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Design and Implementation of an Automatic Solar Panel Based Led Street Lighting System Using Zigbee and Sensors

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Abstract: Electricity has become are indispensable component in the lives of all today. Street lights are one of the most crucial parts for public sector and urban areas. The traditional street lighting System which controlled manually has disadvantages like high power consumption, high cost and there is no effective monitoring system. This paper is proposes an Automatic Solar Panel Based LED Street Lighting System with wireless communication technology and various sensors to facilitate reduced power consumption. The system is connected to ZIGBEE network to transfer the information about street lights by utilizing ZIGBEE transmitters and receivers. The data is sent to base station control to know the status of the street light and to take proper evaluation in case of malfunction. The proposed prototype has been tested in different environmental conditions. The system has achieved 20-22 % of power reduction and economy in maintenance costs. A laboratory prototype was implemented and tested. Experimental results were shown to verify the feasibility of the proposed scheme.

Key words: Automation · LED · Sensors · Zig Bee · Solar Energy

INTRODUCTION

Street lighting systems are a typical case of distributed low-voltage loads located in areas and collecting protected by the same device. Currently, reduction of electrical power consumption has been an extremely noticeable issue in India, Where the wastage of power occurs highly in street lighting zone. A Street light is an important source of light on the edges of the road and it plays a vital role for providing society security, ensuring quality of life and avoiding crimes as well as accidents during night time. Street light systems were manually controlled, later via time control and optical control manner. These methods are very costly and noted for difficulty in monitoring. They involve high Power Consumption. The universal observation is that about 20% of power consumption occurs through street lighting system due their designs as per old standards which do not incorporate the latest technology features [1- 3].

There are three possible solutions for the problem mentioned above. First possibility is use Renewable energy source in the place of conventional power source. The Second is utilization of the latest LED Lighting technology which offers many benefits like, environment friendliness, energy efficiency and about a 50% saving in Power consumption, compared to other lighting technology like compact fluorescent, incandescent, sodium vapour lamp etc. A Third is the Remote-control system which involves, as the nomenclature suggests, Remote Control and monitoring which simplify problems of management and maintenance problem [4-6].

The scope of this paper is to integrate the above three possibilities to develop an automatic solar panel based LED Street Lighting system. The system is controlled remotely using ZIGBEE network which is powered by renewable energy and LED based light source. Many researchers have put in considerable efforts in street lighting matter in the areas of reduction of power consumption, maintenance cost and for ensuring cost effective lighting system. Caponetto *et al* have focused on the different remote control based street lighting system. In this system information of the street lights is transferred periodically to the base station control to solve management and maintenance issues [1]. This type of system has been developed through GPRS (General Packet Radio Services), power line carrier and GSM (global system for mobile communication). Liu *et al* have developed a street lighting system by utilizing latest light

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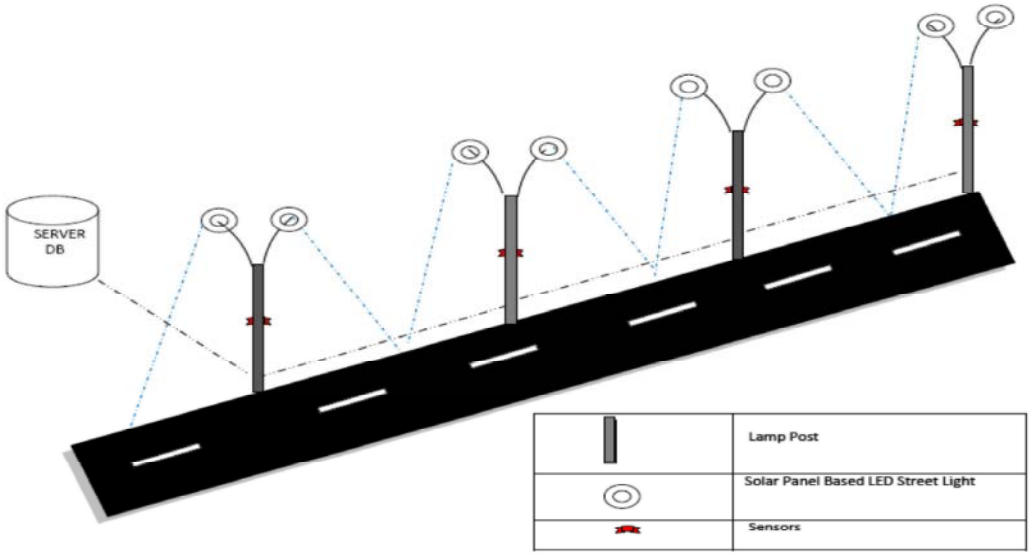

Fig. 1: Prototype plan of the street lighting system.

source technology (such as LED technology) which ensures longer life span and environmental impact [7-9]. Tao *et al* have proposed the intelligent street lighting system by using a renewable energy source instead of the conventional power supply. The street lighting system works via network of sensors to gather street light information and sends to the microcontroller by utilizing ZIGBEE protocol [10]. Chen *et al* have presented an intelligent street lighting system with less number of sensors and a monitoring station which is situated in street lights. These devices sense the data about street lights and transfer the data to the control terminal in order to maximize the fault tolerance. Tao has developed a low power lighting control system, wherein nodes work autonomously to locate and identify communication problem via a remote control system for taking corrective action in the event of power failure [2].

