Design and Analysis of Negative Output Luo Converter for Power Quality Enhancement

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Abstract— **This paper displays the investigation and outline of a negative output Luo converter for the enhancement of power quality as far as enriched power factor and less source current Total Harmonic Distortion (THD). This negative output Luo converter can be used for all kind of AC-DC applications operating under the universal supply voltage of 90 V-260 V. This converter either works in Continuous Conduction Mode (CCM) or Discontinuous Conduction Mode (DCM).The proposed work focuses on a power factor corrected negative output Luo converter operating in DCM of inductor current improves the power factor at AC mains nearly to unity and thereby reducing the THD under the prescribed limits of IEEE and IEC standards. The performance of the proposed converter is analysed using MATLAB/Simulink.**

Keywords— **Discontinuous Conduction Mode, Total Harmonic Distortion, Power Factor Correction, Power quality, Luo converter**

I. Introduction

Customarily Solid-state AC-DC converters are composed utilizing diodes and thyristors to give DC power in a controlled and an uncontrolled fashion [6]. They have the issues of voltage distortion, gradually differing DC ripple, poor efficiency and require huge filters [1], [11]. To overcome these, another type of converters have been produced utilizing Solid-state self-commutating gadgets, for example, MOSFET, IGBT, GTO, and so forth. Such converters are delegated Boost, Buck, Buck-Boost AC-DC converters and are alluded to as enhanced power quality converters [1], [12].

In another paper, they [5] made a review of single phase improved power quality AC/DC converters. IPQC's can be thought to be a superior option for high power quality change in light of the lessened size of general converter and its higher efficiency.

Sanjeev Singh and Bhim Singh (2012) [3] proposed a PFC Cuk converter for aeration and cooling systems based on a PMBLDCM drive. The proposed converter exhibits a THD which is measured as 2.22% and PF is 0.9998. Bhim Singh and Ganesh Dutt (2007) proposed the investigation, plan, demonstrating and advancement of single-switch AC/DC Converters for power factor and efficiency improvement [8]. It has been found experimentally that zeta converter has 4% THD for DCM operation. Vashist Singh and Bhim Singh (2015) [4] explains the proposed converter with a solitary voltage sensor for DC interface voltage control when contrasted with other two designs [2], which decreases the cost of the general system and subsequently it is utilized for low power applications. An enhanced power quality with Unity Power Factor (UPF) is achieved.

Mohammed Mahdavi and Hosein Farazanehfard (2011) [7] proposed a simplified control circuit where a current loop is not required. The converter is intended to work in DCM. SEPIC converter is used to eliminate the requirement of passive filter. The harmonics are below the IEC 51000-3-2 standard. Jae-Won-Yang and Hyun-Lark DO (2013) [10] proposed a brushless SEPIC converter with bridgeless topology, where the conduction losses are reduced. In order to eliminate the need of large inductor, an assistant little inductor and a capacitor is used to lessen the input current swell. PF is 0.995. Vashist Bist and Bhim singh (2014) [9] proposed a converter which operates in DCM to provide an inherent PFC at the AC mains. The proposed bridgeless buck-boost converter uses a variable DC link voltage of VSI for enhanced power quality. THD of the proposed converter is 3.85% at rated condition with UPF.

This paper describes about the open loop and closed loop analysis of negative output Luo converter with a PI controller. The organization of the proposed work is as follows: Circuit configuration is described in section 2. Section 3 presents the design of the proposed converter. Open loop and closed loop results and discussions of the developed software model is demonstrated in section 4. The summary, concluding marks and recommendations for future improvement are given in section 5.

II. CIRCUIT CONFIGURATION

The circuit is appeared in figure 1. It works in a universal supply voltage of 90 V-260 V. The filter in the AC mains, is required to decrease the swell in the input

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current and along these lines help in power factor redress. The power circuit methodology is given three inductors, three capacitors, five diodes and one MOSFET switch working at a switching frequency of 10 kHz.

