

PERFORMANCE EVALUATION OF POWER FACTOR CORRECTION POSITIVE OUTPUT SUPER LIFT LUO CONVERTER FED LED DRIVE APPLICATIONS

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ABSTRACT

A single phase positive output super-lift Luo converter fed high power LED lamp with enhanced input-side power quality has been proposed. With a high gain ratio, this converter increases the input voltage. The suggested converter uses a continuous conduction mode(CCM) of operation. The Matlab/Simulink platform is used to design and simulate a 100 W LED driver with a constant load voltage of 48V. Both inner current control and external voltage control are included in closed loop control. According to the simulation results, the suggested LED light driver and controller combination produces the best results, with unity power factor, minimal total harmonic distortion, and no peak-overshoot under rated conditions.

KEYWORDS: Single-phase AC-DC converter, Positive output super-lift Luo converter, LED driver, CCM, Total Harmonic Distortion (THD), Closed-loop control, MATLAB/Simulink simulation.

1. INTRODUCTION

In recent years, light-emitting diode (LED) lamps have become increasingly popular in both residential and industrial applications. They are widely used in areas ranging from street lighting to automotive headlights. Advances in lighting technology have provided several benefits, including high luminous efficiency, extended lifespan, reduced energy consumption, and environmental friendliness due to lower mercury content. Additionally, LEDs offer features such as easy dimming, low maintenance requirements, flicker-free operation, robust construction, and resistance to vibrations.

LED lamps also present certain drawbacks, particularly the generation of

harmonics on the AC input side and a low input power factor caused by the switching devices used in LED drivers. An LED lighting system mainly consists of two components: the LED driver and the LED module. While much of the existing research focuses on LED development, lighting control, and illumination performance, relatively few studies address the improvement of power quality at the AC supply side of LED drivers.

AC-DC conversion in LED drivers is achieved using a diode bridge rectifier followed by a large capacitor to smooth the DC-link voltage. However, this approach results in highly distorted input current, leading to increased total harmonic distortion (THD) and poor power factor. To address these

issues, harmonic standards such as IEC 61000-3-2 Class C have been established to limit current harmonics and ensure a minimum power factor of 0.9.

The primary objective of this work is to develop a single-phase positive output super-lift Luo converter-based LED driver with improved power quality. The proposed system aims to achieve a high power factor, reduced THD, and stable operation under varying supply and load conditions.

2. Proposed topology of LED driver

The proposed system is composed of a single-phase diode bridge rectifier, filter and boost inductors, fast recovery diodes, DC-link capacitors, and a switching device. The system is carefully designed, and its performance is analyzed under a wide range of variations in both load and supply conditions.

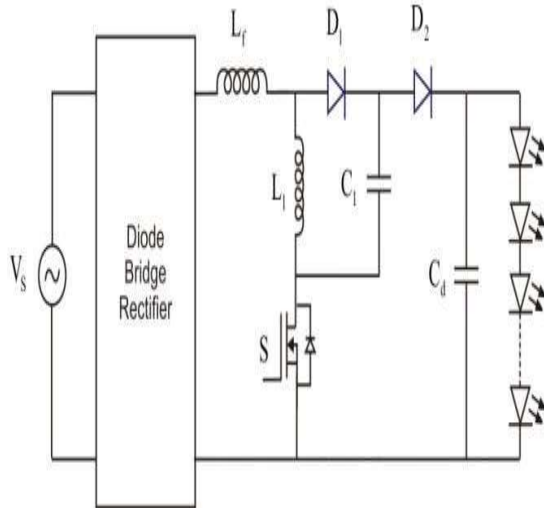


Fig.1. Proposed Single phase positive output super-lift Luo converter based LED driver

MODES OF OPERATION

The operation of the proposed LED driver circuit can be divided into two distinct modes based on its switching behavior. These modes are described below.

