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Energy Efficient LED Driver

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Abstract: This paper describes the high efficiency LED driver with dimming facility incorporated in it. This dimming facility will help to reduce in power saving of LED street light during night time. The design of a current programmable LED driver with efficiency of 92±1% is described in this paper. One major challenge of designing such a LED driver is need for supporting a wide range of output voltages. Thus each LED fixture is powered by a compatible driver of corresponding wattage. There is possibility of circuit damaging in case of incompatibility due to higher voltages or current or flickering may occur in light. This problem can be avoided by having a single driver compatible with all the LED light fixtures .The various parameters related to LED drivers are taken into consideration while designing for a better performance.

Keywords: LED driver, PWM, PFC, THD, PF, Efficiency

I. INTRODUCTION

In today's world power conservation is big problem to researcher. Some researcher is working on power generation from natural resources like sun, wind, etc. Recently LED light proved that tremendous power saving with comparison to CFL and fluorescent light. Street lighting has become compulsory part of not only cities but also in villages [1]. Street Lighting can account for 10–40% of the total energy bill in typical cities worldwide. By replacing vapor lamps by LED lights almost 40-50% of energy can be saved[2].The aim of the proposed system is to design and develop a LED driver which will be driving the LEDs in streetlight which can give the same light output as the high power HPSV gives with minimum power consumption. This system has developed a protection for Street light from parameters such as surge immunity, over voltage protection, under voltage protection. This parameters will protect the LED street light in case of abnormal conditions. Component selection plays an important role in designing of such protection circuits. This paper also presents an energy consumption of designed LED driver and its cost calculation with respect to energy consumed. If this system is implemented in large street lighting projects it will save the cost of ownership.

The LED driver is compatible of driving the both discrete as well as chip on board LEDs. Based on requirement of LEDs a driver is decided; a constant voltage or constant current driver. A constant current driver has a regulated output current with a range of operating voltage and constant voltage driver has specific voltage with current regulating circuit.

If proposed system is implemented almost 70-75% of energy can be saved. Means the 180W HPSV lamp light output can be replaced by 50W LED street light output. To develop the Energy Efficient LED Street Light, the driver needs to be designed having Efficiency >91%. The design of LED driver plays and important role in developing energy efficient LED street light.

II. LITERATURE REVIEW

Ravikishore Kodali described the technique for dimming of LED Streetlight by using a sensor interface. The system was implemented using the Wi-Fi module ESP8266, Light dependent sensor and ultrasonic sensor. The LDR sensor is used to ON-OFF the streetlight based on ambient Intensity level.The ultrasonic sensor is used to glow the light with 100% brightness when a vehicle or person comes in range otherwise the street glows with 60%. The unnecessary power waste is avoided. In this system energy saving is achieved just by dimming of light intensity. The system does not focused on the efficiency of the system & protection of LED street light on Field [1]

Lakshmi Balasubramanian presented the technique of analog dimming done by controlling forward current being fed to LEDs. The current is adjusted using fan-like regulator which has a potentiometer in series with a voltage source and can be manually adjusted to the brightness that is required. The dimming IC used which has a pin allotted for analog dimming. The dimming reduces the LED current linearly. This method is easy to implement but doesn't give the best overall performance due to change in color temperature as the current changes [2].

V. K. Bhangdiya proposed the low power consumption of LED Street light based on smart control system. In this system sensor is used to measure sun light intensity, day night condition and traffic on road. The intensity of LED street light varies with these parameters. The two sensors used are LDR (Light depending resistor) sensor and motion sensor. LDR sensor is used to control the switching action of LED streetlight depending on sunlight condition. Motion sensor is used to change the intensity of LED light, when there is no motion of object at mid night on street then all the street light are dimmed, to reduce the power consumption[3]

III. METHODOLOGY

The surge protection circuit is designed to withstand the surge of ±5kV. The input is rectified, Filtered and feed to the digital controller. The NCL 30186 digital controller is used. The NCL30186 is a controller targeting isolated and non−isolated "smart−dimmable" constant−current LED drivers.

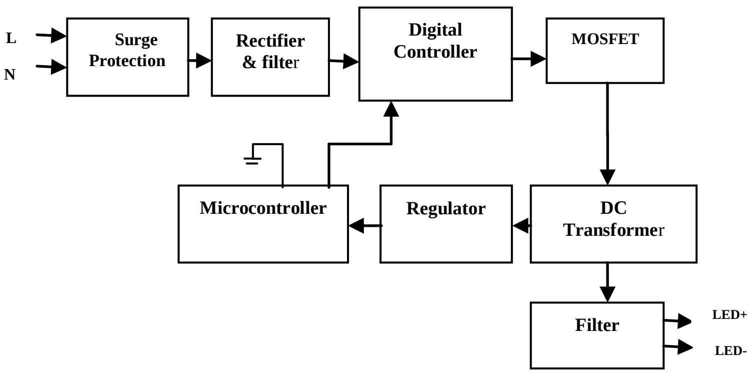

Figure 1. Block Diagram of Energy Efficient LED driver

Its proprietary current− control algorithm provides near−unity power factor and tightly regulates a constant LED current from the primary side, thus eliminating the need for a secondary−side feedback circuitry or an optocoupler. Digital Controller used is programmed using microcontroller to perform the dimming operation. The digital controller output is switched using MOSFET and DC transformer is used to give constant current variable voltage output. The proposed driver efficiency is 90%. The efficiency will be depending upon the design of the transformer & losses of Filter used.

