International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 9, September - 2013

Energy Saving by Implementation of Intelligent Systems in Lighting

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Abstract

An Outdoor Lighting System with Automatic on-off control and a human sensor is designed. The solar power is tapped through a solar panel and the charge is stored in a battery. This charge stored during the day is used at night for the operation of the street light. The automatic on-off control ensures that the circuit remains turned off when natural illumination is available. The street light is made functional from dusk to dawn. A human sensor is used to enhance the conservation of energy. It makes the street light operate on low brightness when there is no movement. When a person is approaching, the brightness increases till the person or vehicle has passed by. This function is useful in remote areas where there is not much movement at night time.

1. Introduction

In a typical area, illumination is one of the major consumers of energy. Extending the usage, residences, offices and other buildings too guzzle energy for the lighting systems. The urge to save energy and cut costs by diverting the source to renewable energy has proven to be a very effective one. Moreover, in rural and suburban areas, there is almost nil human movement at night and the Street Lighting systems glow at full capacity. Recent advances in lighting have brought the Light Emitting Diode as the most advantageous replacement to traditional lighting systems. Street Lighting Systems are required to operate only from dusk to dawn. Also, lighting is required only when there is human activity and hence, intelligent systems are implemented to identify the presence of humans and adjust the lighting accordingly in the street and buildings. A combination of these systems can be used to bring out the optimum saving solution. The Economic impacts in the long term are also analysed.

2. Analysis of Outdoor Lighting Systems

Providing street lighting is one the most important – and expensive – responsibilities of a city: Lighting can account for 10–38% of the total energy bill in typical cities worldwide (NYCGP 2009). Street lighting is a particularly critical concern for public authorities in developing countries because of its strategic importance for economic and social stability. Inefficient lighting wastes significant financial resources each year, and poor lighting creates unsafe conditions.

Energy efficient technologies and design can cut street lighting costs dramatically (often by 25-60%); these savings can eliminate or reduce the need for new generating plants and provide the capital for alternative energy solutions for populations in remote areas. These cost savings can also enable municipalities to expand street lighting to additional areas, increasing access to lighting in low-income and other underserved areas. In addition, improvements in lighting quality and expansion in services can improve safety conditions for both vehicle traffic and pedestrians.

A well-designed, energy-efficient street lighting system should permit users to travel at night with good visibility, in safety and comfort, while reducing energy use and costs and enhancing the appearance of the neighborhood. Conversely, poorly designed lighting systems can lead to poor visibility or light pollution, or both. Quite often, street lighting is poorly designed and inadequately maintained (e.g., there are large numbers of burned-out lamps), and uses obsolete lighting technology—thus consuming large amounts of energy and financial resources, while often failing to provide high-quality lighting.[1]

According to a study conducted by the Kolkata Municipal Corporation, municipal and state owned street lighting accounts for over one percent of India's total energy consumption and roughly 4,400 megawatts (MW) of connected load (2012 estimates).[2]

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Table 1. Comparison between different lighting systems

Parameter	Comparison of Various Lighting Systems		
	LED	**Compact Fluorescent Lamp**	**Incandescent Lamp**
Energy Use	12W	13W	60W
Efficacy	80 lm/W	63 lm/W	14 lm/W
Life Time in Hours	50,000	8,000	1,000
Life Time in Years	17.1	2.7	0.3
Use of Electricity in 50,000 Hours	12W x 50,000h =600kwh = $84	13W x 50,000h = 650kwh = $91	60W x 50,000h = 3,000kwh = $420

3. Solar Powered Led Street Lighting System

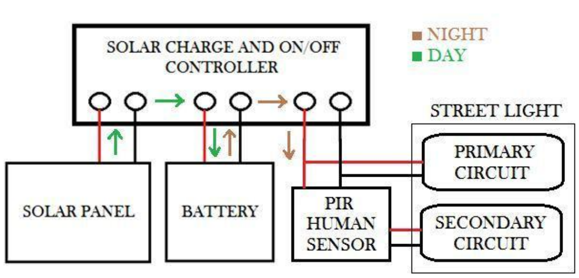

Figure 1. Main block diagram

The Solar Powered LED Street Lights installed, consists of a Solar Panel, a Battery, an LED Street Light, a Human Sensor and a Controller. The functions and design implemented are explained. An analysis of the power consumed and saved when compared to the traditional system is also calculated.

4. Power Consumption of Led Street Lights

The LED Street Light is designed for operation at a height of 15 feet. It consists of an LED luminary, a Charge Controller and a PIR Human Sensor. Each part is discussed in detail.

4.1 LED Luminary

The LED Luminary consists of an array of LED's operated in two circuits – the Primary Circuit and the Secondary Circuit. The Primary Circuit is connected to Controller only and thus switches on as soon as the surrounding illumination falls below a certain level. The Secondary Circuit is connected to the Controller through a PIR Human Sensor and thus switches on only when a person approaches when it is dark. The Street Light glows dimly when there is no human movement and becomes bright when there is human movement.

