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An Interleaved Single-Stage Fly Back AC-DC Converter for Outdoor LED Lighting Systems

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***Abstract*— Due to the high reliability and luminous efficacy LEDs are becoming very popular in lighting applications. So their power supplies also require the same reliability and efficiency. There are two types of LED drivers are available depending upon the output power. Inorder to overcome the disadvantages of the existing systems, another method is proposed here.This paper mainly focused on an LED driver. It deals with an interleaved single stage flyback ac-dc converter to drive an LED for high and low power applications. This converter can provide a regulated output to power an LED for wide power applications. In addition this converter shows power factor(PF) of greater than 0.9 and a total harmonic distortion(THD) of less than 5%. MATLAB based simulations are carried out for open loop and closed loop and are compared .**

Index Terms*— LED(Light emitting diode), single-stage, interleaved flyback, PF(Power Factor), THD(Total Harmonic Distortion)

I. Introduction

LEDs are widely used in outdoor lighting applications such as street light, flood light, beacon light etc. LEDs have so many advantages such as long life time, ease to drive, lower energy consumption, high luminous efficacy. These applications require power usually around 10-200W.

There are two types of LED driver according to the output power rating. Single-stage structure and two-stage structure. In single-stage structure as shown in figure 1(a), power factor correction part and dc-dc converter part are combined in to one stage. Although it has low component count, simple control and high efficiency, it can be used for low power applications only. In the two stage structure as shown in figure 1(b), there are two stages. First stage is the power factor correction(PFC) part and second stage is the d-dc converter for regulating the output voltage. In this the two power stages can be controlled separately, so it can be used for high power applications. But it has large number of components and quite complex control circuit. So inorder to handle high power, an interleaved single-stage flyback ac-dc converter is proposed here.

Flyback converter has remarkably low number of components as compared to other SMPS. Flyback converter here functioning as a buck converter with the inductor split to form a transformer. This transformer provides galvanic isolation between input and output.

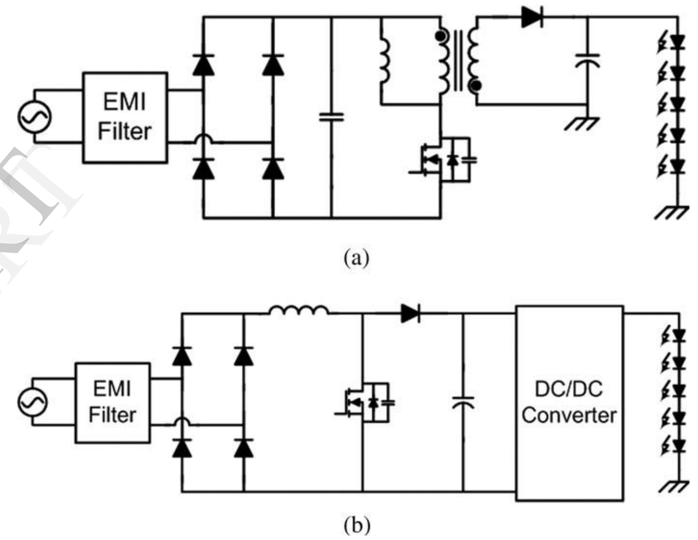

Fig 1. Power stages of LED driver. (a) single-stage structure ,(b) two-stage structure.

A. *Advantages of Interleaved topology.*

- Interleaved topology can reduce the size and cost of power filtering components and also enhance dynamic load performance
- It is an appropriate choice for high power applications
- Because of parallel power stages, the transformer peak and RMS currents are reduced by a factor of 2.
- Reduction of EMI energy due to lower peak currents.
- Output capacitor is larger than input capacitor that suppresses the ripple content in the output voltage.

II. PROPOSED SYSTEM

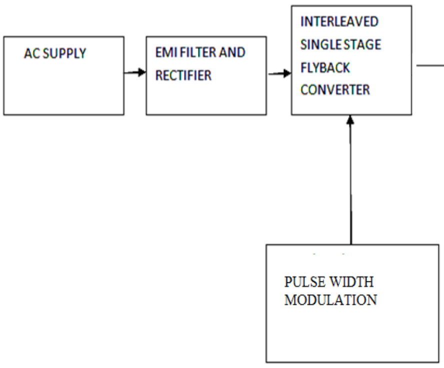

Fig 2. Block diagram of the proposed system.

