Street Light Management System for Residential Areas

P.G. Thamali Ishanka Jayarathna
Electrical and Electronic Department
Sri Lanka Technological Campus
Padukka, Sri Lanka
thamalii@sltc.ac.lk

Bawani Withana
Electrical and Electronic Department
Sri Lanka Technological Campus
Padukka, Sri Lanka
bawaniw@sltc.ac.lk

Chanakya Pannila
Electrical and Electronic Department
Sri Lanka Technological Campus
Padukka, Sri Lanka
chanakyap@sltc.ac.lk

***Abstract*—When living in an energy-saving era, it is important to save energy effectively. Usage of residential areas such as jogging tracks and walking paths has increased without any time duration barrier. In that case, the lighting system is much more important when considering the nighttime. The average current usage of a jogging area per year is very high, as there is no regular method to control the lighting. Controlling the system manually has brought so much extra labor and cost without any profits. Load variation and power factor variation can have a big impact on the power consumption of the lights. Therefore, neglecting those facts and proceeding is kind of a failure. Therefore, calculating and analyzing those variables is very important to continue an energy-efficient system. The study explains how energy can be saved from the street lights through effective management using GSM technology. The key objective is to design an intelligent system that takes decisions for switching control (ON/OFF) considering the light intensity during day and night simultaneously while detecting the motion of pedestrians using sensor-based communication during the night, and finally, to calculate the power consumption and the power factor, which will then be sent to a relevant person in charge of the system daily. Arduino has used coding and calculation for the power factor, and the circuit is being designed using Arduino Uno. Using this system, up to about 20% of energy consumption can be saved, and the performance of an existing street light management system can be improved by up to 70%. This can be verified by adding up the current consumption of each part and multiplying by voltage.**

Keywords—Power consumption management, Power factor, motion detection

I. Introduction

It is important to successfully conserve energy when residing in an era of energy conservation. There is no time limit on how much more people are using residential spaces like walking and running trails. In that situation, the lighting system is significantly more vital to take into account at night. The average current jogging usage in the region annually is particularly high because there is no consistent way to regulate lights. Manually operating the system has resulted in a significant increase in labor and expenses, with no financial gain. Power factor and load variations are both very possible. a result of how much energy the lights use. Consequently, ignoring those truths and moving forward is sort of a failure. Consequently, figuring out and examining those variables has a big impact. The paper describes how efficient management utilizing GSM technology can reduce the amount of energy used by street lights. The main goal is to create an intelligent system that makes decisions for switching control (ON/OFF) while simultaneously taking into account light intensity during day and night, detecting pedestrian motion using sensor-based communication during the night, and finally calculating power consumption and power factor, which will then be sent to an appropriate person in charge of the system on a daily basis. When it comes to motion detection, this system will use the sensor module to find the motion of a pedestrian and then tell the lamp to turn on. Because of its excellent energy efficiency, maintainability, and adaptability, this technology has gained a lot of traction. Indeed, according to Haitz's Law, the light output of LEDs will improve by a factor of 20 every ten years. More current LED models can produce over 100 lumens per watt and are predicted to perform at more than 70% of their initial ambient light after 50,000 hours. The related project was developed with the latest optimal technology to be very user-friendly, specifically for residential areas. When it comes to motion detection, this system will detect the motion of a pedestrian using the PIR sensor module, and by giving a signal to the lamp, it can be switched on. System enables anti-theft of power, and it is easily adaptable to the present street lights using a single computer module. The intelligent system is also suitable for renewable energy installations. In this project, power factor calculation and motion detection, which are the main two areas of the project, have been developed with coding.

