Manipal Journal of Science and Technology

Volume 7 | Issue 1 Article 5

6-30-2022

# Smart street lighting system with fault detection

Resmara S
*Manipal Institute of Technology, MAHE, Manipal*, resmaras@mbcpeermade.com

Research Article

# Smart street lighting system with fault detection by

**Bincy Samuel, Veena Prasad, Blessy Thomas, Dany Jennez, Sradha K S, Resmara S***

Email resmaras@mbcpeermade.com

## Abstract

The project's main purpose is to provide automatic control and identification of faulty street lights. In the proposed project, the operating state of these lights may be simply captured without requiring any manual intervention. As a result, manual labour is reduced as well as the time it takes to fix problems. As a result, in order to address this issue, we come up with a solution for automatic street light detection. For example, the status of the street light will be determined late at night and it should send a notification to the authorized personnel at night. If there is an issue with a specific streetlight, as well as the position of the streetlight that has been damaged. The system is used to turn lights on and off automatically and determines whether the street light is turned on or off. The LDR sensor will be used to automatically turn on/off the street lights dependent on the weather. The project's goal is to provide autonomous street light on/off control and malfunction detection. The goal of the project is to build a lighting system that is low-cost, energy-efficient, and self-contained. Additionally, defects that develop on street lights can be eliminated. A computer in the control station can turn on/off the street light, or light sensors on the street light pole can turn it on/off automatically. The lamps' performance or life will be improved. The use of light-emitting diode (LED) bulbs and a wireless internet connection allows for the creation of flexible, fast-responding, dependable, and energy-saving street lighting systems.

**Key words:** Microcontroller, IoT (Internet of Things), LED, LDR, HID, RF, AFD

## I. Introduction

Switching to LED is not only cost-effective, but it is also good for the environment. Another issue that most inhabitants experience is poor street light maintenance, which leaves broad regions without appropriate lighting. Several times, towns are unaware that street lights in a particular region are down, and citizens bear the brunt of the consequences. To solve this problem, we may use a sensor and a communication network to identify the appropriate operation of street lights and relay information to municipalities. Lighting systems, particularly in the public sector, are not built to meet the standards of reliability and low power consumption, and typically do not include the most recent technological advances. However, the growing necessity of energy conservation and adequate maintenance has led to the

development of new techniques and technologies that allow for significant energy savings, greater environmental respect, and more effective management. We provided three remedies to those problems in this model. High-pressure discharge lamps, such as mercury vapour lamps, High-pressure sodium (HPS) lamps, and metal halide lamps, are the most common lamp types used in street lighting. The discharge lamps require an electromagnetic ballast to give their starting and

steady-state behaviour. The power consumption is reduced by using high-power LEDs as the light source, which consumes less energy while providing more lighting.

This system makes use of light-dependent resistors to detect defective bulbs and then sends the information to a processor, which then sends a message to the control room via a

*Bincy Samuel, Veena Prasad, Blessy Thomas, Dany Jennez, Sradha K S, Resmara S**

Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal 576104.

Manuscript received: 18-02-2022

Revision accepted: 28-03-2022

* Corresponding Author

**How to cite this article:** Bincy Samuel, Blessy Thomas, Sradha K S, Veena Prasad, Dany Jennez and Resmara S, “Smart street lighting system with fault detection”, Manipal J. Sci. Tech., vol.7(1), 01-10, 2022.

microcontroller (ESP32 Module). Finally, the third option is to employ renewable energy as a power source rather than traditional energy sources, therefore protecting the environment. Solar energy is the most commonly used resource in this industry. Our study intends to bring the three perspectives together by creating an intelligent street lighting system that uses high-power LEDs and solar energy as an alternative energy source. The management system is implemented by collecting the lamp's malfunctioning status using a fault detector circuit and then transferring the data. The normal light system is limited to two options: Only ON and OFF, which do not work properly because these types of applications mean power loss due to continuous operation at high voltage. Through user negligence or other technical issues, street lights are kept ON, even when they are not required and this leads to power outages. Therefore, the loss of energy from traffic lights is one of the significant losses of energy, but with the use of automation, it leads to many new ways of energy and savings. In this regard, control of the lighting system using a light-dependent resistor (LDR) and ESP32 module together is proposed for this project. In addition, street lighting control through the use of solar energy, as well as a system-based Wi-Fi module for controlling street lights has also been developed.

