Design and Application of Single Stage Flyback PFC AC to DC Converters for Power Led Lighting Application

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ABSTRACT - **This study investigates single stage power factor corrected AC/DC converters for LED lighting. Specifically, the research examines a single stage Flyback converter with a different configuration from the traditional single stage Flyback converter. The study includes analysis, circuit design, performance comparisons, and implementation. The research also covers the development, characteristics, and state-of-the-art technology of LEDs.**
In addition to design calculations, the circuits are investigated using computer simulations, and the operating theories and modes are researched. To validate the simulation findings and theoretical studies, prototypes are built and tested in the lab. The paper offers a thorough examination of single stage power factor adjusted AC/DC converters for LED lighting and prospective uses.

1. INTRODUCTION

With the increasing demand for energy-efficient and eco-friendly lighting solutions, Light Emitting Diode (LED) technology has gained popularity in recent years. However, the efficient operation of LEDs requires a reliable power supply that can convert the alternating current (AC) from the mains to a direct current (DC) with high power factor and low harmonic distortion. Single-stage flyback PFC (Power Factor Correction) AC to DC converters have become a potential alternative solution for LED lighting applications due to their simplicity, low cost, and high efficiency [1].

A power supply unit (PSU) is required to convert AC input voltage to DC output voltage for indoor or outdoor LED lighting applications, and many topologies have been taken into consideration. Due to power constraints, high power LED lighting applications frequently employ two-stage converters, as opposed to low power LED lighting, which mainly uses single-stage converter types.

In this study, a single-stage PSU for high power LED lighting is demonstrated using the flyback converter topology. Since the main transformer may separate the input and output stages and acts as an independent inductive filter, an inductive output filter is not necessary for the flyback converter design. The proposed circuit uses a PFC controller, with just output, and a critical conduction mode (CRM) voltage feedback is required because the input voltage and switching current are not required[2,3].

Through an experiment using a prototype 5W single-stage flyback converter, this paper evaluates and discusses the viability of the recommended single stage PSU, control system, and feedback mechanisms. Overall, this research offers a viable strategy for overcoming the difficulties associated with high-power LED lighting applications.

2. SINGLE STAGE FLYBACK CONVERTER FOR LED

The circuit schematic for the flyback AC-DC converter is shown in Figure 1. To avoid overload and overvoltage issues, feedback circuits with both constant voltage (CV) and constant current (CC) are required. In LED lighting applications, the output is constantly operating at full load, and the forward voltage drop of the LED increases along with the junction temperature of the LED. In order to sustain optimal performance Objective, it is crucial to have control over the output[3].

In LED lighting applications, the output is normally controlled via the constant current (CC) mode. On the other hand, the constant voltage (CV) mode solely acts as overvoltage protection.

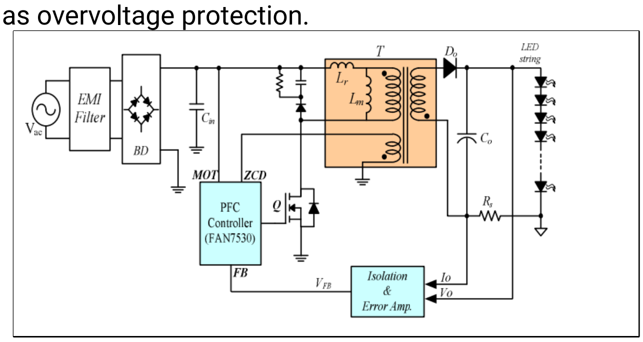


Fig. 1. Circuit diagram of a flyback AC-DC converter

In this work, a voltage mode critical conduction mode (CRM) power factor correction (PFC) controller, more precisely the FAN7530, is used to operate the single-stage flyback AC-DC converter. Figure 2 displays the FAN7530's internal block diagram[4].

