Photovoltaic based automatic LED lighting system
Ajay Arjunan, Sijin Raj K. P, George John P.

Abstract—One of the most important challenges faced by consumer electronics in these days is energy saving. Artificial luminaries account for a great part of day to day total energy consumption. This emphasizes the need for an energy efficient lighting system. In this paper a low cost control solution for LED lighting system with multi level inverter based LED driver is introduced. This brightness control system maintains the desired illumination level with respect to ambient light thereby saving wastage of energy. The proposed system is powered from a battery which is powered from PV cell employing maximum power point tracking. Here brightness of the LED lamp is controlled by variable voltage method. Wide dimming range for LED lamp can be achieved by using this control technique.

Keywords—Daylight control, PV cell, Maximum power point tracking, Multilevel inverter, LED driver.

I. INTRODUCTION
In recent years demand for renewable energy sources are becoming important because of shortage of fossil fuels and environmental issues. Among various types of renewable energy sources, solar energy has become very popular and demanding due to advancement in power electronics techniques and its advantages over the other sources. Some of its advantages over other renewable sources are it can be used almost anywhere and it requires only very low maintenance. While considering light approximately 20 percent of the world’s total energy is consumed by artificial luminaries[1,2]; so along with renewable sources the related studies of energy efficient lighting systems have been done by various researchers around the world. When we consider renewable energy the major problem is that the efficiencies are still poor because of varying climatic conditions and the costs per kilo-watt-hour is high. Solar panels themselves can only convert approximately 30% sunlight to energy. By combining a PV and Maximum Power Point Tracking (MPPT) technique we can utilize the PV power at its maximum to charge the battery. By using this system with an intelligent lighting system we can make an energy efficient lighting system. When compared to other artificial light sources LED has lots of advantages. While considering energy consumption, LED lamps consume only 50 percent of the energy compared to the fluorescent lamp. LED have an Outstanding operational life time expectation of up to 100000 hours There are two types of system configurations for PV powered lighting system[2]. They are PV based stand alone system and PV along with grid connected system. In PV based stand alone system one solar module is used for one light and when battery discharges below the forward voltage of LED it will not work. In PV along with grid connected system the battery can be power during night time when PV powered battery is drained out. But when PV panel generate less energy than the grid there will be power fed back to the system, also it require extra power conditioning units for ac part these are some disadvantage of this system. In the proposed system to reduce cost we are using a single source system with a multi level inverter for driving the LED. For providing sufficient forward voltage for LED the voltage is stepped up with a transformer. When ambient light is not present the lights stays on as normal and when ambient light is available to maintain the desired illumination level the lights switch back off. In this system dimming control of LED is also provided along with on off control. In earlier days two types of light dimming were used, they are by providing a variable resistor and by using TRIAC dimmers[3]. The use of series resistor introduce extra power loss in the circuit so TRIAC based dimmers gain demand. For TRIAC dimmers the dimming range is limited because of flickering and unwanted turn off of lights when the input current of TRIAC dimmer fall below the holding current of TRIAC [3]. Dimming can also be provided by PWM technique where the pulse width of either on time or off time is controlled to achieve dimming, the main draw back of this type of dimming is that there will be flickering which is invisible to human eye but counts in extreme light sensing application like digital photography. Proposed system is a variable voltage based dimming system. This system will eliminates unwanted flickering and provide wide dimming range.

II. PROPOSED SYSTEM
The structure of proposed system is shown in Figure 1. An LDR is used in this system to sense the ambient light and a microcontroller is used to generate a delay to control the frequency of the Inverter and there by controlling the brightness of LED. Power supply is provided from a battery which is powered from a solar panel and MPPT to get maximum power operation from the panel.

![Diagram of PV based intelligent lighting system](image-url)
III. PV MODELLING

Electric equivalent circuit of a PV cell is shown in Figure 2 [5]. The ideal model is used to model a PV cell in MATLAB for simulation [4]. In a practical PV cell we should consider internal resistance of the cell and resistance which control the leakage current from the cell to ground. A single PV cell will produce only less power so a number of cells are connected in series to get desired voltage and in parallel to get desired current.