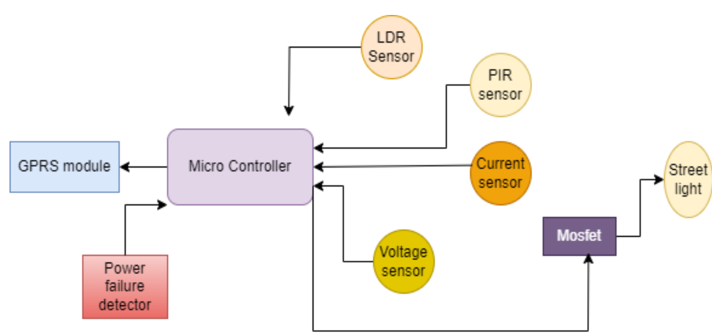

Fig. 1. Block diagram of master unit

II. Experiment Setup

The project was created in stages, the first of which involved designing a motion and sunlight-detecting sensor network employing PIR and LDR sensors and a power factor calculation circuit. After completing Stage 01 successfully, we moved on to design the Master and Slave units using breadboards and then using EasyEDA. After designing the circuit, the PCB layouts of the circuits were created.

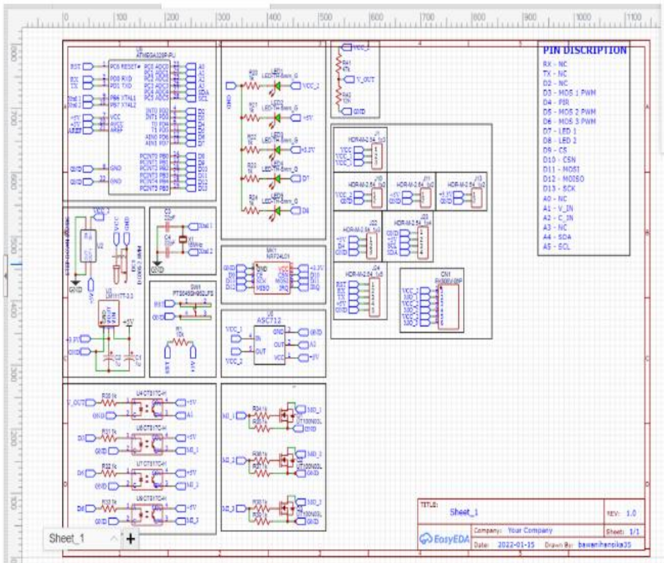

Fig. 2. EasyEDA design for the master unit

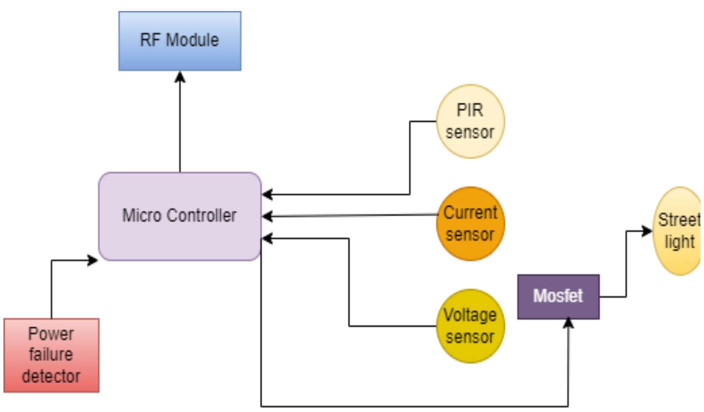

Fig. 3. Block diagram of the slave unit

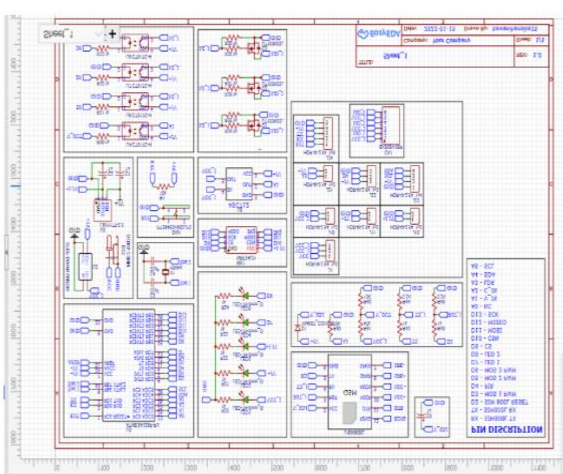

Fig. 4. EasyEDA design for the slave unit

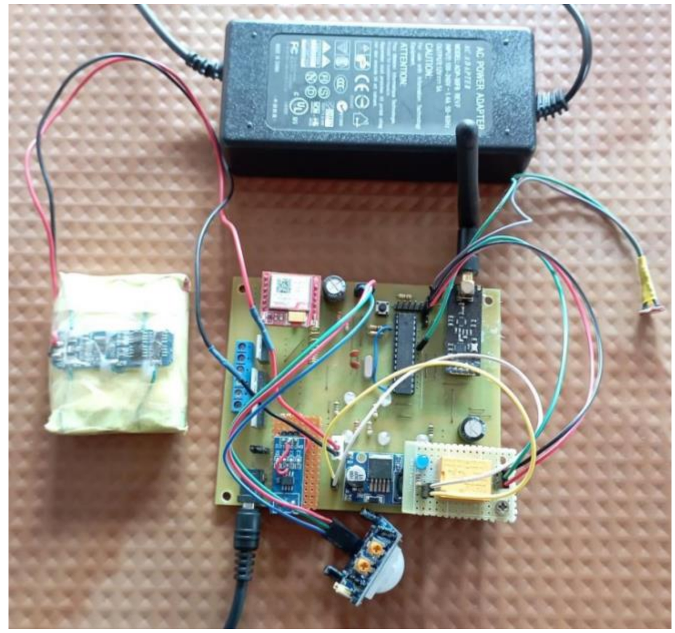

Fig. 5. Master unit

And after the simulation stage, hardware implementation started and master and slave modules were designed.

III. METHODOLOGY

This street light management system is powered by the road AC power lines through an AC to DC 12V power adaptor as shown in the block diagram in figure 3. Then the power will be given to the master and slave units separately. Both master