Intelektual Journal of Energy Harvesting and Storage
Vol. 2, No. 2, 2024, pp. 81~87
ISSN: 2963-6272, DOI: 10.11591/ehs.v2i2.pp81-87

Power management in energy harvesting street lighting system

Shiva Rama Krishna Samala[1], E. V. C. Sekhara Rao[2]
[1]Department of Electrical and Electronics Engineering, Chaithanya Bharathi Institute of Technology and Science, India
[2]Department of Electrical and Electronics Engineering, Matturi Venkata Subba Rao Engineering College (MVSREC), India

Article Info

Article history:

Received May 29, 2023
Revised Oct 5, 2024
Accepted Oct 9, 2024

Keywords:

Light dependent resistor
PIR sensor
Solar energy
Street light

ABSTRACT

The huge amount of electrical power of many countries is consuming in lighting the streets. However, vehicles pass with very low rate in specific periods of time and parts of the streets are not occupied by vehicles over time. This paper presents about power management in energy harvesting street lighting scheme which supplies a safe night time environment for all road users and pedestrian with less power expenditure. The primary aim is to construct this system is for energy saving in the streets and also to introduce solar energy into street lightings. This system automatically switches off the light for the parts of the streets having no vehicles and turns on the light in these parts once there are some vehicles that are going to come. Logically, this scheme may save a great sum of the electrical power. Light emitting diode (LED) is exemplified as the illumination module. This pattern can deliver a large sum of electric energy use compared to conventional street lighting that keeps alight during nights. Moreover, the life of the scheme will be increased. And maintenance and size of the photo voltaic system required for street lighting will reduces. A prototype model was designed and tested successfully.

This is an open access article under the CC BY-SA license.

Corresponding Author:

Shiva Rama Krishna Samala
Department of Electrical and Electronics Engineering
Chaithanya Bharathi Institute of Technology and Science
Gandipet, Hyderabad, Telangana, India
Email: samalashivaram139@gmail.com

1. INTRODUCTION

Nowadays, street lighting is essential for all areas whether urban or rural since people knows street light is an alternative during day/night in order to keep the safety of the road users. Street light management control is quite simple, yet as the urbane, the number of streets increased rapidly. The traditional lighting, street lamp on-off command is based on chronological time, which may inefficient and inflexible [1].

Solar energy has become a promising alternative source because it delivers many advantages such as abundance, pollution free and renewability. The solar photovoltaic (PV) power will play an important role in alleviating the energy crisis and reducing the environmental pollution and has a bright prospect of applications [2]. It can used to provide energy in the form of heat or electricity. Due to the increasing price of energy derived from fossil fuels, energy production costs decreased by using new and renewable energy as progress of science and technology and will be closer to economy it will be economical evaluation using photovoltaic systems for the supply electricity [3].

We also know that for some roads, vehicles pass with very small rate in specific periods of time. In other words, if we divide the roads into small parts, with each part has a length of 500 meters (the minimum visibility range), we can find that in many roads only a very small number of these parts have vehicles that pass through them and the rest of the parts have no vehicles, but still consuming electrical power. This is a dynamic problem that means that any part of the road can be free and then shortly be occupied then free again.

That raises a natural question which is it possible to automatically cut the electricity for the parts of the roads that do not have vehicles and resume the current for these parts once there are some vehicles that are going to come? If this system could be implemented, it can save very large amount of the electrical power that can be used to develop other areas in the country. It can also increase the lifetime of the Lamps and hence decrease the main- tenance cost and solar components capacity. Another benefit is to reduce the environ- ment pollution [4]-[7].