Since the switching signal in the control circuit is created by comparing the output of the error amplifier with the internal ramp signal, the input voltage and current are not required. In the steady state, the switch's turn-on and turn-off times are constant and variable respectively. Because of this fluctuation in turn-off time, the switching frequency also fluctuates in response to changes in input voltage.

Theoretical waveforms for the gating signal, secondary side diode current, and primary side switch current are displayed. The rapid recovery diode (FRD) (Do) shuts off and the MOSFET (Q) switches on when there is no current flowing. On the other hand, when switching is forced, Q turns off and Do comes on[4,5].

A flyback converter's transformer is susceptible to saturation since it is only used in the first quadrant. Additionally, the peak current when operating in critical conduction mode is substantially higher than when running in continuous conduction mode. In order to prevent saturation, an air gap needs to be added to the transformer.

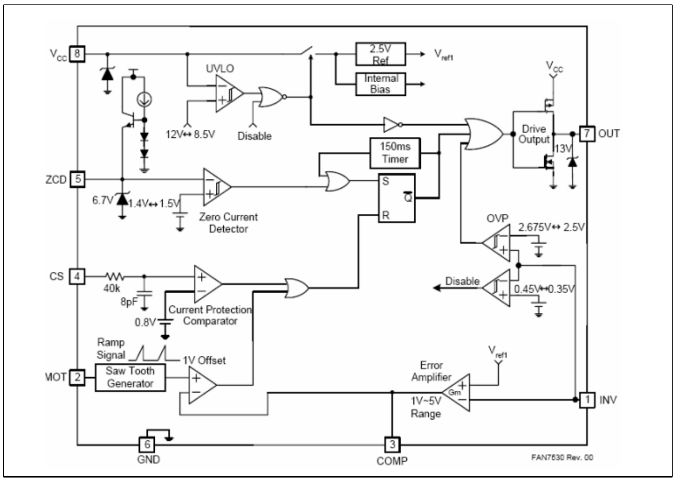


Fig.2. Block diagram of FAN7530

2.1 SNUBBER CIRCUIT DESIGN

In order to prevent MOSFET failures at the flyback converter's turn-off instant, the extremely high voltage spike caused by the resonance must be suppressed. A snubber circuit is required because the MOSFET might be harmed by this voltage spike. A snubber circuit is used in Figure 3 to restrict the voltage and guard against MOSFET failures[6].

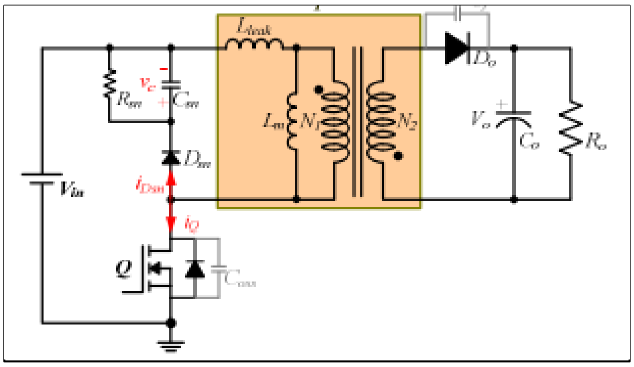


Fig.3. Snubber circuit

$$Vsn = vf + Lleak\frac{\Delta i}{\Delta t} = Vf + Lleak\frac{I\ Dsn\text{-}pk}{ts}$$

The maximum ripple voltage of snubber circuit is obtained as follow;

$$\Delta vc = \frac{vc}{CsnRsnfs@vinmax}$$

The smaller voltage ripple is produced by bigger snubber capacitors, but more power dissipation follows. Therefore, picking the right value is crucial. Estimating that the snubber voltage is typically 1.5 times the flyback voltage makes logical[2,7].