The single phase ac supply is given to an EMI filter to filter out the noises. Then it is given to the rectifier to convert it in to dc. The output of rectifier is given to the interleaved flyback converter. Flyback converter is controlled by pulse width modulation. The regulated dc output is given to the LED string

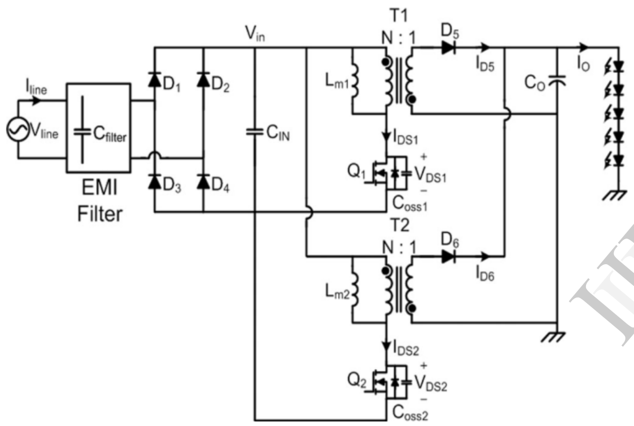

Fig 3. Interleaved single-stage flyback ac-dc converter

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III. PROPOSED CONTROL METHOD

The proposed method adopts discontinuous mode of operation. ie, there will be a time delay between turning ON and turning OFF of the two switching devices. So the stress on the switching device will be less and hence efficiency will be more. MOSFET in the flyback converter is controlled by the sinusoidal pulse width modulation. In sinusoidal pulse width modulation, carrier signal is a triangular wave and reference signal is a sine wave. By comparing the reference signal with the carrier wave gating pulses are generated. The main advantage of PWM(Pulse Width Modulation) is that the power loss in the switching device is very less.

A . OPERATING PRINCIPLE

The switching period can be subdivided in to six modes of operation. The modes 1-3 are same as modes 4-6. So the first three modes are explained here. To make the circuit operation simpler, some assumptions are made

- the transformer leakage inductances are negligible
- EMI filter is larger than input capacitance
- The magnetizing inductances Lm1 and Lm2 are identical
- The phase shift between two switches are 180^0

.Mode 1: In mode 1, Q1 is ON and Q2 is OFF. Energy is built in to the magnetizing inductor Lm1. The energy stored in the inductor Lm2 is transferred to the output through diode D6. The diode current ID6 decreases .

Mode 2: When diode current ID6 decreases to zero this mode begins. Q1 is ON, the diodes D1 and D4 are conducting. The output capacitor Co discharges and load gets power.

Mode 3: When Q1 is turned OFF, this mode begins. Energy stored in Lm1 is transferred to output via diode D5 which is forward biased at that time. This mode ends when ID5 decreases to zero.

IV. OPEN LOOP SIMULATION

The system proposed can be simulated with MATLAB software. The components and various parameters used for simulation is as shown in table 1.

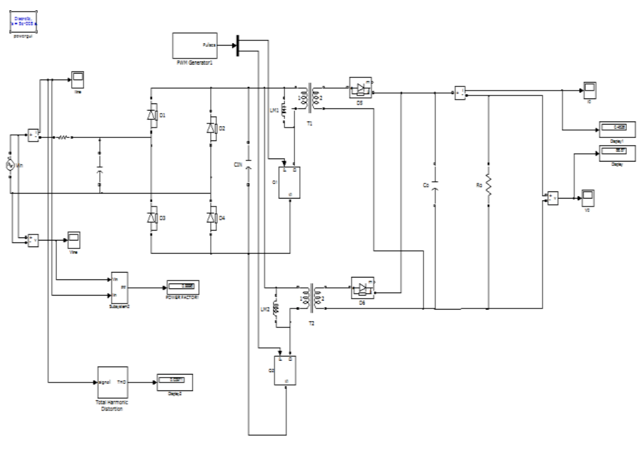

FIG 6. OPENLOOP SIMULINK MODEL

TABLE 1: SIMULATION PARAMETERS

ITEMS	VALUES
V_{IN}	230V AC
V_O	86.87V
I_O	0.4826A
EMI FILTER CAPACITANCE	10μF
C_{IN}	1μF
C_O	10MF
MAGNETISING INDUCTANCE L_{M1}=L_{M2}	215μH
OUTPUT RESISTANCE R_O	100Ω
THD	4%
PF	0.94

The input and output voltage and current waveforms for open loop simulations are as shown figure below. An input voltage of 230V is applied. It is rectified and then regulated. The output voltage and current are obtained as 86.87V and 0.4826A. So output power is 42W. The power factor is obtained as 0.94 and THD is 4%.