The LED's used in the experiment consumed 3 V, 3 W. A row of 4 LED's were connected in series and two rows were connected in parallel, as depicted. The number of LED's used in the Primary and Secondary circuits were 8 each. They specifications of the LED array are as follows:

1. Voltage of LED array = 12 V
2. Luminous Efficacy of one LED = 150 lm/W
   Luminous Efficacy of 16 LED's
   = 150 * 16 * 3 = 7200 lm
3. Wattage of one LED = 3 W
   Wattage of 16 LED's = 3 * 16 = 48 W

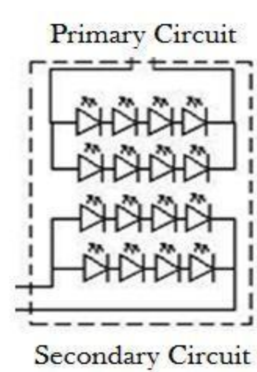

Figure 2. Primary and Secondary circuits of the LED Luminary

4.2 PIR Human Sensor

The PIR Human Sensor is the next stage in enhancement of power saving. It works on the principle of sensing infrared rays emitted by human to sense movement. It operates the secondary circuit of the LED Luminary. Only when human movement is sensed, the secondary circuit operates. Thus the power consumed is further reduced.

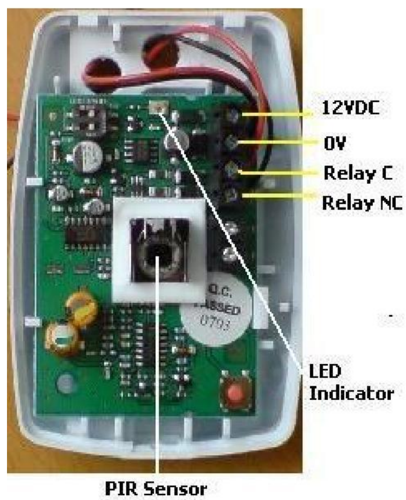

Figure 3. Internal circuit of PIR sensor

Half the power consumed is confirmed as the Primary Circuit is on compulsorily. A movement for about 20 % of the time was observed. Thus the Secondary Circuit is on for about 20 % of the night.

4.3 Battery

The LED Street Lighting System was made independent of the Electricity mains. Calculating the consumption of the Street Light and placing allowances for an uninterrupted supply for 24 hrs, an 80 Ah battery was installed. A lead acid battery was chosen for its well known efficient characteristics.

4.4 Solar Panel

From a study, the proven facts have been taken to be used for the advantage of the project. The study concludes upon appropriate positioning of the Solar Panels in order to obtain maximum power.

Solar Panels of 74 W are commonly available and were installed as the source of the Street Light.

An extended study of the project includes the effects of the placing the Solar Panels in the direction recommended as per Fig. 5. It would be impossible to manually change the inclination of the Solar Panels when placed in large numbers. An automated system is under development to sense and aid the change in angle of inclination as per the following:

- January to April - 50^0
- April to September - 0^0
- September to January - 50^0

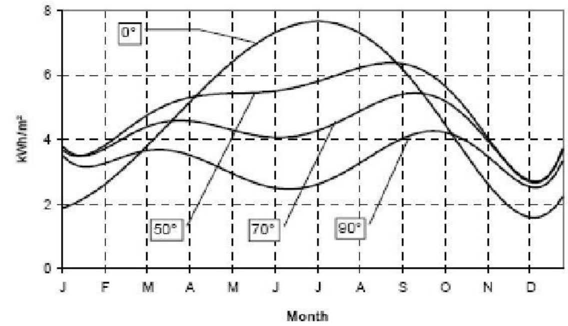

Figure 4. Calculated annual distribution of solar radiation on tilted surfaces.[3]

4.5 Charge and ON/OFF Controller

The Controller is considered the mind of the system as it controls the on/off of the street light based up the surrounding illumination. It is MOSFET based control logic for the charging of the battery and prevents deep discharge too.

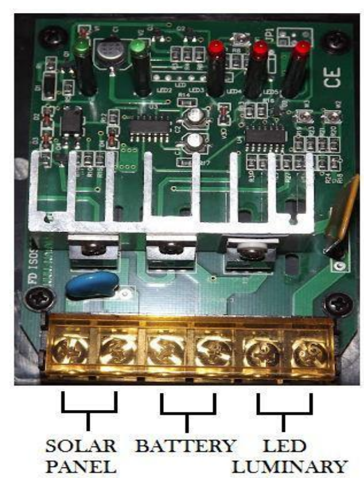

Figure 5. Solar based charging and on/off controller

The Controller is designed to perform the following operations:

1. The output from the Solar Panel is connected to the controller. A voltage regulator limits the output voltage to 14.4 V. It also prevents reverse flow of current to the Solar Panel.
2. The current is limited to 10 A. The maximum capacity of the Solar Panel is 6 A.
3. The Controller prevents overcharging and deep discharge of the battery. It cuts off the input to the battery at 13.6 V and cuts off the load at when the battery discharges to 10.8 V.

