Design of IoT based Smart Street Light System

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Abstract— Energy crisis and environmental pollution are two biggest challenges which India is facing today. To counter these problem we use LED based Street light system which help in reducing energy consumption. The objective of this paper is to design an energy efficient smart street light by dimming the street light during non-peak hour time and to monitor the street light system remotely. This paper will also emphasize on the fault detection and correction as soon as possible. It will drastically reduce the maintenance cost and increase system efficiency and reliability. The Web server gives instant access and control over the entire street light system.

Key words: LED Street Light, Zigbee, Arduino

I. INTRODUCTION

In developing countries the energy crisis is biggest problem. There are various challenges which can be resolved if this problem is resolved. But building power plant costs too much resources and time. On the other hand if we reduce the consumption it will boost economy as well as environment. An important component of power consumption worldwide is street lighting [1]. India is no different. Global trends in street lighting show that 18-38% of the total energy bill goes towards street lighting and therefore this is one domain that needs major attention if we look at improving efficiency of power consumption with an objective of saving energy. Also studies have shown that proper street lighting can substantially reduce fatalities and crashes with pedestrians [2] and lighted intersections and highways have fewer crashes than their unlit counterparts [3].

The utility electricity sector in India had an installed capacity of 307.28 GW as of 31 October 2016. Renewable power plants constituted 28.9% of total installed capacity [4]. The gross electricity generated by utilities is 1,106TWh and 166TWh by captive power plants during the 2014–15 fiscal [5]. The gross electricity generation includes auxiliary power consumption of power generation plants [8]. India is the world's third largest producer and fourth largest consumer of electricity.

India has 35 million street lights which generate a total demand of 3,400 MW. With LED, this can be brought down to 1,400 MW, saving 9000 million kWh of electricity annually, worth over $850 million in the process [6]. To put this into perspective, the electricity deficit in India during 2014-15 was 38,138 million kWh and 7,006 MW.

Streetlights need not be on throughout the night on full intensity. The intensity, for example can be reduced to 50% for early hours of the morning, and further to 33% for later hours, for traffic intensity at these hours is least, thus reducing energy consumption by 46% [7]. We can have automated schedules depending on the day of the week climate, festivals and so on. The assessed energy savings vary in large limits, from 20% to 50% depending on many factors. It is ~ 37% in summer and ~ 4.0-45% in winter [8].

Luminaire Type	Units (million units)	Assumed Wattage	Assumed Hours of Operation	GWh	% of Total (units)	BMC % of Total (units)
Incandescent	1.78	70	2,920	364	2%	
Tungsten halogen	13.34	61	2,920	2,363	17%	
Compact fluorescent	4.97	18	2,920	254	6%	10%
Light emitting diode	3.75	15	2,920	160	5%	
High intensity discharge	19.80	120	3,650	8,673	26%	57%
Efficient high intensity discharge	0	96	3,650	0		
Linear fluorescent	31.70	52	3,650	6,017	41%	32%
Efficient linear fluorescent	1.86	39	3,650	265	2%	2%
Total	77.19			18,094	100%	94%

Table 1: Enlighten Estimates for Outdoor lighting in India 2010

II. LED BASED LIGHTING SYSTEM

A. Light Emitting Diode (LED)

Early LEDs, such as those often used as indicator lights on electronic equipment, created very narrowband, but not quite monochromatic light ranging in color from yellow-green to red. But it was not until the development of AlGaInP and InGaN LEDs with much higher light output than the early indicator lamps, that useful quantities of light could be generated from LEDs. In addition, these materials allowed, for the first time, LEDs with peak wavelengths at any part of the visible spectrum to be made. White light can be made by mixing light from different parts of the spectrum.

Larger devices and packages have increased the overall light output of LEDs to levels that are useful for some lighting applications. In addition to increased size of the semiconducting elements, LED construction has also changed to make them more efficient [9]. The crystals forming early LED junctions were grown on light absorbing substrate materials. Using transparent substrates and optimizing the shape of the semiconducting element have increased the amount of light able to leave the device, as shown in Figure.

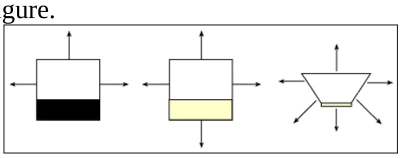

Fig. 1: Improved design of LEDs to increase efficiency.

The substrates are shown as shaded areas. Early LEDs used light-absorbing substrates (left); later, transparent substrates were developed that permitted light to be emitted in additional directions (center); subsequent shaping of the semiconducting elements (right) has resulted in improved efficiency.

