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Development of an Intelligent Security Lighting System using Wireless Communication Technology

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ABSTRACT

Electric power generated all over the world is not sufficient to meet the overall demand at present. Around twenty percent of total power generated by the power utility companies is consumed for the lighting purpose. Reducing the power consumption for the lighting will help in saving great amount of power, which can be utilized in some other areas with more importance. In the recent years with the advent of solid state lighting (LED), a promising future is being achieved towards attaining that goal. Integrating LED security light with embedded system and communication module will add more functionality to it. Not only it will save energy but also it will provide information regarding the surrounding environment. This additional functionality has few advantages which are monitoring the luminaire health status remotely, reduces cost, provides better visual performance, reduces maintenance, provides automatic detection of pedestrian and finally serves the citizen intelligently. In this paper, a detail development of intelligent security lighting system has been described. Some of the properties of Internet of Things (IoT) have been implemented and integrated in this work like remote monitoring of the health of the luminaire and communication with central computer using Zigbee protocol. Detail photometric analysis of the luminaire was done using a 1m diameter integrating sphere. IsoLux diagram of the luminaire was provided at different PWM (Pulse Width Modulation) duty cycle, controlled from central computer. It also proposes the solutions to existing limitations and some of the up-gradations which can be considered in near future to increase its reliability.

KEYWORDS

Luminaire, Light Emitting Diode, Lighting Devices

INTRODUCTION

Security lighting is exterior lighting which is operated every night from dusk to dawn, the main purpose of which is to protect premises, property, and people from criminal attack. While the principal objectives of security lighting are to prevent loss due to criminal acts, it may serve other purposes, such as assisting in safe movement of persons and vehicles on the site, and aiding the performance of work. Security lighting systems provide enhanced night security by deterring the intended criminal; revealing the criminal before, during and after the attack on the premises and in many cases, providing some degree of concealment of the defenders from the view of the attacker. Additionally the lighting may facilitate the safe patrolling of the area by the defenders [1]. Fig. 1 shows the location of security lights around a building premise. With rapidly increasing energy demand all over the world, saving lighting energy in building environments has become increasingly important since lighting accounts for a considerable portion, typically more than 20% of energy consumption in buildings [2], [3].

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Fig. 1 Location of security lights around a building premise

This has led to the exploration of not only new lighting technologies such as solid-state lighting (SSL) [4] but also a smarter approach to utilize these SSL systems. Integrated lighting controls for demand-side energy management in building can significantly improve its overall performance [5]–[7], increase energy efficiency, and enhance occupant comfort [8] and satisfaction with the built environment [9]. One of the main challenges is to develop SSL systems with an innovative driver. Usually, they are switch mode power supplies with a Buck-boost or Fly-back topology [10]. They should be optimized for driving LEDs with respect to energy saving, while considering the following requirements of the application: compactness, cost, high level of integration, smart solutions and safety [11]. For this reason, the trends in driver design aim to reduce the largest components, such as transformer, capacitor, rectifier bridge and to integrate more passive components in the control IC [11]. On the other hand, drivers should be compatible with available wall adapter control, and should have innovative remote control options like wireless and Zigbee, adding features like light and color control, and energy management [10]. Recent proliferation of wireless technologies and choices available to user applications has triggered a tremendous wireless demand, and the wireless nodes are expected to dominate the Internet soon [12]. The availability of wireless resources as substrates has caused an ever-increasing variety of applications [13]. Recent reports show that usage of mobile Web [14] and WiFi by smartphones is increasing sharply. Accommodating this growing wireless demand with cellular capacity does not seem possible in the long run.

In this work a LED security luminaire of 18 watt prototype is developed with dusk/dawn sensor to sense night time and accordingly switch on the luminaire with dimming control from the microcontroller attached to it. The dimming of the luminaire is done by controlling the Pulse width modulation (PWM) duty cycle from the microcontroller. System is also attached with an Occupancy sensor to detect any person near it and accordingly shift the brightness to full illumination level after specified time duration set previously. Wireless communication is used to transmit data between two xbee modules working as router and coordinator. Coordinator module is connected to a Raspberry Pi unit and a computer working as local control unit as shown in Fig.2. Router side module is connected with a microcontroller working as brain for the lighting system as shown in Fig.3.

METHODS

In this work, a luminaire with LED arrays was used to develop the prototype of the security lighting system. Acknowledgement of the status of different conditions of the luminaire was done through use of different sensors. In this work, an occupancy sensor has been used to detect any person near the luminaire and accordingly control action of the illuminance levels provided.

