Design of PI Controller for Positve Output Push Pull Switched Capacitor main Series 2,4 & 8 Lift DC-DC Luo Converter

R.Ranjith Kumar*, Dr.Manjunath Ramachandra**, S.Saranya

** Departementof Electronics & Communication Engineering,Sri Shakthi Institute of Engg. & Tech., Coimbatore.*

*** Departementof Electronics & Communication Engineering, AMC Engineering College, Bangalore.*

**** Department of Electronics and Communication, Dhanalalakshmi Srinivasan College of Engineering, Coimbatore.*

Abstract:- DC to DC converter is a new class of electric power converter, used to converts power from one level of DC voltage into another level of DC voltage evel of DC. That they could stepup, stepdown and invert the given input. Among these, boost converter is found to be applicable in large number of applications like, Hybrid Electric Vehicles (HEV), lighting systems, tramways, railway electrification. The voltage lift technique is a common application in power electronic circuit design. Switched capacitors are very small in size, can easily integrated into power integrated circuit (IC) chip and it has low. The combination of voltage lift and switched capacitor provides a DC to DC converter with small size, high voltage transfer gain, high power density, low Electro Magnetic Interference (EMI) and high power efficiency. This paper introduces a design of a PI controller for positive output main series 2,4 and 8-lift switched capacitor push-pull switched capacitor DC to DC Luo-Converters.The simulation results are presented.

Abstract:- Luo Converter, PWM, PI Controller, Line & Load Distrubances, Matlab-Simulink

I. INTRODUCTION

Micro electronics and computer manufacturing widely uses the micro power consumption technique. Typical DC to DC converters [1][2] contains Inductors/ Capacitors. Due to these combinations, the size usually becomes large. With the advancement in engineering technology, it is possible to design a size down circuit. To scale up the Power density and yet have a smaller converter, a 3rd Generation DC to DC converters have been evolved and categorised as switched component (inductors and capacitors) converters. In particular, they are switched-capacitor (SC) DC-DC converters.DC to DC converters [8] can fall into linear regulator type or switch-mode regulator type. Former, uses a series transistor functioning in its active zone, and hence, acts as a variable resistor for Output monitoring. The demerit of this is high conduction losses and results in efficiency drop (typically 30-60%). With the Latter, due to switching losses being higher, the conduction losses are reduced dramatically eventually ramping up the efficiency factor. These are the ones which are widely used due to high frequency switch though has complex and high Electromagnetic Interference (EMI).The new and different type of DC-DC converter is Switched-capacitor (SC) DC to DC conveter technology. Because a switched capacitor (SC) can be easily incorporated within a power unified circuit chip, these are scaled down in size and in turn have an increased power density. DC to DC conversion utilises current magnificatiomand voltage lifttechniques, provides scale up power density, increased power efficiency and reduced EMI.SC converters can perform in push pull state with conduction (duty cycle) k = 0.5. SC converters constantly functions in push pull condition, and the control circuit is intricate. In case of increased Voltage differences arises due to Input/Output, significant increase in quantity has to be arranged.Finally, the simulation results are evaluated using MATLAB Simulink and the output is presented.

II. LUO CONVERTER

The power transfer efficiency and output voltage (V_o) of the 1st generation DC to DC converters like Step down converters, Step up converters and Step up/down converters are having some constraint because of parasitic effect of the switched components . The voltage-boostsystem [4] is a widespread method which is widely applied in power electronics circuit design, for the reason, that it successfully covers the effects of switched elements and amplifies the voltageoutput (V_0).Luo converter is mainly consist of three series, main,
additional and enhanced series. The main series consist of 2-lift, 4-lift, 8-lift Luo converter and additional series includes 3-lift,6-lift, 12-lift and enhanced series consist of 3-lift, 9-liftand 27-lift.

