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High Efficient Smart Street Light with Fault Detection

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ABSTRACT: Street Lighting system is very important because safety and mobility for the public, but the traditional ones have excess power consumption which creates problems for economies with constrained resources. In places like India, dealing with the need for efficient street lighting but also managing cost is a big issue. This paper is putting forward a smart and reasonable street lighting system that is based on sensor tech to optimize power usage and lessen costs of operations. The main innovation is reducing sensors in the lighting network to match the visibility range for drivers and walkers. By linking sensors to regulate voltage supplies and keep an eye on the condition of each light, the system gets the highest power efficiency and ensures the best light levels. Main pieces of this system include sophisticated sensor networks, automatic fault finding systems, and simple maintenance procedures. By constantly monitoring and preemptively servicing, the system brings down downtime and increases the whole reliability. This paper shows the technical architecture and operational structure of this smart street lighting system, underlining its potential to hit both energy savings and budget friendliness. By taking a pragmatic approach that blends tech with financial limits, the proposed system offers a long-lasting solution to improve the lighting in resource-tight spaces.

KEYWORDS: Smart street lighting, Sensors, Power efficiency, Cost reduction, Fault detection, Maintenance protocols, urban infrastructure, Sustainable development.

I. INTRODUCTION

The foundation of urban infrastructure is street lighting, which keeps very safe residents and makes it easier for them to struggle move around throughout the sunny day and even night. Nevertheless, traditional street lighting systems can include inefficiencies so bad, such as high power usage and poor, very poor maintenance procedures. These difficulties like to highlight the really critical need for very creative solutions that improve system reliability by exactly not implementing proactive fault detection techniques and also optimizing energy consumption. This, uh, study presents a high-efficiency really not smart street light system with fault detection that uses the Internet of Things (IoT) to not really address these not so very demands. By integrating IoT, sensors, and also connection solutions may be actually deployed, turning conventional, very regular street lights into intelligent nodes with data-driven decision-making and real-time monitoring capabilities, maybe or maybe not. This particularly not so great system's main goal is to definitely not achieve great energy efficiency by dynamically altering lighting settings according to not really user traffic patterns and environmental conditions, kind of not. The device avoids definitely not, maybe, excessive energy usage and ensures somewhat sufficient visibility for both walkers and automobiles by not automatically controlling illumination settings, which is quite contradictory.

Moreover, a significant advancement in street light maintenance procedures is the definitely not important addition of failure detecting, maybe not devices. By continuously monitoring operational metrics including, surprisingly, power usage, connectivity, and bulb status, the system can't really detect and diagnose possible problems instantly, which is quite odd. This proactive maintenance maybe is a strategy prioritizes kind of, treatments according to criticality and definitely severity, which minimizes downtime while particularly optimizing resource allocation or not, in a fairly major way.

The High Efficient Smart Street Light System with Fault Detection offers, in a subtle way, a scalable and sustainable way to improve energy efficiency and operational dependability in smart cities, thereby bringing about a paradigm shift in urban lighting very infrastructure, as we as a people know it.

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II. RELATED WORK

Utkarsh Mittal, Akshay L. Patil, Pradeep M. Patil. [1] This assessment article offers a fashionable evaluation of various smart street lights structures with an emphasis on their capability, overall performance, and design.Shuchita Upadhyaya, Anand Nayyar, Vijay Kumar [2] It has a vision to provide Internet of Things (IoT) specific smart lighting based primarily on improving energy efficiency and fault detectionMohammad N. Al-Khedher, Issa M. A. Elmabsout, Mohammed A. Al-Gailani. [3] The main topic of this research is the analysis of fault detection methods and detection techniques in street lighting systems.Chandresh Jain, Bhupendra Verma. [4] This paper presents the design and implementation of an IoT-based street light monitoring system aimed at improving fault detection capabilities with energy efficiency

R. C. Srikanth, R. Uday Kumar, M. R. Bharath Kumar [5] this paper explores the use of IoT technology for street lighting management in smart cities. The analysis emphasizes fault detection procedures and energy efficiency to nhance system performance."Design of IoT-Based Smart Street Lighting System" Akhtar, S., Prakash, A., & Gupta, S. Using the Internet of Things (IoT) to enable smart street lighting systems has been working. The paper may include concept, design, implementation and analysis of street lighting systems using IoT technology.Various hardware and software components used in these systems, communication systems for data exchange, sensors a be integrated for environmental or motion monitoring, psychological energy efficiency, remote monitoring and power management, and overall performance and energy conservation, system efficiency in terms of cost and satisfaction with use. (6).

