IJMTST | Volume: 2 | Issue: 03 | March 2016 | ISSN: 2455-3778

# PV –Fed Led Lighting Systems

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## ABSTRACT

*This paper discusses the principle of operation, dynamic modeling, and control design for light-to-light (LtL) systems, whose aim is to directly convert the sun irradiation into artificial light. The system discussed in this paper is composed by a photo- voltaic (PV) panel, an LED array, a dc–dc converter dedicated to the maximum power point tracking of the PV panel and a dc–dc converter dedicated to drive the LEDs array. A system controller is also included, whose goal is to ensure the matching between the maximum available PV power and the LED power by means of a low-frequency LEDs dimming. An experimental design example is discussed to illustrate the functionalities of the LtL system.*

**KEYWORDS:** *PVArray, LED Array, MPPT, dc-dc converter*



## I. Introduction

Today's literature is rich of discussions and proposals regarding methods and techniques for increasing the energy efficiency of photovoltaic (PV) and LED lighting systems [1]–[24]. Most of them refer to maximum power point tracking (MPPT) optimization [1]–[10] and to systems solutions where the energy is extracted from PV source, then stored into a battery or injected into the grid and finally taken back to feed the load. Several architectures [15]–[24], aimed at compacting the power converters for energy flow management, are discussed. Mostly, these architectures allow a minimization of power devices based on the sequential separation of energy flows from PV source to batteries and from batteries to LEDs. This fits the needs of applications like night street lighting. How- ever, there are emerging applications where direct conversion of sunlight into artificial light can be used (in the following, light-to-light (LtL) conversion), like high-energy-efficient pho- tocatalytic reactors [28]. In such applications UV radiation is needed, which can be generated by means of UV LED. These can be directly powered by a PV source as the variability of the sun radiation is not an issue, rather maximum energy harvesting is preferable to feed photocatalytic reactors with minimum energy consumption, especially in remote large outdoor plants for water treatment. Instantaneous matching between the power extracted from the source and the power absorbed by the LED load is then needed to realize maximum efficiency operation. Other possible applications of direct LtL conversion are in out- door LED displays, where higher LED emission is convenient when sun irradiation is higher: light intensity can be boosted beyond a fixed base level thanks to the direct LtL conversion, thus reducing energy consumption and energy efficiency. This paper is aimed at discussing fundamental issues regard- ing analysis and control design of a LtL system composed by a PV panel, a LED array, a dc–dc converter dedicated to the MPPT of the PV panel and a dc–dc converter dedicated to driving the LEDs array. A controller is included in the system, whose goal is to ensure the matching between the available maximum PV power and the power sought by LEDs array, by means of a low frequency LED driver dimming. Section II illustrates the system architecture and the overall principle of operation of main sub- systems. In Section III, the models and the techniques adopted for system design are illustrated. Section IV presents the results regarding the operation of the proposed design example, including experimental verifications.

## II. Light Emitting Diode (LED)

A Light emitting diode (LED) is essentially a p - n junction diode. When carriers are injected across a forward-biased junction, it emits incoherent light. Most of the commercial LEDs are realized using a highly doped n and a p Junction.

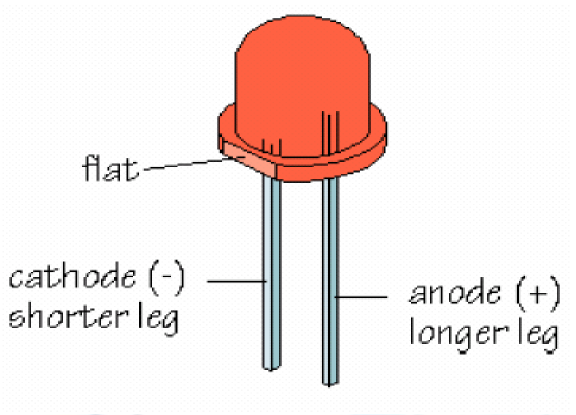


**Fig : 1 LED SHAPE**

The LED structure plays a crucial role in emitting light from the LED surface. The LEDs are structured to ensure most of the recombination s takes place on the surface by the following two ways.

By increasing the doping concentration of the substrate, so that additional free minority charge carriers' electrons move to the top, recombine and emit light at the surface.

By increasing the diffusion length $L = \sqrt{\tau}$ , where D is the diffusion coefficient and $\tau$ is the carrier life time. But when increased beyond a critical length there is a chance of re-absorption of the photons into the device.

The LED has to be structured so that the photons generated from the device are emitted without being reabsorbed. One solution is to make the p layer on the top thin, enough to create a depletion layer. Following picture shows the layered structure. There are different ways to structure the dome for efficient emitting.

