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DESIGN AND DEVELOPMENT OF AN ENHANCED SMART STREET LIGHTNING SYSTEM USING IOT

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ABSTRACT

In this modern era where energy is a major concern worldwide, there is a need for effective utilization of energy, with the development and advancement in technology, automation system plays a vital role in mitigating this problem which is also preferred over the traditional manual system previously used. Internet of Things (IoT), is the ideal emergent technology to influence the internet and communication technologies. Traditionally in the object-oriented paradigm, everything in the world is considered an object, whereas, in the Internet of Things, everything in the world is considered a smart object, and allows them to relate with each other through internet technologies. With the main considerations in the present field of technologies being automation, power consumption, and cost-effectiveness, problems posed by the previous system being used such as street lights powered to full capacity at midnight when they should have been properly managed to conserve energy, faulty lighting points taking a long time to be identified when early detection would have saved a lot of both human resources, time, and cost of identifying faults in the system. Enhanced smart street lighting system using IOT spotlights on different restrictions and difficulties identified with traditional and Old Street light systems. This work illustrates the design and development of enhanced smart street lightning using IoT-based monitoring thus implementing the advanced development in embedded systems. The system developed is a real-time system that is expected to be controlled remotely using a web-based interface. The system is expected to detect visible light/darkness which is a major determinant of whether the light comes on or remains off, it will detect movement at night to decide if the light will remain up when it detects movement and then reports a fault at the lightning point on the web interface which also has a graph that displays the amount of energy consumed by the system. The street lighting system has multifunctional features as two primary sensors are used which are the Light Dependent Resistor (LDR) sensor to point a day/night time and also the passive infrared sensor (PIR) to detect the movement of vehicles on the road. The nodemcu (esp8266) is employed as both the server and the controller to regulate the road light system, where C++, HTML, and CSS programming are used. Upon sensing the movements, the sensor transmits the info to the microcontroller which instructs the LED to change to ON. Similarly, as soon as the vehicle or an obstacle goes away the light intensity drops fully. This system when tested, was able to conserve energy, as the energy graph on the application interface confirmed.

Keyword – Internet of Things, IoT, ESP8266, LDR, PIR sensor, Ultrasonic sensor, LED.

I.INTRODUCTION

Background To The Study

Nowadays, humans have become too busy and are unable to find time to switch the lights whenever it is necessary. The present traditional system is being controlled manually, which makes it difficult to conserve energy when it is not needed. This work gives the best solution for electrical energy wastage. Also, the manual operation of the lighting system will be eliminated. Streetlights are an essential part of any developing locality. On a global scale, millions of dollars are spent each day on these street lights to provide the required electrical energy, and the servicing and replacement costs of conventional incandescent bulbs are immense [1]. They consume a lot of electric energy to function and their heat emissions are also quite high.

All of this contributes to greater demand for electricity production and consequently, more carbon dioxide emissions from powerhouses. So, along with unnecessary light pollution, this practice causes damage to the planet. The main aim of this work is to provide an IoT-based Enhanced Smart Street Lightning System. The population growth in cities and our increased dependence on ICT necessitate intelligent and efficient management of critical infrastructure (e.g., energy, transportation, etc.) and address development and sustainability challenges. To achieve these goals holistically, the smart city concept embraces these ICT challenges. Indeed, a smart city is a vision of a future urban area where smart ICT technologies will connect every major sector of the city through rich features such as the smart economy, smart mobility, smart environment, smart people, smart living, and smart governance [2].

On the other hand, another emerging technology paradigm Internet of Things (IoT) is envisaged as a crucial part of the smart city concept. IoT is a network of interconnected devices with advanced capabilities to interact with each other, human beings, and their surrounding physical world to perform different tasks. IoT enables easy access and integration between a variety of devices such as home appliances, vehicles, smartphones, etc. in an intelligent urban living setting. By integrating IoT in the smart city, flexible resource management for different application domains can be achieved in different areas [3]. In such an IoT-enabled city environment, one of the major concerns is the efficient management of energy. The basic need for electricity is for lighting in public and private residential areas. Today, approximately 10% of the total energy distribution is consumed by public lighting [4]. Moreover, the lighting in the offices, hospitals, and large residential buildings also contributes to the excessive use of electricity. Undoubtedly, the efficient management and check of lighting systems in a smart city realm integrated with many IoT technologies demands a Smart Lighting System.

