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Adaptive Street Light Controlling For Smart Cities

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Abstract

Street lights is one of the basic amenities provided by local municipal body in every town or city. In India, ON-OFF control of street lights is operated manually. Therefore, it is most likely that controlling is not done on time. Also, fixed timings are not suitable in all seasons. Due to this street lights remain glowing for extra time or do not switch on when required. Sometimes, local climate conditions demand switching off street lights. Hence the present practice leads to lot of inconvenience & power wastage. Both issues are addressed here by designing automatic as well as adaptive method of street light control. The system takes into account sunrise & sunset timings, ambient light conditions, dust or mist factor at the location. This new system enables the street lights to adapt the daytime schedule to operate automatically with nanowatt technology based microcontroller and sensors for LED street lights. Hence the new method controls street lights intelligently. This work presented under this paper, along with efficient LED based system, the dimming of light & automated operating principle improves life of street lamps. This serves the purpose of saving energy additionally. The total energy savings can be up to 60% to 65% more in contrast to existing lighting system. This adaptive street light controlling system for smart cities offers simplest solution to save the energy.

Keywords: Street light, adaptive light control ,LED lamps, microcontroller, sunset, sunrise, real time clock,

INTRODUCTION

People at one time or another have surprised with the beauty of red and orange colors during sunrise or sunset. Even vivid sunrises and sunsets are seen at any place, certain parts of the world are very famous for their twilight hues [8]. Then why not to consider these factors to save the energy.

Street lights is one of the basic amenities provided by the local municipal body in every town or city. But in India, ON-OFF control of street lights is operated manually.

It is essential to have a street light with full of brightness. But the controlling mechanism is human dependable. Hence controlling the street lights is not precise with sunrise & sunset timings. Many times lights are ON till late morning. This leads to waste the energy due to negligence.

And in the evening time, street lamps are active in early, but still, there are chances to have light from the Sun for next 1-2 hours. Also manmade dust and pollution tends to defer light intensity during sunset. So even if Street lamps are not required, those are ON with full intensity.

In another scenario, if the weather conditions are cloudy or fog is there, then even if lights are required in daytime, it's not possible to turn them ON. They are turned ON only after someone leads to turn them ON by manual operation. Thus, sometimes local climate conditions demand switching ON or OFF the street lights.

By looking in Indian Street Light Systems, maximum lights are sodium vapor lamps. In order to save the energy, controlling the intensity of the lamp is a critical task with sodium vapor lamps. Nowadays those are being replaced with LED based lamps and also with Solar Energy Based Lamps. Thus, there are new opportunities to control the street light in efficient ways.

A well-designed [6], energy-efficient street lighting system should permit users to travel at night with good visibility, in safety and comfort, while reducing energy use and costs and enhancing the appearance of the neighborhood.

LITERATURE REVIEW

The street light intensity controlling management is worldwide emerging technique. Sei Ping Lau et al. in [1] demonstrated the concept of controlling the street light based on traffic density. Considering real-time adaptive conditions of the lighting scheme, which detects the presence of vehicles and pedestrians and dynamically, this system showed the savings in power consumption. But as the entire system is a wireless network based, the system is costly and critical to maintain.

To get an advantage of Wireless Sensor Network (WSN), for street light controlling, R.F. Fernandes et al. defined a solution in [2] with the help of smart grid concept. The core is developed with IEEE based wireless protocols for large are networks. This system is a supervisory control mechanism for lighting systems. But the implementation in Indian scenario is not a feasible solution.

The Lamps used in street lights are of different types like mercury, sodium vapor, metal halide lamps and LED Lamps. In [3] an advanced approach of LED Lamps and embedded systems based integration to control the intensity levels is elaborated. In this system, the ZigBee network is established between different Street Light Nodes. The flow of traffic is shared between nodes to collect the density of people. By accurate counting of people the intensity of LED street lamps is adjusted. This approach is secured and implemented with a layered structure of communication protocol which increases the complexity.