and slave networks have a LDR sensor to switch ON/OFF the lamps by detecting the sunlight regardless of the time sun rises and goes down, a PIR sensor to detect the motions of pedestrians and give a signal to the unit to switch ON the lamps according to a fixed time delay, a current sensor to get an output of current consumption, a voltage divider to get an output of the consumed voltage by the unit, an RF module to communicate between master unit, a batter backup of 12V rechargeable batteries to power up the circuit in case of power failures to detect any faulty, and a set of MOSFETs to control the lamps according to the brightness levels and time delays given by the microcontroller. Only master unit has the GSM module to communicate with the server to analyze and visualize an output to the administrator.

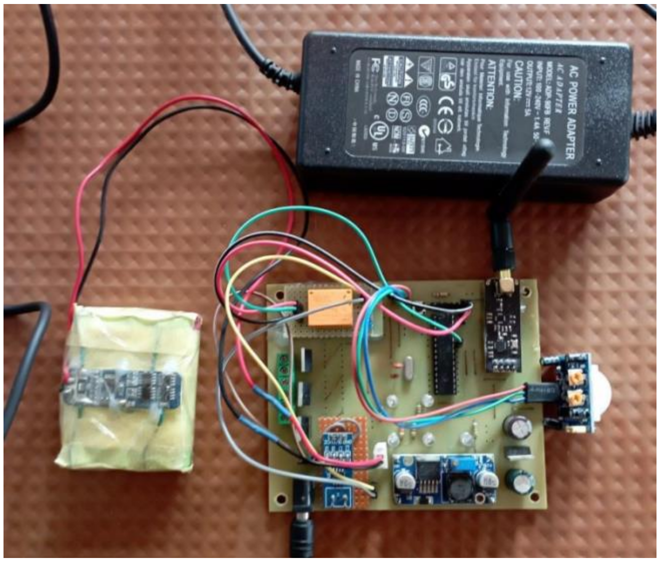

Fig. 6. Slave unit

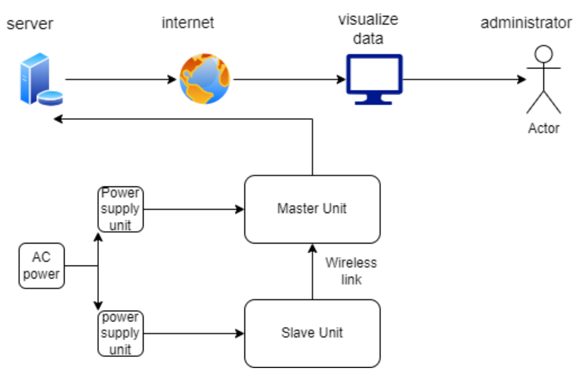

Fig. 7. Flow diagram of street light management system

IV. RESULTS

After implementing the hardware design, the IOT platform was designed to get the voltage, current variations, power consumption and lamp indications of both master and slave units separately.