III. POSITIVE OUTPUT MAIN SERIES SWITCHED CAPACITOR LUO CONVERTERS

3.1. 2 lift

The 2-lift circuit [2][3] and it's off and on period for positive- output (PO) multi-lift push pull switched capacitor DC-DC Luo converter is shown Fig.1. The below circuit has work like boost converter. The above circuit consists of two switches namely S (main switch) and S_1 (slave switch), two capacitors and two diodes. During off period {(1-K)T}, the current flows through $S_1$and during on period {KT}, the current flows through S. Consider R as resistive load, V_o and V_{in} are output and input voltages respectively. Input and output currents denoted as I_{in} and I_o respectively. S_1 and S are connected in the configuration of push pull. During period KT, C_1 charges to V_{in} and during period (1-K)T, C_2 charges to the same V_{in}. So the voltage drop across both the period is double the input voltage and shown in eqn.1 & 2.

$$V_o = 2V_{in}. \quad (1)$$

$$V_o = 2V_{in} - V_d \quad (2)$$

Where V_d represents the voltage drop across diode cum switches.

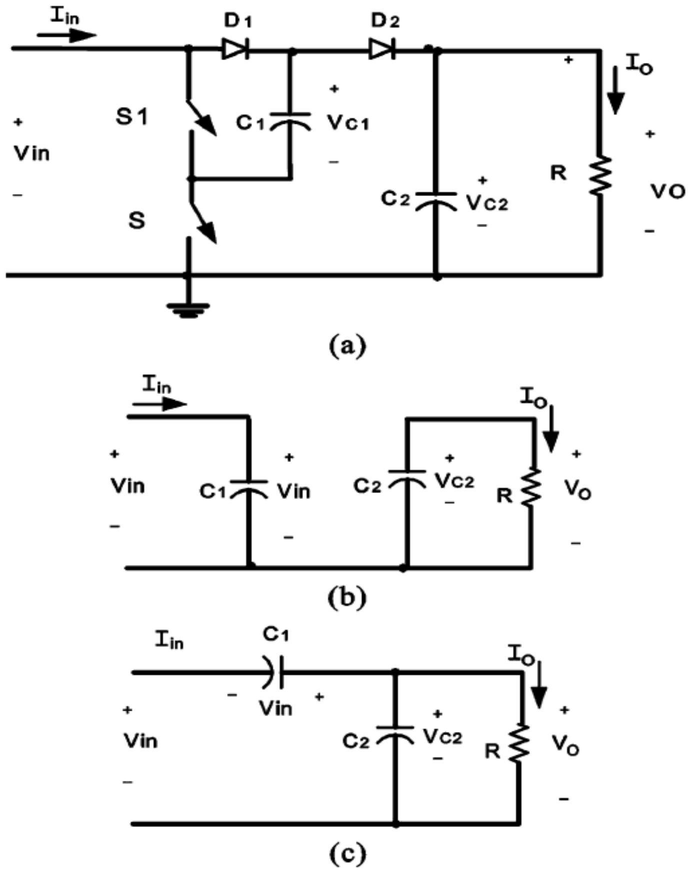

Fig.1. a) 2-lift Circuit b) On period. c) Off period.

3.2. 4 lift

The 4-Lift (Re lift) circuit is expanded from the 2-lift (Elementry) circuit by including 3-diodes, 2-switched capacitors and 1-slave switch. Its equivalent circuits and circuit diagram during Push-pull states are shown in Fig.2. The switches S and (S_1, S_2) operate in push–pull state. The capacitor C_1 is charged to the input voltageV_{in}, which is denoted by $V_1$and the capacitor C_3 is charged to voltage V_1 during switching-on. The capacitor C_2 is charged to V_1.Eqn 3& 4 shows the output voltage.