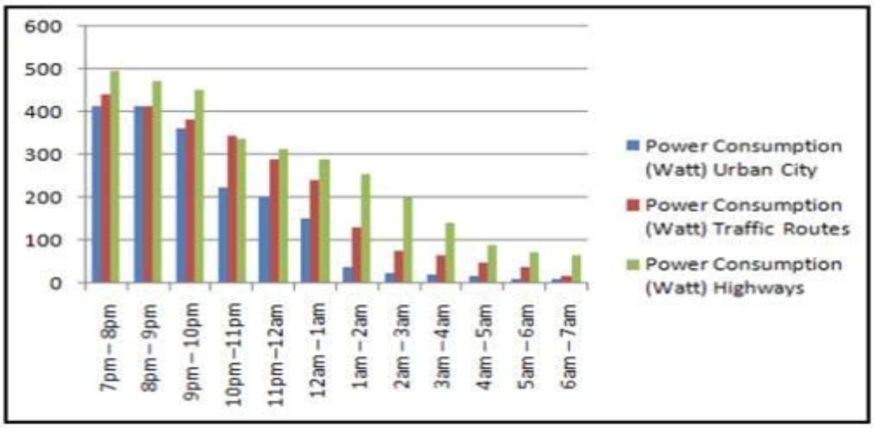

Figure 1. Power consumption for each hour at the urban city, traffic routes and highways

Modern street lights are the product of electricity in the form of incandescent, fluorescent, low pressure sodium (LPS), mercury vapor (MV), and high-pressure sodium (HPS) lamps. High-brightness (HB) LEDs are extremely smart light sources because of their exceptional features (high efficiency and prolonged existence, and low-maintenance conditions) [8]. Since they are driven from a DC source, several categories of power switching converter can be employed to adapt primary energy sources to the constraints of HB LEDs [9] With the increasing interest in the global energy consumption and green environment requirement, the street lighting systems integrating most recent lighting source, light-emitting diode (LED), were under development, as shown in Figure 1

In addition, the PV stand-alone for street light system model needs a battery to store the electric power from photovoltaic module and supply the energy to the street light. As a vital component, there are many kinds types of battery for the PV stand-alone for street light system such as lead acid [10], Lithium-ion [11], [12], and LiFePO4 [13]. It should be noted that different kind of battery will give different

performance [14]. This street lighting automation system is an intelligent system which provides the flexible and efficient system to control the street lighting autonomously and the system powered by solar enegy and the system is controlled with out micro controller, physical arrangement of system shown in Figure 2.

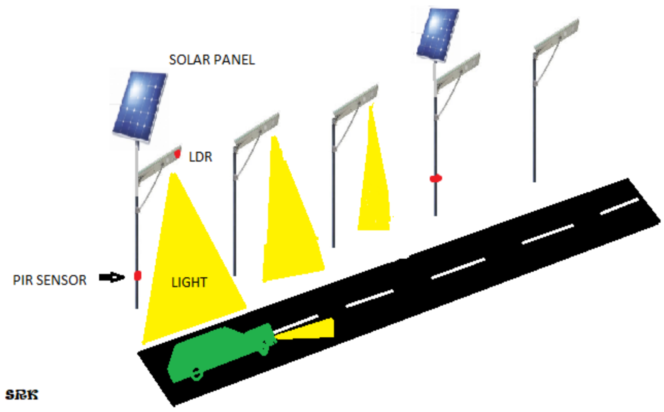

Figure 2. Physical arrangement of proposed system

This system is controlled by two sensors i.e., passive infrared (PIR) sensor and light dependent resistor (LDR) sensor. LDR sensor is used to detect darkness and to activate ON/OFF switch. With the presence of these sensors intensity of the light and physical presence of humans or cars are detected and then to turn on the system automatically. The main reason to provide LED is to reduce the energy consumption as it is very effective in lighting and low light decay in the lifetime. The LEDs have about 110° light emission angle. Meanwhile, the conventional lamps usually have 360° and need a reflector to direct the light beam to the target.

2. RESEARCH METHOD

2.1. Design architecture

The block diagram of the proposed system is as shown in Figure 3. The components for this project have been classified based on the components group consists of input, output and controller. Sensors are used to control the desired system parameters. Sensors will transfer the gathered information to the LED driver. Meanwhile, the purpose of the LED driver is to turn ON/OFF the street light according to PIR sensor output.