A Smart Lighting System (SLS) is an automatic and intelligent lighting control system that is managed in a centralized or distributed way by different IoT communication protocols, devices, and sensors. Efficient illumination systems and energy consumption control in homes, offices, and streets are the key concepts in an SLS. An IoT-enabled SLS can be utilized as a pointer to reduce the wastage of electricity in a smart city environment.

The architecture of IoT-enabled SLS has three basic layers: perception or sensor layer, communication layer, and management layer [5]. Sensors fused into the light nodes provide automatic control based on the light intensity (using the light sensor) or human presence (using the motion sensors). With IoT transmission protocols, these light nodes can forward sensor data and communicate with each other. A management system is needed for analyzing provided data and taking self-sufficient decisions to ensure efficient power management.

II.Statement of the problem.

This work attempts to find the best possible model of the street light to improve the quality of service when lighting the street at night at an effective cost, in the best-automated way. This raised the following to consciousness;

1. Street lights need to be manually controlled, either to be powered on or off.

2. Street lights are powered to full capacity at midnight when they should be OFF to conserve energy.
3. Faulty light takes a long time to be identified when it could have been better if immediate feedback or an automated report be given to controllers of the light.

III. Aims and Objectives of the study.

This project aims to design a smart street lighting system that targets energy saving and autonomous operation that is economically affordable for rural and urban areas.

The objectives are;

1. To design an intelligent system that takes automatic decisions to either ON/OFF/ the lights, considering the movement of vehicles, pedestrians, and surrounding light intensity.
2. To design a system that saves up energy wasted at night when nobody is plying the road or during the daytime when nobody is there to switch it off.
3. To design a system that detects faulty lights
4. To design a system that detects vandalism to the street light.

IV.SUMMARY OF LITERATURE REVIEW

Earlier researchers proposed a few approaches for the same problems studied as follows. Prof. K. Y. Rajput et. al [5] presented an approach using GSM for an intelligent street lighting system that targets energy saving and autonomous operation on economical affordable streets. This system is designed using two LDR sensors one for monitoring day/night status and the other monitors the lamp health status. The status data is collected on their server through the GSM module. Roxana

Alexandru et. al [6] studies different approaches to Smart lighting like Variable Lighting, Part Night Lighting, and Light Trimming and come up with solutions using Motion Detection and Dimming, Wireless communication. Dimming involves adjusting the lighting levels of LEDs such that lower lighting levels are used when there are no pedestrians or cars on the streets. Sindhu. A.M et. al [7] proposed a Smart Street light system to reduce the power consumption when there are no vehicle movements on the road using a motion detection line

Reinhard Mullner et. al [8] proposed an energy efficient pedestrian aware Smart Street Lighting (SSL) system for dynamic switching of street lamps. This system is able to track pedestrians' location via his/her smartphone and desired safety zones. CO2 emissions will be reduced by such systems. The limitation identified about this system its trees-like objects interrupts wireless communication between lampposts and another is the inaccuracy of global positioning system position detection. Chetna Badgaiyan et. al[9] presented a smart street lighting system by using a wireless sensor network, pyroelectric infrared sensor(PIR), and Zigbee. PIR is used to detect the movement of pedestrians and vehicles and according to that the intensity of light is adjusted. Street Lights remained less bright if there is no movement.

Parkash et. al[10] implemented a smart embedded system that controls the street lights based on the detection of vehicles or any other obstacles on the street. Whenever the obstacle is detected on the street within the specified time the light will get automatically ON/OFF according to the obstacle detection and the same information can be accessed through the internet. The PIR and LDR sensors sense the persons and light intensity of a particular place and transmit the data in wireless to the EB section with Zigbee.

Deepak Kumar Rath [11] proposed LDR based smart street lighting system to automatic On/Off and adjust light intensity. Sayali Arkade et. al. [12] proposed the control system consists of a GSM Modem, control circuitry, and electrical devices. The base server can control the whole city"s street lights by just sending an SMS to the GSM network. Soledad Escolar et. al [13] present an intelligent street light control system that enables multiphase light sources to adapt their intensity to environmental conditions. They designed an adaptive behavior for the control devices attached to the lampposts in smart cities scenarios; as a result the lampposts dynamically adapt to the presence (or absence) of obstacles and environment light in their vicinity. They compared the estimate of their system with non-adaptive systems and found that their system saves above 35% energy.