$$V_o = 4V_{in}. \quad (3)$$

$$V_o = 2V_{in} - V_d \quad (4)$$

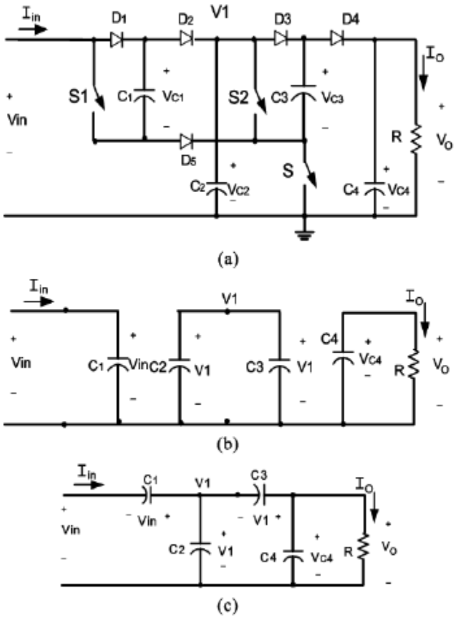

Fig.2. a) 4-lift Circuit b) On period. c) Off period.

3.3 8 lift

The main series PO triple lift (8-lift) circuit [9][10]is including from Re-lift circuit by addition of 3-diodes 2-switched capacitors and 1-slave switch (S_3-C_5-C_6-D_6-D_7-D_8). Its equivalent circuit and circuits diagram during on and off duration of switches are indicated in Fig. 3. Switches S1, S_2, $S_3$and Sare in push-pull mode operation. The capacitor C_1 is charged to the input voltageV_{in}, the capacitor C_3 is charged to V_1 and the capacitor C_5 is charged to V_2 during switch Sis in ON state. The capacitor C_2 is charged approximately tovotage across the capacitor C_1 ,$V_1 = 2V_1$, the capacitor C_4 is charged approximately to the voltage across C_2 ,$V_2 = 2V_1 - \Delta V_2$ and the C_6 is charged to $V_o = 2V_2 - \Delta V_3$ during S-switch is in open condition.Therefore, The total voltage output across the load resistance R_L is shown in eqn. 5,6,7.

$$V_o = 2V_2 - \Delta V_3 \quad (5)$$

$$V_o = 4V_1 - 2\Delta V_2 - \Delta V_3 \quad (6)$$

$$V_o = 8V_{in} - 4\Delta V_1 - 2\Delta V_2 - \Delta V_3 \quad (7)$$

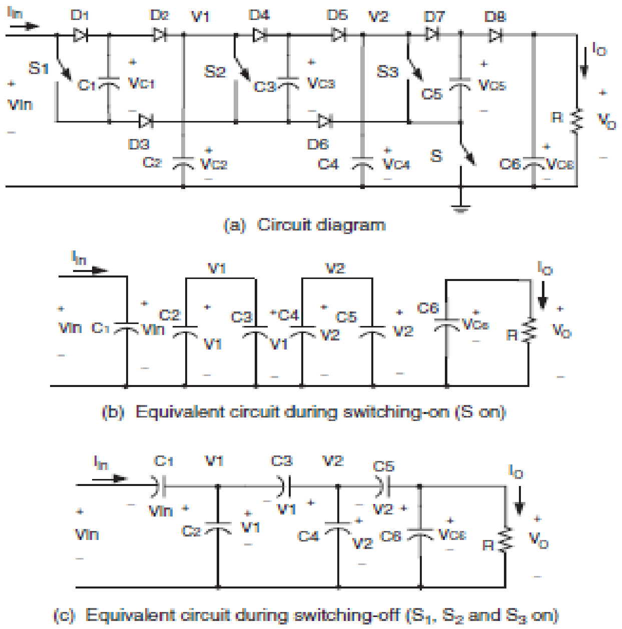

Fig. 3 a) 8-lift Circuit b) On period. c) Off period.