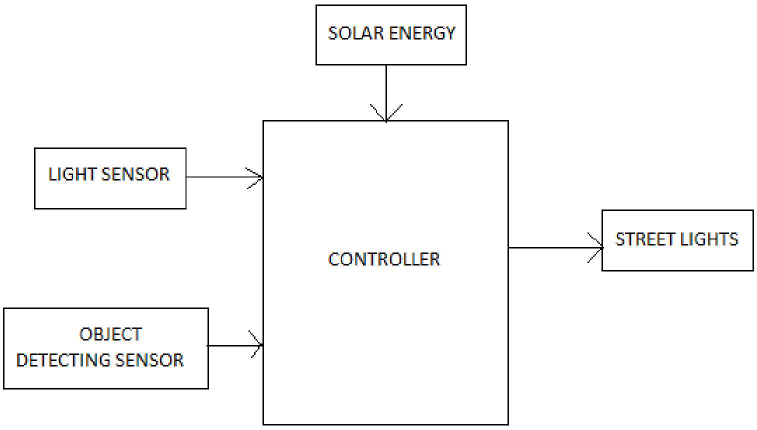

Figure 3. Block diagram for street lighting of automation system

2.2. Hardware specification

LED driver has been selected as the controller for this system due to its low cost, compact size, compatibility, two types of sensors used in this system light dependent resistor (LDR) and passive infrared (PIR) sensor. LDR sensor is an electronic component that has a variable resistance that changes with the light intensity fall upon it. The resistance will drop with increasing incident light intensity. In other words, when there is dark, it has high electrical resistance yet when there is light, it has low electrical resistance. Normally, LDR often used in sensing circuit.

PIR sensor is a passive electronic device that detects motion by sensing infrared fluctuations. It is made up of crystalline material which generates surface electric charge when exposing to heat in the form of infrared rays. PIR sensor is allowed to sense motion, either vehicle or human in or out of the sensor range. This sensor is quite small, inexpensive, easy to use, low power and easy to interface with other applications. Figure 4 shows the diagram complete schematic diagram of the system.

Photovoltaic system collects energy from the sun during the day time and stores it in a lead-acid battery to drive LED street lamps at night. Here two kinds of sensors are used which are light sensor and photoelectric (PIR) sensor. The light sensor will detect darkness to activate the relay switch, so the streetlights will be ready to turn on and the photoelectric sensor will detect movement to activates the streetlights. LDR which varies according to the amount of light falling on its surface, this gives an induction for whether it is a day-night time, the photoelectric sensors are placed on the side of the road, which can be controlled by led driver. The photoelectric will be activated only on the night time. If any object crosses the photoelectric beam, then the street lights will turn ON. Figure 5 shows the flowchart of working algorithm. The sensor node detects motion and light rays, controller receives the information from sensor nodes and sends operating data to the street lights.

