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DESIGN OF CASCADED AND PARALLEL DC-DC BUCK CONVERTER FOR LED DRIVER USING MATLAB/SIMULINK

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ABTRACT

Nowadays, LED has become an emerging technology due to lifetime, luminous efficacy, power rating, and color property. So it becomes an alternative light source to replace conventional light sources in various lighting and display applications. It finds application in television, laptops, advertising displays, computer displays and optical control purposes. The developments in the LEDs have initiated the scope in designing drivers with efficient control. The dc-dc converters which are used to generate bi-level current to improve the luminous efficacy of Light Emitting Diode (LED). Amplitude mode and Pulse Width Modulation (PWM) mode are the two conventional driving techniques used in LED drivers. Amplitude mode driving technique uses constant Direct Current (DC) to drive the LED and provides a higher luminous intensity but lacks in flexibility control. Besides, PWM mode driving technique uses a pulse of dc current having higher level and zero level. It provides more flexible dimming control and color stability, but it has low luminous intensity. The bi-level current driving technique which combines the advantages of the two conventional driving techniques is discussed. A parallel and cascaded buck dc-dc converter is designed to generate the bi-level current for LED. In this paper, Resistive load is used instead of LED. The performances of the converters and tested with the simulation using MATLAB/Simulink.

Key words: LED drivers, PWM, Bi-level current, Parallel and Cascaded Buck DC-DC converter

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1. INTRODUCTION

LEDs are highly energy efficient and are mostly used in different illumination applications. LEDs provide good lumen maintenance, longer operating lifetime and color rendering property when compared to fluorescent lamps [1],[2]. Besides, LEDs are mercury-free and can be safely disposed or recycled. Due to the very low operating voltage of LEDs, lamp drivers are relatively simple to design and more reliable due to less stresses on driver components compared to fluorescent lamps [4],[5],[6]. Strings of LEDs are normally connected in series and parallel to increase the luminous flux for various illumination applications. LED drivers are required to prove that the high-brightness LEDs operate at required DC voltages and current levels. The converters for driving LEDs are almost simple to design and more reliable due to less stresses on driver components.

Power converters based on Switched- mode are recommended for LED drivers due to flexibility of power conversion and the high efficiency of switching topologies.[7]. So LEDs are current-driven devices in which light is produced through the recombination of injected holes and electrons in a semiconductor junction, the luminous intensity of LEDs is controlled by controlling the forward current flowing through the LED. Because LEDs conduct current only in one direction, the previous method for driving LEDs is by using a constant dc. However, it is found that the peak emission wavelength of LEDs tend to shift with the forward current, which can lead to color variations at different luminosity levels. In order to get different luminosity level, the forward current flow through the LED must be varied continuously.

In this paper, an Optical characteristic of LED is presented in part II.Various LED driving techniques are presented in part III.Simulation model and results of the cascaded and parallel buck dc-dc converter to create bi-level current are presented in part IV.

2. OPTICAL CHARACTERISTICS OF LEDS

The basic definition of operating characteristics of LED as follows [1].

2.1 Illuminance

It is defined as the luminous flux per unit area falling on a surface; the unit is lumen per square meter (lm m^2) and is called a lux (lx), where luminous flux (measured in lumen) is a measure of the visual sensation produced by the radiation emitted by a source. Since any wavelength that falls outside the visible range 380 nm – 780 nm cannot be perceived by human eyes, the luminous flux then produced is zero.

2.2 Chromaticity

It is an objective specification of the quality of a color regardless of its luminance, that is, as determined by its hue and colourfulness (or saturation, chromaticity, intensity or excitation purity).

$$VS = if\ Rs + a * Vadj \tag{1}$$

2.3 Luminous efficacy

It is a measure of how well a light source produces visible light. It is the ratio of luminous flux to power. Depending on context, the power can be either the radiant flux of the source's output or it can be the total electric power consumed by the source.

2.4 Luminous intensity

Luminous intensityin a given direction is the luminous flux per unit solid angle. Luminous intensity can be influenced by the forward current and the junction temperature. In general, it has been experimentally observed that the luminous intensity of LEDs increase super-linearly with increasing forward current at low at currents.