3. OPERATION PRINCIPLES

A single-stage charge-pump Flyback PFC converter with constant current control is shown in this example. This converter combines a flyback DC/DC cell and a charge-pump PFC cell. The resonant inductor Lr, charge capacitors Cr and Cb, freewheeling diode Di, and clamping diode Dr make up the charge-pump PFC cell. The charge capacitors Cr and Cb absorb the energy from its AC line when power switch Q is engaged by resonating with the resonant inductor Lr. The charge capacitors' stored energy is transferred to the load or the DC bus capacitor Cbus when the power switch Q is deactivated. The resonant capacitor Cb is charged by the leakage and magnetizing currents to lower the switch Q's voltage rate. At no voltage, the switch can be turned off. It is possible to determine the rectified average input current |Iin|av using the following equation[1,8].

$$|Iin|av = \frac{\Delta Q}{Ts} = fsCr\Delta Vcr = fsCr|Vin| \quad (1)$$

where "Q" and "Vcr" refer to, respectively, the charge and voltage variations of Cr. Equation (1) shows the inverse relationship between the average rectified input current and voltage. A large power factor is thus feasible. The balancing relationship between the input power and the output power determines the input resonant inductor Lr.

Equations (2) and (3) may then be used to find capacitor Cr.

$$Cr = \frac{2Po}{nfsVin2} \quad (2)$$

$$Lr = \frac{nVin2}{32fsPo} \quad (3)$$

where n and Po represent the single-stage converter's conversion efficiency and output power, respectively[4,7,9].

4. EXPERIMENTAL VERIFICATION

To verify its viability, a lab prototype of the suggested approach was evaluated using the following criteria.

- 80V to 130V (nominal voltage 110V) is the input voltage.
- 20 kHz, the switching frequency
- Lamp Current: 430/860 milliamps
- 6 to 22 volts for lamps

In this work, the researchers used high-power LEDs from LUMILEDS with an emitter type and a 1W rating and a forward voltage of 3.42V. The 430mA continuous lamp current of the laboratory prototype may be boosted to 860mA by connecting two LED bulbs in parallel. The prototype was put through a variety of tests, and the results revealed that the source current had a waveform that was almost sinusoidal and in phase with the source voltage.

When compared to a traditional single-stage Flyback PFC converter, the lamp current ripple was noticeably lower. The outcomes demonstrated that a high power factor could be attained under various fluctuations in lamp power and that output constant current control of 430mA/860mA was possible.
need for an extra linear regulator. shows the laboratory prototype's measured waveforms. Iin has

The examined LED lamp power supply's single-stage structure produced great conversion efficiency without the need for an extra linear regulator. shows the laboratory prototype's measured waveforms. Iin has a waveform that is almost sinusoidal and is in phase with Vin, the source voltage[10].