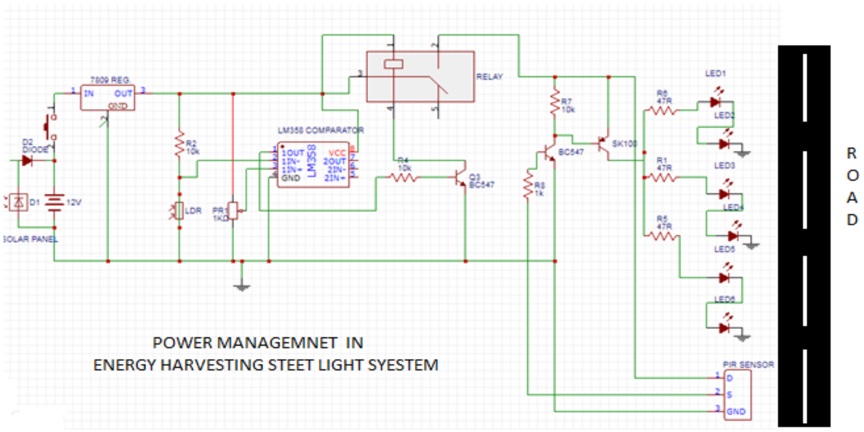

Figure 4. Complete schematic diagram of the system

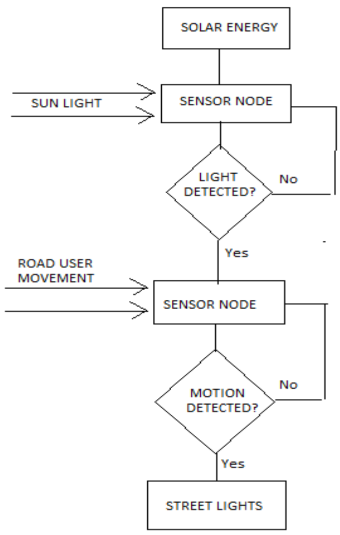

Figure 5. Flowchart of working algorithm

3. RESULTS AND ANALYSIS

3.1. Hardware testing

A prototype of street lighting automation system is developed and the whole prototype design is shown in Figure 4. The design of the whole project was done with 6 LEDs, 1 PIR sensor, and 1 LDR sensor. This was done by calibrating part by part which is started with LDR sensor, then PIR sensor and lastly LED as the light module. During a day, all LEDs and PIR sensor are turned off. This condition is shown in Figure 6.

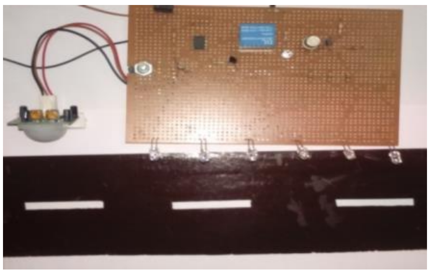

Figure 6. Condition during day

Meanwhile during the night, whereby LDR sensor detects light intensity, circuit will turn on (red led is turned on), this condition is on mode 1. Figure 7 shows the condition of red LED turned on during the night. For mode 2, PIR sensor will detect any movement of vehicles or pedestrians, then, LEDs will turn on. When PIR sensor detects movement, street lights are turned on. This condition is as shown in Figure 8.

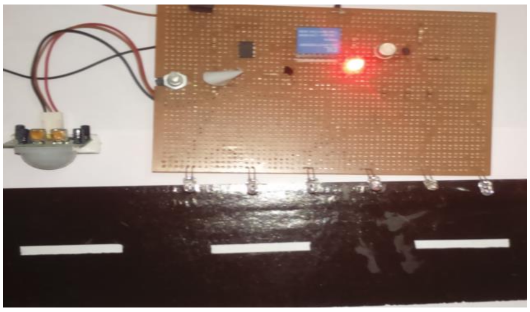

Figure 7. Condition during night, circuit turned ON

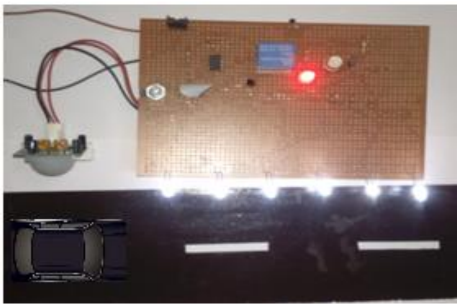

Figure 8. Street lights turned on when PIR sensor detect car movement

3.2. Numerical calculations

Assume for simplicity that from 6:00 pm to 10:00 pm, the flow of the vehicles is large and hence each sector of the road can have at least one vehicle with a probability of 0.9. Also assume that from 10:00 pm to 12:00 am, the flow of the vehicles is with low rate and that the prob- ability that a vehicle exist in a sector is 0.30. Finally, from 12:00 am to 6:00 am, assume that the rate of vehi cles decrease to have a probability of 0.15. The total period of road lighting is 12 hours per day. Although these assumptions are very close to several realistic situations, they are used only for the validation purpose. They are not artificially selected to show that the system is valid and useful. We know that in practice, the gains may be less than the results obtained here. Of course, for any similar assumptions, we will get gains varying based on the chosen values. Power savings:

$$\frac{12-4\times0.9-2\times0.3-6-0.15}{12}\times 100 = 57.5\%$$

increased lamp lifetime= $1-1/0.575=73\%$. The typical lifetime of the LED lamps is generally 50,000 hours. That means that lifetime of the lamps is increased to be 85,000 hours.