IV. PWM TECHNIQUE

To increase the voltage output, concentrating on decreasing the losses due to switching action, for that many methods are introduced. These PWM techniquesis subdivided into 2- categories:One is the quasiresonant technique and another one is the active clamp technique. To attain the Zero VoltageSwitching (ZVS) of the main switch(S) at any load condition, a dynamic frequency control by fine-tuning the switch open (OFF)-time with complementary gate signals has been introduced. Since the secondary switch is closed (ON) for a small durationpreviously the main switch is closed(ON), the reprocessed leakage energy can be used to attain the Zero Voltage Switching of the Primary switch, which minimizes the circulating energy effectively compared to the conventional complementary switching methodologies. The offered load PWM control is used in order to maximize the voltage output and to minimize the lossesdue to switching during load condition. The PWM method is used to produce signals or pulses for adjusting the switches close (ON) or open (OFF). In PWM converters the controller circuit regulates the output by setting the switch operating frequency and changing the switch close (ON) time. In this the final output is compared with a carrier signal and produces a pulse, which is used to drive the switches.

V. PI CONTROLLER DESIGN AND ANALYSIS

The chosen converters have been demonstrated and simulated using MATLAB/SIMULINK Power System Block set. Fig.4 shows the S-shaped response curve with open loop condition and Fig. 5 indicates the block diagram of PO main series DC-DC converter using Proportional Integral controller. The PI controller [6][7]fixing the integral time (Ti) and proportional gain (K_p) arecalculated with the help of ZN tuning technique [11][12] by applying the step test to the state space averaged model of the chosen converters. The delay time and time constantare finding by creating a tangent line at the inflection point of the S-shaped curve [3][5]and finding the meeting of the tangent line. PI control is implemented using control system toolbox and table 1 shows the ZN tuning rules.

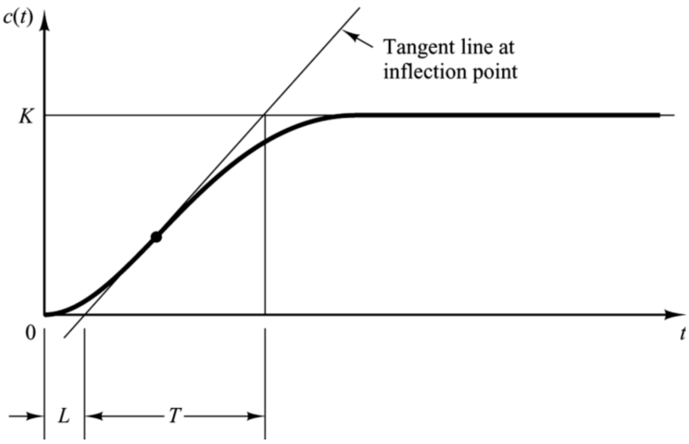

Fig.4 S Shaped response curve

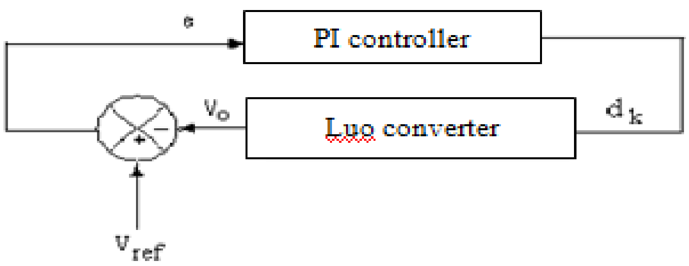

Fig. 5 Block diagram of Positive output main series Luo converter using PI controller

Table 1

Ziegler-Nichols Tuning Rules

Type of Controller	K_p	T_i	T_d
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