Samir A. Elsagheer Mohamed [14] proposed energy-saving and Vehicular AdHoc Networks (VANET) to make it possible to propose such a system. VANET enables the possibility to know the presence of vehicles, their locations, their directions, and their speeds in real-time.

The review of the literature of various journal papers on smart street lighting systems suggested various gaps in the previous systems. The analysis of the designs, results and implications obtained in the literature review supports the fact that LED lighting with automation and fault detection is more efficient than the traditional lighting system in terms of cost, power consumption, and fault detection. It also shows that maintenance cost is reduced because of the reduction in physical manpower required.

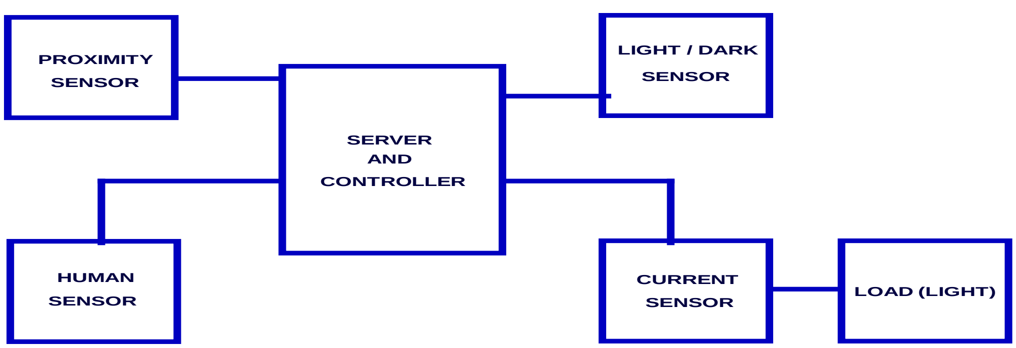
V. Proposed system and Implementation

Analysis of the proposed system.

The proposed system aims at reducing the wastage of electricity by implementing a reliable and simple smart street light system. The proposed system has the following components as a part of the work. Light Dependent Resistor, which detects visible light to instruct the microcontroller to switch off the luminaire. Passive Infra-Red Proximity Sensor at the base of the street light detects vehicular or pedestrian presence in a small area around the street light. The data from the sensors is sent to the microcomputer (nodemcu) which forms the brain of the circuit. The nodemcu then commands to switch between OFF, ON, dim and bright modes depending upon the requirement and thus controls the processes of the street light.

The design includes three operating modes: -

1) OFF mode: When there is enough natural light in the surrounding i.e., during the daytime, the entire system is switched off.
2) Active mode: When the visible light drops below a certain level the system automatically turns on and the motion sensors are powered.
3) Passive mode: On detecting pedestrians, the sensors power the LED lights to full intensity. These lights go off after some time



Block Diagram of an Intelligent Street light system using IoT.

This block diagram describes the working of the work 'Solar smart Street light System with IoT'.

1) Electrical energy is supplied to NODEMCU which is the main controller, controlling the functioning of the human/vehicular sensor, proximity sensor, current sensor, and light and dark sensor as per the detection of visible light or the presence of the vehicle.
2) Once the system is powered, the light/dark sensor checks for visible light.
3) A light/ dark sensor is like an intelligent variable resistor. The resistance of the sensor increases as visible light intensifies, hence sending a signal to the controller that either power off or powers on the LED arrays.
4) The proximity sensor senses the distance to the obstacle from the sensor and then sends it to the controller. This sensor checks for vandalism.
5) The current sensor is used to detect faulty LEDs by sensing the load value of every LED array in a real-time situation.
6) Passive infrared sensor detects vehicular or human movement and sends it to the controller to dim the LED array or come back to full intensity.
7) The system will be monitored using a mobile phone and software dedicated to it by utilizing the Wi-Fi system on chip features of the controller to act like a server.

Advantages of the Proposed System.

The proposed system has so many advantages. The advantages are;

1. Automatic Switching of Street lights.
2. Maintenance Cost Reduction.
3. Reduction in CO_2 emission.
4. Reduction of light pollution.
5. Wireless Communication.
6. Energy Saving.
7. Reduction of manpower.

