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Performance Investigation of Single Stage Luo AC-DC Power Factor Correction Converter

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Abstract: This paper is proposed with the design, simulation, analysis of bridgeless negative output Luo converter with resistive load for open loop and closed loop with PI controller with the aim of improving the power factor and reducing the THD at the AC main side. To eliminate the requirement of front end diode bridge rectifier, the bridgeless topology converter is introduced for reduction in the conduction losses and to improve the power quality of the system. The Bridgeless negative Luo converter has been designed to operate in DICM and to act as an inherent power factor pre regulator. The MATLAB simulation is performed for bridgeless negative output Luo converter in Discontinuous Conduction Mode (DCM) of operation with 48V output voltage, 200 W output power with 30 kHz switching frequency. The PI controller is used to regulate the output voltage and improves the power factor to about 0.99 and reduces the source current THD to about 1.79% which is less than 5% as per IEEE-516 prescribed standard.

Keywords: Bridgeless Luo converter, PI controller, Power factor, THD.

I. INTRODUCTION

Single phase AC-DC rectifier with boost topology provides high power factor, low current harmonic distortion and small requirement, step up voltage, as compared to thyristor and diode rectifier [1].In traditional AC-DC conversion, the conventional diode rectifier followed by filter capacitor is used which have properties of simple structure and low cost. The major drawbacks include total harmonic distortion, resulting in voltage distortion, poor power factor at input mains and slow varying DC output voltage, low efficiency [2]. Negative output super lift technique implements the output voltage increasing in geometric progression. It effectively enhances the voltage transfer gain [4]-[8]. A high switching loss on account of high switching frequency occurs which drastically reduces the efficiency. To overcome these drawbacks buck-boost converters-SEPIC, CUK converters were used [9],[12]. But the main drawback is that there is ripple in voltage. The controller application is improved by designing of good input and output and brain of the fuzzy controller parameters and obtained proper power and dynamic response. Traditional frequency ways for designing of controllers of DC/DC converters are based on small signal model and the validation of small signal model is limited by changes of operation point. Among variation techniques of artificial intelligence, fuzzy logic is most popular for controlling of systems. An intelligent controller, with proper design, works very well even with approximate model of systems [11-14].Super Lift Luo Converters are new series of DC/DC converters that have very high voltage transfer gains in geometric progression on stage-by-stage [15-19]. These converters overcome on parasitic effects with high step up voltage gain ratio. The voltage lift technique is popular method widely used in electronic circuit design. It has been successfully employed in DC/DC converter applications in recent years and opened a way to design high voltage gain converters. But the output voltage increases in stage by stage just along the arithmetic progression [20-25].

II. DESIGN OF BRIDGELESS LUO CONVERTER

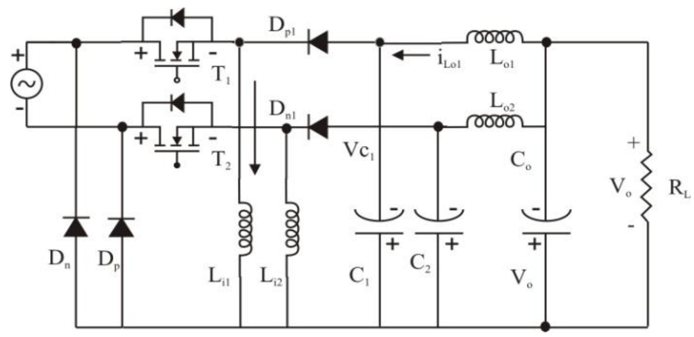

Fig. 1: Circuit configuration of bridgeless Luo converter

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The circuit configuration of bridgeless Luo converter is shown in fig.1. The power circuit strategy is presented with a single phase input supply, two input inductor L_{i1} and L_{i2} , two output inductors L_{o1} and L_{o2} two input capacitorC_1 and C_2, dc link capacitor C_o, positive diode D_M , negative diode $D_O$and a power MOSFET with a switching frequency of 20 kHz.