Based on the survey report made by USAID ECO-III Project [6], only replacing all high-pressure mercury vapor lamp fittings in street lighting with high-pressure sodium vapor lamps with slightly lower wattage savings of 20-25% can be achieved with the life of 15,000 to 24,000 Hours. This savings can be even more if these high-pressure sodium vapor lamps are replaced by LED Lamps. As they are High energy savings devices with low maintenance and having a long life. They are also mercury-free hence eco-friendly.

In [4] Y.M. Jagdish discussed a new concept to in order to reduce the electricity consumption and wastage of energy with Infrared Sensor & Moonlight based approach. Using Proximity IR the intensity is measured to control the lamp. Based on moonlight, the light brightness is reduced to save the energy. This system is simple but not energy efficient. Also, it cannot be used to compute the daylight timings.

Going with image processing approach & Indian environmental conditions, P.C. Veena's [7] study concludes with improved controlling results. According to study, apart from regular ON state and OFF state mechanism, it senses the human presence and vehicle density on streets with camera module. Thus based on images, it controls street lamps in real time. But it can accumulate only single light. Hence it can be expensive if want to use in Indian practical approach.

It is also important to consider the dust or mist factor at the location of street lights. Darcin Akin [5] compared the results between different environmental conditions. In certain rainy season the vehicle speed is 5% - 6% less and also traffic volume if reduced to 64% to 65%. But whereas in mist or dusty situations, the vehicle speed is almost similar to that of clear environment.

Considering the advantages of LED based systems as mentioned in [6], advanced LED lamps will remove the glare effect, reducing visual fatigue for both drivers and pedestrian. Also no warm up is needed hence instant optimum brightness levels can be achieved. The most important factor is dimming of light is possible with flexibility is controlling light levels.

The another scenario [10] is that along with adaptive dimming, savings may be possible when dimmable LED street light systems are an add-on with motion sensors, ZigBee or Bluetooth wireless communication, and ambient light level sensors. Dimming and/or Telemanagement functions on street light systems could be utilized under conditions at dawn, dusk, during full moons, and when no cars, cyclists, or pedestrians.

Hence the existing practice leads to a lot of inconvenience & power wastage for the street lighting system. So, need to replace with new techniques of LED based lamps with the advanced controlling mechanism.

SYSTEM

The street light controlling mechanism depends on various parameters like ambient light, traffic density, the type of light source used and so on. To make this system reliable and energy efficient, microcontroller initiates all controlling actions based on sensor inputs.

The system consists of low power sensors, advanced nanowatt technology based microcontroller and energy efficient LED based power source. Battery powered independent adaptive controlling system along with real-time database, will helpful to work in all conditions.

In this system, the ambient light is considered to sense the darkness in area. The sunset and sunrise timings are tracked with Real Time Clock. An entire system is controlled with an efficient microcontroller. With real-time data, the precise controlling actions are applied on Street Lights. This tends to save the energy.

A. Block diagram

The fig. 2 is defining different components of the adaptive street light system. The system is distributed in 3 different sections. In the first section, Ambient Light Sensor is connected to a microcontroller which provides the real time light intensity in terms of analog signal. In the second section, the advanced microcontroller is connected with the battery operated platform. In the third section, Real Time Clock is providing the current day time with accurate details. Using this clock, the microcontroller computes the time factor to generate the precise controlling actions to adapt the light conditions with sunset and sunrise time.

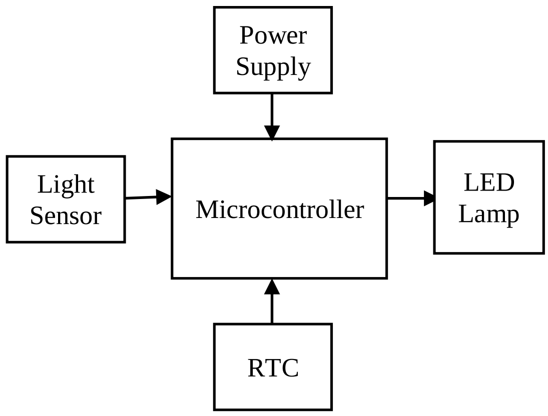

Figure 2. Block Diagram of Complete System

The power supply can be sourced from DC adapter or Battery Operated System. The advanced modes of the microcontroller will tend to save the power of the entire system by utilizing their special features of sleep mode and Run Mode.