Street lighting systems, particularly within the public sector, are still being designed according to the old standards of reliability and they don't exploit the most recent technology. Electricity is the major requirement in the developing countries like India, a big chunk of power is utilized in the street lights. Manual control of street lights results in considerable wastage of power. There is no possibility of dynamic monitoring. Maintenance expenses are high too. All these arise due to absence of a Remote Control technique. Considering these issue, this paper proposes an automatic solar panel based LED Street lighting system which ensures lower power consumption, lower operating costs, no insect swarming and for making cities smarter [11-16].

The rest of the paper has been designed as under: chapter 2 provides a summary of the research efforts already done or the state of the art techniques, in chapter 3 highlights the functional achievements, chapter 4 describes over all architecture of street lighting system, chapter 5 deals with devices and method. Chapter 6 shows details of implementation of street lighting system and chapter 7 presents conclusions.

Proposed Prototype and Functional Achievements: The main theme of this paper is Enlargement of the system to ensure automatic working and remote management. These two procedures can enhance the effectiveness of the street lighting system to reduce the power consumption and maintenance costs. This section shows the requirements of street lighting system to achieve the above two procedure.

First, the street lights behavior should be altered autonomously based on environmental condition. The system should able to predict some individuality of the environment such as passage of vehicle and people. Second, the street lights should adjust the illumination level (dim or bright) based on the environment situation. Finally, the mandatory requirements of the street lighting system are to communicate with control terminal by utilizing some wireless communication technology such as GPRS and GSM.

The aim of this system is to provide a street lighting system which works automatically to the role of street walkers at night times. The (Fig. 1) shows the prototype plan of the street lighting system. The solar street lamp

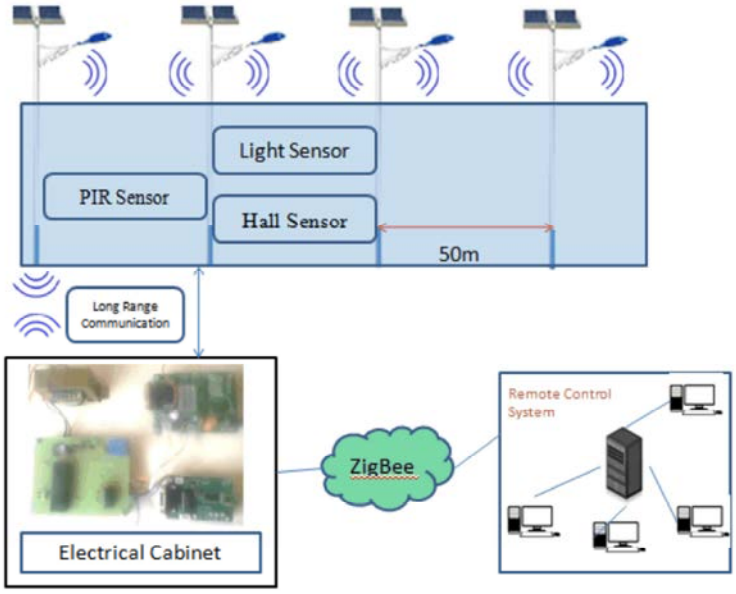

Fig. 2: Shows the overall architecture of street lighting system.

post consists of sensors (Light Sensor, PIR Sensor), solar panel and LED Street lights. Every lamp post has been connected to the server based on zigbee technology (wireless). Each and every LED lights emit power according to the number of LED's and watts of the LED fetched in the lamp post [17].

As per this paper, the two lights will glow (single lamp post) automatically, when the person reaches the previous lamp post. An accordance with light sensor, modern lighting units have their power levels adjusted so that lighting levels (dimming) can be reduced when traffic flows are low or at off peak times. They can be turned up to full power when needed. The dimming of LED's saves energy.

System Architecture: The system consists of a monitoring station on each lamp post and base station lies in close proximity area for all the street lights. The monitoring station uses the sensors, to scrutinize some factors such as light intensity, climate (or) environment condition, season and various factors, based on this factors street lights will automatically turn ON or OFF.

