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Optimal Feedback Control Based Power LED Lamp for Photovoltaic Applications

Kavyashree. D
Department of Electrical and Electronics Engg.
Dayananda Sagar College of Engineering
Bangalore,INDIA

K. Shanmukha Sundar
Department of Electrical and Electronics Engg.
Dayananda Sagar College of Engineering
Bangalore,INDIA

Abstract: **For the past few years we have observed that there is a growth in lighting technologies; today LED lighting is one of the most energy efficient and fast growing lighting technologies. LED lighting is currently available in wide variety home appliances and industrial products and their use increasing every year. This project based on power LEDs with optimal feedback control for photovoltaic applications. This system gives improved energy efficiency and longer useful life when replacing other lighting source. Buck and boost type of converters used to supply the LEDs. LEDs are supplied by source and charge the battery through buck converter. In emergency condition, means solar power is not available the LEDs are supplied by battery through boost converter. The main aim is to reduce the switching losses thereby increasing the reliability of the system by implementing optimal feedback control loop. It also reduces the size and cost. The emergency lighting system follows the Brazilian and International standards. A MATLAB/ Simulink tool used to perform simulation studies on the developed model.**

Key words: - Photovoltaic system, buck converter, boost converter, main sensor, Light emitting diode (LED) Lamp.

I. INTRODUCTION

Lighting includes the use of both artificial light sources like lamps as well as natural light source by daylight. The natural lighting saves energy in place of using artificial lighting but it is not available all the time. The first commercial lamp which was introduced in the year of 1879. Currently artificial lighting is present everywhere either indoor, such as houses, commercial buildings, or in outdoor environments, such as parks, highways. It provides safety, comfort and stimulates physical activities.

The incandescent lamps are widely used in residential lighting nowadays, and have low efficiency [1]. Therefore, replacement of these lamps with compact fluorescent lamps (CFLs) has been an alternative in reducing the energy consumption since the efficiency of CFLs is higher than the efficiency of incandescent lamps [2]-[4]. As compared to fluorescent luminaries LEDs boost high system efficiency even at low ambient temperature. Advancement in the LEDs because of their advantages.

Light-emitting diodes (LEDs) are semiconductor devices that are introduced around 1960s. First, LEDs were used for indication, but the development of more powerful LEDs with high luminous efficiency made possible their use in lighting. These devices cannot be connected directly to the mains because they work with dc voltage and their current must be limited. Therefore, a driver is necessary to regulate the voltage and to control the current through the LEDs in order to supply the lamp. Buck, boost, buck-boost, flyback converters are widely used to supply discharge lamps [2], [5]-[9].These converters are also used to supply LEDs [10]-[13]. LEDs has other important advantages including lifetimes measured in tens of thousands of hours, ruggedness, environmental friendliness, compact size, low operating voltages, and cool operation. Their small size allows design flexibility in the control. It helps in conservation of energy.

The objective is to develop a compact LED- based lamp to replace CFLs and incandescent lamps for photovoltaic applications. The power generation is by using Photovoltaic cells. Furthermore an emergency lighting system and an optimal feedback control is introduced to reduce the switching losses and improve the efficiency of the system.

II. CHARACTERISTICS AND APPLICATIONS OF LEDS

The luminous intensity obtained from the LEDs are increasing every year, due to the advanced research in this technology. The efficiency and also the life of LEDs are greater than incandescent and fluorescent lamps. The light generation does not depend on filament or gas. So they produce less heat and require less voltage for ignition.

Nowadays LEDs not only used in domestic applications but also in advertising, automotives, traffic signals and camera flashing.

III. PROPOSED SYSTEM

The block diagram of the proposed system is shown in Fig.3.1.