MODE 1:

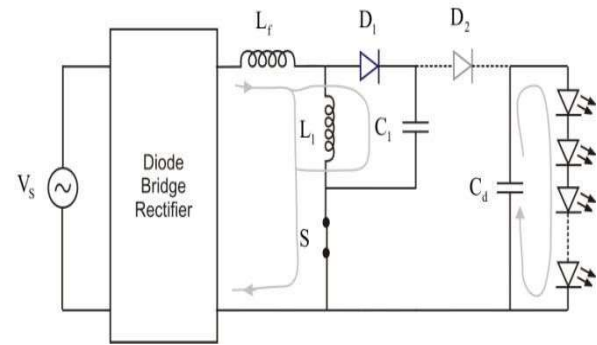


Fig.2. Mode 1 operation

During mode 1 operation, the switch S is considered to be in ON state thereby, capacitor C1 gets charged to Vs. The current iL1 flowing through inductor increases with voltage Vs. The input current is will be equal to $i_{L1} + i_{C1}$. The mode 1 operation is depicted clearly through Fig.2. The characteristic equation during mode 1 operation are given below,

$$|V| = L_1 \frac{di}{dt} = V_{C1} \quad \dots\dots(1)$$

$$C_d \frac{dv_o}{dt} + \frac{V_o}{R_{lamp}} = 0 \quad \dots\dots(2)$$

MODE 2:

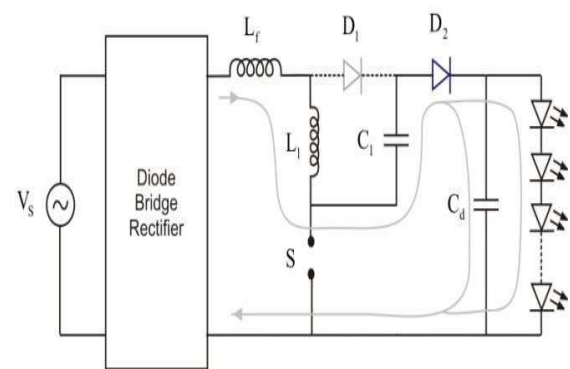


Fig.3. Mode 2 operation

The mode 2 operation of single phase positive output super-lift Luo converter based LED drive. During mode 2 operation, switch S is considered to be in OFF state, diode D1 is reversed biased and D2 becomes forward

biased. During mode 2 operation, input current will be equal to i_{L1} ($=i_{co}$). The characteristic equations are,

$$|V_s| = L_1 \frac{di_{L1}}{dt} + V_{c1} + V_0 \quad \dots(3)$$

$$C_d \frac{dv_0}{dt} + \frac{V_0}{R_{lamp}} = I_{L1} \quad \dots(4)$$

Design of the proposed high power factor LED Driver

The following assumptions are considered to design the proposed high power factor LED driver circuit.

1. All the device components of the proposed LED driver circuit are ideal one.
2. Under normal operating condition Light Emitting Diode behaves as a resistor.

The inductance L_1 is determined by the peak-to-peak ripple current ΔI_L . Therefore, the inductance L_1 can be represented as,