Table I Design Specifications of Bridgeless Luo Converter

Parameters	Values
Input voltage	120V
Switching frequency	20kHz
Output voltage	48V
Output current	2.08A
Output power	100W
Duty ratio	0.30

A Design steps for bridgeless Luo converter:

The design steps for bridgeless Luo converter are as follows,

Dutycycle, $D = \frac{V_{dc}}{V_{in} + V_{dc}}$ (1)

Input inductors, $L_{ic} = \frac{D_{\min}(1 - D_{\min})V_{in}}{2 I_o f_s}$ (2)

Two input capacitors, $C_{12} = \frac{D_{\max} V_c}{2 f_s R_l (\frac{\Delta V_c}{2})}$ (3)

Output inductors, $L_{01,2} = \frac{D_{\max} I_o}{16 f_s^2 C_{in} (\frac{\Delta I_o}{2})}$ (4)

Output capacitor, $C_o = \frac{I_o}{2 \omega_l \Delta V_{dc\min}}$ (5)

Filter capacitor, $C_f = \frac{I_{peak}}{\omega_l V_{peak}} \tan(\theta)$ (6)

Filter inductor, $L_f = \frac{1}{4\Pi^2 f_c^2 C_f}$ (7)

Table II Design Parameters of the Bridge-Less Luo Converter

Components	Rating
Input inductor $L_{i1=} L_{i2}$	212 µH
Output inductor $L_{o1=} L_{o2}$	402 µH
Capacitor C_1=C_2	1.396 µF
Dc-link capacitor C_o	3940 µF
Load resistor	12 Ω

III. MATLAB SIMULATION RESULTS

A. Simulink-model of open loop bridgeless Luo converter with R-load

In this open loop model input voltage is 120V.Desired output voltage is 48V.but output voltage is not regulated at 48V. Source current THD is nearly 5%.Input power factor is nearly unity.

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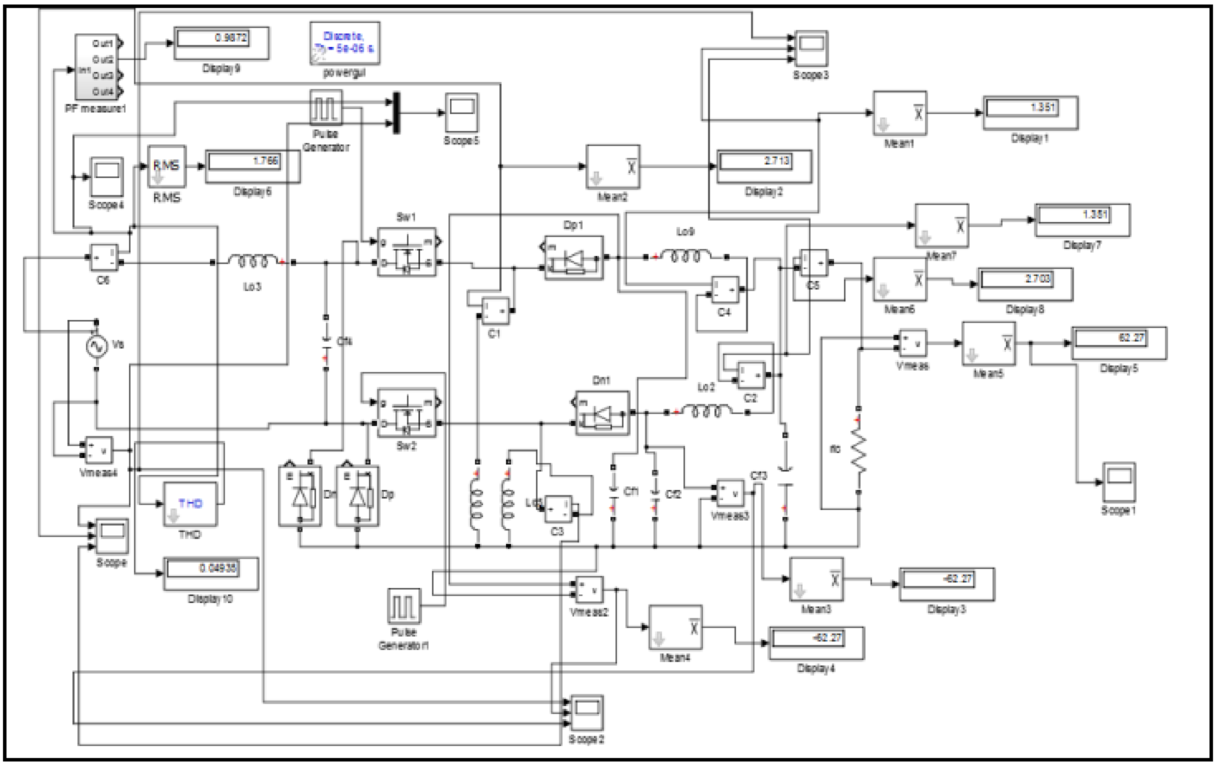