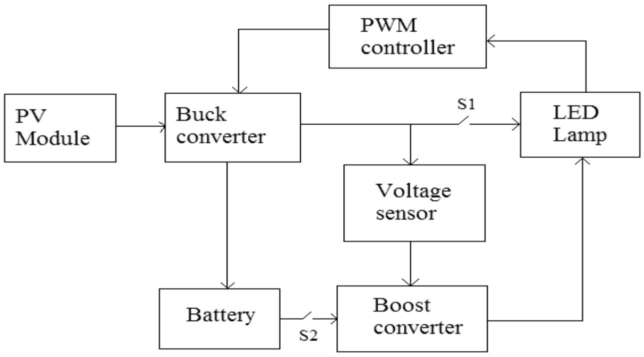

Fig.3.1: Block diagram of proposed system

The system consists of PV module, two converters, battery, mains voltage sensor, switches and LED array. The PV module converts solar energy into electrical energy based on photovoltaic effect. The PV module in turn connected to buck converter which supplies dc power. Buck converter used to supply power to LED as well as to charge the battery. The voltage sensor circuit is used to measure the buck converter voltage in order to enable or disable the boost converter. When the buck converter voltages is not proper or zero the sensor enables the boost converter in order to supply LEDs through battery. The solar energy is not available all the time so in those time the lamp supplied by battery through a boost converter. The PWM controller block is to control the output voltage across the LED lamp. The external switches S1 and S2 helps to enable the LEDs in different conditions. There are two modes of operation normal (LEDs supplied by source) and emergency mode (LEDs supplied by battery).

A. PV MODULE

PV module is a group of solar cells. These solar cells convert light energy directly into electricity. The equivalent circuit of solar cell is shown in Fig.3.2

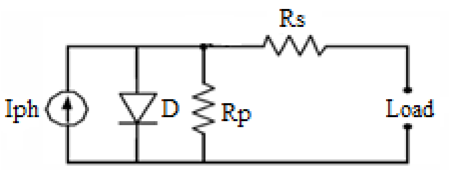

Fig.3.2: Equivalent circuit for solar cell

The Fig.3.2.shows a single solar cell represented by resistance Rs connected in series with the parallel combination of current source, diode and parallel resistance Rp.

By applying Kirchoff's current law, we get

$$I_{ph} = I_d + I_{Rp} + I$$

$$I = I_{ph} - (I_d + I_{Rp})$$

The PV cell output current is given by the following equation

$$I = I_{ph} - (I_d[e(V + I^*R_s / V_T) - l] + (V + I^*R_s/R_p))$$

Where I_{ph} is the solar induced current, I is the cell current, I_d is the saturation current of diode, V is cell voltage, V_T is the thermal voltage, Rs is the series resistance and Rp is the parallel resistance.

B. MODES OF OPERATION

There are two modes of operation namely

- Normal mode
- Emergency mode

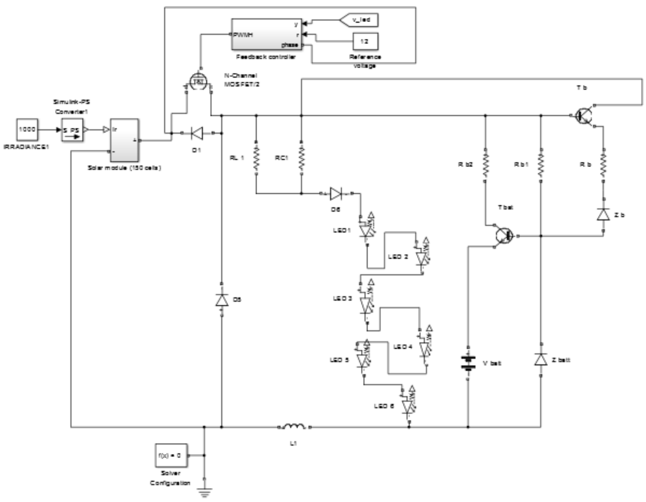

Fig.3.3: Normal mode of operation

The Fig.3.3 shows the normal mode of operation. In the normal mode of operation the LEDs are supplied by source and also it charges the battery. When the PV voltage is available then the buck converter presents an output voltage which is less than the input voltage in order to supply load and to charge the battery. The LEDs are supplied with higher power when it is operated in normal mode.