3. LED DRIVING TECHNIQUES

There are two objectives to be satisfied while designing power electronic LED driver. First, the output of driver should be coordinated to the electrical characteristics of the LEDs. Second, at desired states the luminous intensity and chromaticity of LEDs should be controlled. There are two conventional driving techniques [2] currently used for LEDs, they are amplitude-mode (AM) driving technique and pulse- width modulation (PWM) driving technique. This work brings to provide astudy of the driving techniques for high-brightness LEDs, and the topologies of power converter and control algorithms used in requirements in different lighting a=

$$\frac{Rs}{Rs + R_{adj}} \quad (2)$$

The level of LED current i_f changes inversely proportional to the external control voltage V_{adj}, and the luminous intensity is varied by varying the LED current level. Because of the small dynamic resistance of LEDs, a small deviation of the output voltage of a converter from the desired value will produce a large variation in the LED current.

3.1 Driving Technique based on PWM-Mode

LED emit savery fast current-to-light response; this characteristic makes them to use pulsating driving current in a suitable manner. In PWM driving technique, the current flowing through the LED is periodically switched between a constant level and zero level at high frequencies. The luminous intensity is controlled by varying the duty cycle, which is the ratio of the time for which the device is ON to the switching period and hence the average forward current. Since the peak current level is kept constant during the switching, The dimming control of luminosity level is independent of the color; thus, the light chromaticity is improved [12]. The current given to the LEDs is controlled by varying the duty cycle. The PWM of the high level to the zero level current can be generated by a switch connected in series with the LED. With PWM driving, the average LED current is given by the equations (3), (4). applications.

$$I_f = D * I_f \quad (3)$$

3.2 Driving technique based onAmplitude-Mode

In this driving technique a constant DC current is supplied to the LED. The luminous output of LED depends upon the forward current flow through it [1]. Highly stable output voltage from the dc-dc converter is required to ensure a reliable control of the LED current. The average output current from the converter is based on input voltage; the accuracy of the output current value from the converter can be easily affected by the input and output voltage variations. This drawback can be overcome by using a current controlled dc-dc converter.This is to provide the desired average current to LED. The current regulation is achieved by continuously sensing the LED current using resistor Rs and the voltage controller that vary the output voltage of the converter to a value that supplies the required current. In order to control the output current at different levels, an external voltage Vadj is used for varying the voltage across Rs. The magnitude of the voltage across Rs is related to if and Vadj by the following equations (1) and (2). is the average forward current, Dis the duty cycle, ton and Tare the turn on time and the switching period of switch respectively. In PWM driving technique, a linear relationship of the LED is achieved from the luminous flux emitted from the LED and the average current (and duty cycle) is obtained. The PWM driving technique provides an easier dimming function and higher colour stability [7]. But, the LEDs driven by AM always provide higher luminous efficacy than PWM driving technique due to the efficiency droop effect at high current levels.

3.3 Comparison between Amplitude and Pulse width modulation Drivers

Therefore, these methods are mainly suitable for LCD backlighting applications. Based on study, which LEDs driven by AM always provides higher luminous efficacy than driven by

PWM [11]. For a given luminous intensity, In AM driver, it requiresonly less electrical power for LEDs and also that when operating the LEDs in PWM mode it leads to early degradation of the optical output with time and shortens the lifetime of the devices. From this one can say that the reliability of LEDs is highly sensitive to the peak current level; so the more suitable for maintaining the reliability of LEDs is AM driving technique. That's why the AM driving technique is popular for constant illumination due to the ease of implementation and high efficacy. However, by providing better chromaticity[10] and dimming flexibility, the PWM driving technique is more suitable selection.

3.4 Bi-level current Driving Technique

In the bi-level current driving technique, the driving and control of LEDs can be improved by using the advantage of improved illuminance by introducing a DC component into the PWM current while maintaining its control flexibility, where both current levels and the duty cycle can be used as control parameters.Paralleland cascaded buck dc-dc converter is used to create bi-level current.