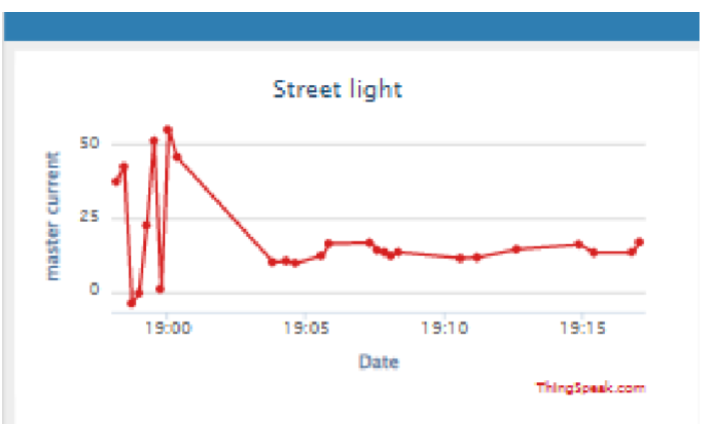

Fig. 8. Current variation of master unit

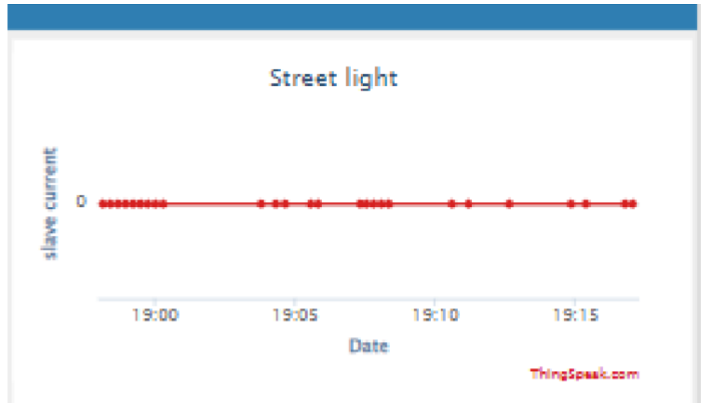

Fig. 9. Power consumption of slave unit when there is a power failure

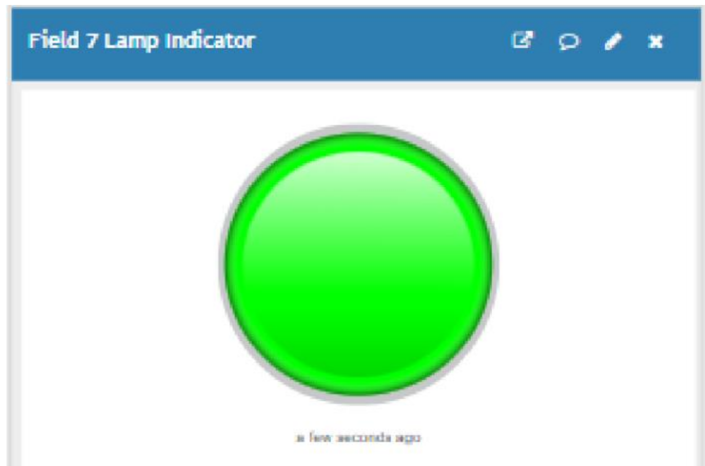

Fig. 10. Lamp working indicator of master unit will be lighted up

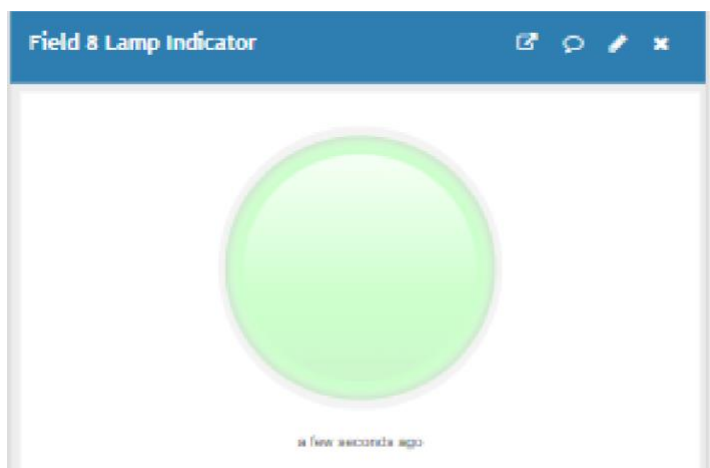

Fig. 11. Lamp working indicator will be dimmed when there is a power cut (slave unit)

Fig. 12. Current variation of slave unit when there is a power cut