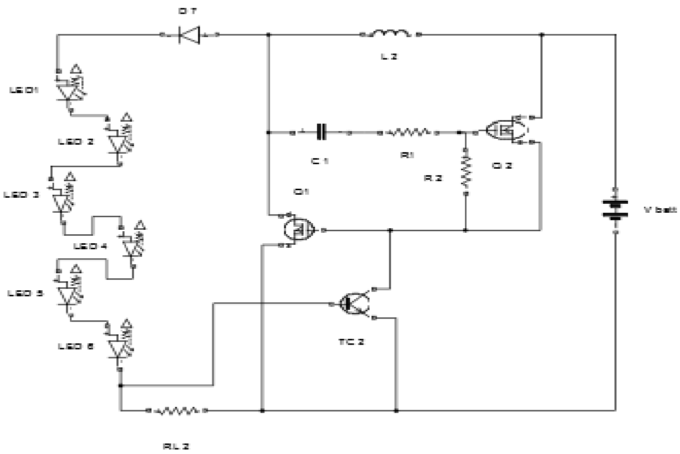

Fig.3.4: Emergency mode of operation

Fig.3.4. shows the LEDs operating in emergency mode of operation. This mode is essential because the source (PV module) doesn't provide energy all the times. So that the LEDs switches in to the emergency mode during this condition such that the LEDs supplied by battery through boost converter. In this mode of operation the LEDs supplied with reduced power.

C. A VOLTAGE SENSOR

The sensor circuit is there in between the converters in order to track the source voltage and to enable the boost converter. While the PV is supplying the lamp, the buck converter presents an output voltage. Therefore voltage sensor turning off the boost converter.

When the PV is not providing power (during night times), the buck converter output voltage decreases and this is tracked by voltage sensor and it enables the boost converter in order to supply LED lamp.

D. LED STRING

The group of LEDs is required in order to illuminate an environment like incandescent lamp. The LEDs can be arranged in different ways: series, parallel and series-parallel combination.

The series connection of LEDs has advantage like it maintains same brightness since its luminous intensity is directly proportional to its current. In parallel and series-parallel combination of LEDs involve some complexity of voltage and current control. As the result difference in luminous intensity can occur.

In proposed system the load is composed of six LEDs in series. Here the brightness of LED lamp increased to higher level when it is operated in normal mode and to a lower level when it is operated in emergency mode. The variation of luminous intensity does not exceed the ratio of 1:20 between two modes.

E. SWITCHES S1 AND S2

The switch S1 is used to supply LEDs by PV source and it remains in on state in order to charge battery at any time. Switch S2 is to enable or disable the boost converter when desired. So the battery energy can be used safely in other conditions.

The Fig.3.5.shows the proposed circuit including solar module, Buck stage, Boost stage, voltage sensor and LED lamp.

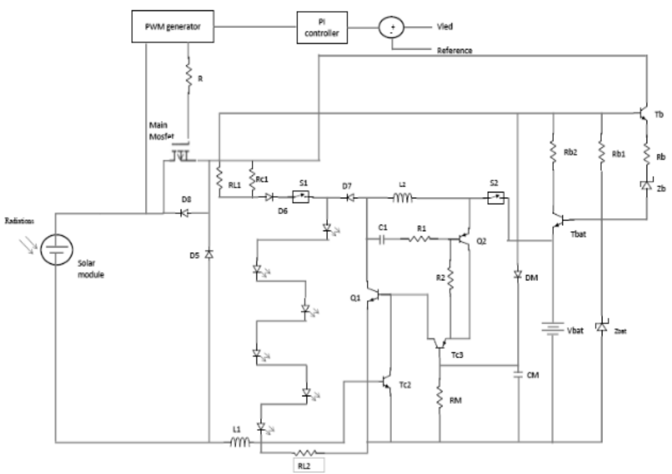

Fig.3.5. Proposed circuit

IV. SIMULATION AND RESULTS

A. Factors affecting the PV output power

Solar cell is a device that converts light energy into electrical energy which is made of semiconductors and solid state devices. The power output of single solar cell is usually small that is 1W or less. However these cells are connected together to generate greater output power. The solar power output depends on various parameters such as solar radiation, terminal voltage and temperature etc. So that it is very difficult to obtain maximum power output.

