DESIGN AND OPTIMIZATION OF HIGH POWER FACTOR SINGLE-STAGE FLYBACK CONVERTERS FOR LED DRIVERS

Dr. P.CHANDRASEKHAR, ***Professor,***
Department of Electrical and Electronics Engineering,
ADAM'S ENGINEERING COLLEGE, PALONCHA.

ABSTRACT: This paper introduces a dynamic model for forward-flyback modulated DC-DC converters. The suggested design has a lot of positive aspects. It is isolated, features a single power switch, a fully capacitive output filter, steady frequency functioning within a conventional pulse-width-modulation scheme, and minimal variation in the output capacitor's current. This unique and dependable converter can be used as a power source with various outputs or to fix power factor. It operates with a broad variety of input voltages. In standard AC/DC flyback converters, a significant amount of energy is lost near the center of the transformer due to uneven current flow across the magnetizing inductor. Traditional forward converters have a reduced power factor when the input voltage for alternating current (AC) drops below zero. Despite having a smaller core loss, they can still convert power rather well. The proposed converter can function as a forward and flyback converter in the on and off stages. This enables it to maintain a high power factor throughout the flyback operation and send power during the toggling period. Regardless of the AC input voltage, a current-balanced capacitor can also efficiently reduce the offset current that passes through the magnetizing inductance of the transformer. As a result, less energy is lost in the core, allowing the generator to become smaller. The proposed converter has an exceptionally high efficiency and power factor as a result. A simulation model created in MATLAB/Simulink is tested by contrasting the output it produces when it is executed on a simulation platform.

Keywords: Forward-Flyback converters; DC-DC converters; Single Switch design;

1. INTRODUCTION

The use of light-emitting diodes (LEDs) in displays and lighting has increased in recent years due to the fact that LEDs have improved efficiency, a longer lifespan, and a reduced impact on the environment. This is the reason why LEDs have become increasingly popular. The utilization of light-emitting diodes (LEDs), which are also frequently referred to as light-emitting diodes, is gradually growing in comparison to the utilization of fluorescent and conventional light bulbs. By implementing switch-mode drivers in LED applications on a large scale, it is possible to achieve an incredible power density and an improvement in efficiency. In order to effectively manage the power supply, it is essential to possess both a power factor corrector and an independent DC/DC converter in order to drive LED lights. There are a variety of objectives that can be accomplished through the utilization of a two-stage system. These objectives include establishing a high power factor, maintaining continuous output control, and achieving a low transient voltage. Each and every one of these characteristics is worthy of praise and admiration. However, these systems generate energy with a lower efficiency, they require a greater quantity of material, and the cost of production is higher. In addition, the amount of material they consume is greater. LED drivers that are low-power often utilize single-stage drivers, whereas drivers that are high-power typically use two-stage drivers. This is because of the fact that single-stage drivers generate less power than two-stage drivers.

Over the course of time, high-intensity LED lights will eventually take the place of more traditional lighting sources such as incandescent and fluorescent lamps. This is something that will take place as LED lights become more widely available. By modifying the current that passes through LEDs, it is possible to alter not only the color of the displays but also the brightness of the displays. As a result of this, LED drivers are accountable for ensuring that the current that they generate is managed in an appropriate manner. It is extremely crucial to take into consideration these qualities when it comes to the building of LED driver systems. This is especially true when they are paired with low voltage requirements and a high Power Factor (PF). The employment of control techniques that are based on the measurement of current on the secondary side is commonly utilized in applications for the goal of correctly controlling the output current. This is done in order to get the desired result. On the other side, this method may result in losses that are more evident and obvious, such as the losses that the transformer has undergone at this point in time.