A. White light LEDs

Presently, there are two approaches to creating white light.

1) Mixed-Color White Light

One approach is to mix the light from several colored LEDs (Figure 2) to create a spectral power distribution that appears white. Similarly, so-called tri-phosphor fluorescent lamps use three phosphors, each emitting a relatively narrow spectrum of blue, green or red light upon receiving ultraviolet radiation from the mercury arc in the lamp tube. By locating red, green and blue LEDs adjacent to one another, and properly mixing the amount of their output (Zhao et al. 2002), the resulting light is white in appearance.

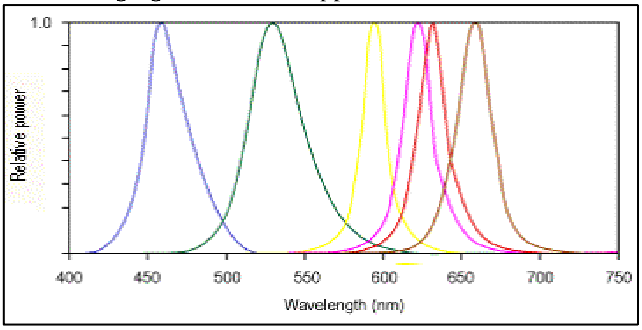

Fig. 2: Spectral power distributions of several types of LEDs

2) Phosphor-Converted White Light

Another approach to generating white light is by use of phosphors together with a short-wavelength LED. For example, when one phosphor material used in LEDs is illuminated by blue light, it emits yellow light having a fairly broad spectral power distribution. By incorporating the phosphor in the body of a blue LED with a peak wavelength around 450 to 470 nanometers, some of the blue light will be converted to yellow light by the phosphor. The remaining blue light, when mixed with the yellow light, results in white light. New phosphors are being developed to improve color rendering as shown in Figure.

The material used in the semiconducting element of an LED determines its color. The two main types of LEDs presently used for lighting systems are aluminum gallium indium phosphide (AlGaInP, sometimes rearranged as AlInGaP) alloys for red, orange and yellow LEDs; and indium gallium nitride (InGaN) alloys for green, blue and white LEDs. Slight changes in the composition of these alloys changes the color of the emitted light [10].

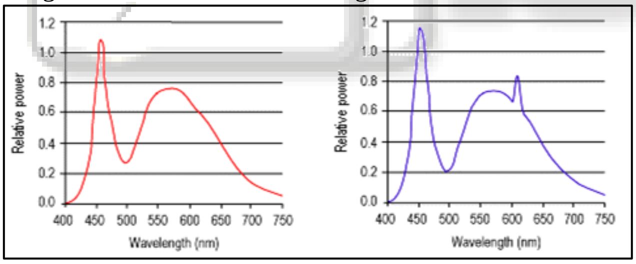

Fig. 3: Spectral power distributions of early phosphor-based white LEDs (left), and white LEDs using more recently developed phosphors (right) with increased output between 600 and 650 nanometers.

III. PROPOSED MODEL

A. Block Diagram

In this model, sensor node has a sensing device to sense whether the light is ON or NOT. The relay switch ON/OFF the street light when the user instructed it. The micro-controller processes signal and forward/receive data from wireless transmission unit. All the data from every sensor node is gathered at the central hub. At the central hub data is processed and compiled. This data is then uploaded through web server on to cloud. From cloud any authorized personal can access the system, thereby control and monitor it.