4. IMULATION AND RESULTS

The bi-level current driving technique, it uses the advantages of AM and PWM driving techniques. It is achieved by applying a DC component into the PWM current while maintaining its control flexibility, where both current levels and the duty cycle can be used as control parameters. The following converters are used to produce the bi-level current.

- Cascaded DC-DC buck Converter
- Parallel DC-DC buck Converter

4.1 Cascaded DC-DC buck converter

This converter consists of two voltages are independent from the converters (converter1 and converter 2) each supplying the required voltage (hence load current) level and alternately supplying to the LED The Fig.1 shows the Basic Structure of LED Drivers based on Cascaded DC–DC buck Converter.

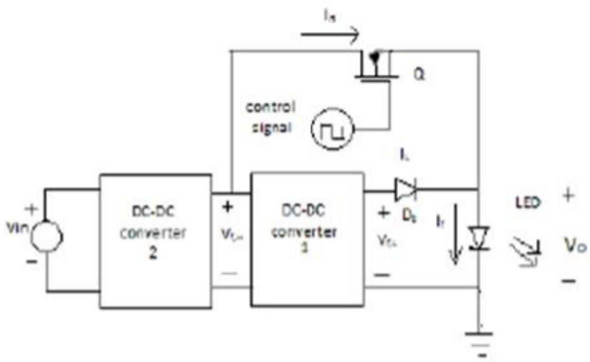

Figure 1 LED Driver Based on Cascaded buck DC–DC Converter

In this case, the output voltage (or current) from converter 2 is always higher than that of converter 1 so as to generate a bi- level current. Since the two converters are connected to the same supply source, the same converter topology is normally used[9]. In this the high level voltage 3.65 V produced converter 2 at that time the series connected diode is reverse biased so the diode does not conduct hence high level voltage appears across the load resistor. When the series connected MOSFET switch is turned off and diode is forward biased and turned on, then the converter1 low level output voltage 2.95 V appears across the load. So that the cascaded dc-

dc converter is used to deliver the two different output voltages alternately to the LED. Figure 2 represents the MATLAB Simulation model of cascaded dc-dc buck converter.

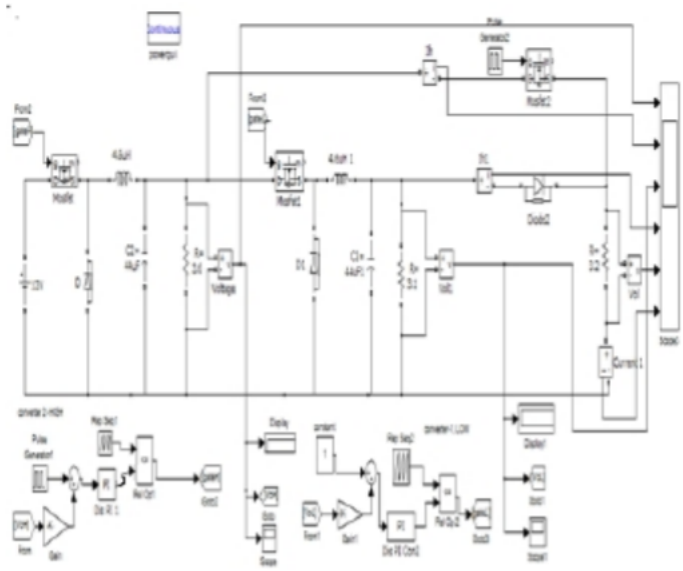

Figure 2 MATLAB Simulation model of Cascaded dc-dc converter

A 12V DC source has been used in the odel. A series R- load 0f 3.65 Ω is used. The converter consists of two DC-DC Converters namely High level converter bridge which is used to produce the output voltage of 3.65 V. The second converter named as Low level Converter is used to produce the output voltage of 2.95 V. MOSFET is used as a controllable switch which is used in the converter. The switching frequency of the converter switch is 500 kHz. The switching frequency of PWM current waveform is 400 Hz.