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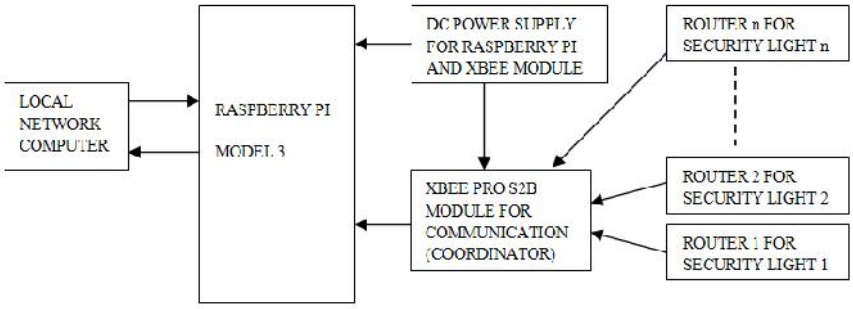

Fig.2 Block Diagram of the Local control unit side (Coordinator)

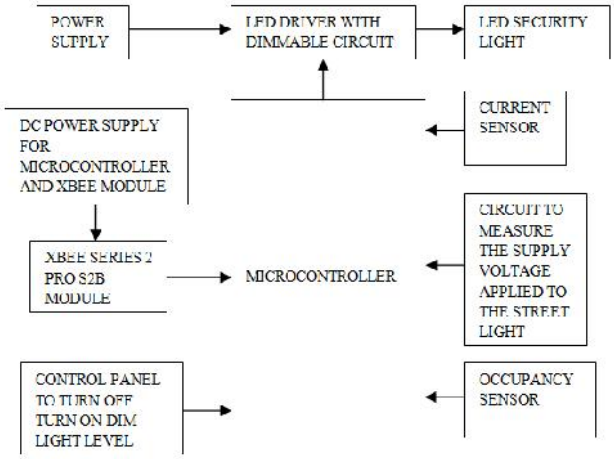

Fig: 3 Block diagram of Luminaire (Router) side

A Microcontroller is working as the brain of the lighting system. Microcontroller along with different circuits connected the sensors along with dimming circuit and LED driver before installation on luminaire is shown in Fig. 4. Main functions of the microcontroller are to send the status informations and receive commands from local control room. In this process, microcontroller collects different datas from the sensors for status informations and transmits through the connected xbee module and receives the informations from the xbee module & accordingly processes those informations and accordingly dim down light output level of the luminaire. Zigbee protocol is used for wireless communication between the modules.

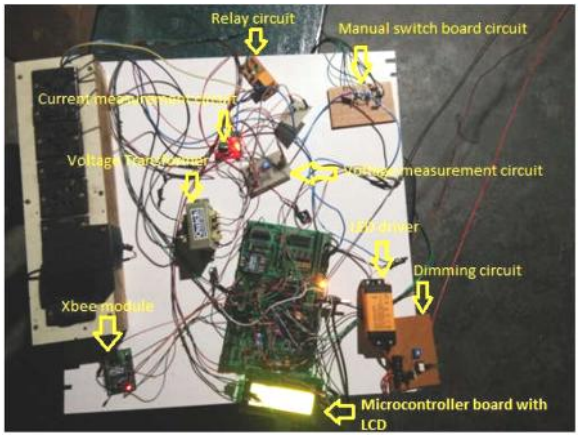

Fig. 4 Diagram of Microcontroller unit with circuits for different sensors before installation at luminaire

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Another function of the microcontroller is to detect presence of any human being near the luminaire. In that case luminaire will shift to full brightness level from dim illumination condition.

Status information of the luminaire pole system is transmitted by the xbee module working as Router, from pole lighting system to another xbee module, working as Coordinator in local control unit side.

Command signal from the coordinator side, local control room from a computer through a Raspberry Pi module is sent to numbers of router modules i.e. multiple lighting systems. Router side block consists of atmega 32 microcontroller, all the sensors are connected and xbee module for communication. This block controls the LED security light.

