Energy saving using Automated Street Light System

Abstract

Currently, in the world, enormous electric energy is consumed by the street lights, which are automatically turned on when it becomes dark and automatically turned off when it becomes bright. This is a huge waste of energy. This paper discusses a smart street light system. The main aim of smart street light systems is that lights turn on when needed with the minimum required intensity so as to not use too much power, and light turn off when not needed. The smart street light system consists of LED lights, brightness sensors, motion sensors and short-distance communication networks. The lights turn on before pedestrians and vehicles come and turn off or reduce brightness when there is no one. It will be difficult for pedestrians and drivers of vehicles to distinguish our smart street lights and the conventional street lights because our street lights all turn on before they come.

Introduction

Automation's main goal is to reduce manual labor or man power with the help of intelligent systems so that humans can be used for more creative and thought-based work instead of physical work. But usage of machines usually requires a lot of electrical power. So one of the main considerations when automating a particular system is cost effectiveness and power consumption. The main aim of the project is Automatic street power saving system using Ambient Light resistor and Infra-red sensors. We can save power automatically using this system instead of someone manually doing it. So it's also cost effective. Nowadays, in the whole world, street lights consume enormous electric energy. The number of street lights is not known accurately, but it is said that one hundred million or one billion street lights exist in the whole world. If one hundred million street lights exist, each street light consumes 20W and a half of all street lights always turn on in the whole world, 8760GWh electric power, which is about 0.8% of annual consumption of electric power in Japan. In the future, many developing countries will install many street lights and consume much electric power. Thus, to save electric power that is consumed by street lights is important to reduce greenhouse gases. Current street lights are controlled only by means of the embedded brightness sensors; they are automatically turn on when it becomes dark and automatically turn off when it becomes bright. This is the huge waste of energy in the whole world and should be changed. There are some attempts in which the energy wastes of the street lights are reduced. A sensor light, which is controlled by a brightness sensor and a motion sensor, is sometimes used to reduce wastes of energy. It only turns on for a while when the motion is detected in front of the light and it is dark. However, usually a sensor light is too late to turn on when pedestrians or vehicles come in front of it. The light should turn on before pedestrians or vehicles come. Ideally, it is desirable that smart street lights look like usual street lights; no one notices that smart street lights are usual street lights. When you get up in the morning you may have noticed that street lights are still ON when it's not necessary & when you travel to rural areas either there is no street lamp or there are not so many vehicles to fully utilize that facility. Simply it means the wastage of electricity. At the beginning, street lamps were controlled manually in which the control switch was set in each of the street lamps. That was called the first generation of the original street light. Another method that has been used after that was based on the optical control method. In this method the high-pressure sodium lamps were used. Even the new automated street lights usually require some kind of human intervention to run perfectly. The amount of resources in the above examples is a little too much for something as simple as a street light, something which even rural areas have. Most rural areas won't be able to afford the cost required for these resources. This project suggests an automatic system which uses less power and provides more features as compared to other street light systems.

Literature Survey

Hengyu Wu, MinliTang[1], proposes that The core technology of the street light control system is an AT89S52 single-chip microcomputer. It integrates a power circuit, a fault detect circuit, a photosensitive detection circuit, an infrared detect circuit, an LCD display circuit, a street light control circuit, an a1ann circuit, a pressed key control circuit and so on. This system scans automatically turn on or off the lights and controls the switches according to traffic flow. It expands the fault detect circuit and the corresponding a1ann circuit. It also has a convenient and flexible button control circuit to switch on and off fictions mentioned above. Main weakness is that they didn't say anything about the working principle behind the system. It is also said to use a fault detection circuit which when it is damaged, the voltage is zero, so it will create a problem. This paper is a theoretic proof and shows only simulation results but not as a real time set up experiments.
From [1], this project will make use of the photosensitive detection, infrared detection and the street light control circuit and integrate them together.

GongSiliang[2] describes a remote streetlight monitoring system based on wireless sensor networks. The system can be set to run in automatic mode, which controls streetlight according to Sunrise and Sunset Algorithm and light intensity. This control can make a reasonable adjustment according to the latitude, longitude and seasonal variation. Also this system can run in controlled mode. In this mode, we can take the initiative to control street lights through the PC monitor terminal. In addition, the system integrates a digital temperature-humidity sensor, not only monitoring the streetlight Real-time but also temperature and humidity. The system is equipped with the high-power relay output and can be widely applied in all places which need timely control such as streets, stations, mining, schools, and electricity sectors and so on.

From [2], this project will make use of wireless communication. It will also vary the light intensity automatically according to the sunset and sunrise timings mentioned above.