Fig. 2: Simulation diagram for open loop bridgeless Luo converter with R-load

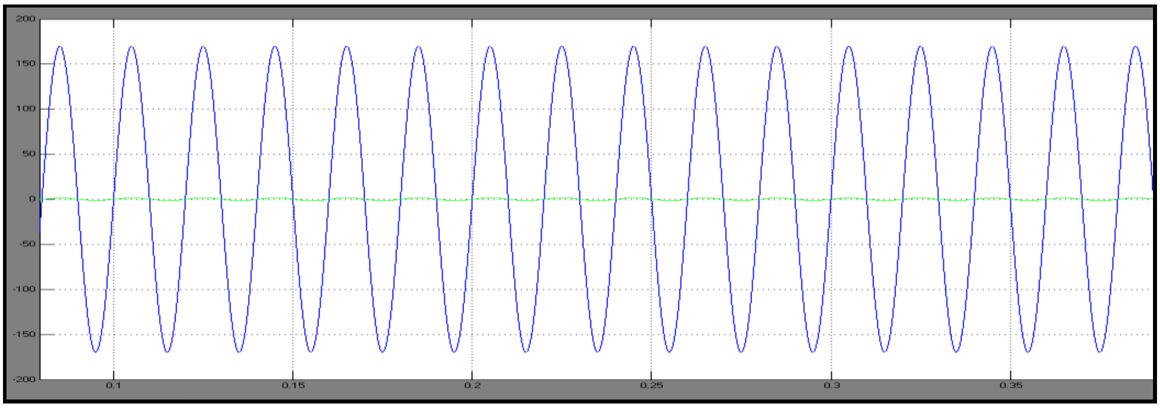

Fig. 3: Input voltage and Input current waveforms of bridgeless Luo converter with open loop

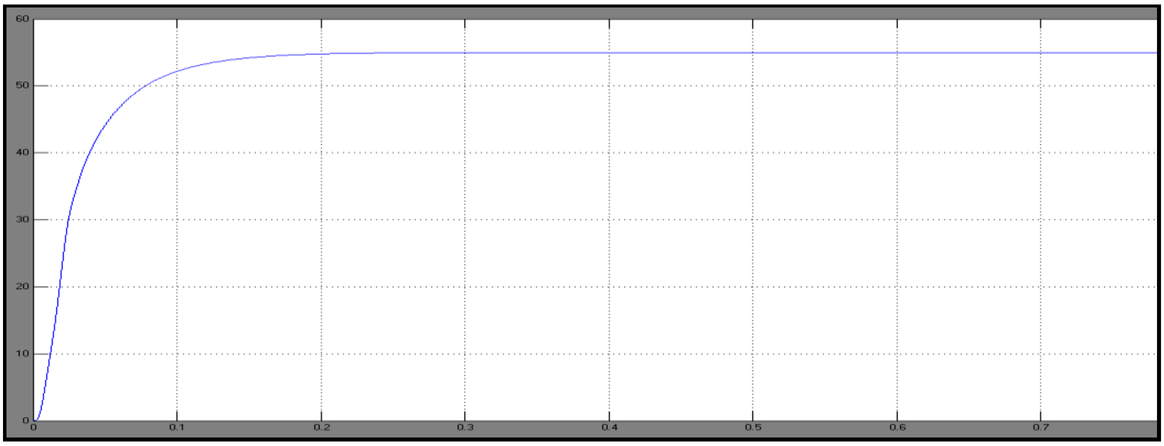

Fig. 4: Output voltage waveform of bridgeless Luo converter with open loop

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From fig.3 it is inferred that the input voltage and input current are in phase. So the power factor close to unity is obtained. The output voltage is not maintained at 48V.By FFT analysis the source current THD is found to be nearly 5 % which is shown in fig 5.

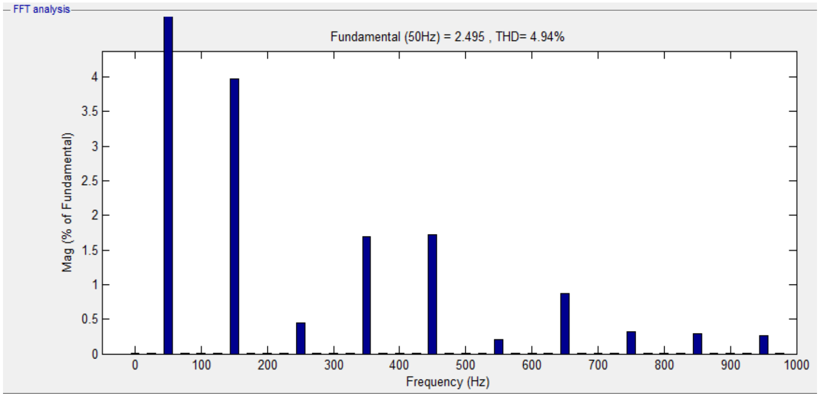

Fig. 5: FFT Analysis of bridgeless Luo converter with open loop

Table III Performance analysis of open loop bridgeless Luo converter for various load

Output Power (W)	Output Voltage (V)	Source Current (A)	Source current THD (%)	Power Factor
100	**62.27**	**1.766**	**4.935**	**0.9856**
80	70.01	1.805	4.899	0.9872
60	82.39	1.901	2.216	0.9864
40	99.23	1.837	2.755	0.9866
20	140.4	1.924	2.737	0.9872

TABLE IV Performance analysis of open loop bridgeless Luo converter for variation in source voltage with constant load resistance.