A very important metric of an LED is the external quantum efficiency $\eta$ ext. It quantifies the efficiency of the conversion of electrical energy into emitted optical energy. It is defined as the light output divided by the electrical input power. It is also defined as the product of internal radioactive efficiency and Extraction efficiency. H ext= P out (optical) / IV For indirect band gap semiconductors $\eta$ ext is generally less than 1%, whereas for a direct band gap material it could be substantial. H int = rate of radiation recombination/ Total recombination

### A. Inside a Light Emitting Diode

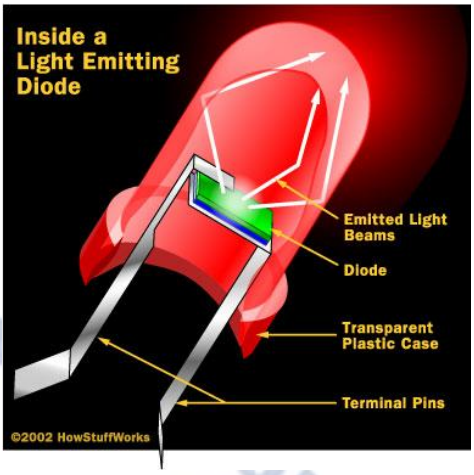


**Fig: 2 Inside a light emitting diode**

1. Transparent Plastic Case
2. Terminal Pins
3. Diode

### B. How to Connect a LED:-

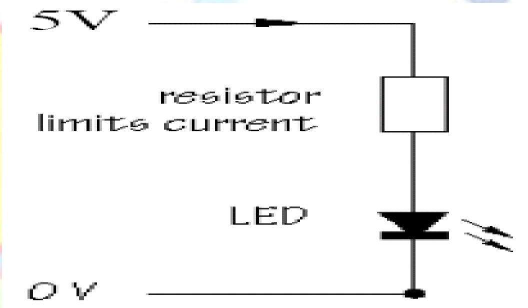


**Fig: 3 inside a light emitting diode**

- Requires 1.5~2.5V and 10 m A
- To prevent overloading, use resistor 470 Ω
- LEDs are solid state semiconductor devices.

LED illumination is achieved when a semiconductor crystal is excited so that it directly produces visible light in a desired wavelength range (color). LED units are small, typically 5mm

## III. Method of Operation

When an LED unit is activated, a power supply converts AC voltage into sufficient DC voltage, which is applied across the diode semiconductor crystal. This results in electrons (negative charge carriers [N]) in the diode's electron transport layer and holes (positive charge carriers [P]) in the diode's hole transport layer combining at the P-N junction and converting their excess energy into light.

**Advantages:-**

- Energy efficient - LED's are now capable of outputting 135 lumens/watt

- Long Lifetime - 50,000 hours or more if properly engineered
- Rugged - LED's are also called "Solid State Lighting (SSL) as they are made of solid material with no filament or tube or bulb to break
- No warm-up period - LED's light instantly – in nanoseconds
- Not affected by cold temperatures - LED's "like" low temperatures and will startup even in subzero weather
- Directional - With LED's you can direct the light where you want it, thus no light is wasted.
- Environmentally friendly - LED's contain no mercury or other hazardous substances
- Controllable - LED's can be controlled for brightness and color

## IV. Experimental Verification

The lighting system with PV, 5 level inverter, step up transformer rectifier and filter are shown in Figure 8. Here the frequency of 5 level inverter is controlled according to the ambient light sensed by LDR .This frequency change with change in ambient light will control the brightness of LED. The proposed system is tested by building hardware. The 5 level inverter output is shown in Figure