The street light is triggered using relays based on controlling action of microcontroller.

B. Selection of Components

Considering different smart street light systems so far studied, the use of ambient light sensor with microcontroller system is most feasible solution. The TEMT6000 X01 ambient light sensor is a silicon NPN based epitaxial planar phototransistor. This sensor along with 10KΩ resistance will give actual voltage levels in real time sunlight intensity changes. As intensity changes it will trigger the transistor and the desired voltage levels are measured from microcontroller. But this will not sustain under high temperature levels.

But rather before selecting ambient light sensor, there is another approach to sense the intensity of sunlight and convert it in physical quantity is Light to Frequency Converting Sensor. This approach definitely ensures to have proper scaling of light intensity in terms of frequency. So, using microcontroller with counter mechanism, the frequency can be measured. Texas Advanced Optoelectric Solutions providing sensor TSL235R with High-Resolution Conversion of Light Intensity to Frequency. This can be used with no external components. The sensor output is in Pulse Width Modulated signal with 50% duty cycle [11].

Using this sensor, square wave is measured with Timer as Counter module from PIC18F microcontroller. As light intensity changes, the frequency changes. So, it is more reliable than ambient light sensor. Also it sustains to temperature levels between -25^{0}C to 70^{0}C.

As sensors are based on low light power consumption approach, the microcontroller is selected in such way that, it should handle mixed signals. It should have flexibility to select the desired control peripherals, separate power saving modes and availability in the market. The sunset and sunrise timing are in string format, so in order to store, it needs much amount of space in Memory. The microcontroller should have rich peripheral integration providing generic design capabilities and lower system cost. Considering this facts, the PIC18F26K40 is suitable for this design.

Real Time Clock is crucial part which consumes more energy. So, it can be sourced separately. The DS1307 in I^{2}C protocol can be used as Real Time Clock to interface with PIC18F series microcontroller.

C. Circuit Diagram

Component selection is done based on required criteria for intensity measurement & Street light controlling function. To implement with working approach, the system is designed as shown in figure no. 3. The TEMT 6000 is connected as NPN transistor and the base is triggered based on sunlight intensity.

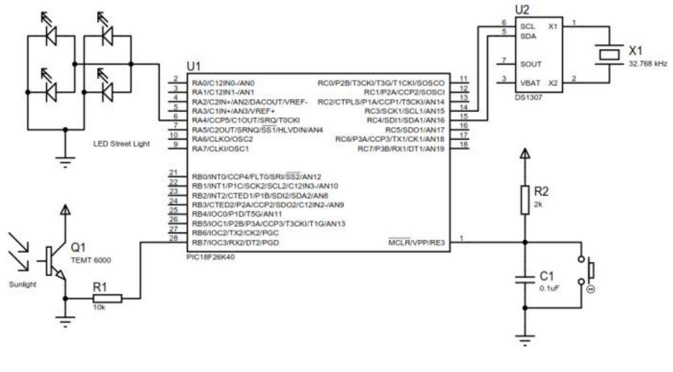

Figure 3. Circuit Diagram of Adaptive Street Light System

The sunset and sunrise timing is stored in EEPROM of PIC18 microcontroller. Hence no need to use an external memory. The output section of system is LED module. This module is connected in such way that using PWM functionality the intensity can be controlled as sunlight varies.

An array of power LED is considered to serve the power output up to 80W. The best possible solution is to use the source as solar power energy. So, using LED based street light and solar power, it can be an efficient light controlling system.

Additional to this circuit an extra cross check mechanism can be connected using TSL235R sensor. So, this sensor is also giving sunlight intensity in terms of voltage levels. So, by comparing both sensor values, the best possible solution is plotted along with sunset and sunrise values.