4.1 EXPERIMENTAL RESULTS

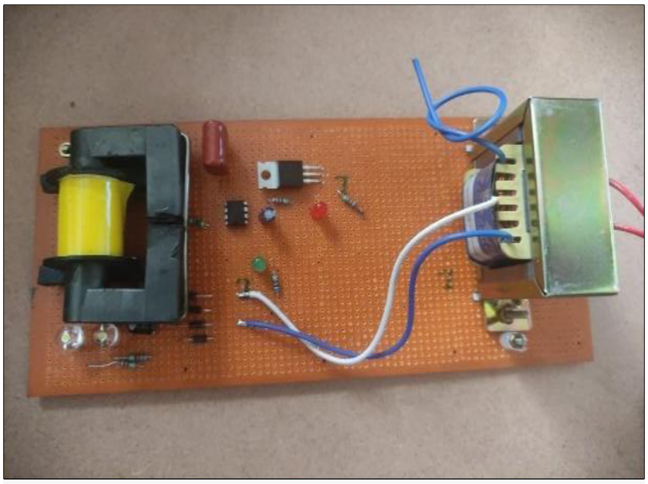


Fig.4.photograph of 5W prototype experimental set-up

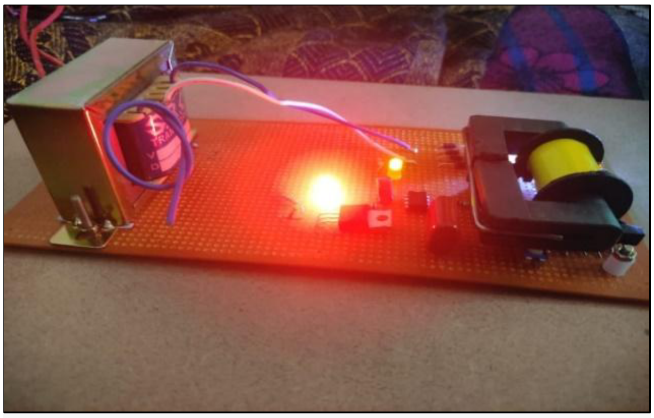
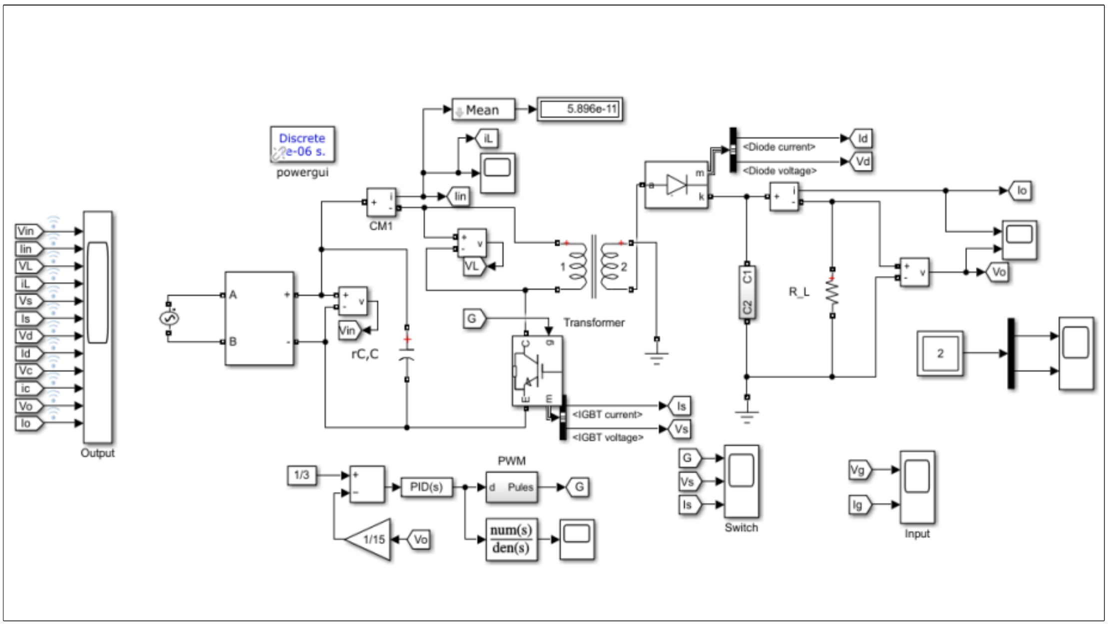


