosourceresistance MOSFET increases rapidly withthe device voltage rating which is the foremost drawback ofthese devices.

The organization of the paper is as follows. Section II discusses the model of the POELC. The PI Control method is detailed in this Section III. The Fuzzy Control method is explained in Section IV. Section V consists of fuzzy PI, results and conclusions are presented in section VI and VII respectively.

II. LUO CONVERTER

(A) TemplateLuo Converter circuit model

The efficient proposed developed DC-DC converter is Luo converter it overcomes to parasitic problems present in the classical dc-dc converter. The harmonics Levels present in Luo converter is less compared to the classical buck converter.

The circuit diagram of Positive output elementaryLuo converter is shown in Fig. 1. In the circuit, S is the power switch and D is the freewheeling diode. The passive elements are inductorsL_1, L_2 and capacitors C_1, C_2, R is the load resistance. Toanalyze operation of the Luo converter can bedivided into two modes.

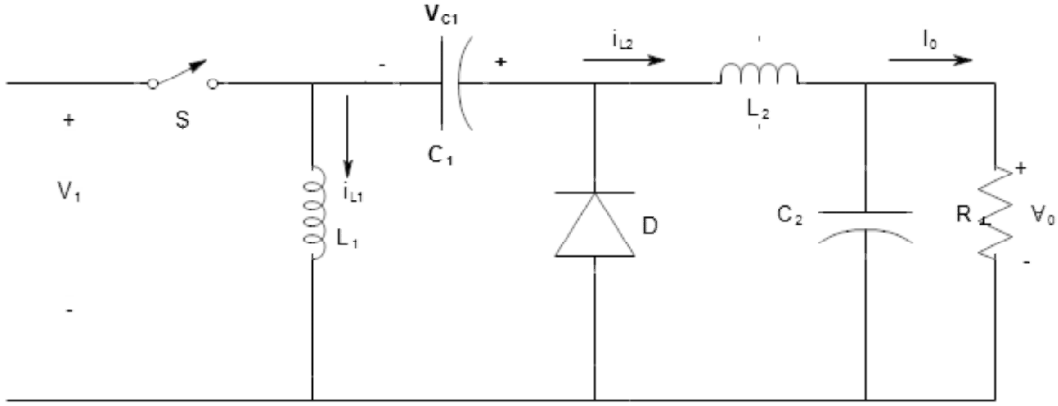

Figure 1: Circuit Diagram for LUO Converter

Mode 1: When switch is ON inductor L_1 is charged for supply voltage E. The same time, theinductor L_2 absorbs the energy source from capacitor C_1. The capacitor C_2load is supplied to the load. The equivalentcircuit of Luo converter in mode 1 operation is shown in fig. 2.

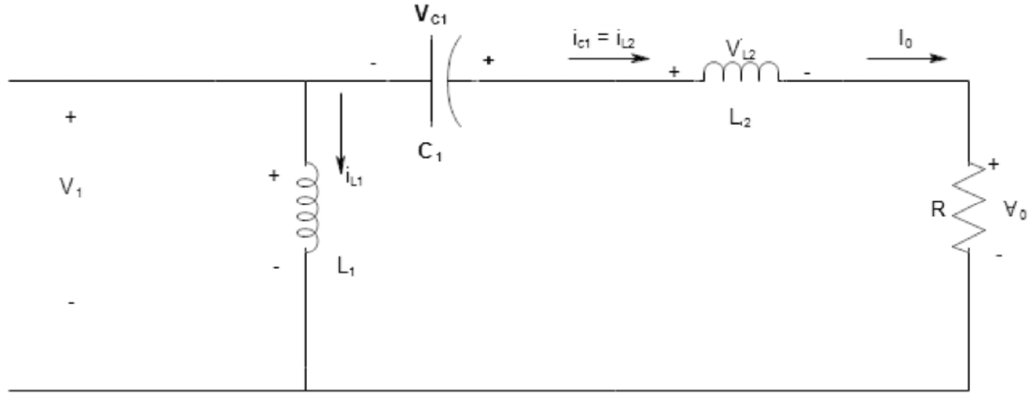

Figure 2: LUO Converter Mode1 Operation

Mode 2: During switch is in OFF state, and hence, the current isdrawn from the source becomes zero. CurrentI_{L1} flows through freewheeling diode to charge for capacitor C_1. Current I_{L2} flows into C_2 –R circuit and thefreewheeling diode D to keep itself continuous.