VI. SIMULATION RESULTS AND DISCUSSIONS

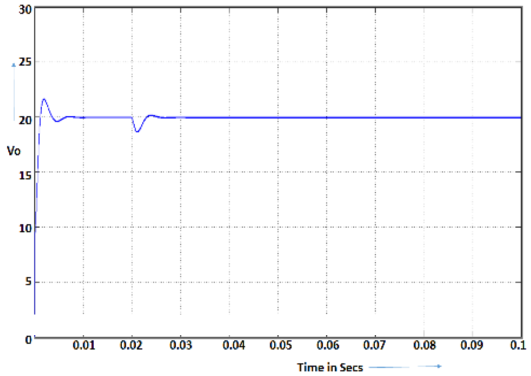

Figure 3.-20% supply disturbances of input 10V

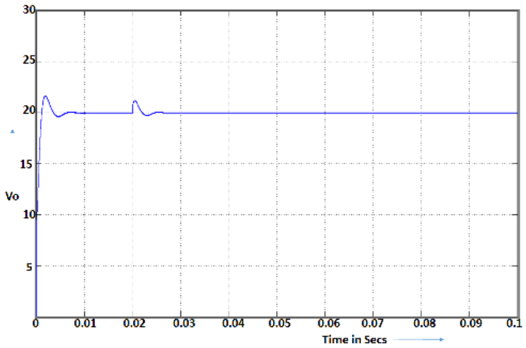

Figure 4. +20% supply disturbances of input 10V

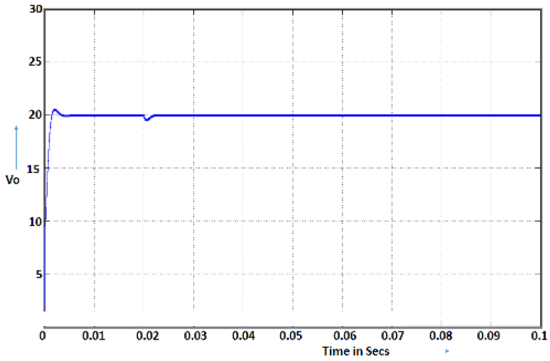

Figure 5.-20% load disturbances of load 1KΩ

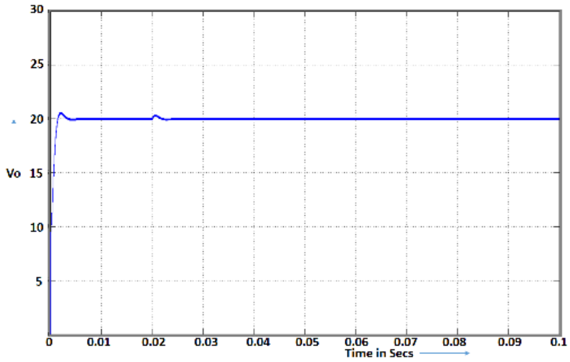

Figure 6. +20% load disturbances of load 1KΩ

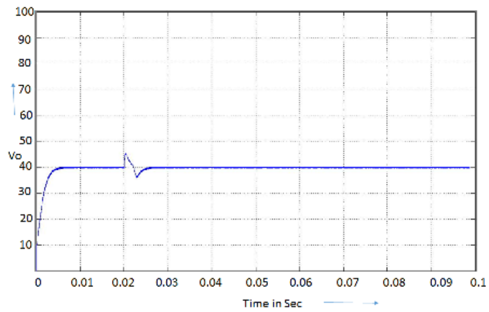

Figure 7.+20% supply disturbances of input 10V

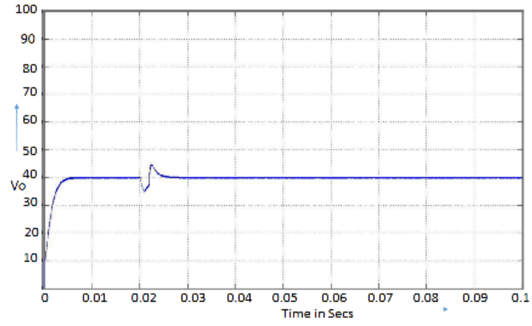

Figure 8. +20% supply disturbances of input 10V

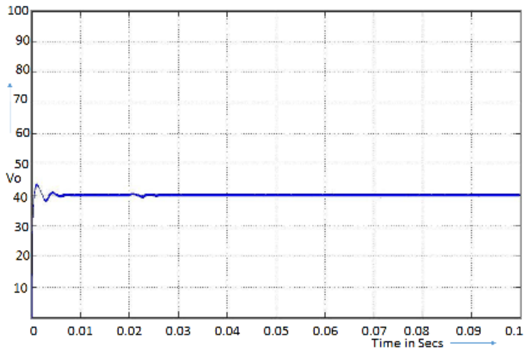