When it comes to pieces of contemporary electronic equipment, it is vital to search for qualities such as quality, portability, compactness, and optimal performance. Using linear regulators, it is feasible to generate power of an incredibly high quality. This is a possibility. As a result of the low power levels that they generate, they are utilized extensively as voltage regulators because they create the least amount of disruption. The electronic components with the least degree of polarity and the active electrical components are what make up linear controllers. Through the employment of switching controllers, it is possible to achieve an increase in voltage. Power semiconductor switches that are capable of transitioning between phases are utilized in the context of switching controllers. The switching controls are able to successfully transfer energy in a quick and efficient manner in the event that the power source fails to function properly. At this point in time, electronic devices are able to operate at frequencies that are considered to be exceedingly high. A reduction in the size and weight of filter inductors, capacitors, and transformers makes it possible for these components to operate at higher frequencies. Additionally, the dynamic features of a converter show an improvement when the frequency at which it runs increases. This is because the frequency operates at a higher frequency.

Hard switching is accomplished by the utilization of a certain sort of direct current-direct current converter known as pulse width modulation (PWM). Resonance and progressive switching are two different applications that cannot be compared to one another.

In spite of the fact that it was intended to be inexpensive, the linear driver is distinguished by its ability to respond quickly to transients and to regulate current with pinpoint accuracy. However, in terms of energy efficiency, it is not very effective because it loses a substantial amount of energy in the form of heat. This is the reason why it is not particularly efficient. It is typical practice for applications that make use of LEDs to make use of switch-mode drivers due to the high power density and efficiency that these drivers are able to accomplish. In order to attain the maximum possible power factor and energy efficiency ratings, a number of various converter topologies has been developed. Some examples of these topologies are flyback and forward converters.

2. LITERATURE SURVEY

To accomplish the goal of acquiring a complete comprehension of LED power technology and DC-DC converters, a thorough analysis of the most recent literature was carried out. This was done in order to achieve the target.

This study will investigate and carry out a novel method to the design and modeling of isolated flyback converters. This technique will be carried out within the scope of this paper. When it comes to the development of models, it is highly suggested to incorporate both parasite and non-parasitic components if their inclusion is feasible. At an early point in the conversation, a topic similar to this one was brought up.

In addition to the formulation of recommendations for control strategies, this inquiry has resulted in the creation of models for flyback converters that operate in continuous conduction mode (CCM). These models are included among the outcomes of the investigation. The objective of this research is to provide evidence that demonstrates the efficacy of transformer models in circumstances in which an application will require more than one output due to the constraints that it must satisfy.

The prospect of building an integrated magnetic DC-DC converter is something that Brad Lehman and Ting Qian are investigating as part of this research project. An excellent level of performance is displayed by the converter when it is placed through conditions that need a high input voltage. Both parallel and serial connections are constructed between the input and output, respectively, in order to accomplish the goal of achieving two-way mixed flyback connectivity. Since these links exist, the prospect of such a flyback is made possible.

Because of these connections, which are what make it possible to carry out the experiment, it is something that can be done. A significant number of transformers have been utilized in concert with one another in order to produce a single magnetic core. This was done in order to accomplish the desired outcome, which was the reason for doing it. When one reaches this point, it is no longer possible to make a connection between the central extremities and the peripheral extremities. This is as a result of the modifications that have been made to the circumstances.

When there is a vacancy, the frequency of voltage spikes that are created by variable winding voltages is reduced, which results in a decline in the frequency of voltage spikes. This is because the vacancy causes the voltage spikes to be lower. This occurs as a result of the reduction in the frequency of voltage spikes that occurs simultaneously.

It is possible to accomplish a reduction in the amount of current disturbance that is not desired by making a connection between the two transformers in an inverted coupling configuration. This will allow for the desired amount of current disturbance to be reduced. Because of all of these factors, it will be possible to make adjustments to the disturbance that is currently taking place.

As soon as the inquiry was ultimately brought to a satisfactory conclusion, the ZVZCS, which is an advanced active restricted dual switch flyback converter, was made available to the general public. Taking into consideration the fact that neither the primary nor the secondary controls are illuminated, it is possible to arrive at the conclusion that there is no power present in this particular area.

Utilizing a rectifier diode is the responsibility of the secondary side, which is responsible for ensuring that there is no power present. The secondary side is accountable for this particular activity that needs to be completed. Through the utilization of slope correction, conventional flyback converters are able to circumvent the issue of an excessive voltage pressure being exerted on the primary switch. In addition to this, slope correction makes it much simpler to achieve duty cycles that are greater than fifty percent. Slope correction is a method that has been utilized for a substantial amount of time and is known by that name.