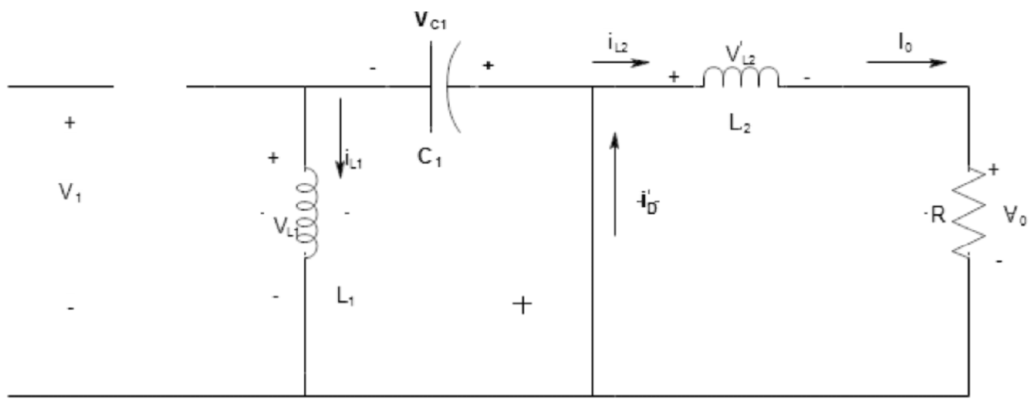

Figure 3: LUO Converter Mode 2 Operation

In discontinuous conduction mode for output are in theform of discontinuous. In this mode diode is not present in the inductor discharge through V_0 and L_2. Therefore output stage of theLuo buck converter is comprised of inductor and capacitor. The output stages are stores and delivers energy to the load, andsmooth out the switch node voltage to produce the constantoutput voltage. Inductor selection directly influences of current ripple seen on the inductor current, as wellas current capability of the buck converter itself. Inductorsare manufacturer material and typically have a tolerance of 20%. Inductors have inherent DC resistance impacts performance of output stage and minimizing in the DCRimproves the overall performance of the converter. Application it requires a high load current is recommendedto select an inductor with a low DCR.

(B) Mathematical model of Luo Converter

The average DC output voltage is given by,

$$V_0 = \frac{a}{1-a} V_{in} \tag{1}$$

The average DC input current is given by,

$$I_{in} = \frac{a}{1-a} I_0 \tag{2}$$

Duty cycle,

$$a = \frac{T_{ON}}{T} \tag{3}$$

The variation in Inductor current ΔI_{L1} is given by

$$\Delta I_{L1} = \frac{aT}{L_1} V_{in} \tag{4}$$

From equation (4) inductor L_1 value,

$$L_1 = \frac{aT}{\Delta I_{L1}} V_{in} \tag{5}$$

The variation in Inductor current ΔI_{L2} is given by

$$\Delta I_{L2} = \frac{aT}{L_2} V_{in} \tag{6}$$

From equation (6) inductor L_1 value,

$$L_2 = \frac{aT}{\Delta I_{L2}} V_{in} \tag{7}$$

DC Voltage conversion ration M is given by,

$$M = \frac{V_0}{V_{in}} = \frac{I_{in}}{I_0} = \frac{a}{1-a} \tag{8}$$

The charge on series capacitor C_1 increases during offperiod by $I_{L2}=I_o$ and decreases during on period by I_{L1}. The change in charge on C_1 must be zero Peak to peak ripplevoltage across the capacitor C_1,