![Figure 2: Equivalent circuit of PV cell](image)

Terms used:
- $I_{PV}$ - photon generated current
- $I$ - output current
- $I_d , V_d$ - diode current and voltage
- $G$ - irradiance (W/m$^2$)
- $T_{ref}$ - reference temperature of PV cell in Kelvin, 25°C
- $I_{SC}$ - short circuit current at a particular temperature
- $n$ - Diode ideality factor
- $K$ - Boltzmann’s constant, 1.38*10^{-23}
- $q$ - Electron charge, -1.6*10^{-19}

Output current of the equivalent circuit in Figure 2 considering ideal mod of PV cell is:

$$ I = I_{PV} - I_d $$

(1)

$$ I_{PV} = G I_{SC} $$

(2)

$$ I_{SC} = I_{SC,T_{ref}}[1+a(T-T_{ref})] $$

(3)

$$ I_d = k V_d^{n}e^{qV_d/kT} - 1 $$

(4)

IV. MAXIMUM POWER POINT TRACKING (MPPT)

A typical solar panel based system converts only 30 to 40 percent of the incident solar irradiation into electrical energy. So to track maximum power from the solar panel with varying irradiance we should use tracking method. Here incremental conductance method is used to track maximum power from the PV module. This method is based on the fact that the slope of the PV array power curve is zero at the maximum power point, positive on the left side of the maximum power point and negative on the right side of maximum power point, as given by the following equations.

$$ \Delta I/\Delta V = -I/V $$

at MPP

$$ \Delta I/\Delta V > -I/V $$, left of MPP

(5)

$$ \Delta I/\Delta V > -I/V $$, right of MPP

MPPT algorithm is shown in Figure 3, here duty cycle of boost converter is adjusted to get maximum power point. The INC method tracks the MPPT by adjusting the duty cycle of the boost converter in a fixed step size on the event of any change in the irradiance to deliver maximum power possible [4]. Boost converter also helps to power a certain load since the V and I of PV changes with load. The block diagram shown in Figure 4 gives an overview of implemented circuit.

![Figure 3: Incremental Conductance Algorithm](image)

![Figure 4: Proposed PV MPPT system](image)

V. MULTI LEVEL INVERTER TOPOLOGY

The proposed inverter topology consists of a single source which is PV array and a multi level inverter is shown in Figure 5. The PV array generates DC supply through solar based MPPT system to charge the battery. This single source is applied to the five-level inverter. A single source five level inverter with control algorithm is implemented in mat lab. The switching of the proposed inverter is shown in Table 1. The five-levels of output voltage are 0, $V_{PV}/2$, $V_{PV}$, $-V_{PV}/2$ and $-V_{PV}$ [6]. An auxiliary circuit which consists of four diodes and a switch S1 is used between the dc-link capacitors and the full-bridge inverter. Proper switching control of the auxiliary circuit can generate half level of PV supply voltage $+V_{PV}/2$ and $-V_{PV}/2$. 

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The modulation technique used in this inverter topology is sinusoidal pulse width modulation (SPWM) technique [6]. The gate signal is generated by comparing a triangular carrier signal with two sinusoidal references signals, which in phase and having same frequency, but different offset voltages [6]. The phase depends on the modulation index. The equation of modulation index is,

$$M = \frac{A_m}{2A_c}$$  \hspace{1cm} (6)

Where $A_m$ is the peak value of reference voltage and $A_c$ is the peak value of carrier wave. The modulation index here is 0.8.

VI. PROPOSED CONTROL

The proposed lighting control is done by sensing the daylight and controlling the frequency of the inverter to control the brightness of the light. There are two types of ambient light controls, dimming control and switching control. In switching control the light is either on or off according to day light and in dimming control there are more than two steps of dimming operation. Here combinations of these two controls are used. An LDR is used to sense the ambient light if no ambient light is available the proposed light will be on its maximum brightness. There are intermediate operations depending on variation in ambient light availability.

VII. SIMULATION RESULTS

Simulation of the proposed system is done in MATLAB 2009.
The proposed system is tested by building hardware. The 5 level inverter output is shown in Figure 9.

VIII. EXPERIMENT AND RESULTS
The proposed system was built, the prototype is shown in Figure 10. A 10W PV is used and the frequency control is done by using 89C51 and multilevel inverter. Inverter output is shown in Figure 11. LED current and voltage waveform for 10W, 300mA LED is shown in Figure 12 and Figure 13. Figure 12 shows output current waveform which is about 2% of rated LED current. Figure 13 shows the output current waveform which is about 90% of rated LED current.

IX. CONCLUSION
By employing the proposed LED dimming control methodology wide range of dimming (0% to 100%) is achieved. Flickering of LED lamp is eliminated by using this system and the ambient light control eliminates wastage of energy. Improvement of the proposed system can be done if we employ grid connection along with the PV system so that if the battery is completely drained out during night the lamp can be powered from grid but this adds up over all system cost.

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REFERENCES


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