In circumstances when the specifications for input voltage, range, and efficiency are of the highest possible standard, it is therefore suitable for usage in those circumstances. As a result of this characteristic, it is appropriate for utilization. The second snubber is not necessary since the converter is able to make efficient use of the energy that is still present in the broken inductor. This eliminates the need for the snubber. This is the reason why situations are the way they are.

Milanovi and other individuals are currently doing an inquiry into the issue of voltage spikes causing leaky inductance in transformers. This investigation is ongoing. At the moment, these responsibilities are being carried out.It has been suggested that the employment of either non-dispersive LCD clamp circuits or dissipative RCD clamp circuits could be utilized as a means of minimizing the negative effects that are related with this topic. Each and every clamp circuit comes equipped with a diode, which is an essential component that is incorporated into the design of the circuit.

In the case that components in the clamp circuits come into contact with one another and reverse the recovery charge of the diode, there is an increase in the amount of power that is spent. This is because the amount of power that is spent is increased. This results in an increase in the amount of electricity that is wasted at an increased rate.

Because of this, it is recommended that an RC-RCD clamp circuit be constructed in order to get rid of the ringing and further restrict the oscillations that take place in the clamp diode. The removal of the ringing will be possible as a result of this. Through the utilization of this clamp circuit, it is possible to accomplish the task of increasing the power-to-weight ratio of the flyback converter. Certainly, this is something that is attainable.

The Frank Chen group has made accessible a few pieces of information that pertain to the forward-flyback zero-voltage-switching (ZVS) direct current to direct current converter. These pieces of information are available to the public. It has been made accessible to them that these pieces of information would be available. Simply because it makes it easier to transmit electrical current, this adaptor makes it possible to regulate and transmit a wide range of input voltages. This is because it simplifies the transmission of electrical current. Furthermore, it makes it possible for the flow of electrical current to be transferred.

The converter must operate in a setting that works as a transition between functioning in a continuous mode and functioning in a discontinuous mode in order for it to achieve zero power. This is necessary for the converter to achieve zero power. In order to successfully complete the process of acquiring zero power, it is necessary to follow this technique. Because of this, the overall efficiency of the system is improved because the transformer core loses less energy when the frequency alternates and the off-time remains the same. This results in the system running more efficiently.

The overall effectiveness of the system is improved as a result of this. This leads to an overall improvement in the efficiency of the system, which is brought about as a result of this. At the moment, a comparison is being carried out between the flyback and forward methods of power distribution. This is being done in order to evaluate the effectiveness and practicability of the converter that has been proposed. The purpose of this assignment is to assess the efficiency of the converter, and it is currently being carried out.

3. SINGLE-STAGE BALANCED FORWARD-FLY BACK CONVERTER

This article describes how to construct a balanced forward-flyback converter with a single stage, power derived output by combining the designs of a forward and flyback converter. A substantial loss of power at the core of the flyback converter and a reduction in operational efficiency can be attributed to an elevated offset current in the magnetizing inductor. In addition, the majority of forward converters are capable of attaining high levels of power conversion efficacy due to their minimal core losses. However, when the input current reaches zero cross AC voltage, it enters an inactive region, rendering it less functional. Additionally, the inactive zone reduces the power factor.

The proposed converter exhibits the capability to function as a flyback converter during both the on and off phases, which could enable it to provide power during the toggling phase while maintaining a high power factor during the flyback operation. A current-balanced capacitor can effectively reduce the offset current that flows through the magnetizing inductor of the transformer, irrespective of the AC input voltage. As a consequence, the generator becomes more compact and experiences reduced core loss. This implies that the converter under consideration possesses an exceptionally high power factor and efficiency. A block diagram of the proposed forward-flyback converter is presented in Figure 1.

