Reliability test of LED driven by PWM technique

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Abstract

The solar-powered LED lighting system has been commercialized for a long time. The system usually consists of a DC to DC converter in order to convert the battery voltage into a fixed voltage or current for the LED lighting luminaire. This will cause energy loss and system reliability due to the failure of DC/DC converter. In the present study, we develop a special technique to drive the LED luminaire directly from battery utilizing PWM technique in order to remove the DC/DC converter. However, instantaneous current overdriven can occur easily due to the variation of battery voltage with the state-of-charge of battery.

In the present study, we setup a thermal chamber with temperature variation to within 40±3°C. A LED luminaire was specially designed for the LED reliability test with four different circuits with each circuit connecting three LED lamps serially. A driver is designed to provide 4 kinds of power inputs to LED: (a) 350mA constant current, (b) 700mA, 100Hz, duty cycle=50%, (c) 700mA, 10K Hz duty cycle=50% and (d) 1050mA, 100Hz, duty cycle=33%. The tests were performed simultaneously to compare light decay between normal drive condition (a) and other PWM driving conditions (b, c, d). The accumulated total test time so far is more then 7,032 hours and has shown no significant light decay in 4 different loops. This reveals that the PWM technique directly driven by battery is feasible and is able to reduce energy loss of DC to DC converter in the solar lighting system.

Key words: LED Reliability test, LED driving technique, Solar-powered LED lighting system, DC current stress, pulse current stress

1. INTRODUCTION

The stand-alone-solar-powered lighting system must be properly designed in photovoltaic power generation capacity Wp, battery capacity C, and the power consumption, for obtaining a proper Lost of Load Probability (LLP) to deal with rainy and cloudy days [1]. A good charge/discharge strategy is also needed for assuring the system reliability [2]. This kind of solar-powered lighting system usually is installed in remote area where the grid power can not reach. It can save the power transmission line cost and has been shown that the stand-alone solar lighting system utilizing Light Emitting Diode (LED) as the light source can save energy with reasonable payback time in remote area [3]. The reason for utilizing LED is that the LED can have long lifetime (about 50,000 hours when properly driven) and can be driven by direct current (DC) from battery. But there is a problem for driving the LED directly from the battery. The battery voltage will change at different state of charge and it may damage the LED. Therefore, the stand-alone solar LED lighting system usually consist a DC/DC converter to convert the battery voltage into the LED driving voltage.
The DC/DC converter may solve the problem of the voltage variation but it also increases the system cost and reduce the system reliability due to additional component.

The LED can be driven by PWM driving technique to maintain an average current through LED which is acceptable. The LED bulbs can resist high current stress [5] which means the LED can be driven directly from battery by utilizing PWM technique. The present study focuses on reliability of LED luminaire using direct PWM driving technique.

2. RELIABILITY TEST DESIGN

The present study first setup a thermal chamber that is heated by two 100W tungsten lamps and uses two on/off controllers to control the chamber temperature to within 40±3°C. Fig.1 shows the design of the LED reliability test that is driven by the direct PWM technique. A LED luminaire was specially designed for this LED reliability test with four different circuits and each circuit connecting three LED lamps serially.

2.1 Special LED luminaire design

Fig.2 shows the aluminum PCB(Printed Circuit Board) and the special LED luminaire design. The aluminum PCB (74mm diameter) has 4 circuits (connecting 3 LEDs in series in each circuit). Each circuit was driven by different driver. A thermocouple was soldered on the middle of the aluminum PCB for measuring the temperature of the aluminum PCB. A heat conducting body was attached to the aluminum PCB to dissipate the heat of aluminum PCB. The LEDs were selected from the same product lot in a production line to reduce the variation of the thermal resistance in mass production. All LEDs were soldered on the aluminum PCB. Therefore, each LED on the aluminum
PCB has the same junction temperature. Fig.3 shows the installation of a photo sensor (S2387) to measure the intensity of the light from LEDs.

![Fig.2 The Aluminum PCB and special luminaire design](image)

Fig.3 Installation design for photo sensor

2.2 Thermal chamber

The size of the thermal chamber is 60x90x60 cm made by 3cm thickness styrofoam. The chamber was heated by two 100W tungsten lamps. There are two on/off controllers to control the chamber temperature. Fig.4 shows the design and the test arrangement of the thermal chamber. Two block boards were placed in front of the two 100W tungsten lamps to avoid heating the sensor of the on/off controller directly. Four thermocouples were placed at the same height and 10cm near the wall to measure the temperature distribution of the thermal chamber. Fig.5 shows the test result at four locations. The result shows that the thermal chamber can control the chamber temperature to within 40±3°C.

2.3 PWM Driver and Controller Design

A LED driver is designed to provide 4 kinds of power inputs to LED: (a) 350mA constant current, (b) 700mA, 10Hz, duty cycle=50%, (c) 700mA, 10K Hz duty cycle=50% and (d) 1050mA, 100Hz, duty cycle=33%. The tests were performed simultaneously to compare different light decay between normal drive condition (a) and other PWM drive condition (b, c, d).

The LED luminaire is put in the thermal chamber to accelerate the light decay of the LED by increasing the
ambient temperature. The power supply can provide a DC input to the driving controller then the driving controller can generate 4 different driving current which are list below to drive the LED.

(a) 350mA constant current:
   It is the most common way to drive the LED. This is the baseline of the LED lifetime.

(b) 700mA, Duty-Cycle=50%, PWM-Frequency=100 Hz
   In Case (b), the average current equal to 350mA but the current stress through the LED is two times greater then Case (a).

(c) 700mA, Duty-Cycle=50%, PWM-Frequency=10K Hz
   The average current equal to 350mA but the current through the LED is two times greater then Case (a) condition and the PWM-Frequency is 100 times greater then (b). This test intends to see the effect of frequency and the pulse stress.

(d) 1050mA, Duty-Cycle=33%, PWM-Frequency=100 Hz
   The average current equals to 350mA but the current through the LED is three times greater then Case (a).

Besides, a controller was designed using microprocessor to control the on/off for the different circuits of LEDs and measure the output of the photo sensor.
3. Test results

Fig. 6 shows the accumulated total test time so far is more than 7,032 hours and has shown no significant light decay in 4 different circuits. The aluminum PCB temperature shown in Fig.6 remains in 55±3°C.

4. Conclusion

The solar-powered LED lighting system usually consists of a DC to DC converter in order to convert the battery voltage into a fixed voltage or current for the LED luminaire input. This will cause energy loss and system reliability problem due to the failure of DC/DC converter.

In the present study, we drive the LED luminaire directly from battery utilizing PWM technique to remove the DC/DC converter. However, instantaneous current overdriven can occur easily due to the variation of battery voltage with the state-of-charge of battery. A LED luminaire was specially designed for the LED reliability test with four different circuits with each circuit connecting three LED lamps serially. A driver is designed to provide 4 kinds of power inputs to LED: (a) 350mA constant current, (b) 700mA, 100Hz, duty cycle=50%, (c) 700mA, 10K Hz duty cycle=50% and (d) 1050mA, 100Hz, duty cycle=33%. The tests were performed simultaneously to compare light decay between normal drive condition (a) and other PWM driving conditions (b, c, d). The accumulated total test time so far is more than 7,032 hours and has shown no significant light decay in 4 different loops. This reveals that the PWM technique directly driven by battery is feasible and is able to reduce energy loss of DC to DC converter in the solar lighting system.

![Fig.6 LED reliability test result](image-url)
5. Reference


Acknowledgement - The present study was supported by Energy Bureau, Ministry of Economic Affairs, Taiwan.