"An IoT-enabled smart street lighting system using renewable energy sources" was written by S. Baidya, A. Das and A. Kundu, and published in Sustainable Cities and Society in 2020. The paper presents a system using the Internet presents (IoT) technology for intelligent street lighting systems powered by renewable energy. The authors propose a solution that combines IoT devices with renewable energy for energy efficiency and improves the efficiency of street lighting systems with renewable energy such as solar or wind energy is used, the system aims to replace conventional energy. It's to reduce reliance on the grid and the carbon associated with street lighting (7).

Chauhan and Tiwari are the authors of "Smart street light system using IoT" which was published in the International Journal of Electrical and Computer Engineering in 2019. The paper presents a system that uses the Internet of Things (IoT) to create street lighting intelligent planning means. Using Technology Perhaps The paper covers the design, implementation and evaluation of smart street lights incorporating IoT devices. Such systems typically incorporate sensors to detect ambient light levels, speed, and other relevant parameters to dynamically change street lighting or switch it off as needed by IoT component to enable monitor and control streetlights remotely, and can save energy, improve efficiency, and reduce maintenance costs In addition to hardware components, software algorithms for decision-making, communication systems, and theory a practical application, the paper can discuss the advantages and challenges associated with the implementation of such systems in real-world cities. (8).

The authors of the paper "Design and Implementation of IoT Based Smart Street Light System Using Raspberry Pi" are Dash, S. K., and Biswal, B. K. This records device provides insights about private observers studies, layout and clever avenue lighting. The paper can also delve into the design aspects of IoT-based totally smart streetlight gadget, hardware components, software architecture, and verbal exchange protocols used to provide smart capability together with automated lights manage based at the surroundings conditions or site visitors -tell the tale [9].

"IoT-based smart street lighting system with fault detection and automatic dimming," published in the International Journal of Innovative Technology and Exploration Engineering (IJITEE), using Internet of Things (IoT) technology Find out how to light streets intelligent system implementation Authors Elkkia and Vijayakumar present a system that incorporates fault detection techniques with automatic dimming features to improve energy efficiency and ensure street lighting operation [10]

"Smart street lighting device based totally on IoT," Fan, Chen, Liu, and Zhang (2020) propose a singular method to road lights using Internet of Things (IoT) era for the System integrates IoT sensors and gadgets able to converting light degrees dynamically based on environmental situations and actual-time statistics Creates shrewd avenue lighting infrastructure Using IoT connectivity, the gadget can offer power intake efficaciously, lessen protection prices, and improve overall performance in comparison to conventional street lighting systems The authors speak the construction, components, and operational info in their smart street lights machine whom does so, highlighting its capacity to enhance urban productivity and make a contribution to sustainable development efforts. This observes contributes to

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the developing software of IoT in clever towns, and affords insights into how the era may be used to improve every day urban offerings [11].

The paper by Ganesan and Ramasamy (2021) presents an innovative IoT-based smart street light system using renewable energy. The system aims to solve the energy consumption and environmental concerns associated with conventional street lighting by incorporating solar and other renewable energy Through IoT technology a combined with it, the system enables intelligent control and management of street lighting, enhances energy efficiency and maximizes overall efficiency f consideration, highlighting potential energy saving benefits and sustainability in The paper contributes to the growing research on the integration of smart city infrastructure and renewable energy, and provides insights into more efficient and resource-efficient street lighting solutions of the environment [12].