$$\Delta V_{C1} = \frac{1-a}{C_1} T I_{in} \tag{9}$$

From equation (8) inductor C_1 value,

$$C_1 = \frac{1-a}{\Delta V_{C1}} T I_{in} \tag{10}$$

The ripple current in inductor L_1

$$\in_1 = \frac{(1-a)R}{2MfL_1} \tag{11}$$

The ripple current in inductor L_2

$$\in_1 = \frac{(a)R}{2MfL_1} \tag{12}$$

The ripple current in inductor C_1

$$\rho = \frac{(a)}{2\, fRC_1} \tag{13}$$

The ripple current in inductor $C_{\epsilon 2}$

$$\text{€} = \frac{a}{8Mf^2 C_2 L_2} \tag{14}$$

III. DESIGN OF PI CONTROLLER FORPOELC

The purpose ofoptimize the stability ofthe positive output elementary Luo converter dynamics, whileensuring correct operation in the working condition for a PI control is a more feasible approach. The PI control has been presented to control of switching power converters.

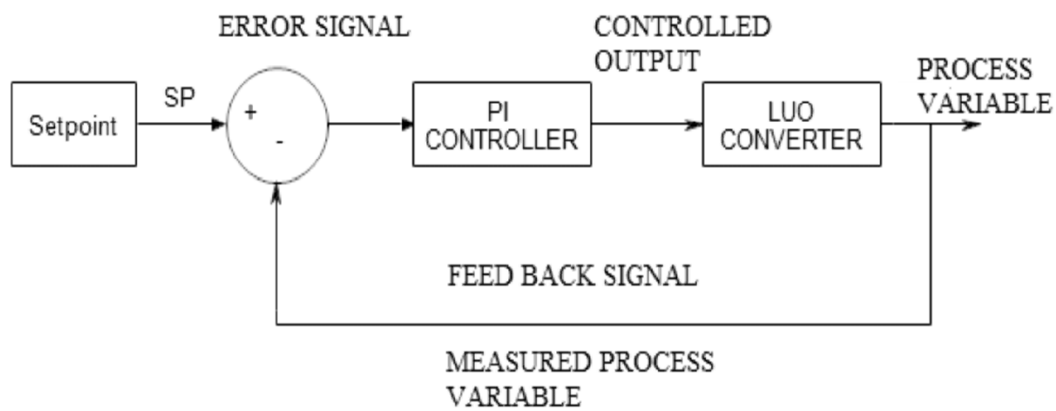

Figure 4: Block diagram for Luo Converter using PI

The PI control is designed to the specifying desired nominal operating point for LuoConverter, then regulating LuoConverter are closer to the nominal operating point in the case of sudden disturbances, set point variation, noise, modeling errors and the components variations. The PI control settings are proportional gain (Kp) and integral time (Ti) are designed to Zeigler – Nicholstuning technique. Ziegler and Nichols suggested to set the values of Kp= 0.25andTi= 0.016s.

The PI control optimal setting values (Kp and Ti) forLuoConverter are obtained by finding the minimum values of Integral Square of Error (ISE),Integral Time Absolute of Error (ITAE) and then Integral of Absolute of Error (IAE).Error in output voltage and change in the duty cycle of the power switch S (n- channel MOSFET) is respectively with input and output of the PI control.

IV. DESIGN OF FLC CONTROLLER FORPOELC

Fuzzy control used to improve existing controller systems by adding extra layer of intelligenceto the current control method. Therefore process of converting acrisp input to fuzzy value is called “fuzzification”.The proposed fuzzy controller utilizes for triangular membershipfunctions on the controller input.

The proposed fuzzy controller is defined to be a Mamdanitype fuzzy logic controller. This means that the output membership functions are single tons. This fuzzy controller has rules form “If E is the error and CEchange of error inputs then output with “and”operation in the rule antecedent is performed bymultiplication.