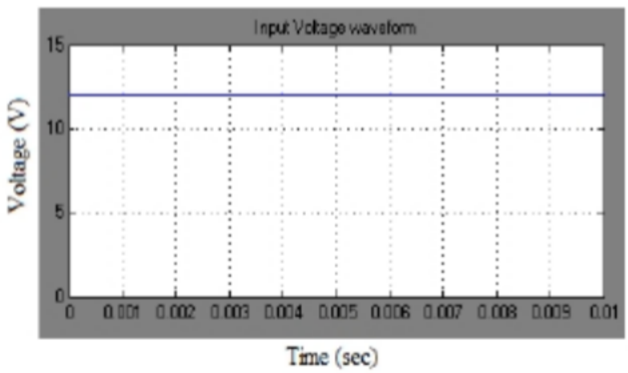

Figure 3 Input voltage of the Cascaded dc-dc converter

Fig 3 shows input voltage waveform of the cascaded dc-dc converter. The low level converter can be operated in Amplitude mode and it produces the output voltage of 2.95 V, which is shown in fig 4. Fig 5 represents the output voltage waveform of High level converter, which can be operated in Pulse Width Modulation mode and it produces the output voltage of 3.65 V The bi-level output voltage of cascaded dc- dc converter is shown in figure 6.

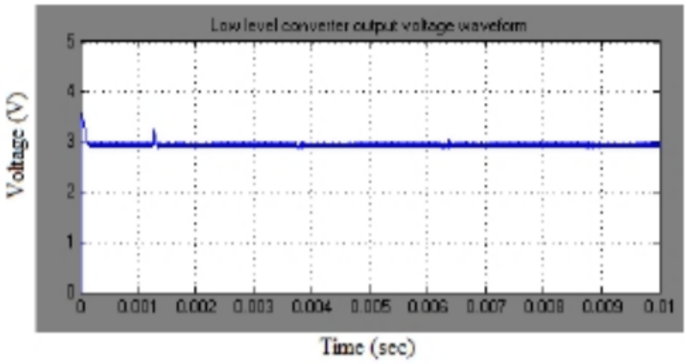

Figure 4 Output voltage of cascaded low level dc-dc converter

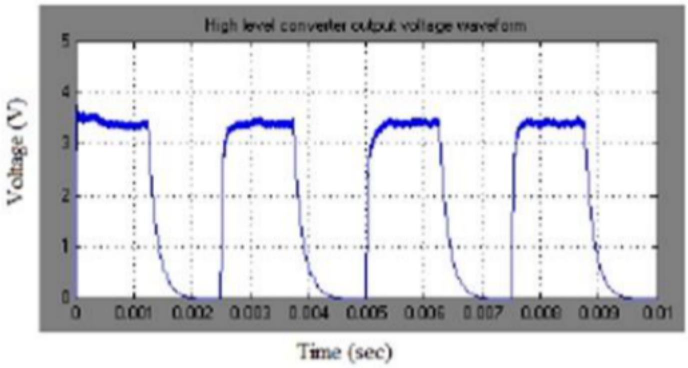

Figure 5 Output voltage of cascaded High level dc-dc converter

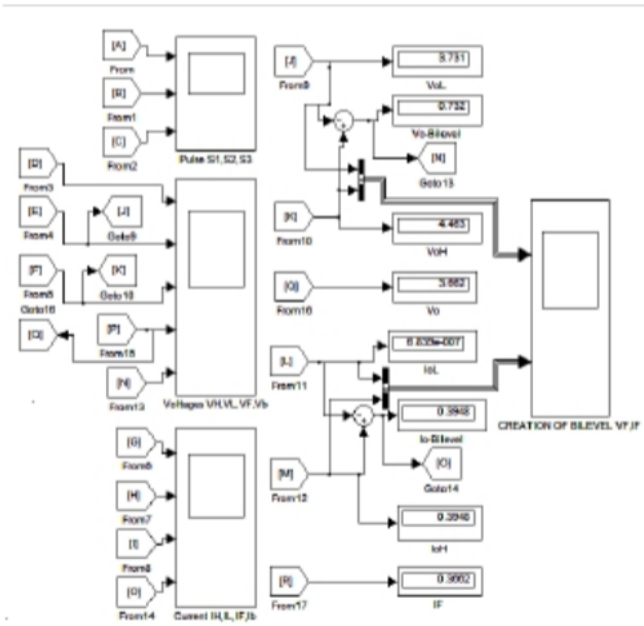

Figure 6 Output Bi-level voltage of cascaded dc-dc converter

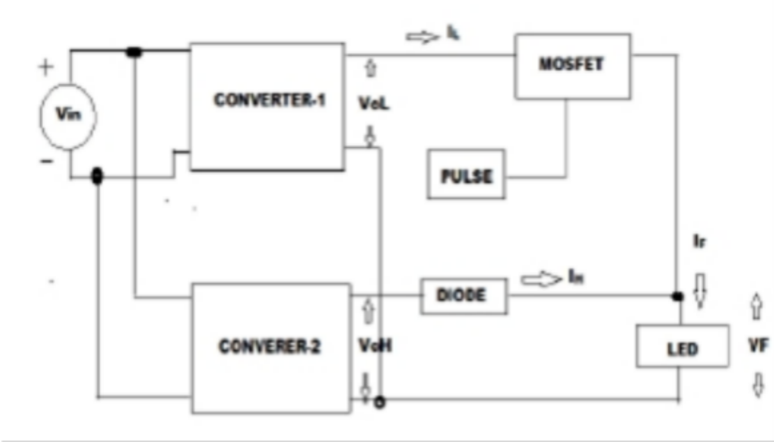

Figure 7 Output bi-level current of cascaded dc-dc converter