The output characteristics of photovoltaic cells vary with different irradiations and environment temperatures.

a. Output power under different irradiance

Under standard temperature T = 25℃. The terminal voltage is 90V.

Irradiation	Output Power across load
Irradiation =1000	Power output =V*I = 2.25 W
Irradiation =800	P = 2.19 W
Irradiation =600	P = 2.14 W
Irradiation =400	P = 2.06 W
Irradiation =200	P = 1.19 W

Table. I

The table I shows the variation of irradiance is directly proportional to power output. For the same temperature level, the power P increased with increase in irradiation level.

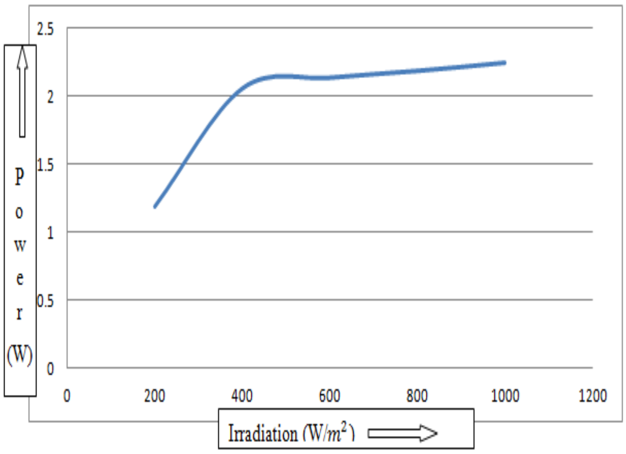

Fig.3.6: Power vs Irradiance characteristics

The Fig 3.6 shows the Power vs Irradiation characteristics. The graph is like exponentially increasing, as the irradiance increases the power output increases. We can observe from the simulation result that the power output is high at maximum irradiance level i.e. 1000.

b. Output power under different temperature

Under Irradiance = 1000 W/m^2 constant and terminal voltage = 90V.

Temperature	Power output
50℃	P= 2 W
25℃	P= 2.25 W
10℃	P = 2.39 W

Table II

As the temperature increases the power output decreases which is shown in the table II. The graph of power output versus temperature is plotted as shown in Fig.3.7.

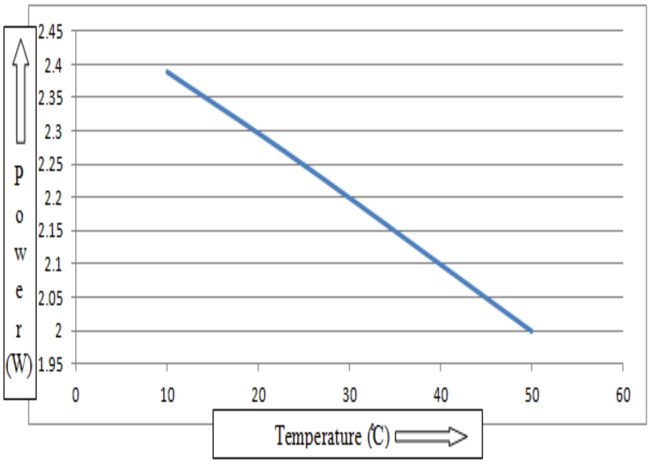

Fig.3.7: Power vs Temperature characteristics

The Fig.3.7. shows the Power vs temperature characteristics. The graph is like exponentially decreasing, as the temperature increases the power output decreases. In other words we can say that the power is maximum at low temperature level.

From these results we can say that the PV cells not only depend on its parameters but also with irradiance and environment temperature. From the characteristics we can observe that output characteristics changes with the variation of irradiance and temperature.