Figure 9.+20% load disturbances of load 1KΩ

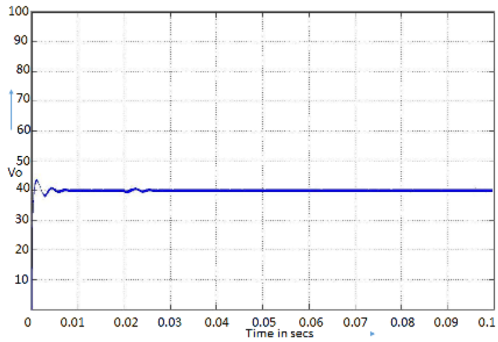

Figure 10.-20% load disturbances of load 1KΩ

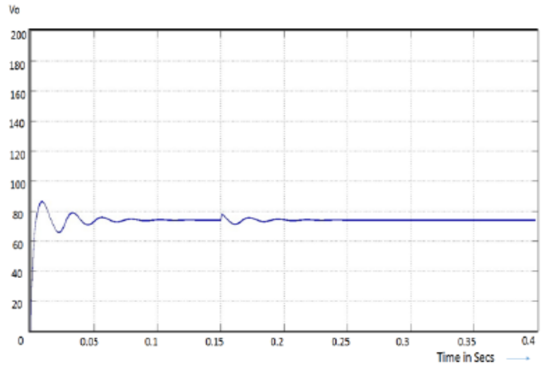

Figure 11. +20% supply Variation of Input 10V

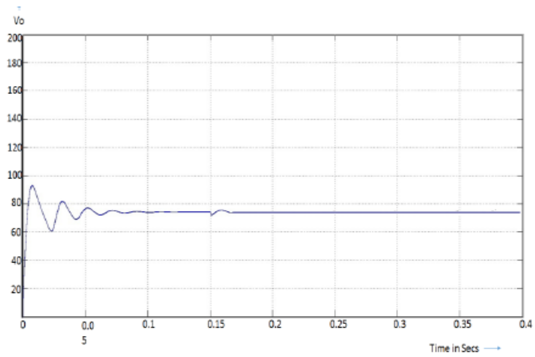

Figure 12. -20% supply Variation of Input 10V

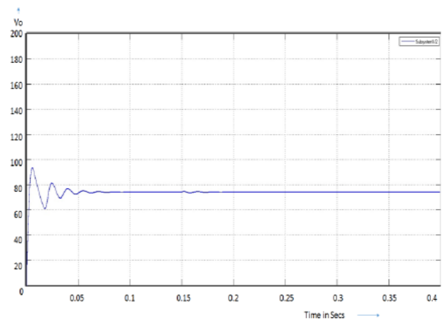

Figure 13. +20% Load disturbances of load 6KΩ

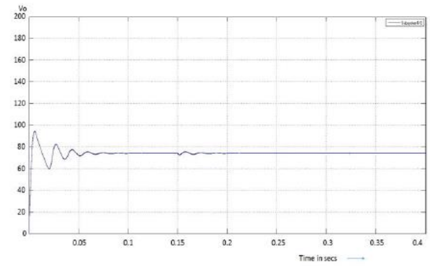

Figure 14. -20% Load disturbances of load 6KΩ

Table 2. The Performance Evaluation of PI Controller for 2,4 &8 Lift Main Series Push Pull SC Luo Converter