Gustavo W. Denardin[3]deals with a control network for a LEDstreet lighting system. The use of LEDs is being considered a promising solution to modern street lighting systems, dueto their longer lifetime, higher luminous efficiency and higher CRI. The proposed control network enables disconnection of the street lighting system from the mains during peak load time, reducing its impact in the distributed power system automatically consumption, decreasing the management cost and monitoring the status information of each street lighting unit.

From [3], this project will make use of LED street lighting. LEDs will consume a lot less power compared to regular street lights, and are also more moddable compared to the regular lights.

Methodology

The model consists of two lanes, the first being a parking space and the other a regular one-way highway. The parking space has two spaces available and there are ambient light sensors at the end of each lane. When switched on, the ambient light sensor detects the light falling on it, and calculates how much light intensity is required to light up the lane i.e., how much voltage is supplied to the street lights. The LDR detects the light and converts it into an analog value between 0 and 255. This value is then subtracted from 255 and stored.

$$Y=255-ldr$$

This Y value is then used to vary the intensity of the street lights. This is done using PWM pins on the Arduino Board. As this is happening, the infrared sensors (IR Sensors) are looking for objects (vehicles) that pass in front of them. When they detect a vehicle, the IR sensor sends a Boolean value to the Arduino and the arduino increases the intensity of **2** street lights, that come right after the sensor, to full intensity regardless of the Y value. One of the major drawbacks of an automatic light system is that it assumes that the vehicles are constantly moving without stopping in the middle of the road. But that is not always the case. It could be a medical emergency or maybe the vehicle broke down. If the car is stopped right next to the sensor i.e., blocking the sensor then the street light will be on. But if the vehicle stops between two sensors, then most street lights would switch off after a while. This drawback is rectified. Let's assume the first sensor is X and the first street light is Y. Let us also assume that a sensor is placed after every street light. So the lane would look somewhat like this:

X	Y	X+1	Y+1	X+2	Y+2	X+3	Y+3	X+4	Y+4	X+5

Sensor X triggers lights Y and Y+1. And usually they switch off if nothing is blocking X. But in this system, the lights will only switch off if the vehicle hits the sensor that comes after the lights. Here X triggers Y and Y+1 to switch on. And they stay on indefinitely until the vehicle passes the X+1 sensor. Then Y is switched off and Y+2 and Y+3 are switched on. When the vehicle passes X+2 then Y+1 is switched off. This goes on until X+5 when all lights until Y+4 are switched off. The system also takes into account that multiple vehicles use the lane, so there is a loop that checks the IR status constantly. The parking lot also employs a similar working system except when it comes to the lights installed at the parking spot. In the parking lot, there are regular street lights put up along with a separate street light for each parking space. When a vehicle parks in the space, an IR sensor placed there detects the vehicle's presence and informs it to the controller. Then all the surrounding street lights are switched off and only the parking space light is on. When the vehicle is leaving, the driver usually takes a reverse to come out of the parking spot. When going back, the vehicle will trigger an IR sensor placed in the regular lane, which will switch on the regular street light of the lane and switch off the parking space light.

The Arduino board and the NodeMCU communicate serially with short messages. For example, to switch on light 1 from lane 1 the NodeMCU sends the message L11O, which means lane 1, light 1, ON. To switch it off we send L11F. The messages sent through MQTT are even shorter as we don't have to specify the lane in the message. The topic to which the message is sent to tells us the lane number. The light levels are communicated by sending the data in a JSON Format from arduino to NodeMCU via serial communication line. Then the NodeMCU sends it to the server using MQTT protocol and the website plots the data in real time. There are 4 different html files that can be rendered. Namely, the home page or the dashboard, the control page for lane 1, lane 2 respectively and the contact page. The Paho-MQTT library for JavaScript is used to receive the data i.e. the LDR readings of both the lanes and are plotted in real time. The control pages have "buttons" that are used to send messages using the MQTT-protocol to the Arduino board to switch on the street lights. Fig 1.2 is the drawn model of the project.