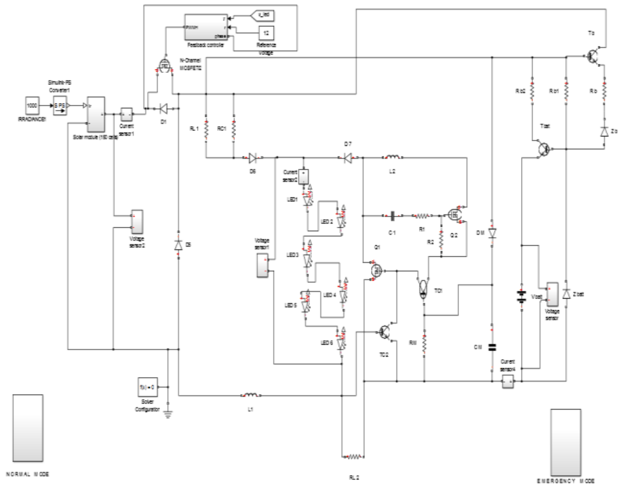

Fig.3.8:Simulation of proposed system for photovoltaic applications (normal mode)

The Fig.3.8. shows the simulation of proposed system in normal mode of operation. In this mode the switch S1 is connected i.e., the solar power is sufficient to supply the LEDs.

The waveforms of the proposed system in normal mode operation are shown below

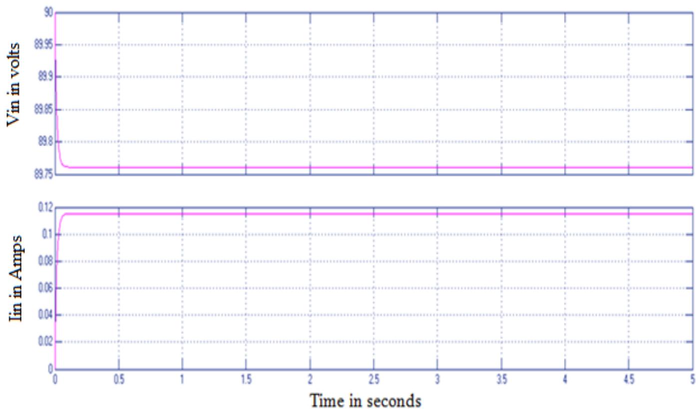

Fig.3.9: Input voltage and current waveforms

In the Fig 3.9 the input voltage and current waveforms are depicted. There are 150 solar cells with the open circuit voltage of 0.6 V. Therefore the input voltage from solar module is ≃ 90V and the input current is around 115mA.

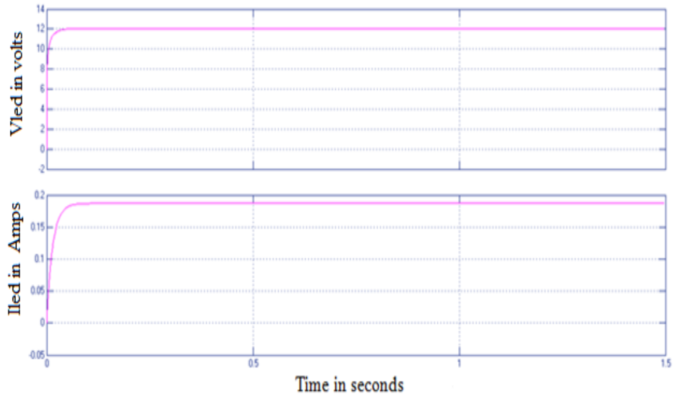

Fig.3.10: .LED voltage and current waveforms in normal mode

In normal mode of operation the input voltage of 90V from solar module is step down by a buck converter to supply LEDs and at the same time it charges the battery. In the Fig 3.10 voltage across the LEDs is approximately 12 V and current is around 187 mA.

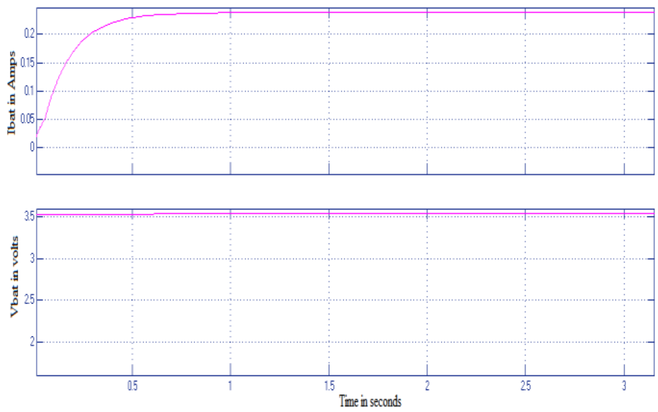

Fig.3.11: Battery current and voltage waveforms

The Fig 3.11 shows the battery voltage and current waveforms. During normal mode the battery charged and in emergency mode it discharges. The battery nominal voltage is 3.6V and current is around 200 mA.