D. Working Principle

- The concept of this system is to trigger the light source based on “sunrise & sunset” timings. And according to light conditions control the intensity of LED lamps.
- The Ambient Light Sensor is used to reject Infrared Rays in light sources allowing the device to operate in environments from sunlight to dark conditions. A selectable range allows the user to optimize sensitivity suitable for the specific sunlight conditions. This sensor will provide the scalable voltage range to the microcontroller based on intensity of light.
- The Real Time Clock (RTC) is connected to PIC18F Microcontroller. Using RTC, the precise time factor is calculated with seconds accuracy. The clock/calendar provides seconds, minutes, hours, day, date, month, and year information [9]. The end of the month date is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The RTC is powered by separate battery powered device. Hence it is reliable and active even if the main supply to the microcontroller is OFF.
- The Sunset and Sunrise timing details are stored in microcontroller based on tropical regions. These values are stored in terms of string in Read Only Memory of microcontroller. The real time is compared with this stored values on a daily basis. So, in accordance with the result, the ON-OFF time of street light is decided.
- Based on Ambient Light Sensor and Computing the Time Factor with RTC, the system will trigger the Street Light Lamps. If ambient light is below the threshold in day time, then microcontroller with the sense the details and take action to Turn ON the lamps. Similarly, during sunset time if still, visible light is present, the light will ON with dim intensity with 25% of actual. And once it is above the preset threshold, it will change an intensity level to 100% factor.

The energy saving is calculated on two factors. One is a traditional system (Manually operated) as pre-adaptive with LED lamps and second, automatic operation with adaptive controlling as post-adaptive. Savings are determined by field measurement of the energy use of the system under consideration. The savings are verified by engineering calculations using short-term or continuous measurements, depending on the expected variations in the savings and the length of the reporting period

So, as mentioned in equation (1) total consumption before and after the adaptive controlling system should be measured and compared. for routine adjustments include agreed burn out, and switching on and off time. Non-routine adjustments include an increase in the agreed burnout, additional load, change of wattage, non-functioning of timers or controls, and unauthorized tapping of power.

$$KWh\ (Savings) = (kW) \times \left(Hrs_{preadaptive} - Hrs_{postadaptive}\right) \pm Adjustments \qquad (1)$$

The operating hours may be reduced in the automatic (post-adaptive) system, hence there are fewer chances to stay the Street Lamps are ON for a longer duration. It helps to lead towards huge energy savings.

E. Algorithm

The RTC is configured first time with current time details. For a configuring first time, an LCD is used to visualize the data. Once data is configured, now it can be compared with the real-time data with stored values of sunset and sunrise timings. Based on comparison results, matching date & time is selected. Once the time has matched, it can interrupt the microcontroller to Turn ON-OFF the street light. The flow of system functionality is shown in diagram 3 below.

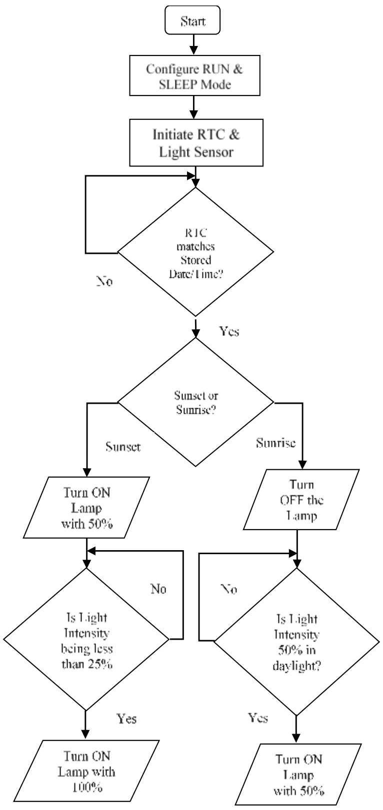

Figure 2. Flowchart of the Execution in System

As mentioned in the flowchart, during day time if the intensity of sunlight is less than 50% of desired value, then based on ambient lights input the microcontroller is TURN ON the Lamp with 50% of full-scale range. Similarly, during evening conditions, the lamp turns ON to 50% of scale based on Sunset values. It may change to full range at 100% if the value of light intensity gets to fall down below 1/4th of sunlight range.