Fig.7 shows the bi-level output current waveform of Cascaded dc-dc converter having the duty cycle ratio of 0.5. The luminous intensity of LED is strongly depends upon the forward current flowing through it [8]. The luminous output of LED is increased by using this bi-level current driving technique. Generally the average current or forward current flow through the LED is given by

$$If = DIH + 1 - D\ IL \quad (5)$$

The average current can be varied by varying the duty cycle ratio (D) and the magnitude of current level. Here the higher current level is maintained at 1000 mA and lower current level is raised from zero under bilevel current driving technique. Parallel DC-DC converter The Fig.8 shows the Basic Structure of LED Drivers based on Parallel buck DC–DC Converters.

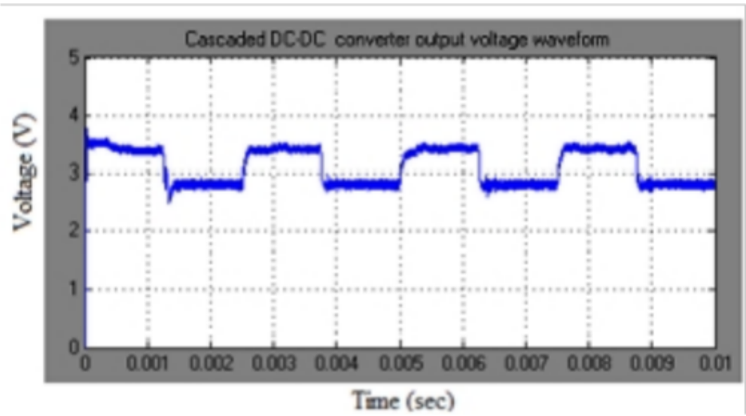

Figure 8 LED Driver Based on Parallel buck DC–DC Converters

The Fig.8 shows the Basic Structure of LED Drivers based on Parallel buck DC–DC Converters. converters (converter1 and converter 2) each supplying the required voltage (hence load current) level and alternately supplying to the LED.