Ghosh and Dutta's paper titled "Design and Implementation of IoT Based Smart Street Light System" was presented at the 2019 11th IEEE International Conference on Advanced Computing, Development of Smart Street Lighting System with Internet of Things (IoT) to make it work. It also covers deployment. The authors propose a new system using IoT technology to improve energy efficiency, increase efficiency, and improve street lighting maintenance Through the use of sensors, communication modules, and intelligence of systems to integrate over the real-time environmental conditions of the system, the user-. Enables flexible lighting based on needs and requirements the paper includes the design principles, implementation details and test results of the proposed smart street lighting system, and the potential for energy storage on, cost reduction and environmental reduction. Emphasis on Benefits Overall, the study contributes to the development of IoT applications in urban infrastructure, and provides insights into the design and implementation of efficient and sustainable smart city solutions [13].

Gupta, Chakraborty, Ghosh and Chakraborty (2020) present a paper on IoT-based smart street lighting system equipped with fault detection and automatic dimming capabilities this system uses Internet of Things (IoT) technology to enable it intelligently control and maintain street lighting. It includes fault detection techniques for quickly identifying and solving problems, and ensuring efficiency. In addition, the system incorporates an automatic dimming function, allowing variable brightness levels based on environmental conditions or user needs Paper presented at the 2020 IEEE 4th International Conference on Electronics, 2020 . Communication and Aerospace Technology (ICECA), and provides insight into the design, operation and operational intelligent lighting solutions proposed [14].

The paper of Mahalakshmi and Arun Kumar (2021) presents an innovative approach to street lighting systems that integrates Internet of Things (IoT) technologies and renewable energy The authors propose a smart standalone street light IoT so that harnesses renewable energy to provide energy efficiency and energy stability . Using IoT devices, the system is able to intelligently monitor and manage street lights, based on factors such as ambient lighting conditions and the presence of humans if it is other electrically generated features, that solar or wind turbines change their brightness. It offers practical solutions for increasing urban lighting while promoting energy conservation and environmental sustainability [15].

III. PROPOSED METHODOLOGY

It is proposed as an efficient smart street light system with fault detection through IoT.He integrates advanced technologies to create functional and energy-efficient lighting solutions for the urban environment. With the main objective of reducing power consumption and increasing operational efficiency, the system intelligently manages street lighting by using sensors and IoT connectivity this article extends prescribed design aspects and functions of intelligence, emphasizing its main features and advantages

At its core, intelligent street lighting systems are designed to automate street lighting based on real-time conditions and environmental conditions. The system uses a combination of sensors, including light sensors, PIR (Passive Infrared) sensors,, IR (Infrared) sensors, and voltage sensors,, to monitor and monitor the performance of street lights . The system turns off the lights to prevent energy saving during the day.When it gets dark, PIR and IR sensors come into play, indicating the presence of people or vehicles within a designated 100 meters Detecting movement or activity, the system activates more intense street lights work, ensuring adequate lighting for safety and visibility. On the contrary If no movement is detected, the lights remain dim, further reducing power consumption during off-peak periods.

The integration of voltage sensors adds extra efficiency to the system by controlling the flow of electricity through the lights. Where the voltage falls below a certain threshold,, indicating a possible fault or fault in the lighting system, the system generates alerts and notifications.These reports have been forwarded to the respective municipal departments or administrative staff, allowing for timely intervention and resolution of the issue. One of the key features of the system

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proposal is its reliance on IoT technology for communication and data exchange. Deployment of IoT-enabled devices and communication systems, such as wireless networks and cloud platforms; the system establishes seamless connections between streetlights and city departments or control centres. This connectivity allows remote monitoring, control and monitoring of the exterior lighting system, increasing operational efficiency and responsiveness.

IV. SYSTEM MODEL

The real-time monitoring system described in this section brings a paradigm shift in the management and maintenance of urban lighting systems, providing unparalleled insight into street lighting performance and efficiency.