RTC continuously keeping track during entire operation. This system is independent of each other (between street lights), hence no need to keep track of any sensor networks. This new system enables the street lights to adapt the daytime schedule to operate automatically with nanowatt technology based microcontroller and sensors for LED street lights.

The ambient light is sensed to give the actual light intensity. So, by adding comparative mapping between TEMT6000 sensor value and TSL235R, the proper light intensity is measured. The drastic fall or rise in light intensity is mapped with cross check mechanism.

RESULTS AND DISCUSSIONS

This new system enables the street lights to adapt the daytime schedule to operate automatically with nanowatt technology based microcontroller and sensors for LED street lights.

As mentioned in Table I, LED based Lamps can save 20% more energy than traditional High Pressure Mercury Bulbs.

Table I. Comparison between types street lights

Type	**Life of Lamp & Energy Saving**		
	Life	***Energy Saving***	***Remark***
High Pressure Mercury Vapor	5000 Hrs	0%	Not useful
High Pressure Sodium Vapor	15000 Hrs	10 %	Energy Efficient
Light Emitting Diode (LED)	50000 Hrs	25 %	High Energy Savings
Light Emitting Diode (LED) with adaptive brightness control	55000 Hrs	35 – 40 %	Improved Life, Automatic

Source: Lamp Technology [6]

Using this system it is possible to avoid negligence factors by human operators by means of the sunset and sunrise time validation for Turn ON and Turn OFF the street lights. With combining excellence of LED Lamps & the technique of dimming light based on intensity achives 25-30% more energy saving. Hence it is most suitable for the upcoming smart cities in India.

These cost savings can also enable municipalities to expand street lighting to additional areas, increasing access to lighting in low-income and other underserved areas.

The system implementation in Indian environment under rural area is possible because of compact design & independent controlling actions. So, even if person is from non-technical background, once this system is instrumented at location it works without any flaws.

This system provides more reliable controlling mechanism of street lights using tripple check mechanism. As the most systems were using only ambient light sensor and image processing, this approach tends to keep realtime track of output control with microcontroller and tracking of sunset-sunrise durations. Using extra feature of frqeuncy based sensor, an additional cross check mechanism is possible to implement to avoid malfunctioning of ambient light sensor.

Assuming that one lamp is switched on for 4,000 hours per year. One streetlight can have median consumption of 2000 W yearly.

Modern LED based energy efficient lighting systems consume about 45%- 55% less energy than older and inefficient systems that are installed in almost the entire country. Hence the power consumption will reduce up to 550 W yearly[13] per Street Lamp, which can save a lot of energy. By the system presented under this paper, along with efficient LED based system, the dimming of light & automated operating principle improves life of lapms. This serves the purpose of saving energy more by 15%. Thus, the total energy savings can be up to 60% to 65% more in contrast to existing lighting system.

CONCLUSION

This paper represented new approach for controlling street lights with adaptive approach based on sunlight intensity & daylight timings. After implementation of the system following conclusions are drawn:

- This approach requires minimum hardware with simple software.
- As the system itself is smart to take decisions to control Street light, it is possible to avoid negligence factors by human operators.
- It is adaptable to ambient light conditions as per season as per location and also governed by sunrise and sunset timings.
- It is controlled by redundant sensor mechanism, hence if any sensor fails to give proper output, secondary leads to complete the action.
- As all components and material is available in local market, this system is low cost.
- Due to ambient light adaptive system, the life of LED lamps is increased.
- With LED Street Lights & adaptive controlling mechanism the energy consumption is reduced by 25 – 30% more than traditional High Pressure Mercury Bulbs.

The implementation of this system is simple and more reliable. Hence in smart city approach of Indian Government, this system can be helpful to save the power wastage from street lights.

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