The simulation model and the output results are verified using MATLAB/simulink. The simulation model of parallel buck dc-dc converter using MATLAB/simulink is shown in the fig.9. The simulation model of output block of parallel buck converters using MATLAB/simulink is shown in the fig.10. d1=0.25, d2=0.25 and d3=0.25 at a switching frequency of 500 KHz for switches S1, S2 and S3 respectively. The specifications of the parallel buck dc-dc converter as follows, the Input voltage (Vin)=12V,Converter1output voltage(VOH)=4.46V,and the Converter2 output voltage (VOL)=3.73V,Bilevel output voltage(VF)=3.66V, Converter1 output current (IOH) =0.3948A , Converter 2 output current(IOL)=0.00068A,Bileveloutput current(IF)=0.3662A

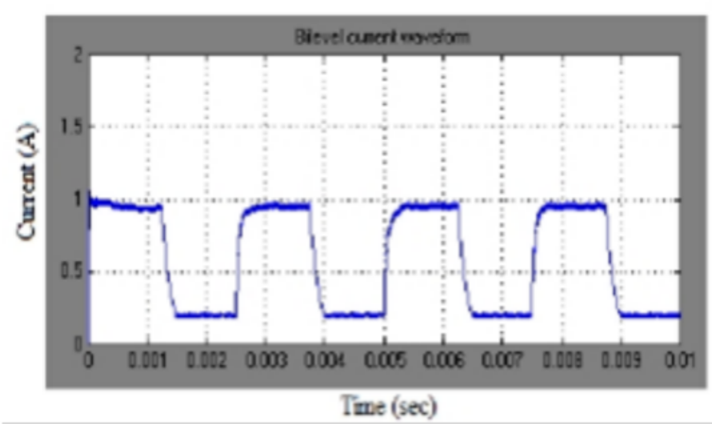

Figure 9 Simulation model of parallel buck dc-dc converter using MATLAB

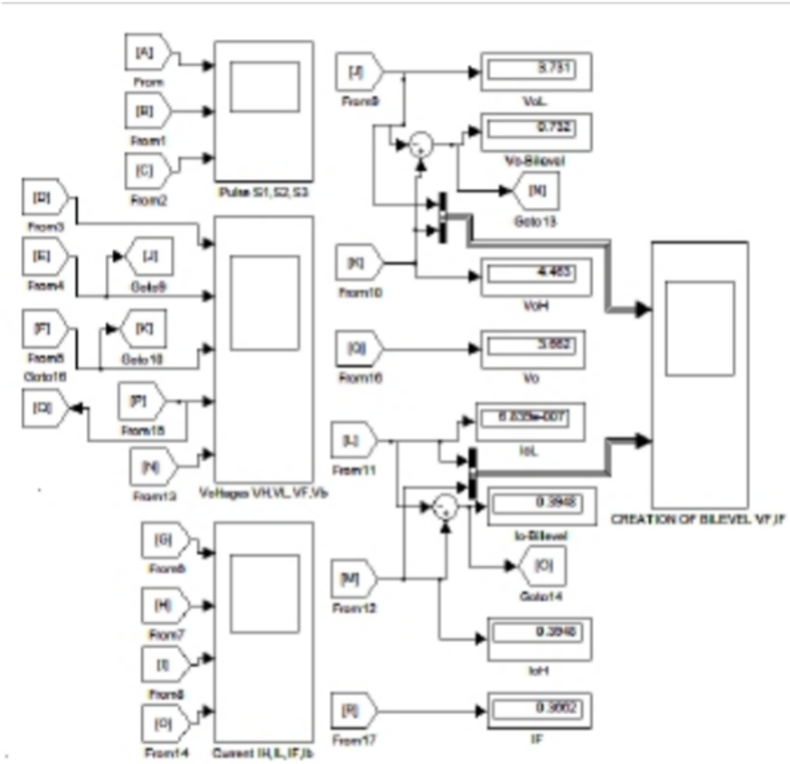

Figure 10 Simulation model of output blocks of parallel buck dc-dc converter using MATLAB

The switching signals for Switches S1,S2 and S3 of parallel buck dc-dc converters using MATLAB/simulink is shown in the fig.11.Each switching signal has same duty ratio but phase shifted by an angle 120 degrees. Pulse width modulation technique is used in this converter.