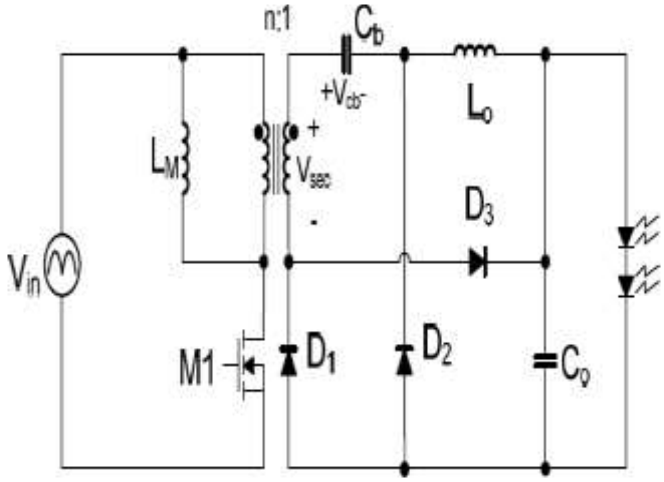

Figure 1: Block diagram of forward-flyback converter

4. OPERATION PRINICIPLE

The operational modes of the forward-flyback converter being investigated are illustrated by the patterns in Figure 2. The conduction status of each switch determines its mode. The subsequent elements facilitate the observation of the steady state mode:

Without the supplied diode, the M1 switch functions without any issues. One limitation of the transformer is its comparatively high magnetizing inductance (LM). The values of Vo and Vcb indicate that the DC block capacitor Cb and the output capacitor Co are both sufficiently large to be considered as sources of continuous DC voltage. The circuit provided operates in boundary conduction mode (BCM).

When M1 concludes prior to t0, the energy contained in LM is transferred to the load side via D3 and D1. ILM is presently levying charges against Cb, whereas ILo is aimlessly wandering around D2 without a predetermined course of action. At time t0, Mode 1 [t0t1] commences, characterized by an immediate light intensity (iLM) that completely disappears. Vin is increased by LM when Mode 1 is engaged. The result is an increase in ILM in accordance with a linear trend whose slope is equivalent to Vin/LM. At the input side of the output LC filter, it exceeds Vo (Vsec plus Vcb), while at the secondary side of the transformer, it is lower than Vo (Vsec). The high conductivity of D1 facilitates the transfer of energy from the source to the load. Additionally, the voltage across D2 can be documented by denoting Vo. The constraint on Vo is D1 (Vin/n+Vcb).

Power is transmitted from the load side to the LM through D2 and D3 in Mode 1, which is initiated at time t1 when M1 is not in operation. The secondary current of the transformer is equivalent to the amount of energy required to charge the correcting capacitor Cb. Concurrently, D2 does not impede the electrical current passing through Lo. When ILM is applied to LM, a straight line with a slope of n(Vo+Vcb)/LM is produced. Modes 1 and 2 are activated when the ILM value reaches zero, with M1 being enabled.