$$L_1 = \frac{V_0 - 2V}{\Delta I_{L1} f}$$

The capacitor value can be calculated by the formula given below,

$$C_1 = C_0 \frac{(1-K)V_0}{f R_{lamp} \Delta V_0}$$

The output voltage equation of proposed LED driver is,

$$V_0 = \frac{2-k}{1-K} V_{in}$$

The voltage across the diode bridge rectifier is given by,

$$V_{in} = \frac{2(V_m)}{3.14}$$

where,

k is the duty cycle

V_0 is the DC output voltage

V_m is the peak value of the input voltage

V_s is the supply voltage

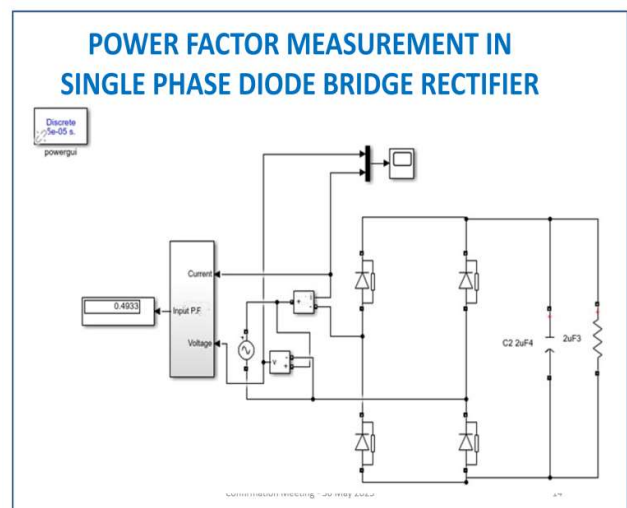
V_{in} is the voltage across the diode bridge rectifier

f is the switching frequency

Parameter	Specification
Supply Voltage(V_s)	20V
LED lamp voltage(V_{lamp})	48V
LED lamp power (P_o)	100W
Supply frequency(f)	50Hz
Inductor L_f	1.4mH
Inductor L_1	1.6mH
Capacitor $C_1=C_d$	2000 μ F