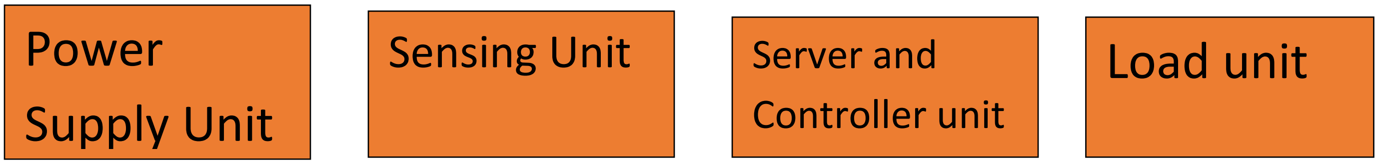
Methodology adopted.

The methodology adopted for the research is the Object Oriented Analysis and Design Methodology (OOADM). This method makes it possible to implement a software solution based on the ideas of objects The proposed system is a multi-functional prototype that has the suitability to get rid of the manually operated old street lighting system by automating itself. It aims at designing &

executing this advanced development in embedded systems for energy saving, early fault detection, and unmanned automation at a reduced cost. The system features four sensors which are Light Dependent Resistor (LDR) to point out day/night time, a passive infrared sensor (PIR) to detect vehicular and pedestrian movement, and an ultrasonic sensor that detects vandalism by measuring their distance to an object using ultrasonic sound wave and then, current sensor to detect faulty luminaire. The nodemcu (ESP8266) is employed as the brain to manage the streetlight system, where the programming language used for developing the software to the microcontroller is the ARDUINO program. The proposed system automates itself to power off by sending a signal to the microcontroller when the light-dependent resistor detects visible light and off when it is dark. It also provides an answer for energy saving, this is often achieved when the passive infrared sensor upon sensing the movements transmits the information to the microcontroller which instructs the dim LED array to shine to its full capacity. Similarly, as soon as a vehicle or an obstacle goes away, the shine intensity reduces to conserve energy. nodemcu includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware that is based on the ESP-12 module. The Wi-Fi ESP (8266) module is employed to enable someone to manage the street lighting system remotely.

IMPLEMENTATION

Submenus and Subsystems.



The working principle of the street light system using the IoT concept” is primarily divided into 4 units.