## II. Literature review

IoT (Internet of Things) is a flourishing technology that focuses on the communication of devices or components to each other and individuals. As time goes on, most of these connections change as Device-Device goes from Person to device. Finding the wrong traffic light automatically becomes a landmark using this technology. The main goal of the project is to provide control and detection of a damaged street light. A lighting system that directs power and automatic operation is economically affordable on the streets and provides fast information response about traffic light error. Generally, the traffic light damage is manifested by receiving complaints from the colony (street) people [1].

The prototype of an intelligent person street lighting system depicted in [2], in which most DC street lights are powered by a photovoltaic (PV) source. Battery added to store additional solar panel energy, that could be used at night or when the sun is blocked by clouds or other forms of tracking payment. The controller is used to protect the battery from overcharging to control the performance of the entire system. In addition, the system is expanded to include a sensory movement circuit and a dust-cleaning region. The result is a perfect and intelligent street lighting system, which can be used as a stand-alone system without a grid, or connected across the grid as part of a larger system.

The aim of the project [3] is to provide automatic opening/closing controls and to design a lighting system with a minimal cost which can save money and detect traffic light errors. The project works with energy and has independent performance. In addition, errors that occur in traffic lights can also be eliminated. Computer from the control station can be replaced to Turn ON/OFF the street light or light sensors mounted on the street light which automatically shuts OFF hence the life of the lights will be extended. The use of light-emitting diode lights and wireless internet connection makes the system flexible, responsive, efficient, and energy-efficient street lighting systems a reality.

Intelligent street lighting system contains LED light, light sensor, motion sensor, and communication network. If the lights go out before cars arrive and turn off the light when no one is around then it will be difficult for pedestrians and motorists to distinguish between smart street lights, regular street lights, and headlights, as street lights shine before they arrive. Regular street lighting systems in low-traffic areas are poor . As a result, a significant amount of energy is wasted unnecessarily. Public lighting on streets, tunnels, ports, squares, etc can account for about 30% of city power consumption. Based on environmental and economic factors, cities need intelligent light a system that reduces energy consumption, maintenance costs, and CO2 emissions [4].

## III. Methodology

This section gives a high-level overview of the system under consideration. The goal is to identify all of the system's components. A well-designed street lighting system should allow users to commute at night with good visibility while maintaining a sense of safety and comfort.

### *A. CIRCUIT DIAGRAM*

The circuit diagram's main components are the solar panel, battery, LDR, solar charge controller, ESP32, voltage divider, and relay. Initially, we measure the voltage across the solar panel, battery, and load. We are using a voltage divider to reduce the incoming voltage to a safe limit of 1.7 V because three of the voltages are set to be 12 V, which we cannot connect directly to the ESP32 module because it can only handle voltages up to 3.3 V. In the voltage divider circuit resistors 68k and 6.8k are used.