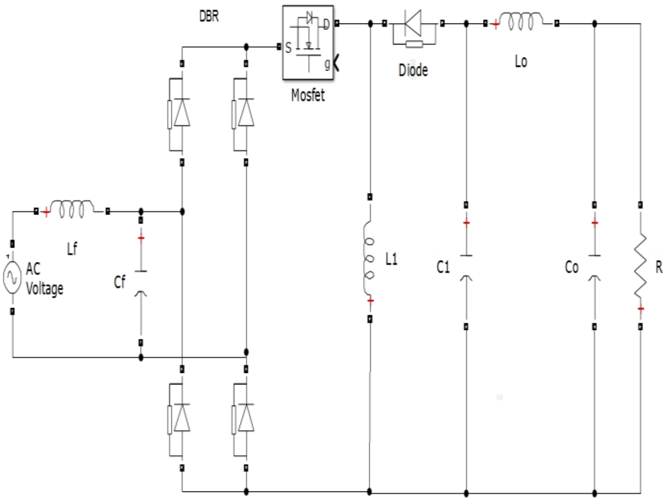

Fig. 1 Negative output Luo converter

The converter is designed for 100W applications. The regulated output voltage and output current will be 48 V and 2.083 A respectively. The plan details of the proposed converter are shown in TABLE I

TABLE I: DESIGN SPECIFICATION OF THE CONVERTER

PARAMETERS	VALUES
Supply Voltage (V_{in})	90 V– 260 V
Filter Inductor (L_f)	100 mH
Filter Capacitor (C_f)	2000 µF
Input Inductor (L_1)	470 µH
Intermediate Capacitor (C_1)	2.2 µF
Output Inductor (L_0)	1200 µH
DC Link Capacitor (C_0)	2200 µF
Output Power (P_0)	100 W
Output Voltage (V_0)	48 V
Switching Frequency (f_s)	10 KHz

III. RESULTS AND DISCUSSIONS

The negative output Luo converter is simulated in MATLAB/Simulink.

A. Open loop Simulation of negative output Luo converter

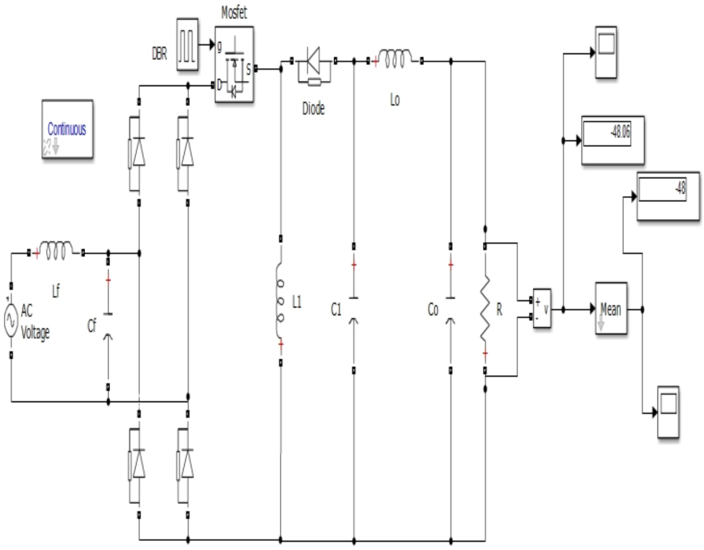

Fig. 2 Open loop simulation of negative output Luo converter

Figure 2 shows the open loop simulation diagram of the proposed converter. In this, to demonstrate the importance of supply side filter, two different analyses are carried out.

Figure 3 shows the output voltage waveform of the negative output Luo converter under open loop control without filter. The desired output voltage of -48 V is not obtained in open loop control; instead we obtained an output voltage of -50.5 V.