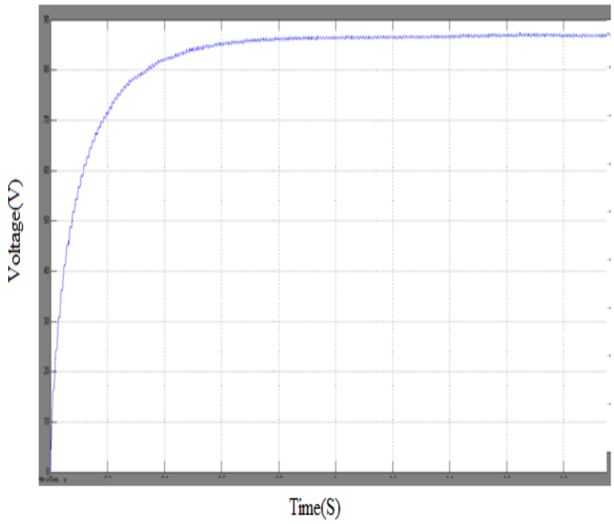

Fig 5. Output voltage waveform

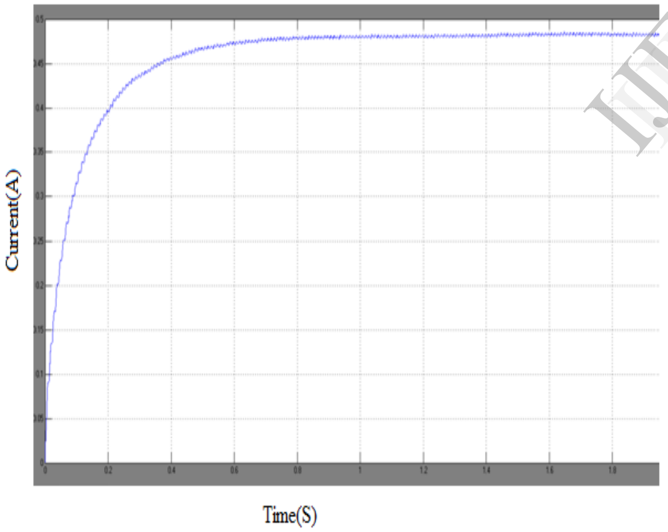

Fig 6. Output current waveform

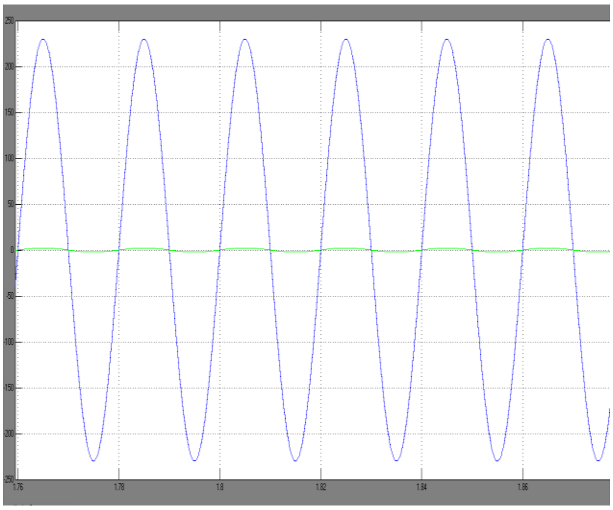

Fig 7. Input power factor(Voltage and current in phase)

V CLOSED LOOP SIMULATION

As a modification closed loop simulation is done using a PI controller . The simulink model is as shown in figure 7 below. Parameter values and input voltage is same as in open loop simulation. Closed loop simulation is done to regulate the voltage.

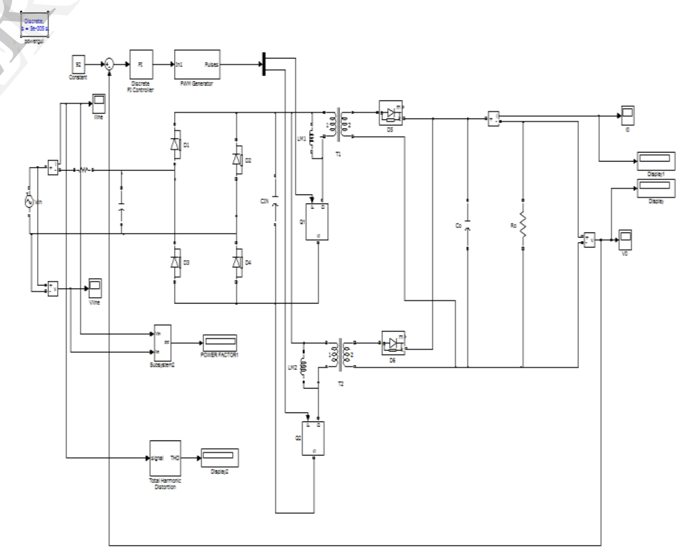

Fig 7. Closed loop simulink model

An input voltage of 230V ac is given. Output voltage and current are obtained as 98.52V and 0.821A. So the output power is 81W. ie, by doing closed loop simulation , THD is reduced to 3%. Power factor is obtained as 0.96. The voltage and current waveforms of the closed loop simulation are as shown in figure 8 below.