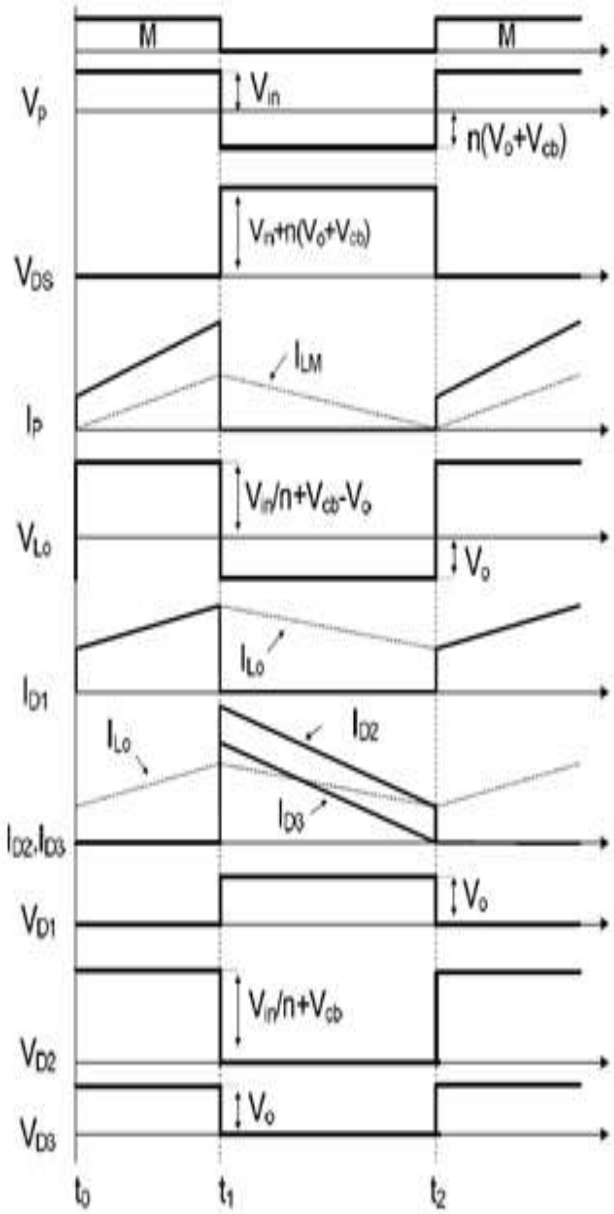

Figure 2: Waveform of forward-flyback converter

5. COMPLETE SIMULATION MODEL OF FORWARD- FLYBACK

CONVERTER

By combining Cb and Vcb, this converter can function as a flyback and forward converter throughout the entire input voltage range. When the sum of the turning ratio (Vin/n) and the input voltage (Vin) exceeds the output voltage (Vo), energy can flow from the input to the output of the converter without requiring Cb. When Vin/n is equal to or less than Vo, an event occurs that alters the course of events. It is recommended to reduce the offset current caused by magnetization by employing the compensating capacitor Cb. As a result, the transformer exhibits reduced core loss and possesses a more compact design.

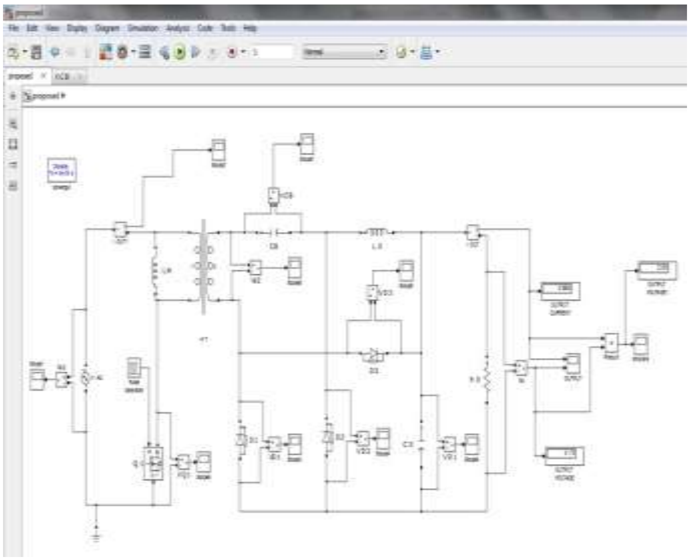

Fig 3: To simulate a forward-flyback converter, a model of such a device is proposed.

The following are the specifications for the electrical layout:

Table 1: Construction Guidelines for a Forward Flyback Conversion

Parameters	Value
Input Voltage [Vin]	90V
Magnetizing Inductance [Lm]	1.8mH
Frequency	100KHz
Primary Voltage [V1]	100V
Secondary Voltage [V2]	180V
Balancing Capacitance [Cb]	100 µF
Output Capacitance [Co]	10mF
Output Resistance [Ro]	73.68Ω
Output Current [Io]	0.56A
Output Voltage [Vo]	42V
Output Power [Po]	24W

As shown in figure – the waveforms are as below:

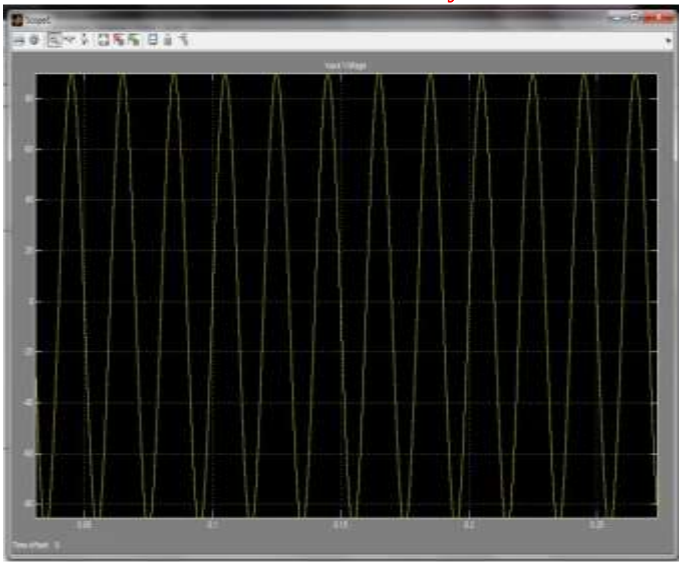

Fig 4: the waveform of the supplied electrical current.

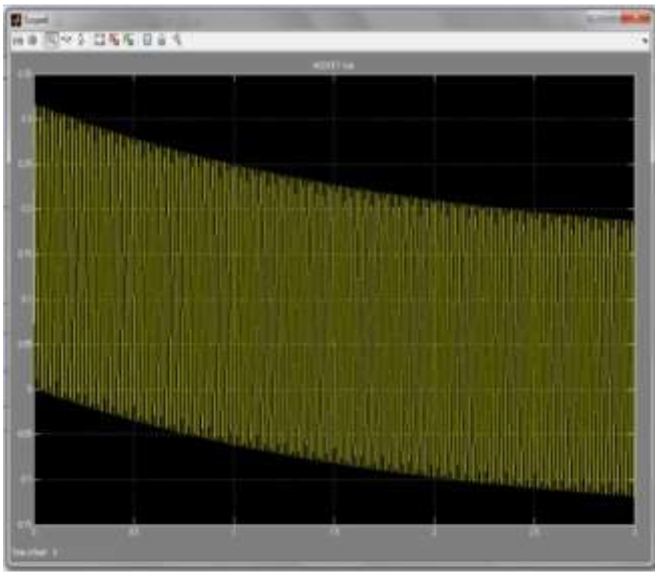

Fig 5: As observed, the PWM switch of the forward flyback converter under consideration exhibits the Mosfet Vds waveform.

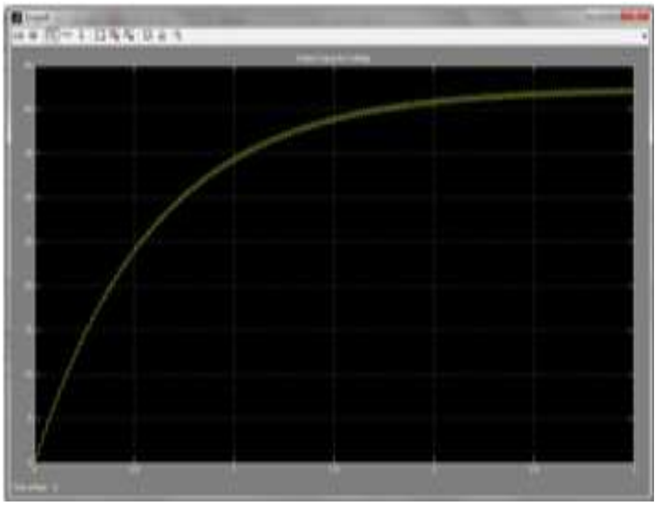

Fig 6: This image illustrates the voltage waveform of the output capacitor utilized in the proposed forward flyback converter.