The simulation results of converter1 output voltage, converter 2 output voltage, bi-level output voltage and difference between the output voltage of the both the converters are shown in the fig.12.

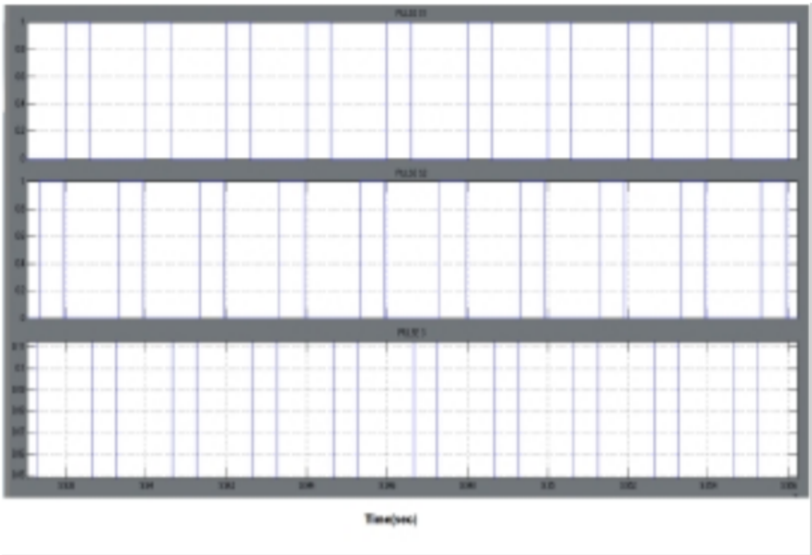

Figure 11 Switching signals of parallel buck converter using MATLAB

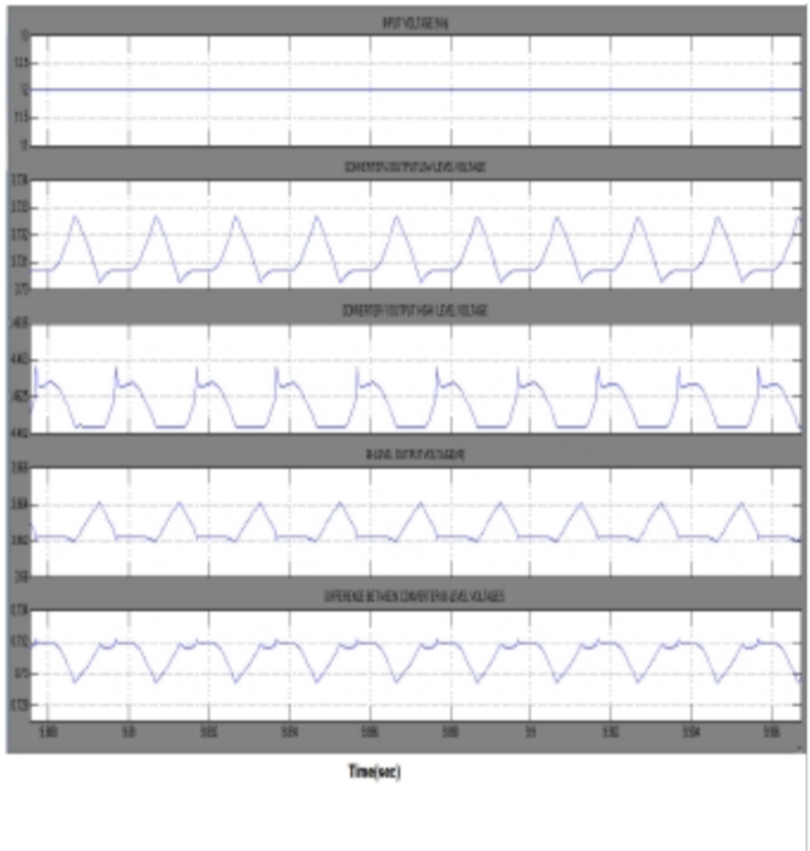

Figure 12 Simulation results of Output voltages of parallel buck converter using MATLAB

The values of inductance and capacitance are L=100 µH and C=88 µF were used for the converter.The duty ratios are The simulation results of converter1 output current, converter 2 output current,bi-level output current and difference between the output current of the both the converters are shown in the fig.13.