- **Transformer Design**

The Fly back transformer is designed here in order to provide range of output voltage. The design of transformer plays an important role in deciding the wattage of LED driver. The present transformer is designed having variable dc output range of 45-65V and 0.9A dc current. The dc voltage and current depends upon the number of wires and number of turns given to the pins of PQ2625 bobbin. The transformer is designed to give conctant current output to provide a regulated current to LEDs.

TRANSFORMER SPECIFICATION SHEET

Winding	No of Wires	Turns	Wire	Start Pin	End Pin
1/2 P	2W	16	25 SWG	3	2
Sec	3W	18	25 SWG	12,11	7,8
Bias	2W	8	32 SWG	4	6
1/2 P	2W	16	25 SWG	2	1
Inductance					
Pin 3 to Pin 1	240uH				
Tolerance	± 10%				
Leakage Inductance	< 10uH				
Bobbin	PQ 2625,12 Pin,Horizontal,Nylon 6,30%GF,FR				
Core	PQ 2625,N87/CF139/PC44,Gapped				
Tape	Polyester,Yellow,3 mil				
	2 turns after each winding				
	2 turns on core				
Bonding of cores	Araldite,Loctite applied on the lateral sides of core.				
Varnish	Elmoluft 1A with suitable thinner,Air drying varnish				
HV Test	On sampling basis upon approval				
Between P - S	3.5KV for 1 mnt				
Between Cores and Terminals	3.5KV for 1 mnt				

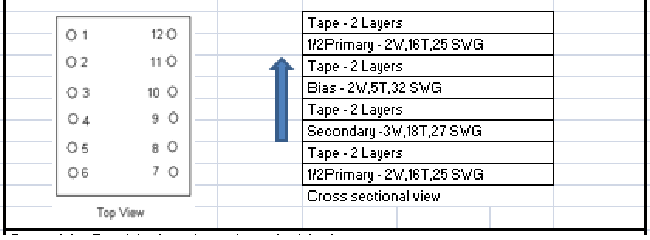

Figure 2. Transformer Specification sheet

- ***Digital Controller***

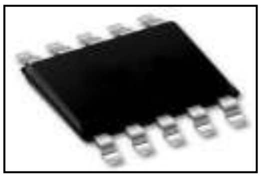

Figure 3. NCL30186 IC

The NCL30186 is a digital controller targeting isolated and non-isolated smart dimmable constant current LED drivers IC Designed to support fly-back, buck boost topologies. Its Proprietary current control algorithm provides unity power Factor and regulates a constant LED current from the primary side, and eliminates the need for a secondary side feedback Circuitry or an opto-coupler This IC is responsible for dimming Operation of driver. Pin no. 1 of IC is the dimming pin. The PWM signal from the dimming section is giving to this pin. Then as per program from the microcontroller the dimming is done by adjusting the output current of LED driver.

The circuit diagram shown in figure.4 is divided into following sections

- Input protection section
- Rectification section
- Controller section
- Transformer section
- Dimming section

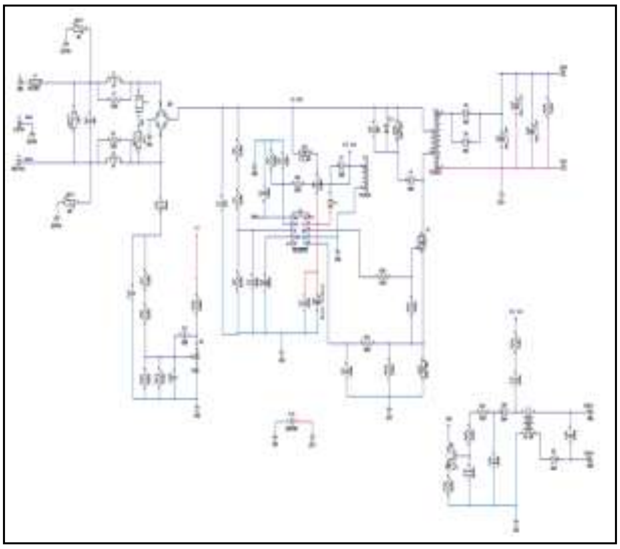

Figure 4. Circuit diagram of LED driver

- **Input protection section**

The objective of this section is to give 4KV surge protection to LED driver and to protect it for 440V double phase. This can be achieved by using MOV and GDT. The combination of MOV and GDT value helps to protect further circuitry part form high voltage spikes.