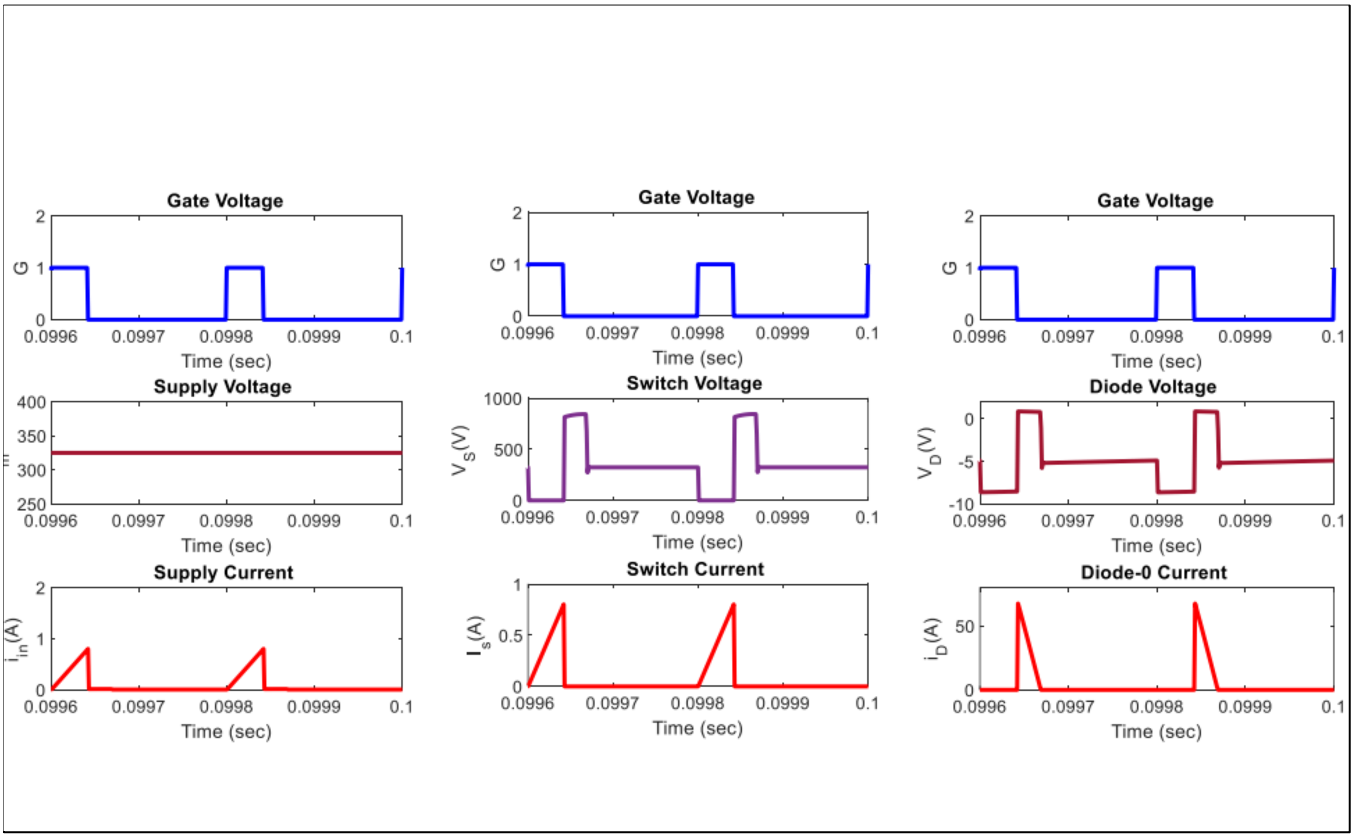
Fig.5 Working of prototype

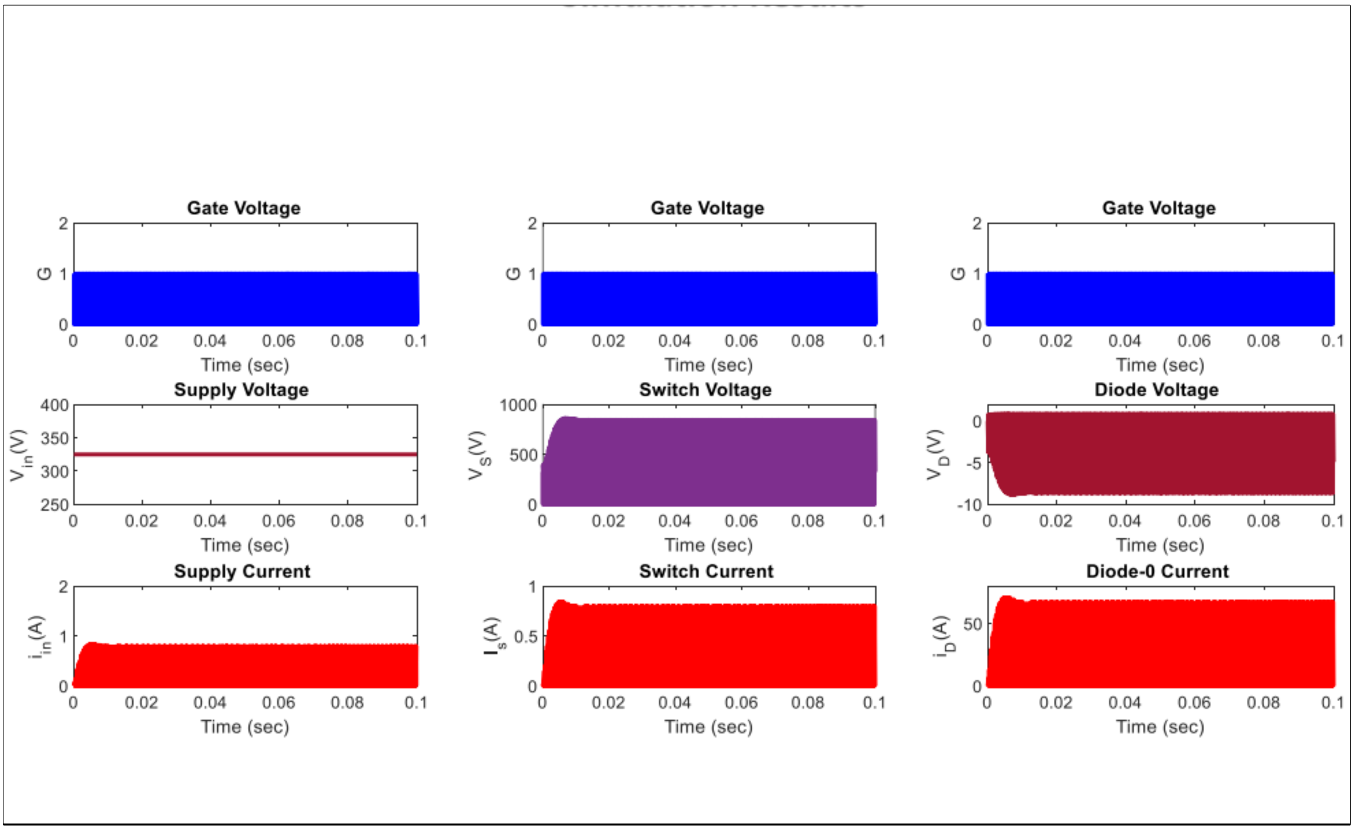
a waveform that

MATLAB CIRCUIT:



SIMULATION RESULT:


Gate Voltage
G
Time (sec)
Supply Voltage
Supply Current
i_in (A)
Switch Voltage
V_S (V)
Switch Current
I_s (A)
Diode Voltage
V_D (V)
Diode-0 Current
i_D (A)