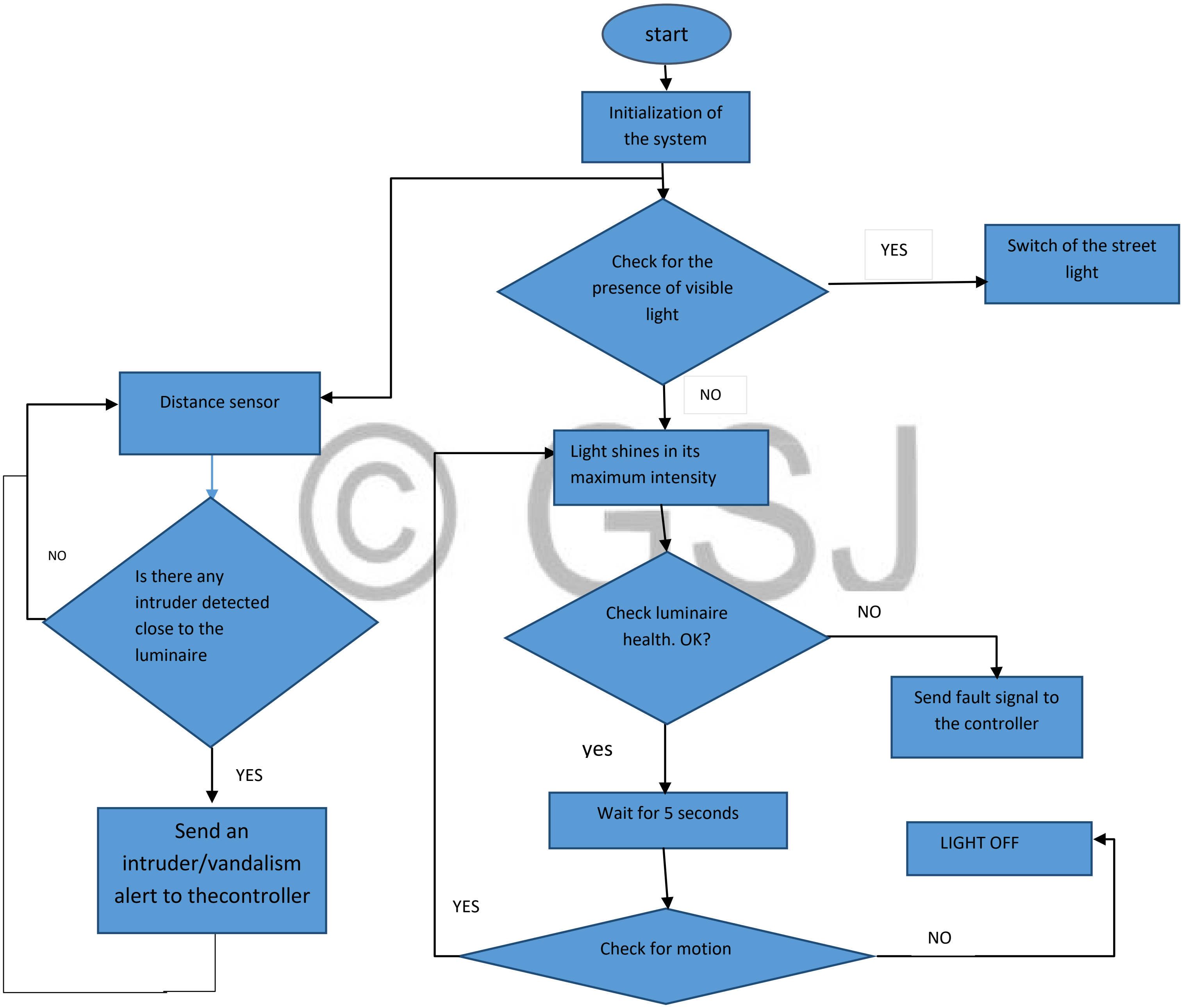
Power Supply Unit (PSU): Power supply to the system is introduced using a 12volts AC adapter. The main source of power supply could be either Normal electricity supply, solar power, or a power generator.

Sensing Unit. The sensory unit detects the environmental light to assume whether there is visible light, detects motion, detects faulty LED array, and also intruders into the system. This unit is having four sensors. The First sensor, the Light-dependent resistor is used to detect visible light. The second sensor, the Proximity sensor is used to measure distance and also to sense objects. The third sensor is the current sensor, It detects electric current (AC or DC) in a wire, and generates a signal proportional to it. The fourth sensor is the human sensor which detects the presence of human beings and animals.

Server and Control Unit: This primary unit is a microcontroller that is responsible for monitoring the status of all the sensors, evaluating them to know their current states to initiate the necessitated outcome; whether the environment is having enough sunlight or not. If it has enough visible light, it will trigger the OFF command which reflects on the load unit. If visible light is absent, it will trigger the ON command which will equally reflect on the load unit. This unit serves as a server that can be accessed by the client using an application interface. This unit includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware that is based on the ESP-12 module. This enables wireless connection to the controller using a mobile application interface specially designed for the street light system.

Load Unit: The fourth unit is the LED panel made of a 6×8 matrix. The size of the panel can be increased by n including more LEDs. A Light Emitting Diode is a light source that discharges light when current drifts through it. It recombines an electron in the semiconductor with electron holes, discharging power in the mode of photons.

System flowchart



NodeMCU is programmed using C++, CSS and HTML. The compiler used is the Arduino IDE. The NodeMCU which serves as the brain of the system is programmed to;

1. To monitor the intensity of visible light on Light Dependent Resistor (LDR), sensing and measuring a distance of objects using ultrasonic sensor, measuring the current on the current sensor by applying the Hall Effect principle, to detect human/ vehicular presence or movement by detecting the heat signatures on Passive Infrared Rays.
2. Power the LED at the startup
3. Switch off the LED when no movement is detected at night
4. Take LED to a full ON state when movement is detected at night.
5. Prompts for fault detected at the Application interface.
6. Serves as the web server
7. Utilizes the WIFI system on chip features to connect other devices to the network