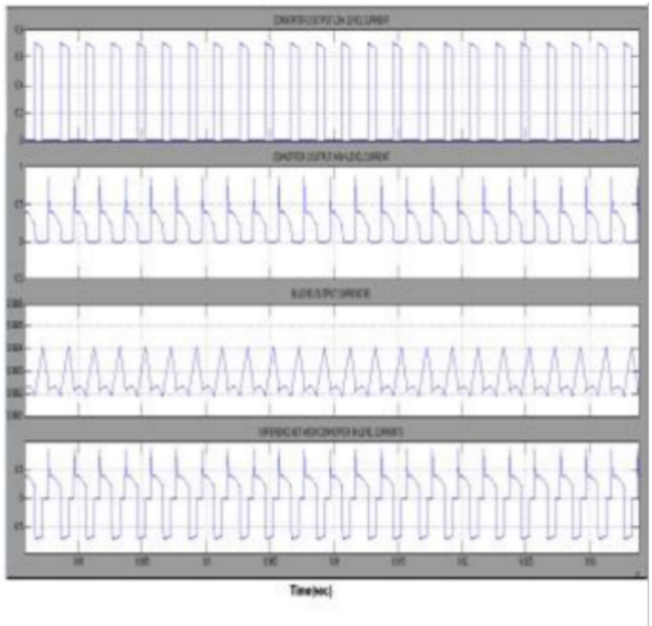

Figure 13 Simulation results of Output current of parallel buck converter using MATLAB

The simulation results of creation of bi-level output voltage and current of parallel buck converters are shown in the fig.14

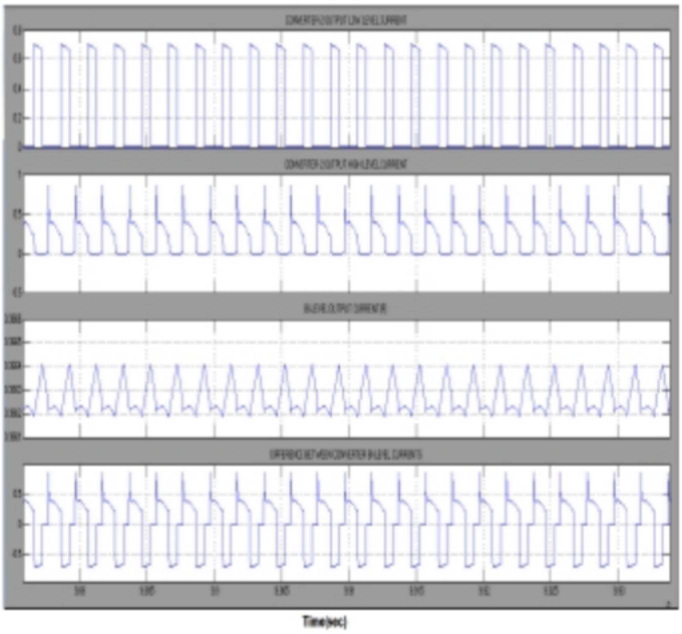

Figure 14 Simulation results of creation of bi-level voltage and current of parallel buck converter using MATLAB

Therefore, with the bilevel current driving technique, the driving and control of LEDs can be improved by simultaneously using the advantage of improved illuminance by introducing a dc component into the PWM current while maintaining its control flexibility where both current levels and the duty cycle can be used as control parameters.

5. CONCLUSION

The bi-level current driving technique has been discussed by combining the conventional Amplitude Modulation and Pulse Width Modulation driving technique to control the forward current of LED. It has been studied that the optical performance of LEDs is strongly dependent on the amplitude of the applied forward current. A parallel and cascaded buck DC-DC converter is designed for switching two voltages to generate bi-level current. The performances of the parallel and cascaded buck dc-dc converter are tested with resistive load instead of LED using MATLAB/simulink.

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