V. DESIGN OF FPIC CONTROLLER FOR POELC

The inputs of fuzzy logic controller is error and change of error. The output is the incremental change of the control signal. Considering a fuzzy controller with constraints, the input membership functions are triangular are not necessarily evenly distributed.Fuzzy PI controller used in this paper is based on two input FLC structure with coupled rules.

The linguistic labels are used to describe Fuzzy sets were 'Negative Big', 'Negative Medium', 'Negative Small', 'Zero', 'Positive Small', 'Positive Medium', 'Positive Big'. Therefore possible to assign the set of decision rules as shown in Table IV.

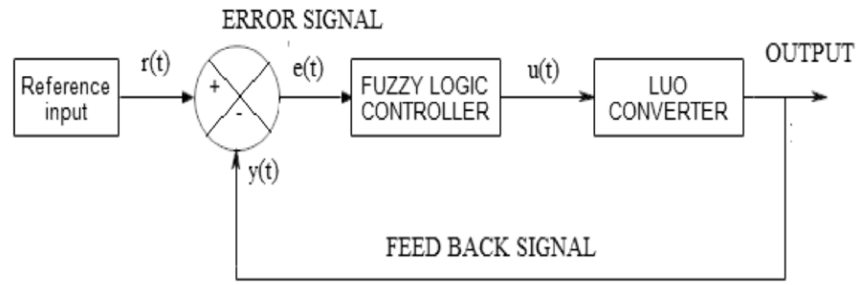

Figure 5: Block diagram forLuo Converter using FLC

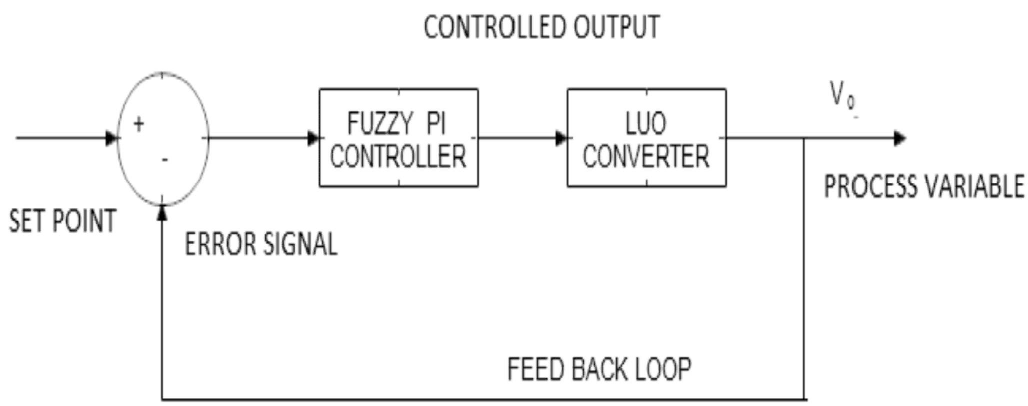

Figure 6: Block diagram forLuo Converter using Fuzzy PI Integral Controller

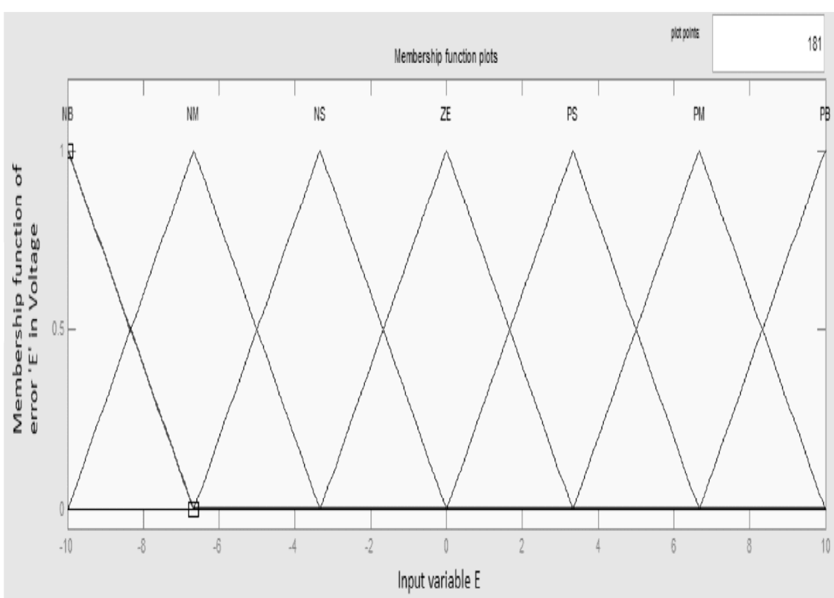

Figure 7: Membership functions of input E

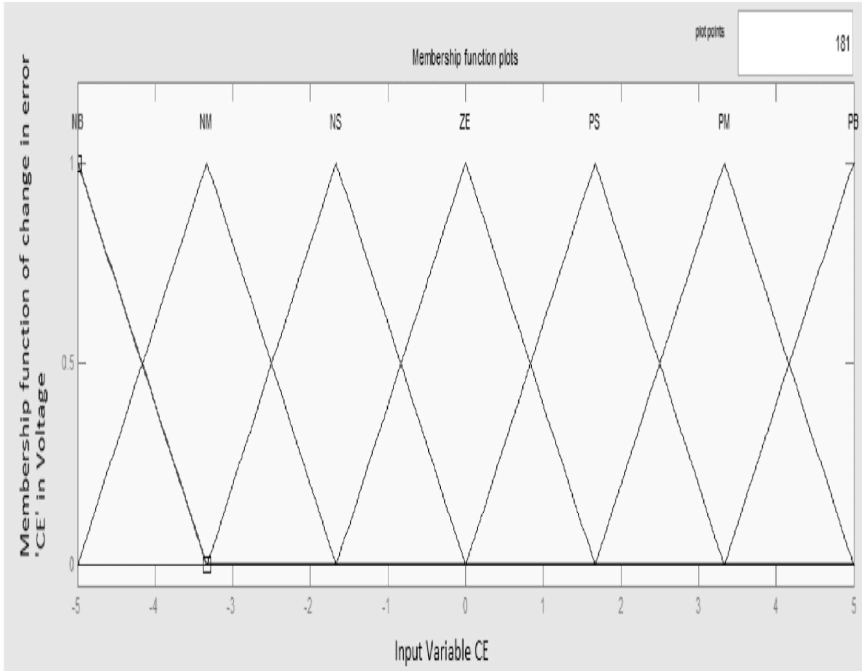

Figure 8: Membership functions of input CE

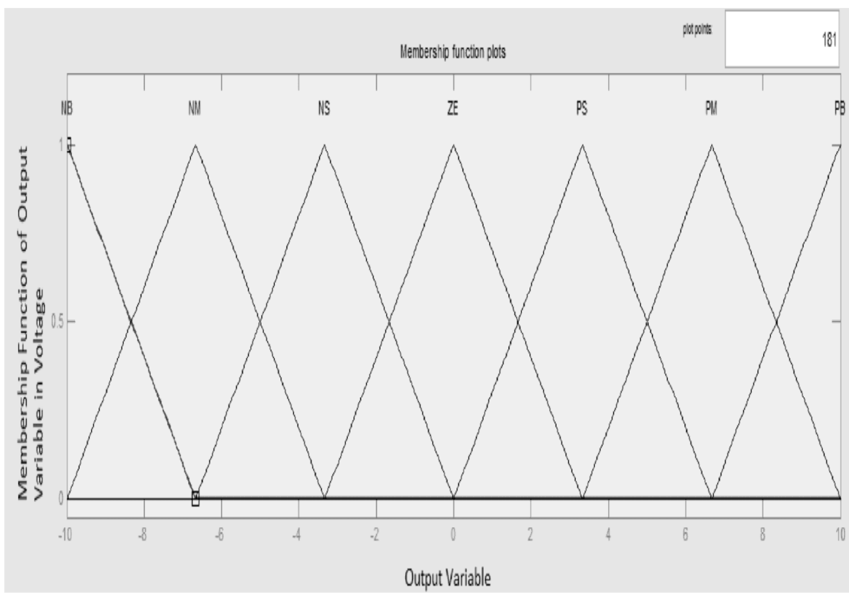

Figure 9: Membership functions of Output

Table 1
Table of Fuzzy Rule

CEE	*NB*	*NM*	*NS*	*Z*	*PS*	*PM*	*PB*
NB	NB	NB	NB	NM	NS	Z	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