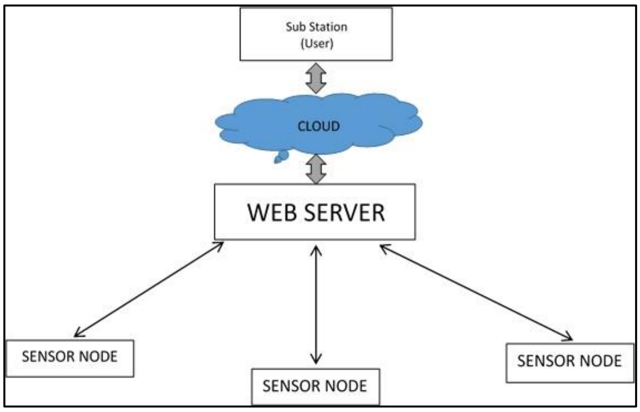

Fig. 4: System block diagram

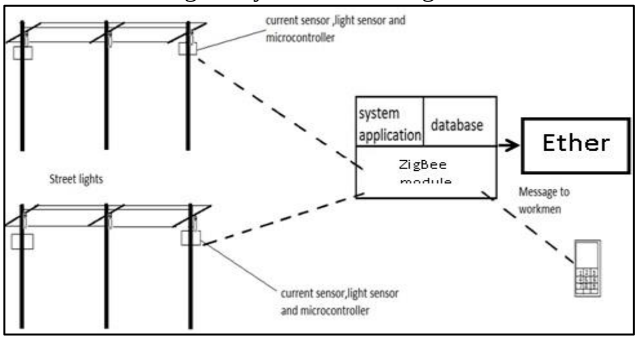

Fig. 5: Sensor Side working

In this model we use ZigBee [11] to communicate between two street light and the central control node. ZigBee is arranged in mess like network in which there is more than one way to communication between devices.

B. Working

When the environment light intensity is quite low then the resistance of LDR becomes high and street light will glow on the other hand when intensity is high so resistance of LDR become low and circuit breaks up. The led driver circuit consist of buck converter with PWM dimming control. A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load).

The microcontroller Atmel328 is use in designing the circuit. The ZigBee sends and receive the data as well as signals from server side. The micro controller generates PWM signals which controls the voltage across led light. The current and temperature measuring sensors are used for the feedback as well as for fault detection.

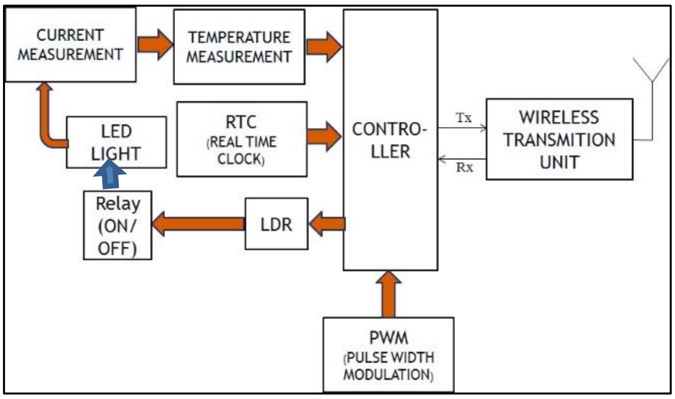

Fig. 6: Systematic block diagram of sensor node

C. Simulation of the Proposed Prototype

On the sensor side we have Atmega328-P from which we have connected oscillator circuit to provide appropriate clock. When light is ON LDR resistance changes and generates a signal which is then processed in Atmega328. After comparing the voltage level the transistor is turned ON which energies relay and switch on the LED light see fig. 7.

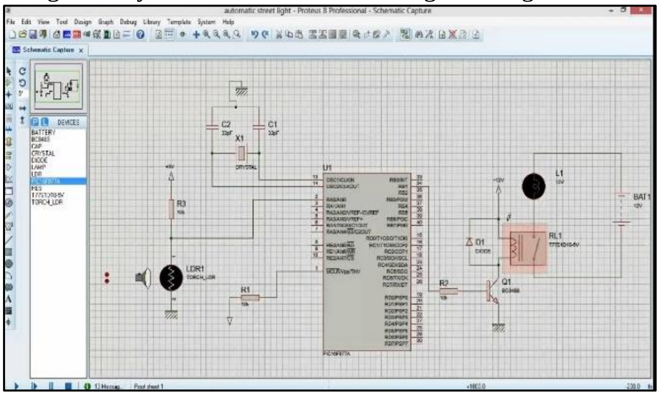

Fig. 7: Senor Side Simulation

On the server side we have Arduino board which is connected with ZigBee module, Ethernet shield and RTC (Real Time Clock) circuit. RTC provides the switching time for the intensity change which is from 75% to 35% PWM (Pulse Width Modulation) at 23:00 hrs. The Arduino is programmed to act as a web server. It collects the data from ZigBee which gets his data from sensor nodes and stores it for further uses see fig 8.