Table 1.Design Parameter Of Proposed LED driver

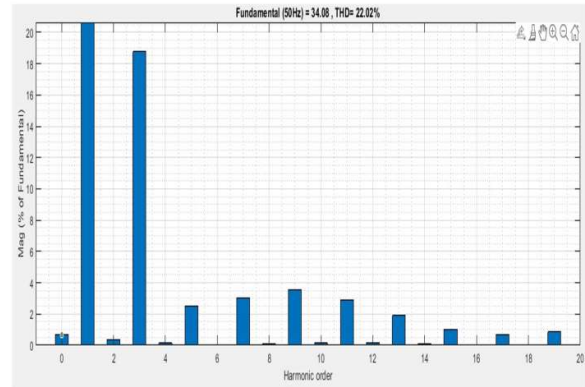
SOFTWARE RESULT



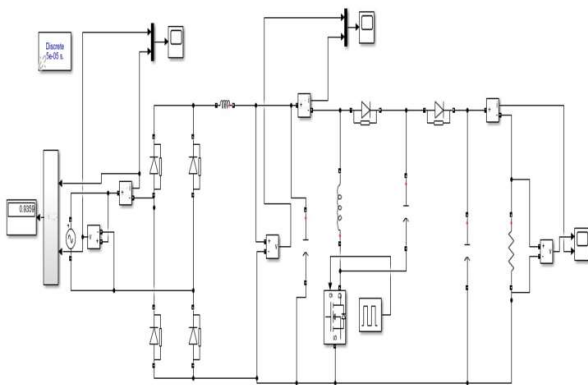
SUPPLY VOLTAGE AND CURRENT WAVEFORMS OF DIODE BRIDGE RECTIFIER



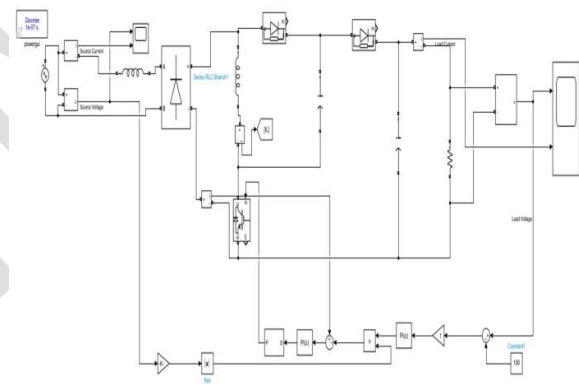
FFT Analysis – Source Current



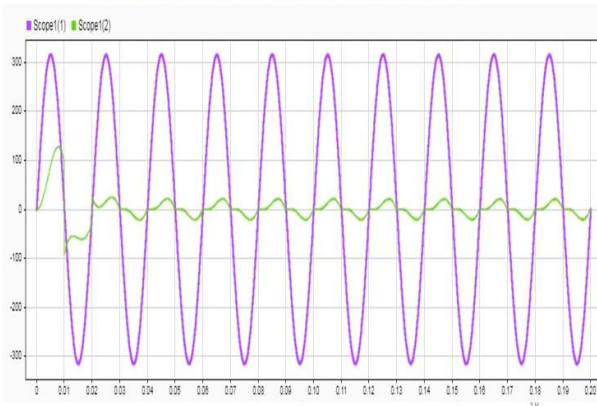
SINGLE PHASE DIODE BRIDGE RECTIFIER WITH POSITIVE OUTPUT SUPERLIFT LUO CONVERTER (POSLLC)



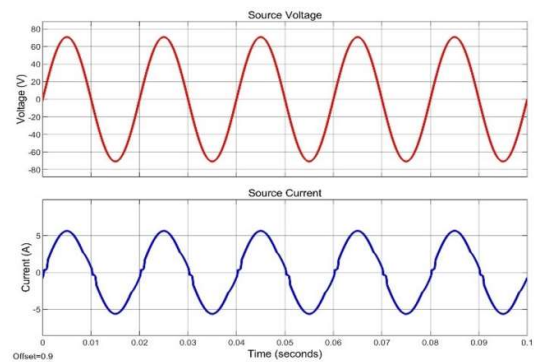
CLOSED LOOP PI CONTROL OF POSITIVE OUTPUT SUPERLIFT LUO CONVERTER



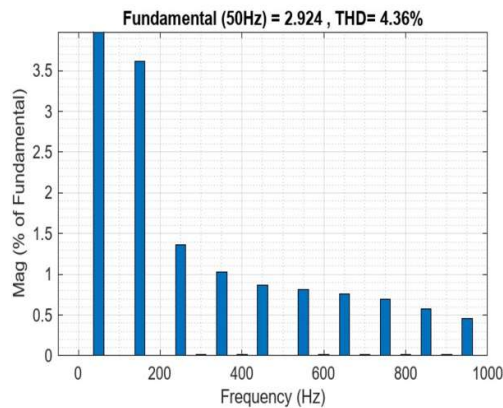
SUPPLY VOLTAGE AND CURRENT WAVEFORMS OF DIODE BRIDGE RECTIFIER WITH POSLLC



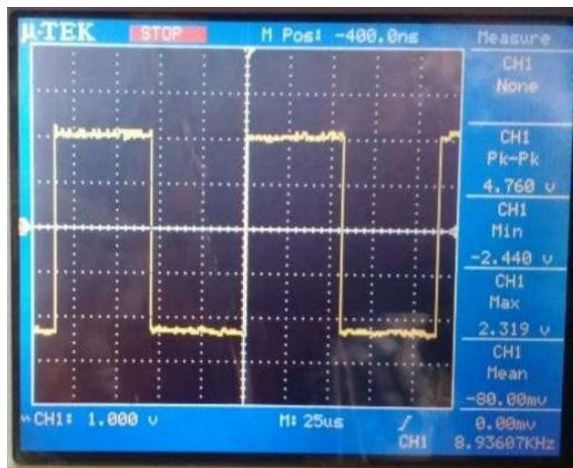
Case (i) Source Voltage and Current Waveforms