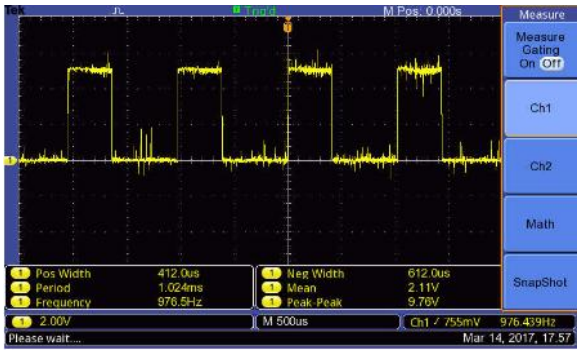

Fig.5 Microcontroller PWM output

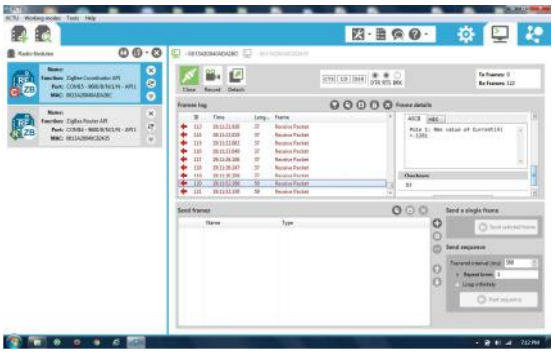

Fig. 6 Data receiving by Xbee module

This coordinator block receives all the data from the Luminaire (router side blocks). Microcontroller manufactured by Atmel, ATMEGA32 is used for controlling purpose. A xbee module, model number Xbee Pro S2B series 2 is being used for serial communication purpose. On the receiver side xbee is used in Application Programming Interface (API) mode for transmitting or receiving data to or from another xbee module. Fig. 5 shows PWM duty cycle of microcontroller output. Fig. 6 shows Screen shot of the luminaire status data received by the xbee module at coordinator side. In Fig. 7 the Luminaire system, the developed prototype is shown. A grid mat is used to measure illuminance at the grid points.

Fig. 7 Diagram of the luminaire glowing on a flexible pole inside Illumination lab

A dusk to dawn sensor is connected to sense low sky light during evening time and switch on the luminaire. Current and voltage sensors are used to detect illumination conditions of lamps as status intimation. The sensors have been used to detect luminaire on or off status by the current flowing through it. The sensor measures less current while the luminaire is in dimmed condition. Voltage sensor measures terminal voltage at

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connecting terminal of the luminaire. Current and voltage sensors together measure lamp failure status by proper voltage signal but no current signal by the microcontroller. A dimming circuit is used to dim the light level after getting the dim signal sent by the microcontroller. In evening time to pre determined time duration luminaire will glow at full brightness level for four hours has been set for general illumination, and then it will be dimmed by controlling PWM duty cycle. During dimmed illumination condition, the luminaire will glow to its full brightness level by an interrupt signal from the Passive infra red motion sensor, in presence of any human being.

The developed prototype has been experimented in Illumination Engineering laboratory of Jadavpur University and wireless communication distance is obtained of 5.2 meter.

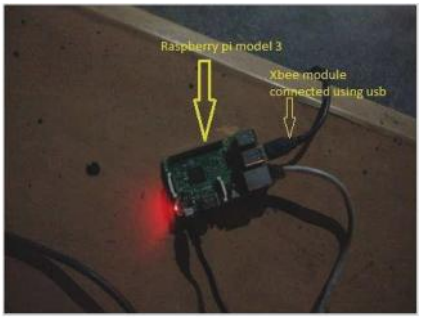

Fig. 8 Raspberry Pi module is connected to Xbee module

Raspberry pi Model 3 is used as internet gateway. It acts as a bridge which helps to access the luminaire status data being uploaded to it. Fig. 8 shows Raspberry Pi is connected to xbee module. Raspberry Pi module is also connected to internet network through mobile handset. Raspberry pi Model 3 also acts as a central hub for receiving and storing all data (for certain period of time). All the information regarding the status of the luminaire can be accessed by any computer having a proper IP address and connected to the local network.

RESULTS

Here the diagrams show different illuminance distribution values transmitted from local control unit to the luminaire and accordingly microcontroller provided that output to the driver of the luminaire.