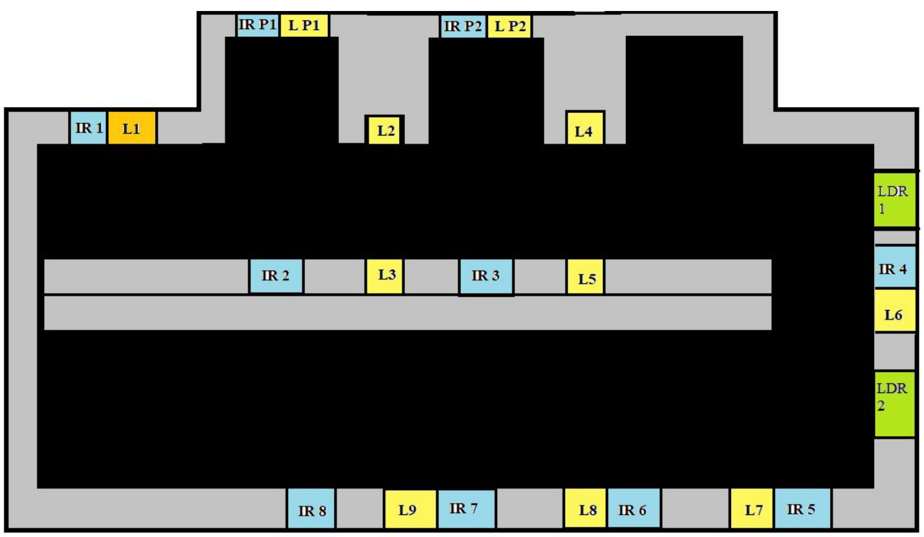

Fig. 1.2 Drawn model

IR denotes the infra-red sensors, L denotes street lights and LDR is a light dependant sensor. When the IR sensor is triggered, it switches on the light that is next to it and switches on the light that is before it. The vehicle passes from IR 1 to IR 4 in the first lane and then turns into the second lane. In the first lane, IR 1 triggers L1, IR 2 triggers L2 and L3 and IR 3 triggers L4 and L5. In lane 2, IR 5 triggers L7 and L8, IR 6 triggers L8 and L9 and switches off L7. And when the vehicle passes IR 7, L6 is switched off and L9 stays on. Finally, the vehicle reaches IR8 and switches off L9.

Result

Most developed countries around the world have adopted LED street light technology whereas our country still uses CFL (Compact Fluorescent Lamp), metal halides or sodium vapor lights. There are more than 27 million street lights in India and take up between 20 to 40% of the energy produced in our country.

Table 1.1 shows the comparison between different light technologies.

Table 1.1 : Light Technology Comparison

Light Technology	Average Lamp Life in Hours	Lumens per Watt	Consideration
Incandescent	1000-5000	11-15	Very inefficient and short life time
Mercury Vapor	12000-24000	13-48	Very inefficient, ultraviolet radiation and contains mercury
Metal Halide	10000-15000	60-100	High maintenance UV radiation contains mercury and lead, risk of bursting at the end of life
High Pressure Sodium	12000-24000	45-130	Contains mercury and lead
Low Pressure Sodium	10000-18000	80-180	Contains mercury and lead

Fluorescent	10000-20000	60-100	UV radiation contains mercury, prone to glass breaking and diffused non-directional light.
Compact Fluorescent	12000-20000	50-72	Low life/burn out, dimmer in cold weather and contains mercury
Induction	60000-100000	70-90	Higher initial cost, limited directionality, contains lead and negatively affected by heat
LED	50000-100000	70-150	Relatively higher initial cost

We can tell from the above table that LED street lights have a higher lamp life and lumens per watt consumed, making it ideal for street lights. And by using the system proposed in this project, we can further reduce the power consumption. The lights only turn on with full intensity when a vehicle passes by, so if there is a lot of traffic the lights would be at full intensity throughout but if we take a highway as an example, not many vehicles use a highway during night except for goods carriers. Let us take a single LED street light that consumes 60W of power per hour at full intensity. If it is turned on from 6pm to 6am then it consumes 720W of power. If this system is implemented, then when there are no vehicles the street light will be at 40 to 50% brightness depending on its surroundings, because if it is located near a city then the city lights would illuminate the road and the sensor will record a higher light intensity causing the LED street light to glow at 20% or less intensity. So, if we assume it goes down to 40% i.e., 24W of power. Depending on the number of vehicles passing through the number of times it burns with full intensity changes. The best-case scenario is that no vehicles used the road that night which means only 288W were consumed which is far less than 720W. And the worst case is that the road was really busy that night and the lights were always at full intensity which means it is at 720W. By this we can tell that the amount of power consumed will always be 720 or less, and the average power consumed will be 504W. The street lights we use today use 250W of power per hour. So, in a month the energy consumed by a single street light is 90kW. If we were to use the proposed system with automated LED lights then the average power consumed will be 21.6kW. Which is already 75% less than normal street lights. Using our system, average power consumed per night is 504W, so in a month it is 15.12kW.Therefore, by using the proposed system energy consumption can be reduced by almost 85%.

References

1) https://ieeexplore.ieee.org/document/6518523

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4) https://ieeexplore.ieee.org/document/6072726?arnumber=6072726