Fig 3.12 shows the simulation of the system in emergency mode of operation. When the solar energy is not sufficient to supply LEDs the switch S2 gets connected to supply LEDs by battery through a boost converter. The efficiency of the system is more than 90 %.

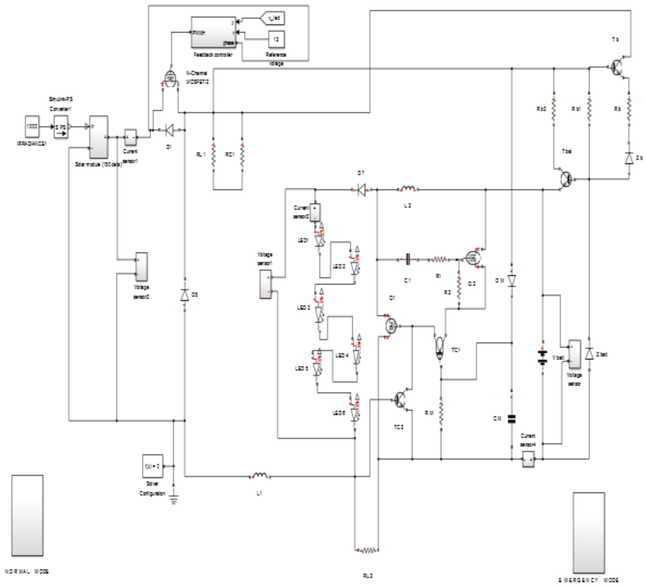

Fig.3.12: Simulation of proposed system for photovoltaic applications (emergency mode)

The current and voltage waveforms of the proposed system in emergency mode are shown in Fig 3.13

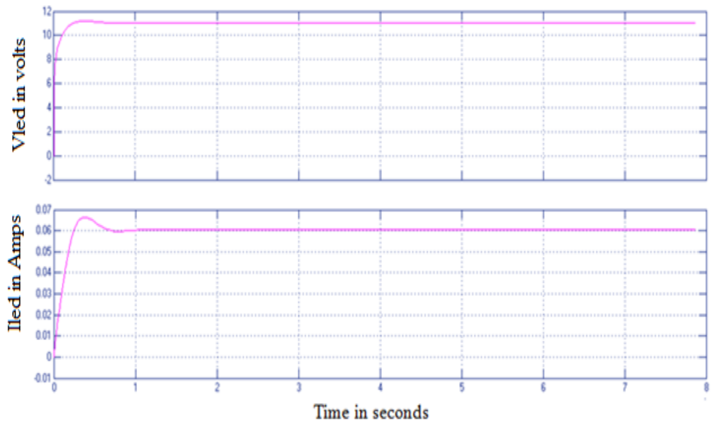

Fig.3.13: .LED voltage and current in emergency mode

The forward voltage of single LED is around 1.8V to 4V. In the proposed system, six LED's are used; by considering the voltage drop of LEDs we are getting the total voltage across the LED string is 11.1V as shown in Fig 3.13. We know that the solar energy is not available all the time so a battery is necessary in emergency situations. In emergency mode we obtained reduced power output compare to normal mode.

V. CONCLUSION

In this proposed system of controlling compact LEDs an optimal feedback control is introduced. It allows increased efficiency, reliability and reduced the switching losses, size and cost. Along with battery backup we are using a solar power module for the continuous lighting of LEDs. Moreover, this proposed system is simple, compact and has few components. The LEDs have more useful life compare to incandescent and fluorescent lamps.