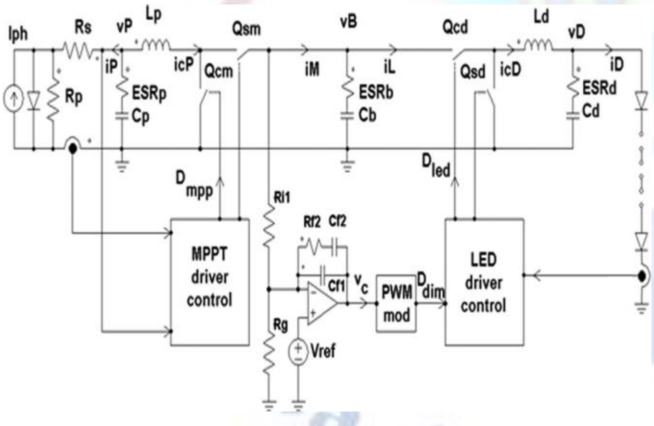


Fig 4: Light-to-light system

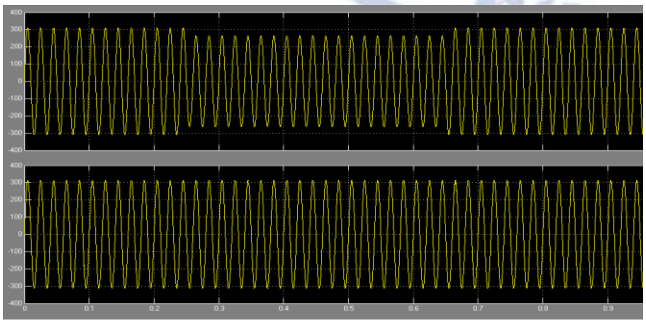

Fig 5: Model of single phase photovoltaic system

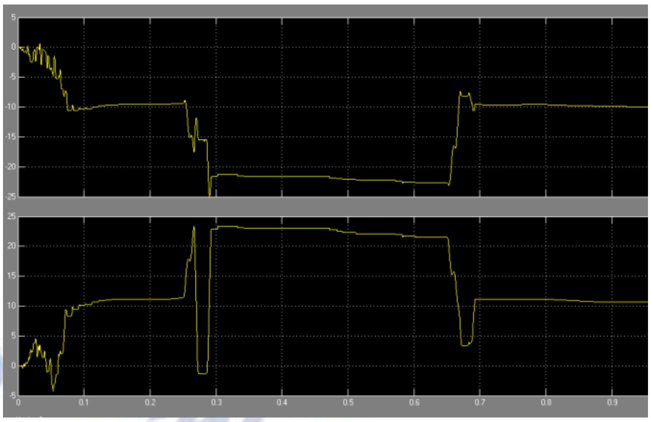

Fig 6: Active and reactive power provided by the shunt-connected multifunctional converter to compensate the voltage sag of 0.15 Pu.

The proposed system was built, the prototype is shown in Figure 4. A 10W PV is used and the frequency control is done by using 89C51 and multilevel inverter. Inverter output is shown in Figure 5.LED current and voltage waveform for 10W, 300mA LED is shown in Figure 7 and Figure 8. Figure 6 shows output current waveform which is about 2 % of rated LED current. Figure 5 shows the output current waveform which is about 90% of rated LED current.

Fig 7: Experimental setup

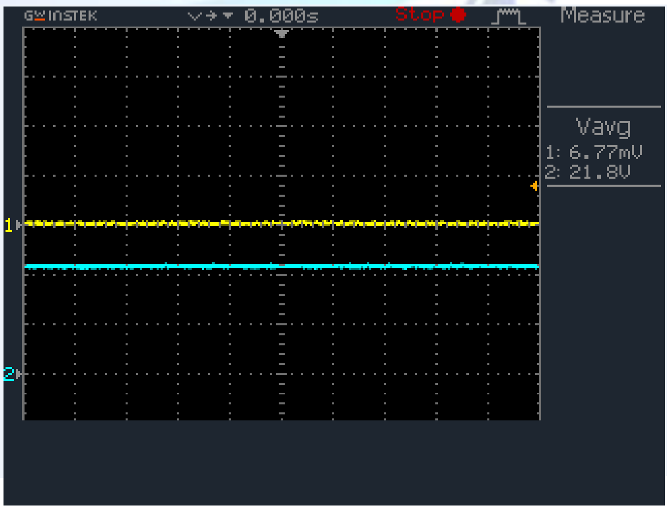


Fig 8 LED current , 6.77 m A

## V. Conclusion

In this paper, modeling issues and design guidelines for LtL systems in which the sun irradiation is directly converted into artificial light have been discussed. The LtL system investigated in this paper is composed by a PV panel, a LED array, a dc–dc MPPT converter, and a dc–dc converter dedicated to driving the LEDs array. Using the dynamic model presented in the paper, a system matching the power extracted from the PV source and the power absorbed by the LED array, by means of a low- frequency dimming driven by a suitable controller, can been designed. A numerical example has been discussed to highlight the fundamental gain functions and related constraints to be adopted in the control system design. An experimental prototype has been designed and realized to prove the functionality of the LtL system. Experimental results obtained by means of the LtL prototype system show the correct operation and the stability of the BVC in the presence of sudden sun irradiance variations. Future evolution of this paper is aimed at a full digital integrated implementation of the MPPT, LED driver, and bulk voltage controls by means of a unique microcontroller.

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