5. Working

1. The Solar panel taps solar power throughout the day when natural illumination is present. The

controller limits the output voltage and supplies to the battery.

2. This output voltage is also used by the controller to operate the street light. When the surrounding illumination is low and the output of the solar panel falls below a threshold voltage, the street light is switched on. Conversely, when the output voltage from the solar panel increases, the street light is switched off.
3. When the LED Street Light is on, the Primary Circuit remains on at all times. The Secondary Circuit is switched on only when there is human movement in the vicinity. Thus, an approaching person is sensed and the Street Light provides additional brightness.
4. The Controller also cuts off the battery when it is charged fully to 13.6 V and, also when it reaches 10.8 V, to prevent deep discharge.

Figure 6. Primary Circuit's LED – switched on

Figure 7. Primary and Secondary Circuit's LED – switched on

6. Comparison of Consumption by Street Lighting

Let us consider a 7200 lumen fluorescent lamp which would approximately consume 100 W. (The luminous efficacy of the fluorescent lamp lies in the range 68 – 94 lm/W)[4].

The energy consumed by 100 W lights is calculated: For 20 Street Lights:

Total Wattage = 100 * 20 = 2000 W

Consider the operation time to be from 6pm to 6am, for 12 hours,

Total Energy consumed = 2000 * 12
= 24 kWhr

In a month's duration,

Total Energy consumed in a month = 24 * 30
= 720 kWhr

Thus the approximate energy consumed by 20 Fluorescent Street Light is calculated to be 720 kWhr in a month.

The LED Luminary is designed to produce 7200 lumen and consumes 48 W as calculated above.

For 20 Street Lights:

Total Wattage = 48 * 20 = 960 W

Consider the operation time to be from 6 pm to 6am, for 12 hours,

Total Energy consumed = 960 * 12
= 11.52 kWhr

In a month's duration,

Total Energy consumed in a month = 11.52 * 30
= 345 kWhr

Thus the energy consumed by 20 LED Street Lights is 345 kWhr in a month. These figures are true for the entire LED Luminary operated at night. When compared to the traditional lighting system, the LED Luminary saved about 50% of the energy consumed.

Considering the operation of the Human Sensor, the power consumed through the Primary and Secondary Circuits are calculated.

Energy Consumed by Primary Circuit = 345 / 2
= 173 kW

It was detected that about 20% of human movement exists between dusk to dawn.

Energy consumed by Secondary Circuit = 173 * 0.2
= 35 kW

Total Energy consumed = 173 + 35 = 208 kW

Thus by the implementation of a PIR Human Sensor, about, 40% an additional energy was saved.

The power consumed by one LED Street Light working with the control of a human sensor is averaged at 30 W.

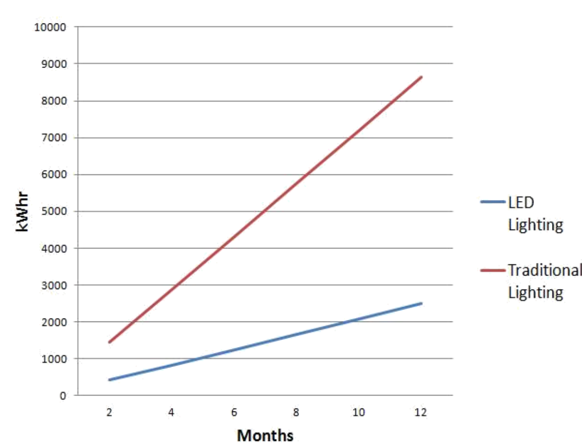

Figure 8. A graphical comparison of LED lighting and traditional lighting

Let us keep under consideration that the battery should be able to provide a back-up for 2 days. At 12 V, 30 W, the Street Light consumes 2.5 A. For 12 hrs, and a back-up of 2 days,

$$2.5 * 12 * 2 = 60 \text{ Ah}$$

Considering the Battery Cycle Life factor[5] of 0.8, battery capacity required is,

$$60 / 0.8 = 75 \text{ Ah}$$

Hence, an 80 Ah battery was installed due to availability.

The size of the Solar Panel was chosen so that the battery charges optimally and quickly. The output parameters of the panel are controlled by the Charge Controller and the Battery is charged constantly at 14.4 V. The Charging current can safely reach upto 5 A.

$$\text{The Panel's capacity} = 14.4 * 5 = 72 \text{ W}$$

Solar Panels of 74 W are commonly available and were installed as the energy source of the Street Light.

The analysis thus produced the results that LED Street Lighting Systems, bearing the capability to reduce the energy consumed in illumination, could also be combined with other sensors to enhance the process of energy saving.

7. Conclusion

An Intelligent Outdoor Lighting System focuses on conservation of electricity by every means. The addition of a human sensor enhances the life and power saving capability in street lighting. The indirect costs reduced are that of individual cables for the street lights, the transmission losses, the manual operation is excluded and convenient fixation in remote areas where electricity is absent. It is for the public to take advantage of the system for its negligible maintenance required and also the credibility the system possesses for providing lighting of the required illumination when required.

8. References

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