3.3. Proto type system results

Power consumed by the entire system with out object detection circuit i.e the system works for entire night i.e from night 7 pm to 5 am.

Voltage rating the circuit= 9 V
Current= 0.4 amps
Power consumed by circuit= 9*0.4=3.6 watts
If system worked for 10 hours total power consumed= 12*3.6=43.2 watts (1)

Total power consumed by the system =power consumed by system with and with out object detection:

- Power consumed by the entire system with out object detection circuit.

Power consumed by circuit without LED lights= 9*0.1=0.9 watts
As per the above mentioned asumptiom the circuit power consumption
for 12 hours is 6.21 watts (2)

- Power consumed by the entire system with object detection circuit i.e the system works only when vechile or object passing through Road during night i.e from night 7 pm to 5 am.

Power consumed by circuit with LED lights= 9*0.4=3.6 watts
As per the above mentioned asumptiom the circuit power consumption
for 12 hours is 16.1 watts (3)

Total power consumed by the system= controller consumption+street light consumption.

Add (2) and (3)= 6.21+16.1=22.31 watts (4)

Power saving: (4) from (1) 43.2-22.31=20.89 watts. Percentage of power saving: 20.89/43.2*100=51 %. This 51% power saving reducing the size of photovoltaic required capacity i.e., size of panels and battery ratings and also incresing life time of LED lights.

4. COMPARISON

The Table 1 explains the cost comparison between conventional street light, solar powered street and proposed street light system. The cost mentioned for 10 street lights with a period of 1 year.

Table 1. Cost comparison

	Conventional street light	Existing solar street light	Proposed street light
Capital cost	1,00,000	2,50,000	1,50,000
Replacement cost	15,000	30,000	20,000
Maintainance charge	10,000	1,000	0
Electricity charge	2,00,000	0	0
Total cost (Indian Rupees)	3,25,000	2,81,000	1,70,000

5. CONCLUSION

Power management in energy harvesting street light system using LDR and PIR sensors proved saving of power approximately 55 to 60 % which concludes that size of photovoltaic system requirement i.e., panels and battery sizes reduces and also overall cost of solar street lighting system decreses using this system.

REFERENCES

[1] N. L. Ramli, N. Yamin, S. A. Ghani, N. M. Saad, and S. A. M. Sharif, "Implementation of passive infrared sensor in street lighting automation system," *ARPN Journal of Engineering and Applied Sciences*, vol. 10, no. 22, pp. 17120–17126, 2015.

[2] R. Aparnathi and V. Vyas Dwivedi, "A voltage controller in photo-voltaic system with battery storage and applications," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 3, no. 4, pp. 417–423, Dec. 2013, doi: 10.11591/ijpeds.v3i4.4549.

[3] H. Shahinzadeh, M. M. Najaf Abadi, M. Hajahmadi, and A. Paknejad, "Design and economic study for use the photovoltaic systems for electricity supply in Isfahan Museum Park," *International Journal of Power Electronics and Drive Systems (IJPEDS)*, vol. 3, no. 1, pp. 83–94, Mar. 2013, doi: 10.11591/ijpeds.v3i1.1797.

[4] S. A. E. Mohamed, "Smart street lighting control and monitoring system for electrical power saving by using VANET," *International Journal of Communications, Network and System Sciences*, vol. 06, no. 08, pp. 351–360, 2013, doi: 10.4236/ijcns.2013.68038.