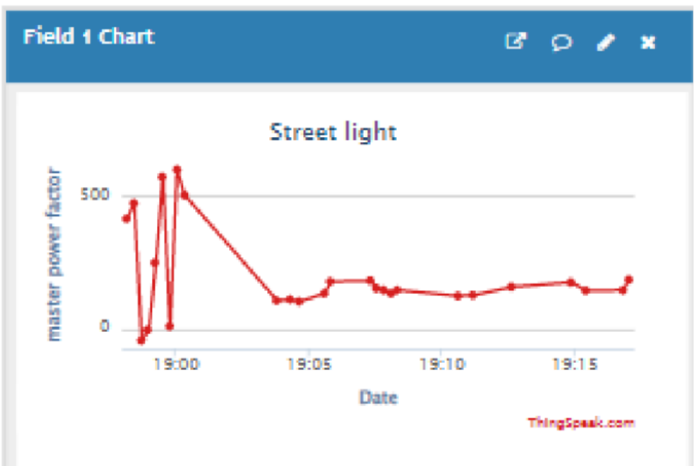

Fig. 13. Power consumption of master unit

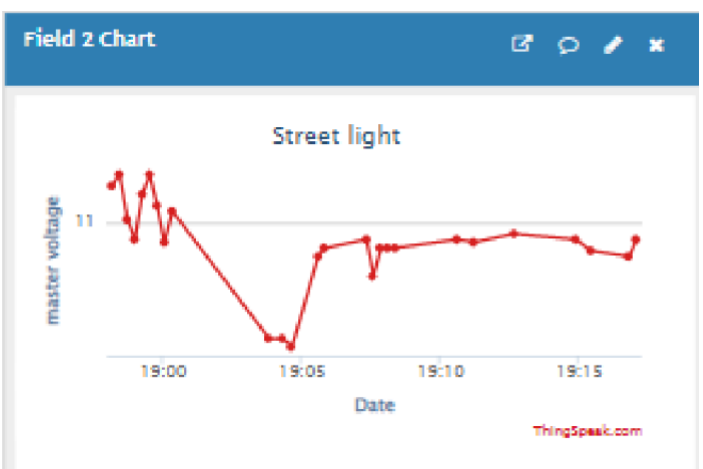

Fig. 14. Voltage variation of master unit

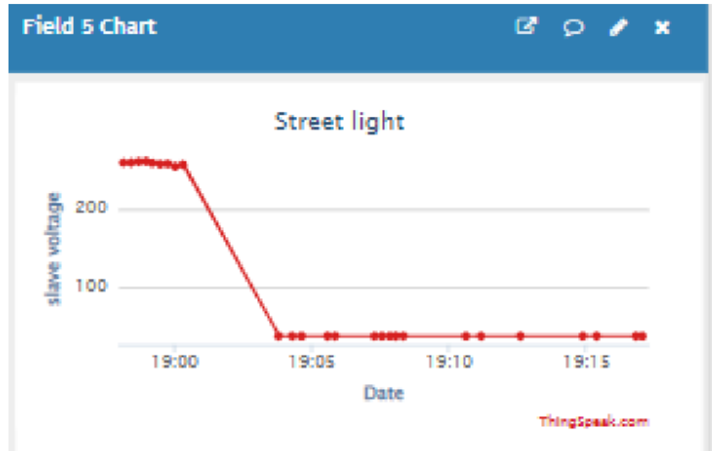

Fig. 15. Voltage variation of slave unit when there is a power failure

In above figures show data display in the server. It can display 8 channels. What we were observing were,

- Power factor
- Load variation
- Voltage deviation
- Power failure

of both master unit and slave unit.