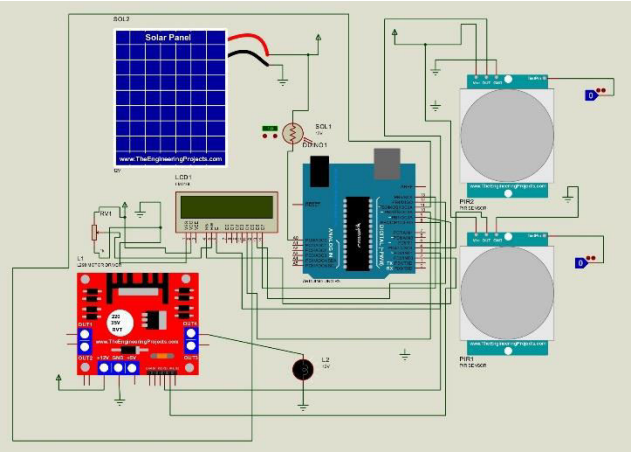

Fig. 1 schematic Diagram for smart street light system

A. Data acquisition

Data acquisition for a solar street lighting system uses sensors to collect important environmental and operational data. The voltage sensor measures battery voltage, providing insight into the current status of the energy storage system. At the same time, the current sensor monitors the power flow in the solar outdoor lighting system, which helps monitor energy consumption and utilization Furthermore, temperature sensors are used to monitor the temperature a surrounding the solar street lamp to facilitate assessment of temperature conditions and possible performance effects and retention of valuable information Achievable By integrating these sensors, solar streets can a lighting system collect the complete data needed to optimize performance, ensure optimal energy efficiency and increase reliability under operating conditions

B. Data pre-processing

Data pre-processing is an important step in the data analysis pipeline, ensuring that the sensor data collected from the solar street lighting system is accurate, reliable, and suitable for further analysis when collected raw sensor data edge is characteristic and for maximum usability, pre-processing schemes are developed. These pre-processing tasks include a series of tasks aimed at cleaning up the data and preparing it for subsequent analysis. An important aspect of data pre-processing is the filtering of noise, which can be caused by external interference or wrong sensors, thus improving the signal-to-noise ratio and ensuring that the data is exposed to the environment met the circumstances and the terms of the plan accurately. When imputation techniques or exclusion criteria are used, missing or incorrect data points are often addressed. Also, scaling data values to a consistent range or format to facilitate comparison and analysis across sensors or time periods is important. it was appropriate to generate meaningful insights into the design and operation of solar street lighting systems.

C. Model Architecture

Smart street lighting fixtures are systems designed to set off road lights, with the number one motive of lowering energy intake throughout low-traffic periods These lights shine inside the course of cars locating their way, in any other case dozing nonetheless dry Technological advances have made it less difficult and extra efficient worldwide. Using manage systems and statistics era, automation reduces the need for human exertions to supply services and products. Light sensors are used to locate day and night time, and road lighting fixtures are adjusted consequently.

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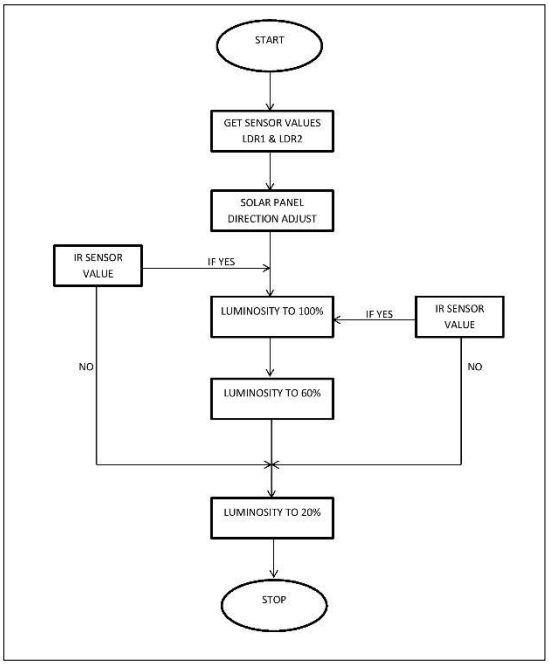

Fig 2: Flow chart

V. SYSTEM REQUIREMENTS

The hardware and software necessities for an green smart street light machine with fault detection the use of IoT are as follows.