Gate Voltage
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Time (sec)
Supply Voltage
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Supply Current
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Switch Voltage
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I_s (A)
Diode Voltage
V_D (V)
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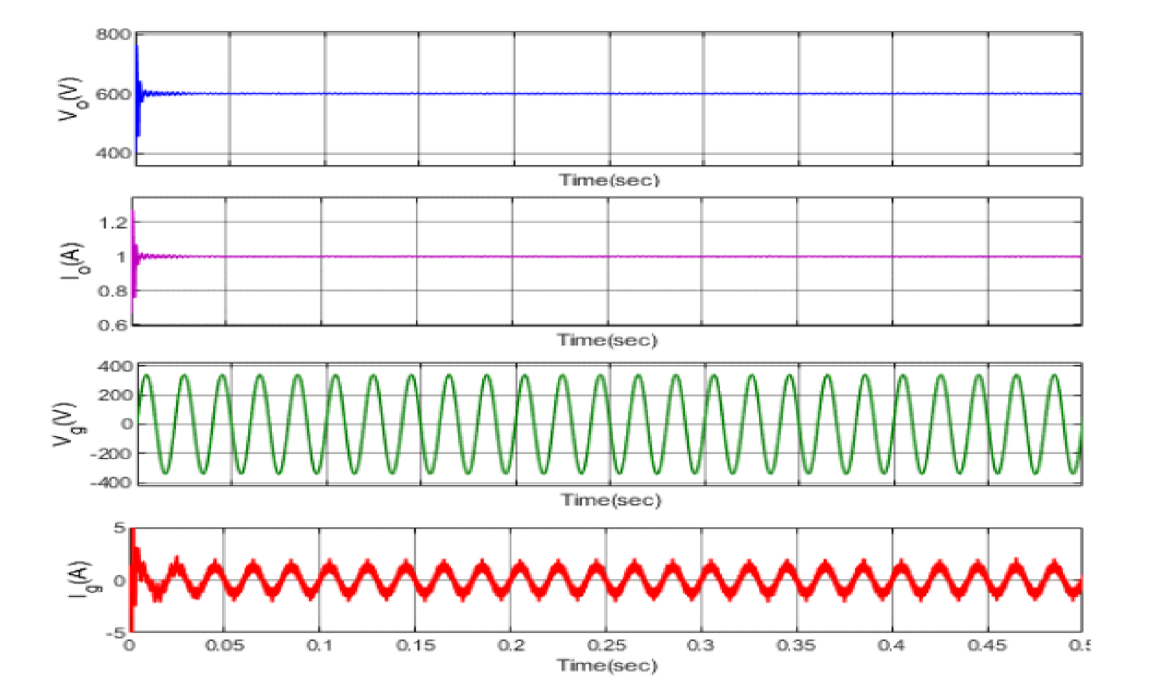

4.2 SIGNIFICANCE OF SINGLE-STAGE FLYBACK PFC AC TO DC CONVERTER FOR POWER LED LIGHTING APPLICATIONS

The proposed converter has several advantages over traditional AC to DC converters. The single-stage topology reduces the complexity of the circuit and lowers the cost of the components. The PFC circuit improves the power factor, which results in a lower energy consumption and reduces the amount of power wasted in the form of heat. Additionally, the flyback topology provides isolation, which enhances safety and reduces the risk of electric shock.

The proposed converter is also well-suited for dimming control, which is an essential feature in LED lighting applications. The converter can be easily integrated with a dimming controller to enable smooth dimming of the LED lights without affecting the power quality.

The proposed converter is expected to have a significant impact on the LED lighting industry. The high efficiency and low THD make the converter a sustainable and cost-effective solution for powering LED lights. The converter's ability to improve the power factor also makes it a valuable contribution to reducing the carbon footprint and promoting energy conservation [3,7,10].

5. CONCLUSION

In conclusion, the suggested single-stage flyback PFC AC to DC converter is an appropriate choice for applications requiring power LED lighting. The converter has a high power factor, minimal THD, and great efficiency. The design is simple, low-cost, and can be easily implemented. The simulation and experimental results validate the proposed design and demonstrate its suitability for practical applications.

Furthermore, the proposed converter can be improved by implementing advanced control algorithms, such as predictive control, to further improve the efficiency and reduce the THD. The proposed converter can also be extended for use in other applications, such as motor drives and renewable energy systems.

Overall, the proposed single-stage flyback PFC AC to DC converter is a promising solution for improving the efficiency and reducing energy consumption in LED lighting applications. Future research can focus on further improving the converter's performance and exploring its potential for other applications.

6. REFERENCES

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