The fuzzy rules are extracted from fundamental knowledge and human experience the process. These rules are containinput/the output relationships that define the control strategy. Each control input has seven fuzzy sets so there are at most 49 fuzzy rule.

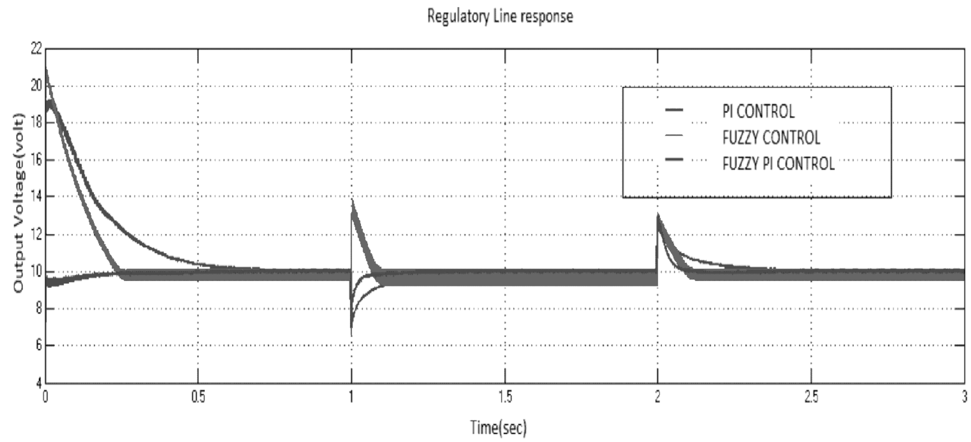

Figure 10: Step response of converter for input voltage change from 10V to 15V at 0sec , 15V to 12V at 0.6sec and 12V to 15V at 1sec with R = 10Ω

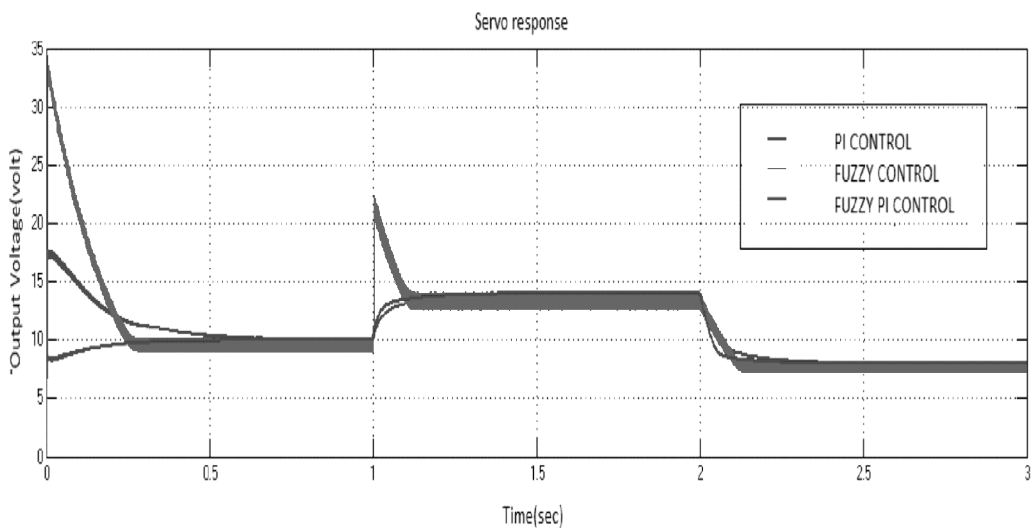

Figure 11: Step response of converter for setting output voltage change from 10V to 14V at 1sec, 14V to 8V at 2sec with R = 10Ω