Input voltage (V)	Output voltage (V)	Source current THD (%)	Power Factor
120	**54.52**	**2.73**	**0.9941**
130	59.12	2.74	0.9941
150	68.27	2.756	0.9941
170	77.4	2.775	0.9941
200	91	2.80	0.9941
220	100.2	2.81	0.9941

The performance analysis of bridgeless Luo converter with open loop for R-load shown in table III and table IV. Even when the load and source voltage is varied to a greater extend the output voltage not remains constant.

B Simulink-model of closed loop bridgeless Luo converterwith PI controller

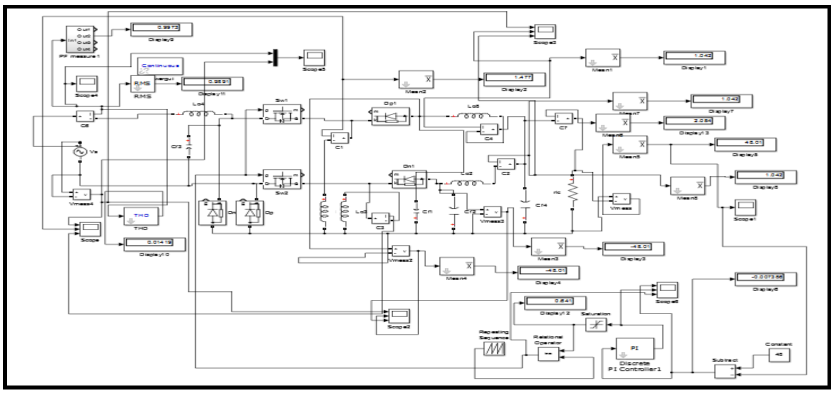
Fig. 6: simulation diagram of closed loop bridgeless Luo converter with PI controller for R-load

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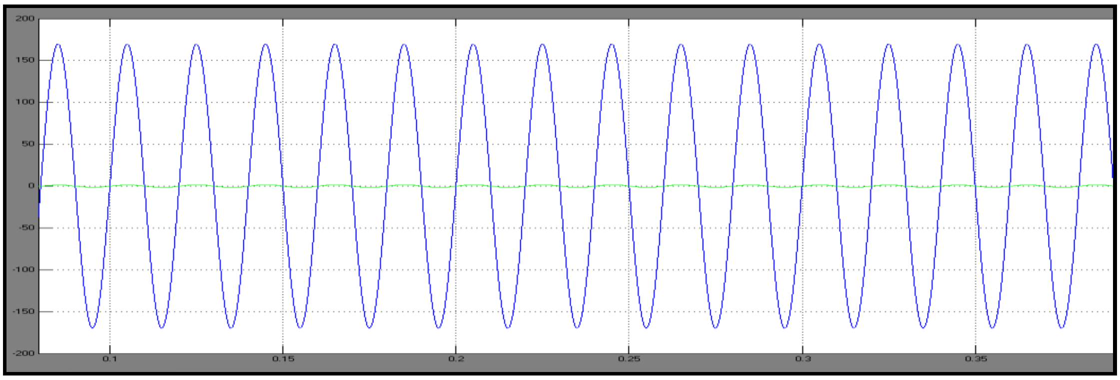

Fig. 7: Input voltage and Input current waveforms of bridgeless Luo converter with PI controller