The sensed information of a measuring station is sent to the base station via wireless communication. In the event of failure, information is transmitted to the service engineer through GUI to take necessary action.

Devices and Methods:

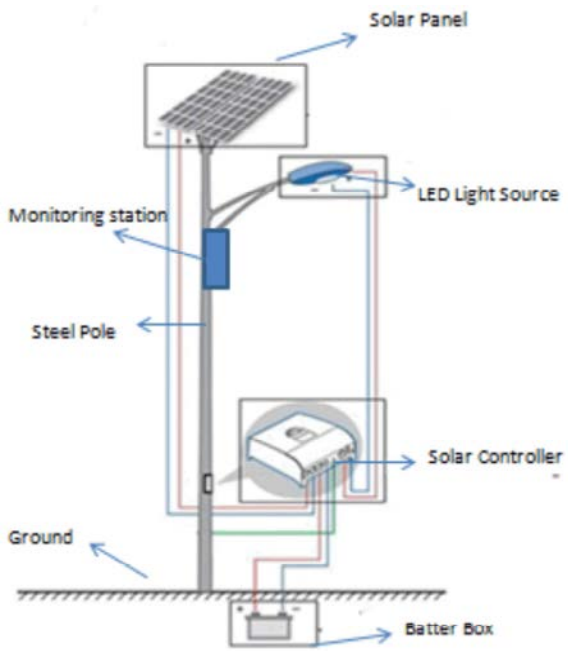

Fig. 3: Schematic image of Street Station.

Monitoring Station: Monitoring station is placed each lamp post. It has various types of sensors such as Light Sensor, PIR Sensor, Hall Sensor and Emergency Device. All these sensors work together and transmit the information to the microcontroller, then the sensed data are processed and remedial action is taken.

Fig. 4: Light Sensor

Fig. 5: PIR Sensor

Light Sensor: A Light Sensor (Figure 4) is used to sense the illumination level of the street light and surrounding brightness of the sunlight. The sensed information is sent to a microcontroller in order to maintain the constant lighting level of the street light [18].

There are different types of Light Sensors such as Photo transistor, Photo Diodes and Photo Resistor. In this system Photo Transistor is used to change the lighting level based on the weather condition. The exploit of this sensor is required in some cases such as, in morning and at dusk but it is not required at daytime. The electrical power is saved through the use of this sensor, because it is controlled by pooled action of sensor and microcontroller, to provide minimum illumination of the street light as required.

Presence Sensor: The utility of PIR (Figure 5) sensor is to identify the passage of vehicles and perambulator. In India, particularly in rural area there is no passage of vehicles or perambulator at mid night. If the street light glows all over night, the wastage of power occurs more. To solve this problem SE-10PIR Sensor is used in this system.

PIR Sensor is used to Turn ON the street light; only it identifies the passage of vehicles or people. The Sensor should not be placed too low (to avoiding monitoring the small animals) nor too high (can't be sense kids or children). So the placement of the sensor should be at right place.

Hall Sensor: Hall Sensor is used to recognize, whether the street lights is switched ON or NOT. It mainly focuses on switched ON conditions. The system identifies and

Fig. 6: Hall Sensor

Fig. 7: Emergency Device

sends the liability values to the base station via ZIGBEE devices and then the operator informs the technician to take right action. It helps to recuperate fault maintenances and system management.

Emergency Device: The Emergency Device (Figure 7) is connected to inclusive sensor network and is used in the case of any emergency situation (system abortive condition). When the emergency device is activated, the light lamps of the entire street are turned OFF. The system should be active all the time but it is not required at day time.

Base Station Control: Base Station Control is used to monitor the street lights through Graphical User Interface (GUI). This system shows hallucination of entire street lighting system.

The Base Station system is interfaced with computer via Universal Asynchronous Receiver-Transmitter (UART). It receives sensed information of street lights from monitoring station by utilizing ZIGBEE device.

(Figure 8) shows Graphical User Interface of the street lighting system. Through GUI, street lights can be controlled remotely by sending commands over ZIGBEE network. When clicking Power Consumption, a second window (Figure 9) appears, showing total working time of individual Street light and power consumption details.

Zigbee Network: ZigBee is a wireless communication technology and is used to communicate with multiple devices in Wireless Personal Area Network. It is based on IEEE 802.15.4 standard. ZigBee technology consumes less power, high battery life and low cost comparing to Bluetooth & Wi-Fi.