Converter	Start up transient				Supply increase (20%)		Supply decrease (20%)		Load increase (20%)		Load decrease (20%)	
	Delay time (msecs)	Rise time (msecs)	Peak over shoot (%)	Settling time (msecs)	Peak over shoot (%)	Settling time (msecs)	Peak over shoot (%)	Settling time (msecs)	Peak over shoot (%)	Settling time (msecs)	Peak over shoot (%)	Settling time (msecs)
2 Lift	1	3	10	5	5	6	10	5	2.5	4	2.5	2
4 Lift	2	5	0	7		3				-	10	4
8 Lift	3	10	23	8	23	22	17	17	15	18	18	17

Fig. 3 shows -20% supply disturbances of input 10V for which converter output voltage has 5ms settling time. Fig. 4 shows +20% supply disturbances of input 10V for which converter output voltage has 6ms settling time. Fig. 5 shows -20% load disturbances of load 1KΩ for which converter output voltage has 2ms settling time. Fig. 6 shows +20% load disturbances of load 1KΩ for which converter output voltage has 4ms settling time. Fig.7 shows +20% supply disturbances of input 10V for 4 lift converter output voltage has 3ms settling time and Fig.10 shows -20% load disturbances of load 1KΩ for 4 lift converter output voltage has 4ms settling time.

The Experiment conducted for load and supply variations of the converters are accepted out to check the controller performance. Fig.11 indicates the voltage output across the load resistor R_L of converter for the taken voltage input changes from 10 V ~ 12 V (+20% line disturbances) for which the converter produces the voltage output has 22ms of time settling (t_s). Fig. 12 indicates the voltageoutput across the load resistor R_L of converter for the taken voltageinput changes from 10 V ~ 8V (-20% load variations) for which the converter producesvoltageouput has 17ms oftime settling (t_s). Fig. 11indicates the voltage output across the load resistor R_L of converter for the takenOutput load resistance changes from 6000 Ω to 8000Ω (+20% load disturbances) for which the converter produces the output voltage has 18ms of settling time (t_s). Fig. 14 indicates the voltage output of converter for the taken load resistance step changes from 6000Ω to 4000 Ω(-20% load variations) for which the converter voltage output has 17ms of time settling (t_s).

The PO main series multi-lift push- pull switched capacitorelementary DC/DC converter converts the positive load voltage from the positive supply voltage. Table 2, indicatesthe startup response for the 2 lift Lu converter and PI controller performance of the 2 lift , 4 lift and 8 lift Luo converter The Maximum Overshoot is maximized about 10% to 5%. This is tolarable and finest one because the Maximum allowable Overshoot less than 25%.

VII. CONCLUSION

In this work, PI controller structure are considered, developed and simulated for chosen Luo converters. In comparison with the PI controller, may be the proposed intelligent controllers yield better dynamic performances with less settling time, zero steady-state error and less overshoot.

ACKNOWLEDGEMENTS

The authors of the paper, wishesto thank AMCEC, Bengaluru and SSIET, coimbatore to provide the laboratory infrastructure to complete this work.

REFERENCES

[1] X. S. Li, *et al.*, "Analysis and Simplification of Three-Dimensional Space Vector PWM for Three-Phase Four-Leg Inverters," *IEEE Transactions on Industrial Electronics,* vol. 58, pp. 450-464, Feb 2011.

[2] Fang Lin Luo, “Luo Converters-Voltage Lift Technique”, in Proc. *IEEE Power Electronic Special Conference PESC’98*, Fukuoka, Japan, pp. 1783-1789 (1998).

[3] K.Ramash Kumar, S.Jeevanantham,” PI control for positive output Elementary super lift Luo converter”, *ISSR, Electrical and computer Engineering,* Vol. 4,no: 3,2010.

[4] Silpa.N, Chitra.J, “An Improved Luo converter for high voltage Applications”, *IJETAE,* ISSN 2250-2459, Vol.4, Issue5, May 2014.