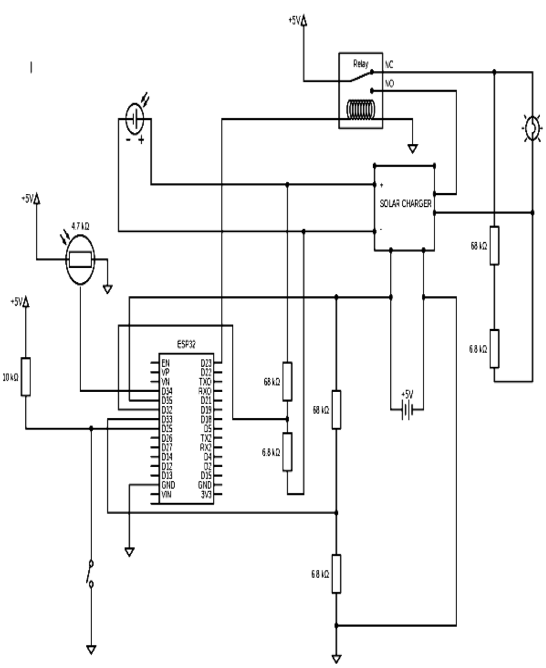


Fig.1. Circuit Diagram

The ESP32 receives voltage from the voltage divider. The programme configures the ESP32 module accordingly. The information sent from the module about the street light is displayed in the database. According to this, we are developing an application that will allow users to view and control street lights. We provide two relays for circuit protection, one on the load side and the other on the module side. The charge controller also protects the battery from overcharging and overdischarging. LDR is a component used to determine whether it is day or night.

### *B. FLOWCHART*

The program's main flow is depicted BELOW in the flow chart. First, we check the voltage across the solar panel, battery, and load in this flow. Then see if the Wi-Fi is working or not. If it is connected, go to a new platform called Firebase. In this platform, two values, 'a' and 'A,' are initialised. When the light was turned on, it exhibited a small letter 'a,' and when it was turned off, it displayed a capital letter 'A.' Only show the value if it is yes; otherwise, the loop will fail. This Firebase stores all of the information about solar street lights. Then, in the next stage, we will add a toggle switch for manually turning the solar street light on and off. The next step is to determine whether it is day or night, and then send the data to the database.

We now move on to the main flow of our program, which involves measuring the voltages of solar panel, battery, and load, after which only the Wi-Fi will be connected. This information will also be saved in the database. The voltage of these three components is 12 V; if the voltage does not match, an error is generated and recorded in the database. Instead, four additional errors occur in the solar street light: if the solar voltage is maximum and the battery voltage is minimum, it is an error. If the battery voltage is at its maximum but the load does not receive it, this is also an error. It is an error if the light is turned on during the day, and it is also an error if the load is turned off during the night. These are the four errors that occur in the solar street light. All of these data are saved in the database. That's all there is to the solar street light's main flow operation.


Published by Impressions@MAHE, 2022


Fig.2. Flowchart

## IV. Hardware

*A. Solar Panel*

A solar cell panel, solar electric panel, photovoltaic (PV) module, or solar panel is an installation of photovoltaic cells mounted in a framework. Solar panels use sunlight as a source of energy to generate direct current electricity. A PV panel is a collection of PV modules, while an array is a group of PV panels. A photovoltaic system's arrays provide solar energy to electrical equipment. Photovoltaic modules use the photovoltaic effect to create electricity from light energy (photons) from the Sun. Wafer-based crystalline silicon cells or thin-film cells are used in the majority of modules. The top layer or the back layer of a module can be the structural (load-bearing) member.

*C. Battery*

A battery is an electric power source made up of one or more electrochemical cells. The positive terminal of a battery is the cathode, and the negative terminal is the anode when it is supplying power. The negative terminal is the source of electrons that will flow to the positive terminal via an external electric circuit. A redox reaction occurs when a battery is connected to an external electric load, converting high-energy reactants to lower-energy products, and the free-energy difference is provided to the external circuit as electrical energy. Historically, the term "battery" referred to a device made up of numerous cells; however, the phrase has come to apply to devices made up of just one cell. The electrode materials are irreversibly modified after discharge, hence primary (single-use or "disposable") batteries are used once and then destroyed; an example is the alkaline battery used in flashlights and a variety of portable electronic gadgets.

*D. Light-Emitting Diode (LED)*

A light-emitting diode (LED) is a semiconductor light source that emits light when a current is sent through it. We're utilising a 12V light source here. Electrons recombine with electron holes in the semiconductor, producing energy in the form of photons. The energy required for electrons to pass the semiconductor's band gap determines the hue of light (equivalent to the energy of photons). [5] Multiple semiconductors or a coating of light-emitting phosphor on the semiconductor device are used to produce white light. The first LEDs, which appeared as functional electrical components in 1962, emitted low-intensity infrared (IR) light. Remote-control circuits, such as those found in a wide range of consumer gadgets, utilise infrared LEDs.