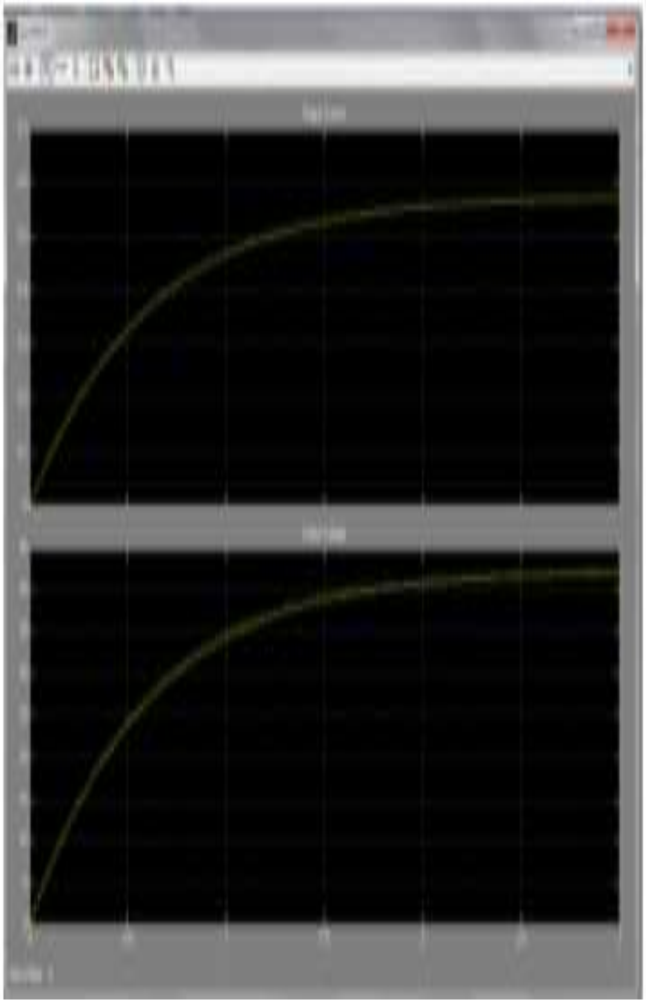

Fig 7: The voltage and current waveforms of the forward flyback converter as they appear

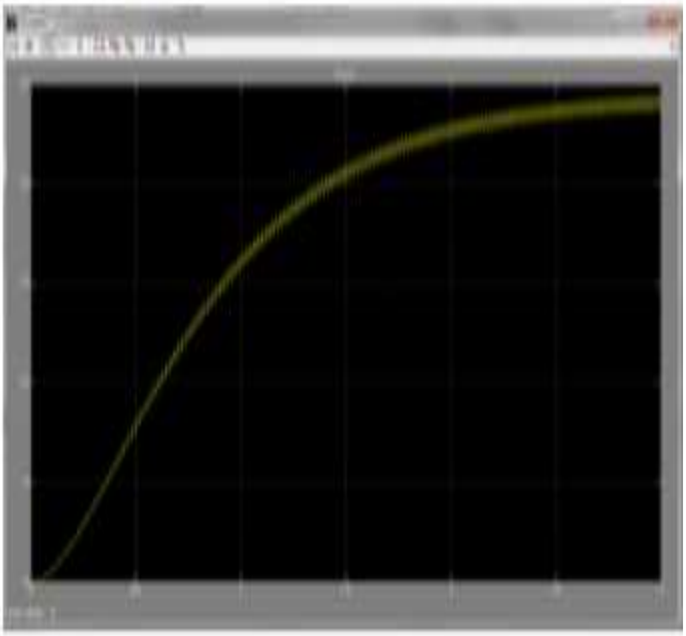

Fig 8: the power flow waveform of the forward flyback converter under consideration.

6. CONCLUSION

This Scientific research centered on a balanced forward-flyback converter for LEDs with a single power factor variation is discussed in this article. Regardless of the input voltage, the proposed forward-flyback converter will autonomously transition between forward and flyback modes if it is equipped with a balancing capacitor. This is accomplished by decreasing the offset current generated by magnetization, thereby reducing core loss and transformer core size. Disabling the primary power switch is a critical step towards optimizing the capacitance and efficiency of the proposed converter. As it consumes less energy than the flyback circuit, the forward converter is typically employed for tasks requiring 100 to 200 watts of power. To assess the functionality of the proposed designs, LED-specific modeling circuits are constructed. The circuits' capability to precisely measure power factor and efficiency is a noteworthy characteristic. During the transitional phase, the proposed circuit additionally transfers electricity in an efficient manner. All parties agree that the suggested design is optimal for a variety of LED driver applications due to the truth of the following.

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