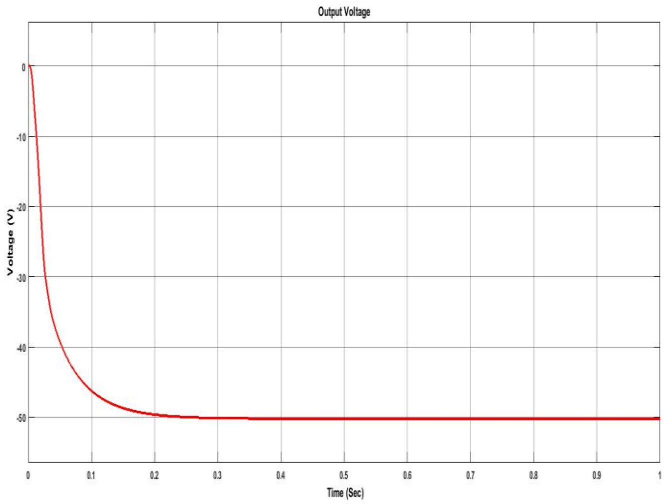

Fig. 3 Output Voltage of open loop simulation of negative output Luo converter

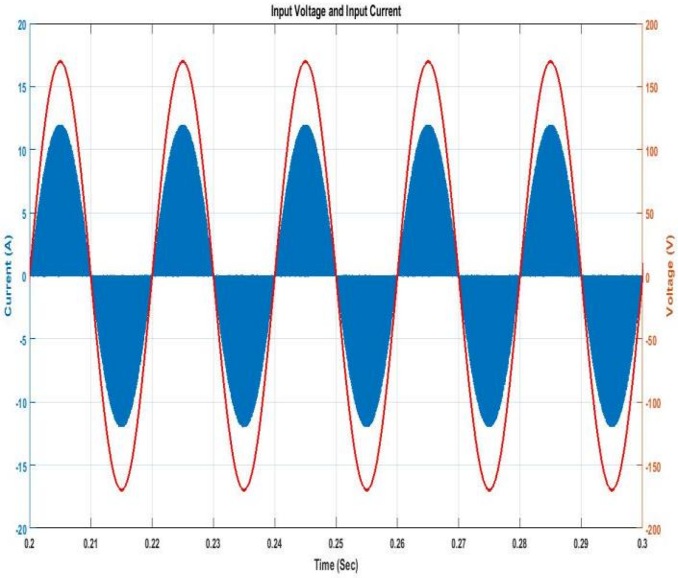

Fig. 4 Supply current and supply voltage without filter

Figure 4 & 5 shows the source voltage, distorted source current waveform and its corresponding FFT analysis respectively. It shows that, in the absence of LC filter, there is an injection of a very high amount of harmonic content in the source current, which is not under the permissible limits of IEEE standard. Its THD is around 226%. Also it exhibits a very low power factor of 0.35.

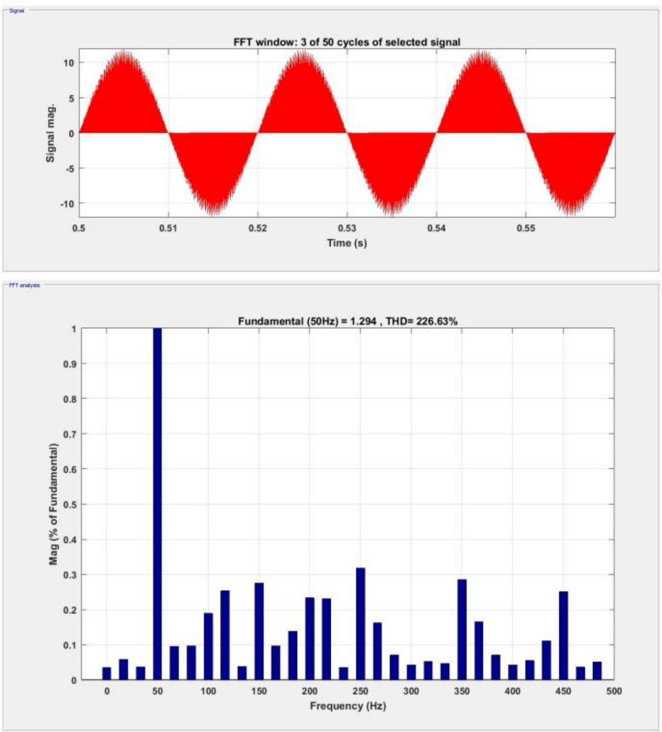

Fig. 5 THD of supply current without filter

Figure 6 shows the output voltage waveform of the negative output Luo converter under open loop control with filter. The desired output voltage of 48 V is not obtained in open loop control; instead we obtained an output voltage of 51.5 V under rated conditions.