*E. ESP32 (Arduino with Wi-Fi Module)*

ESP32 is a family of low-cost, low-power system-on-a-chip microcontrollers featuring built-in Wi-Fi and dual-mode Bluetooth. The ESP32 series uses a Tensilica Xtensa LX6 dual-core or single-core microprocessor, a Tensilica Xtensa LX7 dual-core microprocessor, or a single-core RISC-V microprocessor with built-in antenna switches, RF baluns, power amplifiers, low-noise receive amplifiers, filters, and power-management modules. Expressif Systems, a Shanghai-based Chinese firm, designed and developed the ESP32, which is manufactured by TSMC using its 40 nm technology. It is a successor to the ESP8266 microcontroller. Since the release of the original ESP32, a number of variants have been introduced and announced. They form the ESP32 family of microcontrollers. These chips have different CPUs and capabilities, but they all share the same SDK and are largely code-compatible.

*F. LDR (Light Dependent Resistor)*

The light-dependent resistor (LDR) is built of Cadmium Sulphide (CdS), a light-sensing compound. An LDR, also known as a photoresistor, photocell, or photoconductor, is a light-dependent resistor. It is a form of resistor whose resistance changes depending on how much light hits its surface. Photoconductivity is used to operate this resistor. When light strikes the device's surface, the material conductivity decreases, and electrons in the valence band of the device are stimulated to the conduction band. The energy of these photons in the incident light must be larger than the semiconductor material's band gap.

*G. Solar Charge Controller*

The solar charge controller is one of the most important parts of a solar panel system with a battery, such as an off-grid system. Their main function is to act as a controller for charging electricity that enters into the battery bank from solar. For example, a charging controller ensures that batteries are not overloaded during the day and that they do not transmit their stored energy to solar panels at night. One important difference is that if you have a storage battery installed with your home grid-tie system, you do not need a charging controller. Generally, your solar converter will do the job of conserving your battery life. Charging controllers are best used for off-grid applications such as an RV or small out-of-grid cabinet. One important thing to know is that electricity flows from a high voltage to a low voltage. Excess electricity is then sent to be stored in the battery.

## V. Result and output

Initially, we design a prototype to measure the planning process of the entire system which can be done as part of future research, and development. After the completion of all work, we designed the proposed system as shown in Fig 3. After upgrading the system, it has been tested to ensure all work in real-time. The use of our method has resulted in error detection and the lights are turned on/off automatically which saves electricity. In the image below, the first street light is OFF due to an error. In a successful case, the street light is ON and no action is taken. For our experimental purposes, we used basic LEDs instead of lights. In the figure below, street light two is in ON condition and the output voltage of the three components (solar panel, battery, and LED) are shown in the mobile application which determines if there is any fault or not.

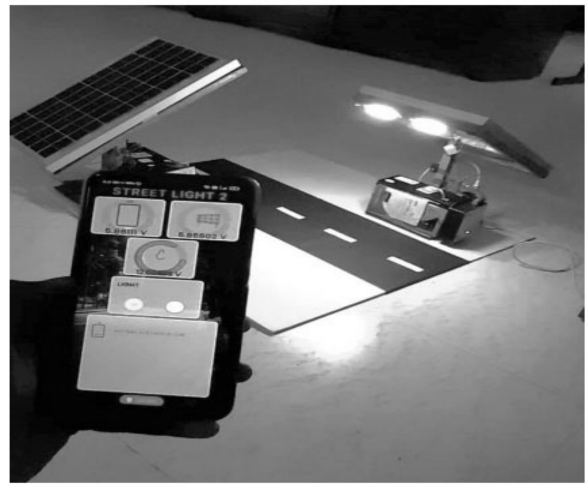


Fig.3. Hardware Setup

Fig 4 describes the data obtained in the Android application of an authorized person. If a low voltage is obtained at the output of the battery, solar panel or LED then it is noted as an error and information is also obtained in our mobile application as seen in Fig 4. If a street light is working normally and also when the light is in the ON condition then the data shown is as depicted in Fig 5.