The lighting output of LEDs are increasing every year, which has great advantages in energy saving, high luminous, long life etc. The implementation of LEDs in various domains helps to reduce energy consumption, require less maintenance.

The solar energy inexhaustible energy which can be installed anywhere. So we can say the scope of power generation using solar energy is very bright. The improvements in use of renewable energy help in economical development of nation.

REFERENCES

[1] European Commission, "Phasing Out Incandescent Bulbs in the EU,"Technical briefing, 2008. [Online]. Available: http://ec.europa.eu/energy/efficiency / ecodesign / doc / committee / 2008_12_08_technical_briefing_household_lamps.pdf

[2] C. S.Moo, K. H. Lee, H. L. Cheng, andW.M. Chen, "A single-stage highpower-factor electronic ballast with ZVS buck–boost conversion," *IEEE Trans. Ind. Electron.*, vol. 56, no. 4, pp. 1136–1146, Apr. 2009.

[3] J. M. Alonso, M. A. Dalla Costa, M. Rico-Secades, J. Cardesin, and J. Garcia, "Investigation of a new control strategy for electronic ballasts based on variable inductor," *IEEE Trans. Ind. Electron.*, vol. 55, no. 1, pp. 3–10, Jan. 2008.

[4] J. Hsieh and J. Lin, "Novel single-stage self-oscillating dimmable electronic ballast with high power factor correction," *IEEE Trans. Ind. Electron.*, vol. 58, no. 1, pp. 250–262, Jan. 2011.

[5] T. B. Marchesan, M. A. Dalla-Costa, J. M. Alonso, and R. N. Prado, "Integrated zeta–flyback electronic ballast to supply high-intensity discharge lamps," *IEEE Trans. Ind. Electron.*, vol. 54, no. 5, pp. 2918–2921, Oct. 2007.

[6] M. A. Dalla Costa, T. B. Marchesan, J. S. da Silveira, A. R. Seidel,R. Nederson do Prado, and J. M. Alonso Álvarez, "Integrated power topologies to supply HPS lamps: A comparative study," *IEEE Trans. Power Electron.*, vol. 25, no. 8, pp. 2124–2132, Aug. 2010.

[7] J. Zhang, D. D.-C. Lu, and T. Sun, "Flyback-based single-stage powerfactor-correction scheme with time-multiplexing control," *IEEE Trans.Ind. Electron.*, vol. 57, no. 3, pp. 1041–1049, Mar. 2010.

[8] R. Orletti, M. A. Co, D. S. L. Simonetti, and J. L. F. Vieira, "HID lamp electronic ballast with reduced component number," *IEEE Trans. Ind. Electron.*, vol. 56, no. 3, pp. 718–725, Mar. 2009.

[9] M. A. Dalla Costa, J. M. Alonso, J. C. Miranda, J. Garcia, and D. G. Lamar, "A single-stage high-power-factor electronic ballast based on integrated buck flyback converter to supply metal halide lamps," *IEEE Trans. Ind. Electron.*, vol. 55, no. 3, pp. 1112–1122, Mar. 2008.

[10] D. Gacio, M. Alonso, A. Calleja, J. Garcia, and M. Rico-Secades, "A universal-input single-stage high-power-factor power supply for HB-LEDs based on integrated buck–flyback converter," *IEEE Trans. Ind. Electron.*, vol. 58, no. 2, pp. 589–599, Feb. 2011.

[11] A. A. M. de Oliveira, T. B. Marchesan, A. Campos, and R. N. do Prado,"Distributed emergency lighting system LEDs driven by two integrated flyback converters," in *Conf. Rec. IAS Annu. Meeting*, 2007, pp. 1141–1146.

[12] H. Van Der Broeck, G. Saüerlander, and M.Wendt, "Power driver topologies and control schemes for LEDs," in *Proc. Appl. Power Electron. Conf.*, 2007, pp. 1319–1325.

[13]Rafael A.Pinto, Marcelo R.Cosetin, Alexandre Campos, Marco A. Dalla Costa, " Compact emergency lamp using power LEDs" *IEEE Trans. Ind.Electronics* , vol. 59, no.4, pp. 1728-1737, April.2012