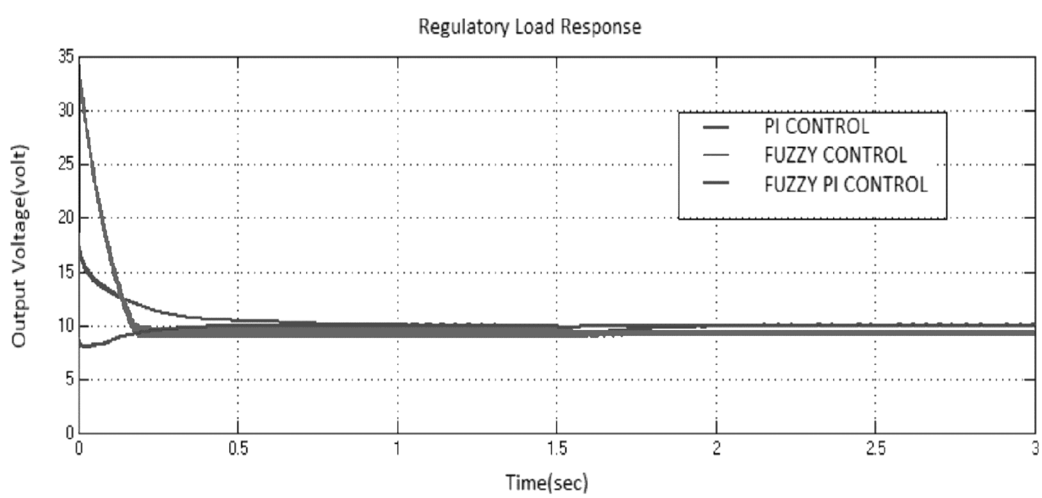

Figure 12: Step response of converter for load change from 66.66 Ω to 75Ω at 1.5 sec

VI. SIMULATION RESULT

With regard to the state equations for the converter and taking into consideration in V_{in}=24V, L_1,L_2=1mH,C_1=47 µF ,C_2=100µF,F=10.8 KHz, R=10,D=0.5. To design for Vo=10V the PI and Fuzzy Control and FPIC method is used

Table 2
Performance Evaluation of POELC with Pi, Flc and Fic

System Performance		*PI Controller*	*Fuzzy Controller*	*Fuzzy PI Controller*
Transient Response	Rise Time(t_r)	0.0015	0.0035	0.68
	Peak Overshoot(%M_p)	17.5	34.25	8.5
	Peak time(t_p)	0.0025	0.0055	0.0025
	Setteling time(ts)	0.46	7.5	0.2
Perfomance Indices	ISE	0.23	18.29	0.01
	IAE	4.72	35.23	0.90
	ITAE	7.07	52.80	1.35

VII. CONCLUSION

The proposed Luo converter is designed using PI controller and Fuzzy Logic controller and Fuzzy PI Controller.For line change FLC respond in a Highly over damped manner whereas PI respond in a overdamped manner.Thesimulation results confirm that PI controller rejects both the line and load disturbances. Also the results proved that Fuzzy PI controller gives the smooth response for Servo response and also it shows smooth regulatory response for both line and load disturbance according to the desired voltage with reduced ISE, IAE,ITAE. Using this method stable and ripple free output is obtained. Simulation results are verified using design and calculations. This developed dc-dc converters are suitable and convenient to be applied into the electric vehicle applications with low ripples.

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