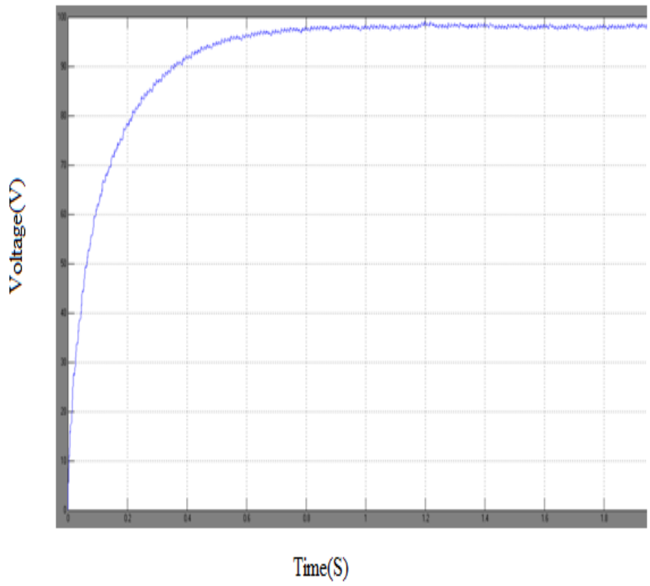

Fig 8. Output voltage waveform

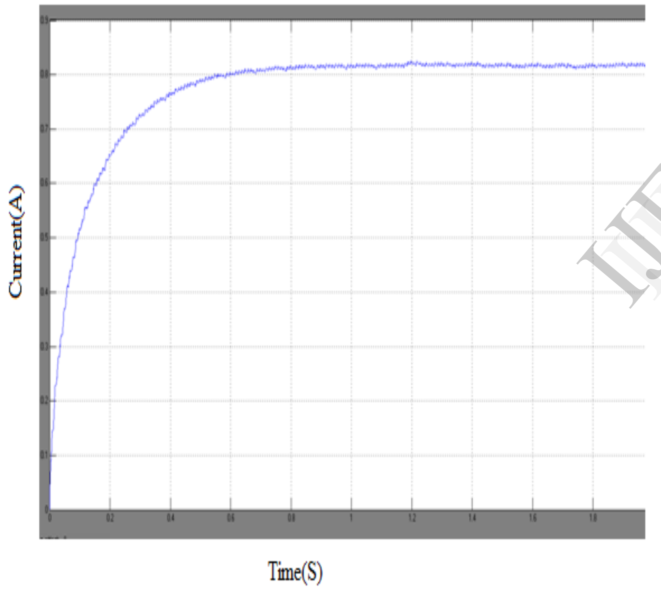

Fig 9. Output current waveform

VI. COMPARISON OF OPENLOOP AND CLOSED LOOP SIMULATION

The results of open loop and closed loop simulations are compared and as shown in the table 2 below.

TABLE 2: COMPARISON OF SIMULATION RESULTS

	OPEN LOOP	CLOSED LOOP
Input voltage	230V ac	230V ac
Input current	2.5A	2.5A
Output voltage	86.87V dc	98.52V dc
Output current	0.4826A	0.821A
Output power	42W	81W
THD	4%	3%
PF	0.94	0.96

VII. ADVANTAGES OF LED LIGHTING

- LEDs are cooler: LEDs run much cooler than incandescent bulbs and significantly cooler than CFLs.
- Get instant full light: We can get the full brightness of an LED bulb when we turn it ON
- LEDs don’t attract bugs

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VII. CONCLUSION

In this work, an LED driver for outdoor lighting systems is presented. The proposed converter provides almost regulated output with very low ripple content. This can be used for wide power range with lesser component count and small filtering components. In open loop simulation we are getting an output power of 42W .THD is only 4% and power factor is 0.94. By doing closed loop simulation, we can regulate the output voltage. Thus we can reduce the THD to 3% and increase the power factor to 0.96. Hence an interleaved single-stage flyback ac-dc converter operating in the DCM mode is an appropriate choice for wide output range LED applications.

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