Table 1: Comparison between Low Power Wireless Technologies

Parameter	*ZigBee*	*Wi-Fi*	*Bluetooth*
Year	1998	1991	1994
IEEE Standard	802.15.05	802.11bgm	802.15.01
Data transmission rate	250kbps	1mbps	1-5mbps
Power consumption	Low	High	Medium
Network topology	Mesh	Star	Point to point, Master slave
Spread spectrum technique	DSSS	DSS,CCK,OFDM	FHSS
No of nodes	>6500	2007	8
Range	100-1600m	100m	10m
Frequency range	2.4GHZ	2.4GHZ	2.4GHZ
Cost	Low	Normal	High
Success metrics	reliability	Cost convenience	Flexibility

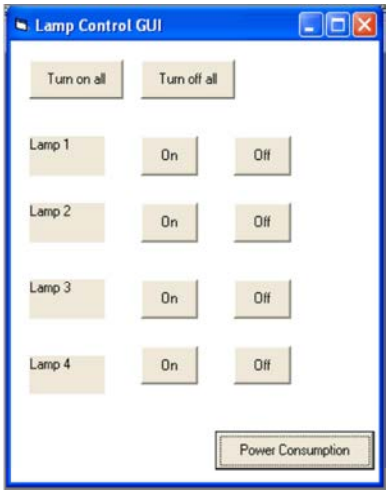

Fig. 8: Lamp control GUI

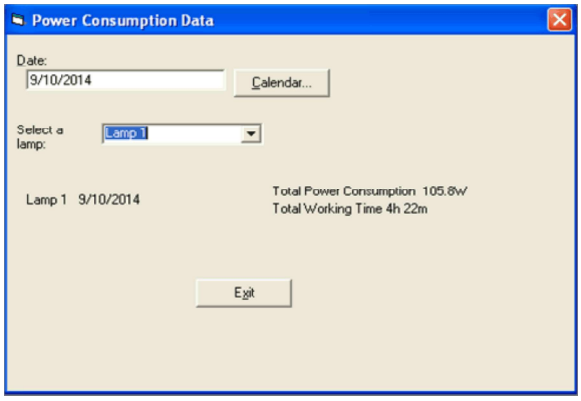

Fig. 9: Observation of Power Consumption

In this system, the data of street lights is transferred from the monitoring station to the base station. The data is transferred from one lamp post to the next nearest lamp post, this process continues until the data reaches the base station. If any failure occurs in one lamp post during transformation of data in a chained network, then the data should the reach next lamp post without breaking the chain based on transmission distance between lampposts.

In this system Xbee module is used to ensure the communication between the lamp posts, the indoor range of the Xbee is 10m and 100m in outdoors. Xbee Pro has high transmission speed and vast range (1.5 km) comparing to Xbee module but Xbee Pro consumes high power.

RESULTS

(Figure 10) shows prepared test system in real life condition. The system has been tested in real time environment to see the overall functionality and performance. While testing of the system, the measurement has been collected, to enable calculation of the total.

Power Management: The system has been designed to ensure automatic working and supply of renewable source energy in order to avoid conventional power and cost. Utilization of renewable energy source (Solar Panel) lower power consumption and minimizing battery capacity which is achieved through the use of Xbee modules which transmit and receive information which an LED lamp instead of the traditional one.

The system is controlled through a program and it is intended to save energy. First, the street light system is needed only at night time, to reduce power consumption. During day time the solar panel only works to recharge the battery. Second, PIR, Light and Hall Sensors allow the system to work, when it required. Third, the system use LED Light Source, which ensures proper lighting level and saves the energy.

(Table 2) shows the power consumption and operating time of New and Old lamp posts. The reading was taken while testing the system with (or) without sensor and with traditional lamp post such as mercury vapor lamp.

Table 2: Power Consumption and Operating Time for new and old Lamp Posts

Lamp ID	Power Consumption				Plant Costs				
	Time (h)	I(A)	kWh	Costs h X kWh (INR)	Battery type and costs (INR)	Solar panel type and costs (INR)	Battery recharger (INR)	Cost (lamp) (INR)	Power supplier
New Lamp (L1)	74.10	1.47	1.330	0	5 A-1150	19w-3500	713	1290	0
New Lamp Without Light Sensor(L2)	250	1.48	4.600	0	20 A-1784	80w-15000	713	1290	0
New Lamp Without Presence Sensor And supplied by Conventional Power (L3)	251	0.08	5.200	70	none	none	713	1290	30
Mercury Vapor Lamp Without Presence Sensor and supplied by Conventional Power(L4)	251.7	0.20	13.14 9	200.50	none	none	713	1100	40

Fig. 10: Test System

CONCLUSION

The paper describes an automatic solar panel based LED street lighting system; it integrates latest technology such as LED technology and Renewable Energy Source in order to reduce power consumption, cost and manual controlling method.

An extra benefit is obtained through controlling the lamp posts remotely which ensures effective management by utilizing ZigBee technology. Around 20-25% of power consumption and maintenance cost reduced through this prototype. This street lighting system is appropriate for rural and urban areas. The designed system is flexible, extendable and fully adjustable to user needs.

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