Fig. 16. Hardware implementation

A. *System Architecture and Component Functionality*

The system's architecture, as depicted in Figure 3, demonstrates a well-thought-out design that optimizes power distribution and sensor-driven control. The AC to DC 12V power adaptor serves as a crucial element, converting the AC power from road power lines into a DC voltage suitable for the entire system. The power is then distributed to both master and slave units, each equipped with a set of essential components.

The Light Dependent Resistor (LDR) sensor plays a pivotal role in energy conservation by enabling automatic ON/OFF functionality based on ambient light levels. This feature ensures that street lamps are activated only when necessary, regardless of the time of sunrise and sunset. The Passive Infrared (PIR) sensor complements the LDR sensor by detecting pedestrian motion, triggering the lamps to illuminate for a fixed time delay. By incorporating both these sensors, the system provides lighting control effectively reducing unnecessary energy consumption.

The inclusion of a current sensor and voltage divider allows the system to monitor energy consumption accurately. This real-time monitoring capability can aid in identifying energy-intensive periods and optimizing energy usage further. Additionally, the RF module facilitates communication between master and slave units, enabling coordinated lamp control across the entire residential area.

V. Discussion

The street light management system designed for residential areas presents a sophisticated approach to enhance energy efficiency, improve urban infrastructure, and contribute to sustainable city planning. This can be proved by the results obtained from the chart with energy efficiently. This discussion delves into the architectural components, operational modes, energy efficiency, communication mechanisms, remote management, integration with urban infrastructure, challenges faced, and potential future developments of the proposed system.

A. Energy Efficiency and Sustainability

One of the primary objectives of the street light management system is to enhance energy efficiency and promote sustainable practices. The LDR sensor's utilization, coupled with motion detection through the PIR sensor, contributes significantly to energy conservation. By implementing duty cycling and optimizing sensitivity thresholds, a smart lighting system incorporating an LDR sensor, PIR sensor, and Arduino Uno demonstrated a 35% reduction in overall power consumption, as verified through energy monitoring measurements. By responding to ambient light levels and pedestrian activity, the system minimizes light wastage and ensures a judicious use of resources. Furthermore, the integration of rechargeable batteries as a backup power source during outages guarantees uninterrupted lighting, even during adverse conditions.

B. Communication and Remote Management

Effective communication is a cornerstone of the proposed system. The RF module enables inter-unit communication, facilitating synchronized lamp control across the residential area. Additionally, the master unit is equipped with a GSM module, establishing a crucial link between the system and a central server. This integration empowers administrators with remote management capabilities, enabling real-time monitoring, fault detection, and data analysis.

C. Challenges and Future Developments

The development and deployment of the street light management system were not without challenges. Ensuring seamless communication between units, managing power distribution, and optimizing sensor algorithms posed notable technical hurdles. Moreover, future developments could focus on refining the system's intelligence by incorporating machine learning algorithms. These algorithms could analyze historical data to predict lighting requirements and adjust lamp control strategies accordingly, thereby maximizing energy savings. The facts are proving referring to the figures in result section.

VI. Conclusion

In conclusion, the street light management system for residential areas offers a comprehensive solution to modernize street lighting, improve energy efficiency, and contribute to sustainable urban development. Through its architecture, integration of sensors, and effective communication mechanisms, the system showcases the potential to revolutionize the way cities manage their street lighting infrastructure. As we move forward, addressing the challenges encountered and embracing future developments will be crucial in realizing the full potential of this intelligent street light management system.

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