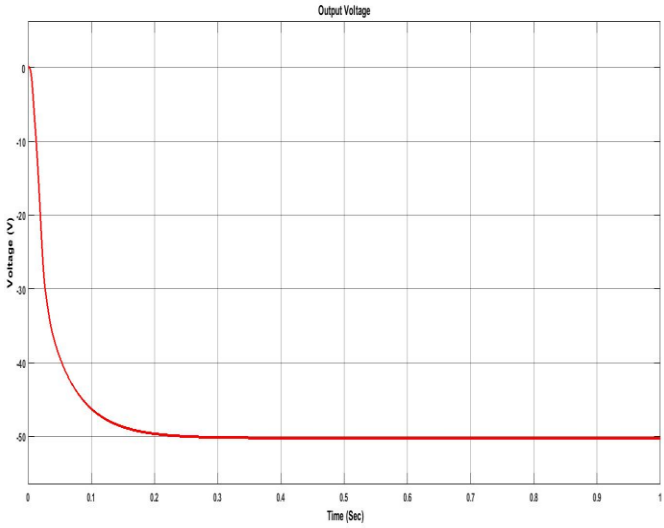

Fig. 6 Output Voltage of open loop simulation of negative output Luo converter

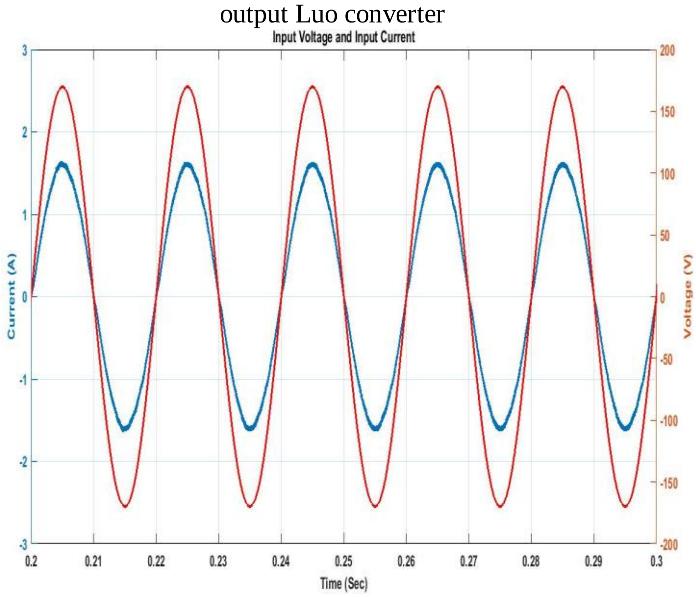

Fig. 7 Supply current and supply voltage with filter

Figure 7 & 8 shows the source voltage, source current waveform and its corresponding FFT analysis. It shows that, in the presence of LC filter, the injection of harmonic content in the source current is very low, which is under the permissible limits of IEEE standard. Also, as the voltage and current are in-phase with each other, it leads to a near unity power factor.

B. Closed loop Simulation of negative output Luo converter

The PI controller is the most generally utilized as a part of closed loop systems due to its execution as far as effortlessness. It creates an error signal by contrasting the coveted output signal and the actual output signal. Figure 9 demonstrates the closed loop recreation chart of the proposed converter.