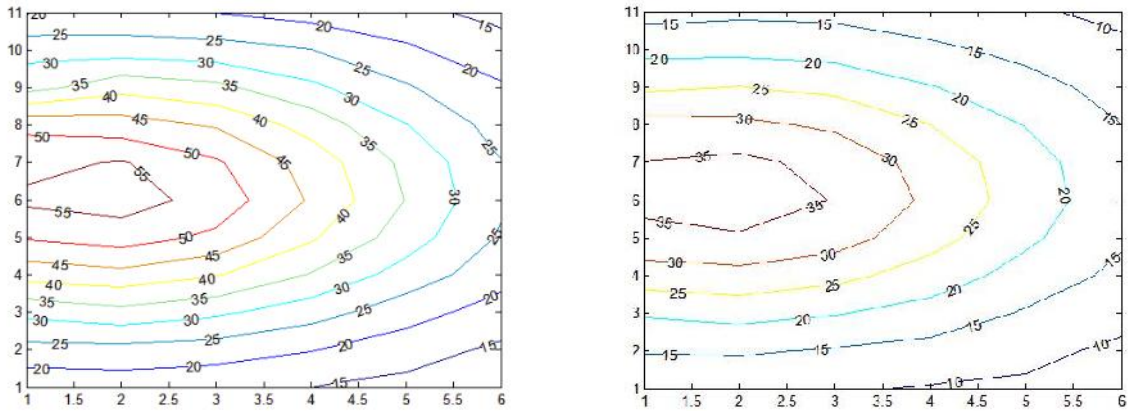

Fig. 9 Isolux Diagram at PWM duty cycle 100% and 30%

In order to determine the isolux plot of the 18W LED security light, rectangular area of 3m X 5.5 m is used to collect the illumination values in front of the streetlight pole. This area is subdivided into 0.5m X 0.5m area grid square. Grid points are 0.5m apart from each other.

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The height of the security lighting Luminaire is kept 3m for measurement of isolux diagram over the surface shown in Fig. 9.

Table 1 Light distribution values mentioned

	PWM Duty cycle		
	100%	**60%**	**30%**
Illuminance (Max) Lux	57.3	46.1	37.5
Illuminance (Min) Lux	10.6	8.5	6.9

Table 2. Electrical test report of 18W cool white security light Luminaire

Voltage (V)	Current (A)	Power (W)	Power Factor	Frequency (Hz)
230.05	0.1693	18	0.465	49.88

Table 3.Photometric test report of 18W cool white street light Luminaire

Lux	Luminous Flux (Lumen)	CCT: (^oK)	x	y	Efficiency (lumen/W)
342.4	1711.6	5969.5	0.3452	0.3401	95.088

Sphere Diameter: 1meter
Stabilization Time: 10mins
Globe Internal Temperature: 34 deg C
Communication Distance 5.2 meter

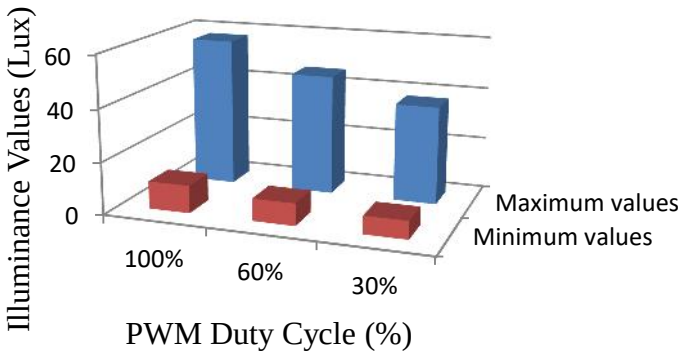

Fig. 10 Bar graph of the luminaire illuminance max & min values at different PWM duty cycle values

Fig. 9 shows isolux diagram drawn based on the illuminance values on the lighted surface in front of the lighting pole with two different conditions, one at pulse width modulation (PWM) duty cycle 100% i.e. when there is no dimming, the other one when PWM duty cycle is 30% i.e. when the lighting level is dimmed. Figures here show two PWM duty cycle levels. There were total three dimming level changes for change in duty cycle. Summary of that is shown in Table 1, with change in maximum and minimum illuminance for change of PWM duty cycle is shown with bar graph in Fig. 10.

DISCUSSION & CONCLUSION

In this work, the design and development of a intelligent security lighting system prototype is done. The system uses zigbee as communication protocol to transmit data between two xbee modules that is utilized to make the system intelligent and make the whole system self operative. The system has the limitation of poor communication distance, it can be improved by other version of xbee module. It also enables supervisory control of the system from local control station. Raspberry Pi module with specific IP address is connected with the system to transmit & receive information using internet network . In that sense the system can be accessed from any place with internet connection. In that scenario encryption & decryption methodologies become very important to make the system secure enough and fault free in future, not allowing unauthorized access.

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