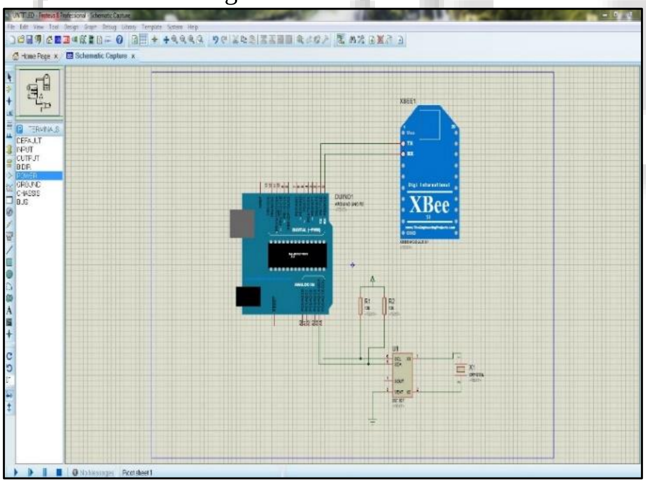

Fig. 8: Simulation of Server Side

IV. RESULTS

The server side Arduino, contains the coding of PWM and Web page (HTML based). And in the receiver side i.e. sensor side we have LDR to detect the change in light intensity which in turn turns switch ON/OFF the street light. When the LDR is activated the system it gives a signal to Arduino to switch ON the LED light which causes the current value to change which in turn send a signal to ZigBee to transmit that the LED is ON. This signal is then received by the server side ZigBee which give it to the Server side Arduino which records the current, temperate and time in the memory. This database is shown on the web page. From this web page we can control the LED Street light and monitor it from anywhere.

The web page have two modes; namely auto and manual mode. In auto mode the street light functions normally just as described above. While in manual mode the street light can be controlled through web page whether it is day or night, we are able to turn ON/OFF street light according to our requirements. The manual mode is strictly for administrator use only. It will come in handy when in there is an occurrence of fault, we are able to detect the fault and turn ON/OFF street light manually.

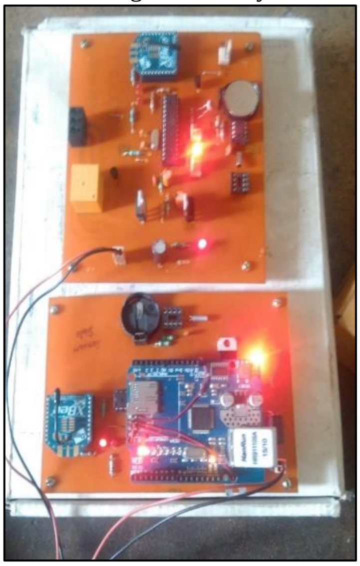

Fig. 9: Working of Proposed model

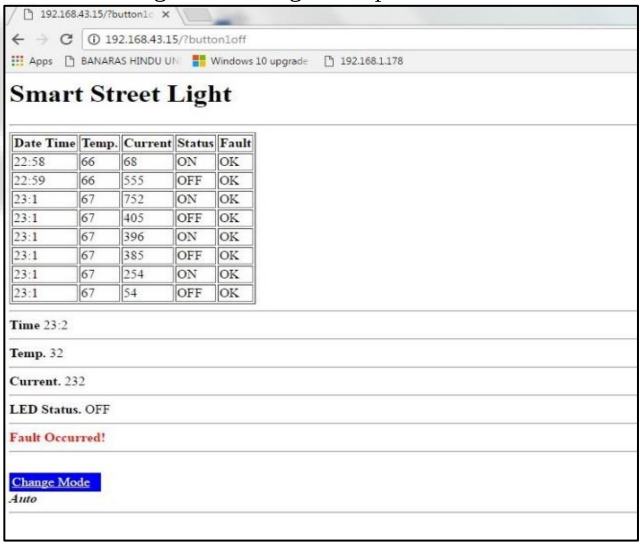

Fig. 10: Web page which controls and monitor LED Street light

	Previous Model	Our Model
Automatic Switching	No	Yes
Fault Detection	No	Yes
Remote Control	No	Yes
Intensity control	No	Yes
Energy Saving	Normal	Smart (Save a lot)
Other	NA	Do not create hot Spots

Table 2: Comparison between previous model and our design

Time	Lights	Energy Saving

6am ~ 5pm	All lamps are off	0%
5pm ~ 11pm	All lamps are at 75%	25%
11pm ~ 6am	All lamps are at 35%	65%

Table 3: Energy saving for full day with comparison to present LED Street Light

V. Conclusion

A low cost IoT based street light monitoring and controlling system is developed to give clearer and more detailed view of energy consumption and saving. It will be beneficial in many low cost applications. Also such system is in reach of all individuals irrespective of economical class. This system is extension for all available system, which are working on the LED with using wireless network to monitor over a larger area. In addition to that, this system provides some additional features like continuous data monitoring from more than one place, temperature detection in areas, monitoring at different parts of the street light at the same time.

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