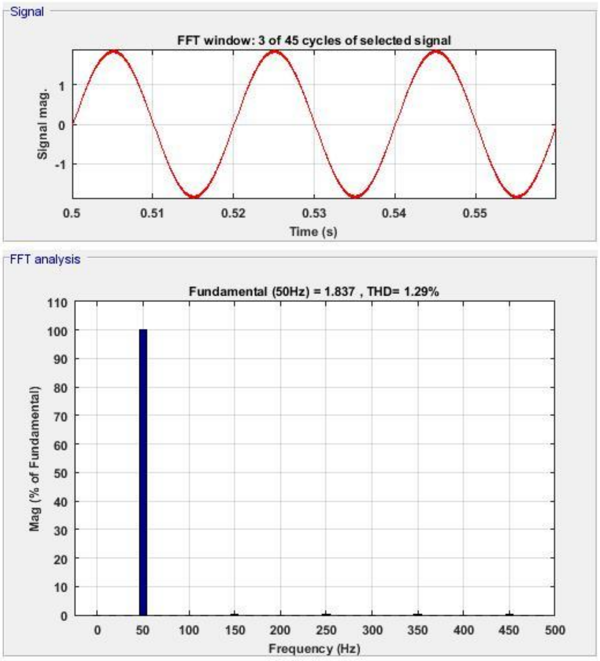

Fig. 8 THD of supply current with filter

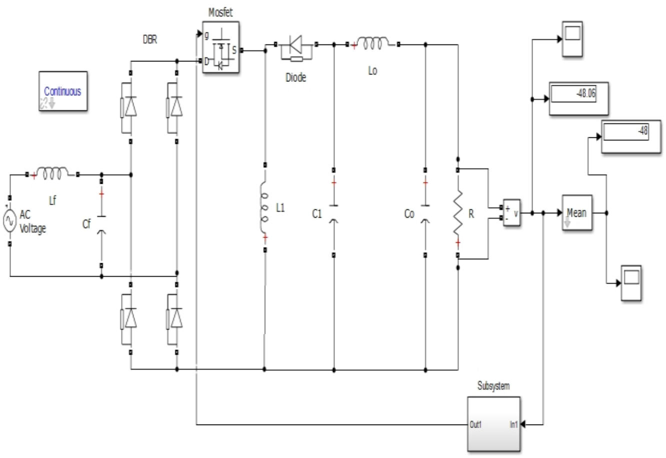

Fig. 9 Closed loop simulation of negative output Luo converter

Figure 10 shows the output voltage waveform of the negative output Luo converter under closed loop control. The desired output voltage of 48 V is obtained in this type of control; which is attained at a time t=0.6 second. Also it is inferred from the waveform that, the voltage ripples is also very less.

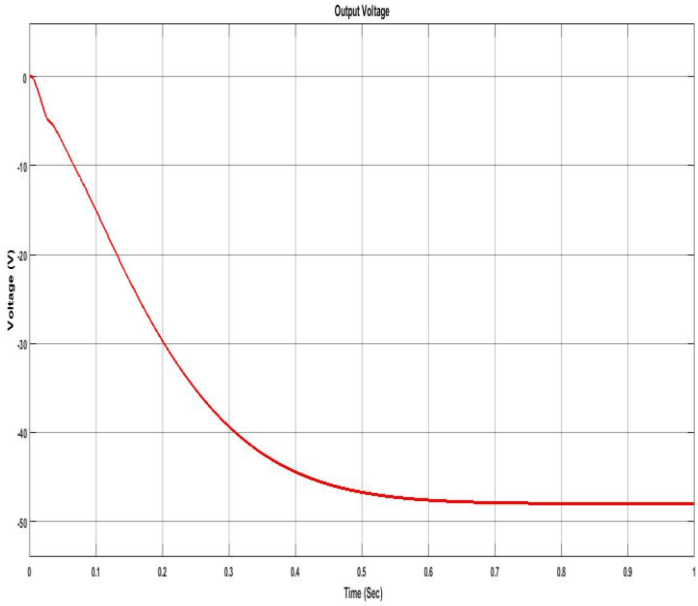

Fig. 10 Output Voltage of closed loop simulation of negative output Luo converter

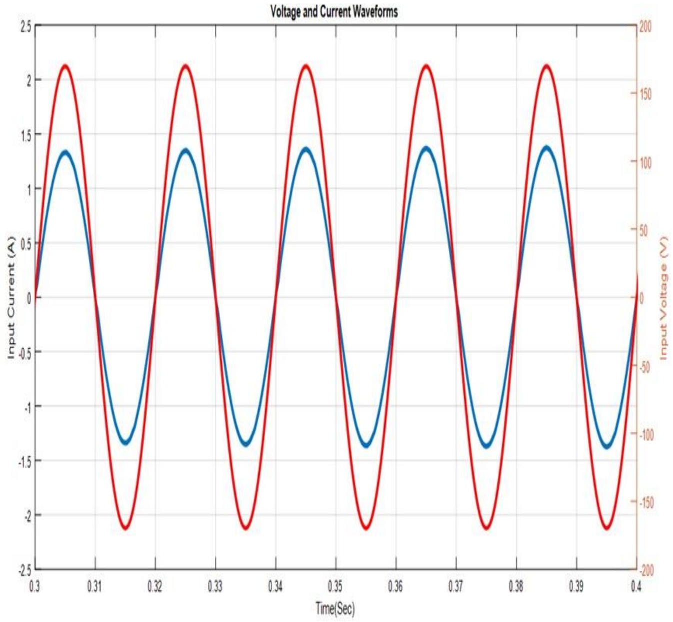

Fig. 11 Supply current and supply voltage

Figure 11 & 12 shows the source voltage, source current waveform and its corresponding FFT analysis. It shows that, in the presence of LC filter, the injection of harmonic content in the source current is very low, which is under the permissible limits of IEEE standard. As, the voltage and current are in-phase with each other, it leads to a near unity power factor. The corresponding THD value is found to be 1.42% which is very less.