[5] A.Joseph Basanth, S.P.Natarajan, T.S.Sivakumaran,”Performance Analysis of Positive Output Super-lift , Re-lift Luo converter with PI and Neuro controllers”, *IOSR-JEEE*(2013) 21-27.

[6] Saranya.s, Kalaiselvi.K,”Tuning of PID Controller for Positive output elementary Super-lift Luo converters using AI techniques”, IJERT, Vol. 2, Issue 11, e-ISSN 2278-0181,NOV-2013.

[7] Sivakumar.A, Ajinsekhar.S.C, Ronal Marian.A, SasiKumar.M,”Performance Evaluation of Convolution controller for Positive Output Relift Luo converter”,IJIRCE,ISSN:2320-9801, Vol. 2, Issue 1,Jan-2014.

[8] R.Ranjith Kumar, Dr.Manjunath R,S T Bibin Shalini, S,Saranya, “Design and Performance Evaluation of PI Controller for Multi Lift Main Series Push Pull Switched Capacitor Luo Converters” ,*IJAER*, Vol. 10 ,number 44 (2015), pp 31836-31838

[9] B.Nagalakshmi, V.Bindu, “Performance Analysis of Positive Output Super Lift Re Lift LUO Converter using PI and Fuzzy Logic Controllers”, *International Journal of Computer Science and Engineering Communications (IJCSEC)*, Vol.3, Issue 2, 2015, Page.953-959, ISSN: 2347–8586.

[10] M.Manohar, Chenchi Reddy, “Performance Evaluation of a New Closed loop high setup DC-DC converter for photo voltaic application”, *International Journal scientific Engineering and Technology Research (IJSETR)”* vol.4, issue 24, July 2015, pp. 4600 – 4606.

[11] A.Joseph Basanth, S.P.Natarajan and T.S.Siva kumaran, Development of FLC for ZCS LUO QRC , *International Conference PESA-09*, Hong Kong.

[12] R.Ranjith Kumar , Dr.Manjunath Ramachandra ,S. Saranya ,H. Divya, “Design and Performance Evaluation of PI controller for Multiple Lift Main Series 2 and 4 Lift Push Pull Switched Capacitor Luo Converter”,International Conference for Circuits, Power and Computing Technologies, paper number, 2016.

BIBLIOGRAPHY OF AUTHORS

R.Ranjith Kumar was born in Uthamapalayam, Tamilnadu, India, on 1979. He has obtained DECE (ECE) in 2000 from Tamilnadu Technical Board, B.E (ECE) in 2003 from Kamarajar University and M.E (PC&I) in 2007 from Annamalai University. He is presently pursuing Ph.D in the Department of Electronics and Communication Engineering, Visvesvaraya Technological University. He has more than one decade of teaching experience. His areas of interest are DC-DC converter and implementation of intelligent control techniques for power electronic converters. He is published 30 Technical papers in various National, International Conferences and Journal and member in IEEE, Life member in Indian Society for Technical Education and IMAPS.

Dr. Manjunath Ramachandra has about 20 years of work experience in the overlapping verticals of Signal processing- including medical Image processing, Wireless/mobile and networking. Research in the same field led to PhD, about 150 journal & conference publications, patent disclosures and a book. He represented Philips in international standardization bodies such as Wi-Fi Alliance, served as the editor for the regional profiles standard in Digital living network alliance (DLNA) and as the industrial liaison officer for the CE-Linux Forum. He has chaired about 30 conferences. His areas of interests include Signal & image processing, database architecture, Artificial intelligence etc.

S.Saranya was born in Cumbum, Tamilnadu, India, on 1986. She has obtained B.E (ECE) in 2007 from Anna University and M.Tech (DEC) in 2015 from Visveswaraya Technological University. She has more than two years of teaching experience. Her areas of interest are DC-DC converter and implementation of intelligent control techniques for power electronic converters. She is published 5 Technical papers in various National, International Conferences and Journal.