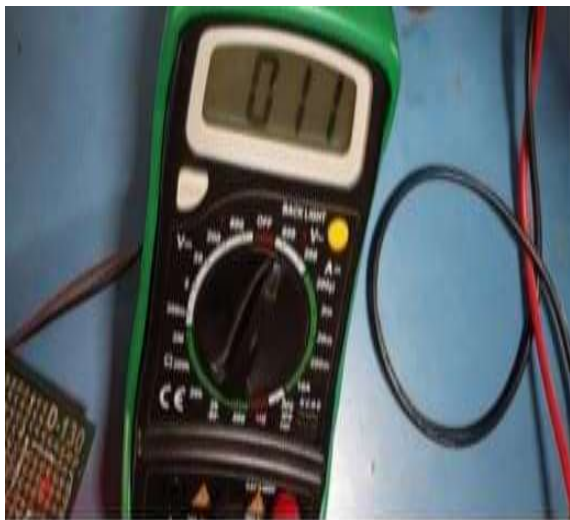
Case (i) FFT Analysis – Source Current



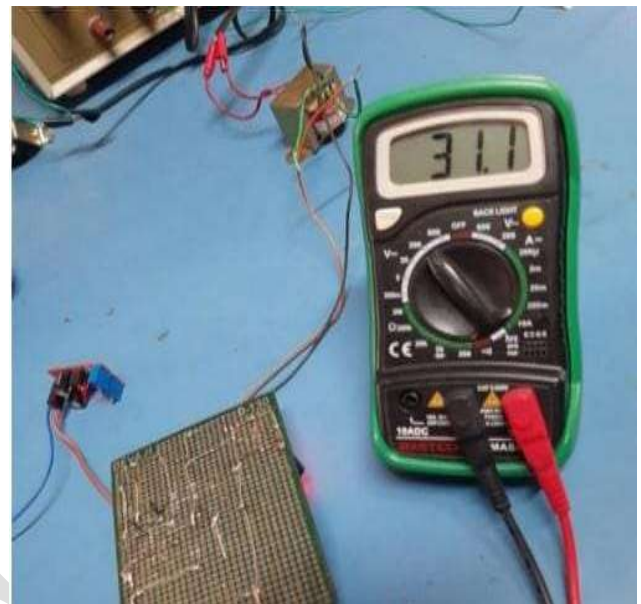
HARDWARE RESULT



Timer IC PWM Output



Output Voltage from Step Down Transformer



Output Voltage of Super Lift Luo Converter

ADVANTAGES

1. High Voltage Gain: The super-lift Luo converter provides higher voltage gain compared to conventional DC-DC converters.
2. Unity Power Factor: It achieves near-unity power factor, improving the overall efficiency of the power system.
3. Reduced Source Current Harmonics: Input current harmonics are minimized, resulting in low Total Harmonic Distortion (THD).
4. Improved Power Quality: The converter improves the quality of power drawn from the AC source.
5. High Efficiency: Provides efficient energy conversion suitable for high-power LED lighting applications.
6. Stable LED Operation: Ensures constant and stable output voltage for reliable LED lamp performance.

7. Reduced Component Stress: The super-lift technique reduces voltage stress on switching components.
8. Energy Saving: High efficiency and power factor correction reduce overall energy consumption.
9. Compact Design: Requires fewer passive components, leading to a compact LED driver circuit.
10. Longer LED Life: Stable current and reduced ripple increase the lifespan of high-power LED lamps.

DISADVANTAGES

1. Complex Circuit Structure – The converter uses multiple components which makes the circuit design complicated.
2. Higher Implementation Cost – Additional inductors, capacitors, and switching devices increase the overall cost.
3. Control Complexity – Maintaining unity power factor requires sophisticated control techniques.
4. Switching Losses – High-frequency switching leads to increased switching losses in the converter.
5. Electromagnetic Interference (EMI) – Fast switching may produce EMI affecting nearby electronic devices.
6. Heat Dissipation Issues – Power electronic components generate heat requiring proper cooling systems.
7. Design Sensitivity – Performance depends strongly on accurate component values and circuit parameters.
8. Output Voltage Ripple – Improper filtering may cause ripple affecting LED performance.

9. Maintenance Difficulty – Troubleshooting and repairing the circuit can be difficult due to complexity.

10. Reduced Reliability Under Stress – Continuous high-power operation may reduce component life if not properly managed.

CONCLUSION

An enhanced power-quality positive output super-lift Luo converter is introduced for high-power LED industrial lighting applications. The proposed LED driver demonstrates superior performance, including low total harmonic distortion (THD) and a unity power factor, even under variations in LED load power and supply voltage.

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