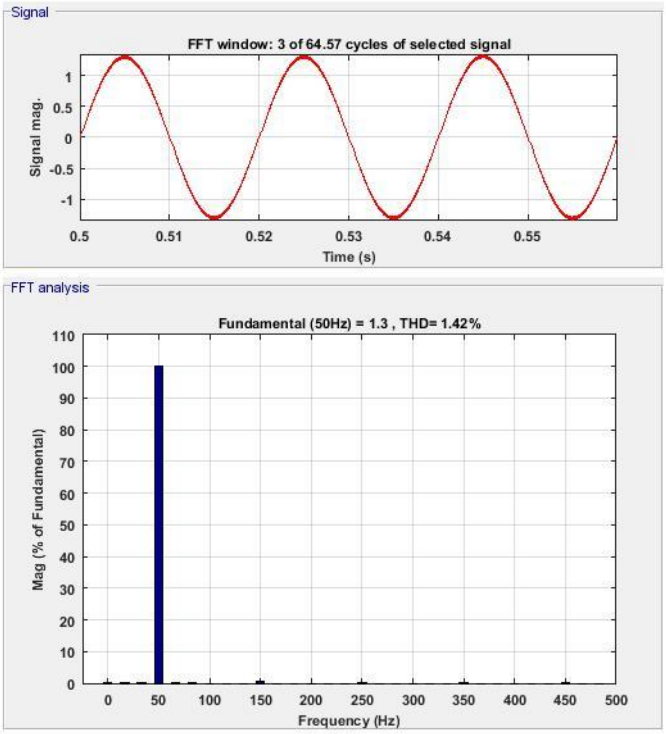

Fig. 12 THD of supply current

TABLE II: PERFORMANCE ANALYSIS - BY VARYING SUPPLY VOLTAGE

Input Voltage (V)	V_o (V)	I_o (A)	I_s (A)	THD (%)	Power Factor	Efficiency
90	48	2.083	1.25	1.42	0.9901	85.92%
120	48	2.083	0.93	2.41	0.9885	85.5%
150	48	2.083	0.75	2.55	0.9881	85.21%
180	48	2.083	0.63	2.76	0.9870	84.48%
210	48	2.083	0.55	3	0.9840	83.57%
230	48	2.083	0.50	3.21	0.9825	82.84%
260	48	2.083	0.45	3.56	0.98	81.6%

From table II it is inferred that for any given supply voltage the converter never compensates its power quality.

TABLE III: PERFORMANCE ANALYSIS - BY VARYING LOAD WITH V_{IN} = 120 V

% Load	V_o (V)	I_o (A)	I_s (A)	THD (%)	Power Factor	Efficiency
100	48	2.083	0.93	1.42	0.9901	85.92%
80	48	1.666	0.75	2.41	0.9850	85.5%
60	48	1.249	0.56	2.55	0.9801	85.21%
40	48	0.835	0.39	2.76	0.9770	84.48%
20	48	0.421	0.21	3	0.9740	83.57%

From table III and IV it is inferred that for all the loads, the converter works in proper condition with less THD and improved power factor.

TABLE IV: PERFORMANCE ANALYSIS - BY VARYING LOAD WITH V_{IN} = 230 V

% Load	V_o (V)	I_o (A)	I_s (A)	THD (%)	Power Factor	Efficiency
100	48	2.083	0.50	2.21	0.9845	82.84%
80	48	1.666	0.41	2.51	0.9805	82.38%
60	48	1.249	0.32	3	0.9750	81.35%
40	48	0.835	0.23	3.9	0.9720	78%
20	48	0.421	0.13	4.9	0.9687	73%

TABLE V: PERFORMANCE ANALYSIS - BY VARYING REFERENCE VOLTAGE WITH V_{IN} = 120 V

Ref. Voltage (V)	I_o (A)	I_s (A)	THD (%)	Power Factor	Efficiency
48	2.083	0.931	1.42	0.9901	85.5%
40	1.736	0.662	3	0.9885	84.83%
32	1.389	0.424	3.21	0.9881	83.47%
24	1.042	0.248	3.56	0.9870	82.74%

From table V and VI it is inferred that for all kinds of voltage, the output voltage settles in the set point voltage with less THD and improved power factor.