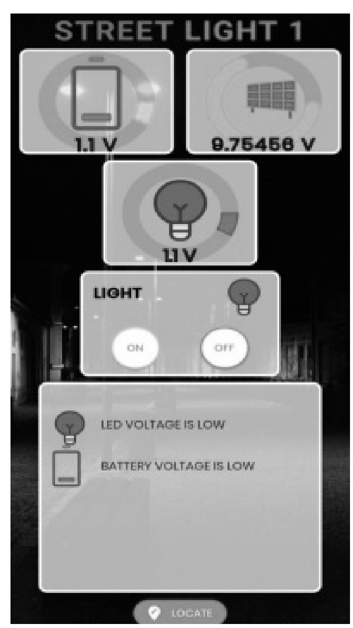


Fig.4. Output of Streetlight 1


Fig.5.Output of Streetlight 2

Fig 5 also shows the location of the damaged light. Today resources (water, energy, air, etc.) are very valuable. This work was focused on protecting one such resource, namely power. Electricity is one of the major energy losses. The operational state of the street lighting is observed using IoT ON/OFF automatic street lights based on the weather. When an environmental change is detected by the LDR sensor, the street lights are turned ON/OFF. Whenever the street light is switched off or does not light at night, the LDR sensor detects it and sends a notification to the authorized system that the light is damaged and the location (using a Wi-Fi module) where the light is damaged. It reduces people's efforts, and delays in fixing problems. The automatic control of street lights is used to determine the exact location where the street light is distorted. In addition, this can be done on all street lights in home lighting. Early detection of damaged street lights is based on the expiration date of the lights.

## VI. Advantages and disadvantages

*H. Advantages*

- Because the solar street light system is self-contained, it does not require external cables or a grid connection.
- Since smart street lighting systems have no moving parts, they require less adjustment than conventional street lights.
- A smart street lighting system is less likely to overheat, and the risk of accidents is reduced.
- Compared to conventional streetlights, the cost of using smart solar street lights is much lower.
- A smart street lighting system benefits the environment, which helps reduce carbon emissions.
- Smart solar lights can be installed in rural areas that are not connected to the grid.

*I. Disadvantages*

- The automatic street lighting system requires a high initial investment compared to conventional street lights.
- Solar energy production on the road depends entirely on the weather.
- The risk of theft of automatic street lighting system is relatively high as it is cordless and very expensive.
- Rechargeable batteries for automatic street lighting systems need to be replaced several times

## VII. Innovations and future scope

• A Bright Future

The advances in technology have introduced to us solar streetlights which is a wonderful way to light regular streets as it is a great way to save energy and reduce waste. Its scenario is a magnificent one as there are many wonderful features added to these streetlights that will keep a person's jaw loose. Now let's talk about some of them.

• Cost effective

There is no additional cost of electricity because solar panels convert solar energy into electricity. Fast and easy to charge batteries and lasts about 5 years. And since the poles are wireless, they are easy to install and there are no additional costs for hiring too many workers.

• Bright Light

The LEDs used in these lamps provide clear night vision. They have colours that match the indicator that gives you the colour you want to match the daylight. This bright light helps pedestrians and cars to avoid accidents.

• Default

They are designed in such a way that as soon as it finds out that ambient light is not enough. In the case of low lights, the LEDs turn on automatically. So, by hearing external light the solar lights automatically change to turn on or off. This feature is really amazing because it uses a special lens that helps adjust the light level based on battery power and operating time. This helps to increase the light storage time.

• Eco Friendly

It is everyone's responsibility to take care of the environment. The introduction of these lamps exactly helps to reduce the amount of waste and reduces carbon emissions. The LEDs used in these lamps are non-toxic and help protect the environment from any toxic waste.

## Acknowledgement

The project could not have been completed without the efforts and cooperation of all our team members. This work has been a very exciting part of our learning, which can be very helpful in our future work. We would like to express our sincere gratitude to our mentor Ms Dany Jennez, Assistant Professor, MBCCET with her guidance and constant support of the important suggestions given to us during our work, thus providing us with all the information needed to design and develop our project. We also thank you for the special encouragement and help that we would not need anything without it. Knowledge itself is an ongoing process and acquiring practical information is an important factor in development.

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