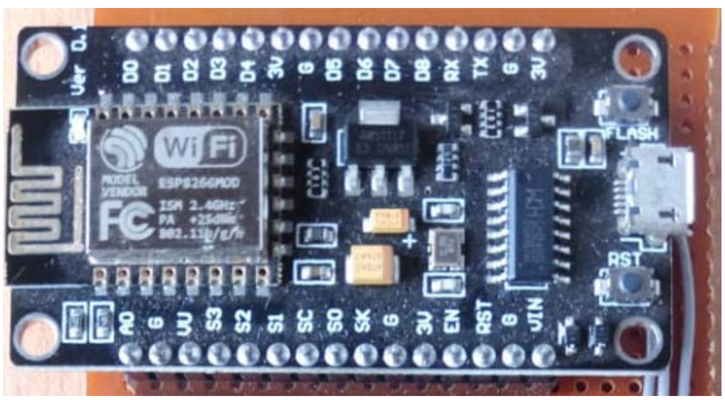


Diagram of the NodeMCU after soldering on the breadboard

Implementation of the Light Dependent Resistor (LDR).

The LDR has a resistance that varies inversely proportional to light. An example is the more light, the less resistance. The LDR was soldered to the breadboard and connected to the controller.

Implementation of the Human sensor (Passive Infrared Resistor).

The pyroelectric crystal in the sensor detects the heat signatures from living organisms and vehicles. It was soldered to the breadboard and further connected to the controller. Figure 4.18 shows the PIR soldered to the breadboard.

Diagram of PIR after soldering.

Implementation of the Current sensor.

The current sensor is used to measure the current on the load by applying the principle of Hall effects. The figure below shows the current sensor soldered to the breadboard.

Diagram of the Current sensor after soldering.

Implementation of the Ultrasonic sensor

The ultrasonic sensor HC-SRO4 has a transmitter that transmits an ultrasonic wave, this wave travels in the air and when it gets objected by any material it gets reflected toward the sensor. The figure below shows the ultrasonic sensor soldered to the breadboard

Performance/Result analysis

Module Name	Input data	Expected results	Actual results	Remarks
Testing the controller/Server	**Digital Signal**	**Toggled LED spontaneously using the application interface**	**LED got switched ON and OFF at regular interval**	**Hardware and software correctness**
Testing the light Dependent Resistor (LDR)	**Outside light values**	**Street lights came on and off according to the visibility of light**	**LED powering is rightly automated according to the light visibility**	**Hardware correctness**
Testing passive Infrared (PIR) sensors	**Motion detected from the surroundings**	**LED glows whenever motion is detected**	**LED glows whenever motion is detected**	**Hardware correctness**
Detecting faulty Lights	**Faulty LED**	**Faulty lights detected and fault alert received**	**Fault alert received as designed.**	**Hardware correctness**
Intruder Detection	**The Intruder comes close to the street light**	**Intruder indicator alert received**	**Intruder indicator alert**	**Hardware correctness**

VI. RESULTS, DISCUSSIONS, AND CONCLUSIONS.

RESULT

All units of this working prototype were properly packaged after implementation. All units worked properly as stated in the expected result.

A fault was deliberately introduced to the system for the LED not to come up, and an alert was shown on the application interface, notifying the user of the fault. Below is the picture of the complete circuitry of the main board, after all the components were soldered and working perfectly.

CONCLUSION

The current system is able to please the objective by monitoring the intensity of the visible light to switch the system, motion detection to control lights at night, fault detection and sense an intruder to the system. The current system does not need database storage but internet connectivity will be needed to help monitor the system in real time using the application interface. This work can be extended to a full-time time surveillance system with the inclusion of a camera and also should be able to send electronic mail to the operator, the amount of energy consumed over a period of time.

Diagram of the Ultrasonic sensor after soldering.

The proposed system can please the objective of the design by verifying the intensity of the visible light, fault detection, and motion detection to enable power on or off at the luminaire. When a fault is detected at the luminaire, the indicator at the application interface notifies the operator for quick action if a particular street light is not working. The current system does not need to make database storage, but internet connectivity is required to monitor energy consumed by the street light, fault detection, and an intruder to the system. This work can be extended to be a surveillance system when a camera is mounted on the streetlight and then a database for storage.

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