TABLE VI: PERFORMANCE ANALYSIS - BY VARYING REFERENCE VOLTAGE WITH V_{IN} = 230 V

Ref. Voltage	I_o (A)	I_s (A)	THD (%)	Power Factor	Efficiency

(V)					
48	2.083	0.504	2.21	0.9715	82.84%
40	1.736	0.362	2.76	0.9645	81.7%
32	1.389	0.245	3.74	0.9520	80.48%
24	1.042	0.155	4.5	0.9105	74.14%

IV. CONCLUSION

In this work, the simulation of the proposed converter has been carried out for 120V and 230V input. A nearly unity power factor is attained for the proposed converter. By and large the usage of PI controller has lessened peak overshoot and THD with enhanced power factor.

REFERECES

[1] Chellappa, Vidhya, J. Gnanavadivel, and N. Senthil Kumar. "Power quality improvement techniques in AC-DC Cuk converter." In *Emerging Trends in Electrical and Computer Technology (ICETECT), 2011 International Conference on*, pp. 430-435. IEEE, 2011.

[2] de Pádua Finazzi, Antônio, Gustavo Brito De Lima, Luiz Carlos De Freitas, Ernane AA Coelho, Valdeir José Farias, and Luiz CG Freitas. "Proposal for preprogrammed control applied to a current-sensorless PFC boost converter." *Microprocessors and Microsystems* 38, no. 5 (2014): 443-450.

[3] Singh, Sanjeev, and Bhim Singh. "A voltage-controlled PFC Cuk converter-based PMBLDCM drive for air-conditioners." *IEEE transactions on industry applications* 48, no. 2 (2012): 832-838.

[4] Singh, Bhim, and Vashist Bist. "Power quality improvements in power factor correction Luo converter fed brushless direct current motor drive." *International Transactions on Electrical Energy Systems* 25, no. 5 (2015): 898-919.

[5] Singh, Bhim, Brij N. Singh, Ambrish Chandra, Kamal Al-Haddad, Ashish Pandey, and Dwarka P. Kothari. "A review of single-phase improved power quality AC-DC converters." *IEEE Transactions on industrial electronics* 50, no. 5 (2003): 962-981.

[6] Sahid, Mohd Rodhi, and Abdul Halim Mohd Yatim. "Modeling and simulation of a new Bridgeless SEPIC power factor correction circuit." *Simulation Modelling Practice and Theory* 19, no. 2 (2011): 599-611.

[7] Sabzali, Ahmad J., Esam H. Ismail, Mustafa A. Al-Saffar, and Abbas A. Fardoun. "New bridgeless DCM Sepic and Cuk PFC rectifiers with low conduction and switching losses." *IEEE Transactions on Industry Applications* 47, no. 2 (2011): 873-881.

[8] Singh, Bhim, B. P. Singh, and Sanjeet Dwivedi. "AC-DC Zeta converter for power quality improvement in direct torque controlled PMSM drive." *Journal of Power Electronics* 6, no. 2 (2006): 146-162.

[9] Singh, Bhim, and Vashist Bist. "Power quality improvements in a zeta converter for brushless DC motor drives." *IET Science, Measurement & Technology* 9, no. 3 (2014): 351-361.

[10] Bist, Vashist, and Bhim Singh. "A reduced sensor PFC BL-Zeta converter based VSI fed BLDC motor drive." *Electric Power Systems Research* 98 (2013): 11-18.

[11] Gnanavadivel, J., Senthil Kumar, and P. Yogalakshmi. "Comparative Study of PI, Fuzzy and Fuzzy tuned PI Controllers for Single-Phase AC-DC Three-Level Converter." *Journal of Electrical Engineering & Technology* 12, no. 1 (2017): 78-90.

[12] Gnanavadivel, J., N. Senthil Kumar, C. N. Priya, S. T. Christa, and K. S. Veni. "Single phase positive output super-lift luo converter fed high power LED lamp with unity power factor and reduced source current harmonics." *Journal Of Optoelectronics And Advanced Materials* 18, no. 11-12 (2016): 1007-1017.