[5] Y. Wu, C. Shi, X. Zhang, and W. Yang, "Design of new intelligent street light control system," in *2010 8th IEEE International Conference on Control and Automation, ICCA 2010*, Jun. 2010, pp. 1423–1427, doi: 10.1109/ICCA.2010.5524348.

[6] M. A. D. Costa, G. H. Costa, A. S. dos Santos, L. Schuch, and J. R. Pinheiro, "A high efficiency autonomous street lighting system based on solar energy and LEDs," in *2009 Brazilian Power Electronics Conference*, Sep. 2009, pp. 265–273, doi: 10.1109/COBEP.2009.5347688.

[7] W. Yongqing, H. Chuncheng, Z. Suoliang, H. Yali, and W. Hong, "Design of solar LED street lamp automatic control circuit," in *2009 International Conference on Energy and Environment Technology*, 2009, pp. 90–93, doi: 10.1109/ICEET.2009.28.

[8] G. Carraro, "Solving high-voltage off-line HB-LED constant-current control-circuit issues," in *Conference Proceedings - IEEE Applied Power Electronics Conference and Exposition - APEC*, Feb. 2007, pp. 1316–1318, doi: 10.1109/APEX.2007.357685.

[9] H. Van Der Broeck, G. Sauerländer, and M. Wendt, "Power driver topologies and control schemes for LEDs," in *Conference Proceedings - IEEE Applied Power Electronics Conference and Exposition - APEC*, Feb. 2007, pp. 1319–1325, doi: 10.1109/APEX.2007.357686.

[10] X. Wang, P. Adelmann, and T. Reindl, "Use of LiFePO4 batteries in stand-alone solar system," *Energy Procedia*, vol. 25, pp. 135–140, 2012, doi: 10.1016/j.egypro.2012.07.018.

[11] K.-P. Kairies, D. Magnor, and D. U. Sauer, "Scientific measuring and evaluation program for photovoltaic battery systems (WMEP PV-Speicher)," *Energy Procedia*, vol. 73, pp. 200–207, Jun. 2015, doi: 10.1016/j.egypro.2015.07.672.

[12] S. Anuphappharadorn, S. Sukchai, C. Sirisamphanwong, and N. Ketjoy, "Comparison the economic analysis of the battery between lithium-ion and lead-acid in PV stand-alone application," *Energy Procedia*, vol. 56, pp. 352–358, 2014, doi: 10.1016/j.egypro.2014.07.167.

[13] A. Dell'era *et al.*, "Experimental tests to recover the photovoltaic power by battery system," *Energy Procedia*, vol. 81, pp. 548–557, Dec. 2015, doi: 10.1016/j.egypro.2015.12.128.

[14] D. Linden and T. B. Reddy, Eds., *Handbook of batteries*. New York, NY, USA: McGraw-Hill, 2002.

BIOGRAPHIES OF AUTHORS

Shiva Rama Krishna. Samala PG Scholar, Dept. of EEE, Chaithanya Bharayhi Institute of Technology, Gandipet, Hyderabad, Telangana, India. He can be contacted at email: samalashivaram139@gmail.com.

E. V. C. Sekhara Rao obtained his diploma in Electrical Engineering from S.M.V.M. Polytechnic, Tanuku, West Godavari district, Andhrapradesh. He was graduated in Electrical and Electronics Engineering from JNTU, Hyderabad. He was post-graduated with specialization in Industrial Drives and Control from University College of Engineering, Osmania University. His doctorate was awarded by Osamnia University in the Faculty of Electrical Engineering for Design of PMH Stepper Motor using FEM and Equivalent Circuit Methods. He has 14 years of academic experience out of which 10 years in post graduation teaching and 14 years in under graduation teaching. He has 12 years of industrial experience in electrical power generation and transmission. He has three years of research experience and guiding eight research students. He is giving his services as Associate Professor in the Department of Electrical and Electronics Engineering for Maturi Venkata Subba Rao Engineering College (MVSREC), Nadergul, Hyderabad, Telangana India since Feb. 2018. His areas of interests are electrical special machines, electrical drives and power electronics, energy management, and RES.