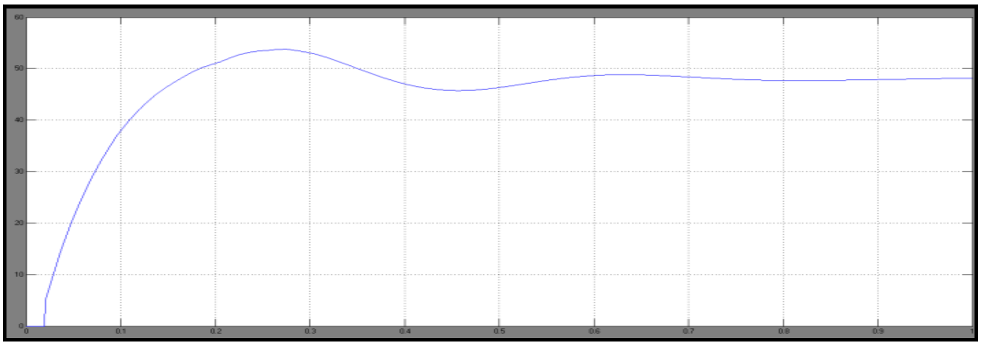

Fig. 8: Output voltage waveform of bridgeless Luo converter with PI controller

From fig. 7 it is inferred that the input voltage and input current are in phase. So the power factor close to unity is obtained. The output voltage is maintained at 48 V. By FFT analysis the source current THD is found to be 1.79% which is shown in fig. 9.

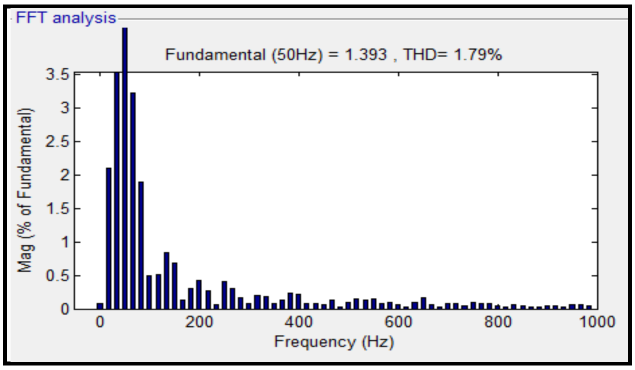

Fig. 9: FFT Analysis of bridgeless negative output Luo converter with PI controller

IV. COMPARATIVE ANALYSIS OF BRIDGELESS LUO CONVERTER FOROPEN LOOP AND CLOSED LOOP WITH PI CONTROLLER

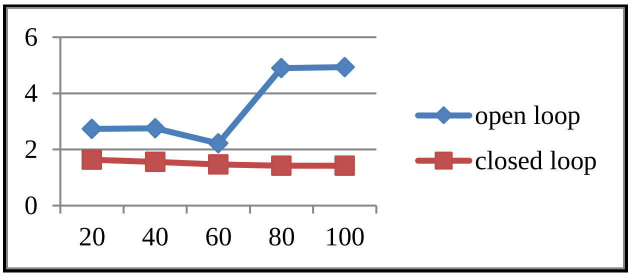

Fig. 10: Output power Vs THD comparisons

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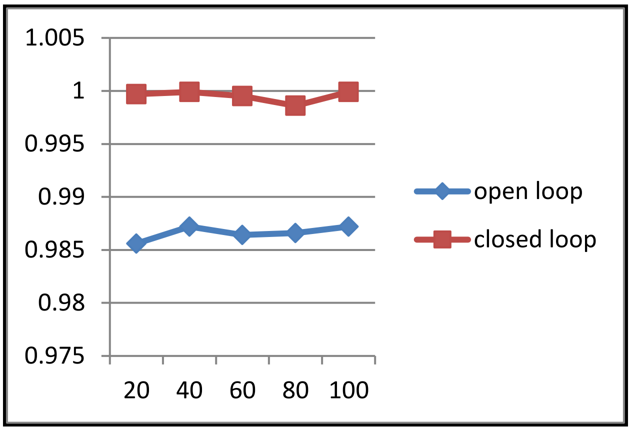

Fig. 11: Output power Vs power factor comparisons

TABLE V Comparative analysis of open loop control with closed loop control with in terms of power quality

Analysis	**THD**	**Power Factor**
Open loop	4.94%	0.97
Closed loop	1.79%	0.99

From fig. 10 and fig. 11 it is found that the PI controller reduces the THD to 1.79% and increases the power factor to 0.9999 whereas open loop control reduces the THD to 4.94% and increases the power factor to 0.9556.Hence when compared to the open loop control, closed loop with PI controller shows good results in terms of power quality.

V. CONCLUSION

The design and analysis of bridgeless negative output Luo converter for open loop and closed loop with PI controller has been carried out for 48V and 200W output. The open loop and closed loop with PI controller is compared and results were analysed for variation in load resistance and source voltage. The closed loop analysis of bridgeless negative output Luo converter with PI controller shows good results in terms of regulated output voltage, improved power quality at the of AC main side. The source current THD has been reduced to around 1.79% which is less than 5% as per IEEE-516 prescribed standard and the power factor has been improved to 0.99 by implementing the PI controller.

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