- **Rectification section**

This section functions as ac to dc convertor. The rectified output using voltage divider is fed to pin no. 9 of digital controller IC 30186.

- **Controller section**

The controller section is the brain of the LED driver and is responsible for proper operation of driver. The controller section performs switching activity, dimming activity and constant current regulation.

- **Transformer section**

The transformer section generates the voltage and current required to driver the load. The filter is used at output side to reduce the ripple content in the circuit. The auxiliary winding of transformer supplies the dc voltage to dimming section of driver.

- **Dimming Section**

The dimming section helps in dimming of output power by reducing the dc current in the circuit. The dimming concept used is PWM dimming. The required dimming levels are achieved by programming the microcontroller. The output of dimming section is given to dim pin of digital controller. The PWM dimming relies on the ability of the human eye to perceive pulsed light at fast rate, as the average light intensity. As the name suggest, the width of pulse determines the current and hence the brightness.

IV. RESULTS AND DISCUSSION

The dimming of LED driver is done by PWM PCB which have been designed to generate the dimming levels in LED driver. The PCB will be mounted on main PCB of LED driver. The dc supply to PWM PCB is given through the auxiliary pin 4 and 6 of transformer. The output of PWM PCB is Dim+ and Dim – pin given to the pin no. 1 of IC 30186. This Pin no. 1 is dimming pin of IC which dims the output of LED driver. In the absence of this PCB the driver will be operating in full load condition. Fig. 5 shows the PWM PCB mounted on LED driver PCB.

Figure 5. PWM dimming PCB

- ***Electrical Parameters of LED driver***

The Electrical parameter results of Energy efficient LED driver are shown in Table 1.

Table 1. Electrical parameter results of LED driver

Input Voltage	Input Current	Input Power	Power factor	ITHD
230 V	213mA	45.98 W	0.995	5.48%
Output Voltage	**Output Current**	**Output Power**	**Efficiency**	
49.0 V	884.0 mA	43.31 W	94.39%	

- **Calculations**

Efficiency Calculations:

Input Power (P_{ac}) - Input Voltage * Input Current * PF
Output Power (P_{dc}) - Output Voltage * Output Current
Driver Efficiency - P_{dc} / P_{ac}

Total Harmonic Distortion (THD) Calculations:

The method for measuring THD is to measure the amplitude of the fundamental frequency and each harmonic and then use those measurements to calculate THD. This measurements are done using THD analyzer.

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} V_{n\_rms}^2}}{V_{fund\_rms}}$$

- ***Dimming Results***

Table 2. Dimming level results of LED driver

Sr. no.	Dimming Percentage	Power(W)
1	20%	10
2	40%	18.5
3	60%	27.6
4	80%	36.8
5	100%	46

Table 3. Cost calculation of LED driver with respect to Energy consumed.

Energy Efficient LED Driver			COMPETITION	
Price of the Product	750.000	VS	Price of the Product	1350
Product Wattage (W)	45.98		Product Wattage (W)	46.56
Product KW	0.04598		Product KW	0.04656
Operation Hours per Day	11		Operation Hours per Day	11
Current Energy Tariff	₹8.80		Average Energy Tariff	₹8.80
Project Tenure in Years	1		Project Tenure in Years	1
Project Tenure in Days	365		Project Tenure in Days	365
Cost of Ownership =	₹2,374.57		Cost of Ownership =	₹2,995.06

Table 4. Case Study depending upon the results achieved

Product	Power	Luminous Flux	Efficacy	PF	Cost per piece	Working hours/Day	Rate of Energy(Rs.)
Competitor Street Light	47.38	7429	156.78	0.975	2850	11	8.8
Energy Efficient Street Light	46.11	7769.9	168.51	0.993	2250	11	8.8

- **Using 20 nos. Competitor street lights by competition, the total lumens that can be achieved = 20 nos. x 7429 Lm = 1, 48,580 Lm.**
  The total cost = 20 nos. x Rs. 2850 /- = 57,000
- **Using Energy Efficient LED street lights, to get a total lumens of 148580, only 19Street lights are required since the total lumens of Energy efficient Street light is much higher than that of competition. So 19 nos. x 7770 Lm = 1, 47,630 Lm.**
  The total cost = 19 nos. x Rs. 2250/- = 42750/-
- **So almost Rs.14250/- is saved using energy efficient LED driver for street light.**

V. CONCLUSION

This paper focuses on development of the LED driver circuit which helps in energy saving without involvement of any external peripherals such as sensors. Greater the efficiency of driver more energy will be saved. So the LED driver with 94% efficiency is developed to reduce the power loss. The LED driver perform better with pulse width modulated signals. The PWM dimming relies on the ability of the human eye to perceive pulsed light at fast rate, as the average light intensity. As the name suggest, the width of pulse determines the current and hence the brightness.The parameters such as Surge immunity, over-voltage protection under voltage protection are considered so that driver can be protected and be operating when an abnormal condition arises.

ACKNOWLEDGMENT

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