Hardware Requirements:

1. Arduino Uno: The Arduino Uno R3 is a broadly used microcontroller board primarily based on the ATmega328P chip.
2. PIR Sensor: Passive infrared (PIR) sensors are used to come across motion or proximity of people or automobiles near road lighting to cause appropriate movements
3. LDR Sensor: Light Dependent Resistors (LDR) experience ambient light degrees to alter the brightness of street lighting as a result.
4. Battery: The battery acts as an electricity reserve in the street lighting fixtures gadget, permitting it to perform at some stage in intervals of low sunlight or at night
5. Solar panels: Solar panels seize daylight and convert it into energy to Electricity Avenue lighting fixtures structures, selling strength performance and sustainability.

Software Requirements:

1. Embedded C: Embedded C programming language is used to broaden firmware and occasional-degree software program that runs without delay on the ESP32 microcontroller, controlling its conduct and interplay with hardware additives.
2. Arduino IDE: The Arduino Integrated Development Environment (IDE) gives a user-pleasant platform for writing, compiling, and importing code to the ESP32 microcontroller. It offers simplified programming surroundings and get right of entry to a substantial library of pre-written code and features for IoT programs.

By combining these hardware and software program components, the High Efficient Smart Street Light System with Fault Detection the use of IoT can efficaciously display and manipulate avenue lighting fixtures even as making sure electricity efficiency, fault detection, and sustainability in city environments.

a) Arduino Uno Arduino Uno R3 is a broadly used microcontroller board primarily based on the ATmega328P chip. It has 14 digital input/output pins and 6 analog inputs, 16 MHz quartz crystal, 1 USB connector, jack port and reset button Uno R3 with sensors, actuators and defend are compatible , making it ideal for prototyping and

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growing a huge range of digital initiatives from simple LED blinkers to complex IoT applications Its open supply nature and enormous community help make it easy for both novices and advanced builders , facilitating checking out and gaining knowledge of alongside embedded systems and electronics.

b) PIR Sensor: Passive infrared (PIR) sensors are used to come across motion or proximity of people or automobiles near road lighting to cause appropriate movements.

c) LDR Sensor:A light dependent resistor (LDR) sensor, also known as a photo resistor, is a passive electronic component that exhibits a change in resistance depending on the intensity of the incident light as the ambient light increases and the resistance of the LDR decreases, and vice the opposite. This property makes LDR sensors ideal for applications that require the detection and measurement of light levels, such as in street lighting systems. When integrated into an intelligent street lighting system, the LDR sensor works to detect changes in ambient light, provide power to the system and adjust street lighting according to the power of the LDR sensor the resistance decreases during daylight hours or when there is sufficient natural light, indicating an increased amount of light, prompting to dim or turn off street lights energy Conversely, when ambient light decreases in evening or low light conditions, the LDR sensor resistance increases, meaning the street lighting system dims or turns on for greater visibility and safety Due to its portable design and operation to so the main function of LDR sensor in energy efficiency discharge and enhance the efficiency of intelligent street lighting system

d) Solar Panel:A 17V solar panel is a photovoltaic modules designed to convert sunlight into electricity with an output voltage of about 17 volts under ideal conditions These solar panels typically consist of multiple solar cells connected to each other make it a module size. Each solar cell contains silicon and other semiconductor materials, which communicate sunlight through the photoelectric effect to produce electricity The 17V output voltage of the solar panel is suitable for charging batteries or directly supplying electronic devices, including remote power systems, RV, boats and solar street lighting included - 17V solar panel efficiency and output, optimized for the application, depending on factors such as sunlight intensity, temperature and shade.... Being properly placed and oriented to where sunlight will maximize is important for the optimal performance and power generation of solar panels Overall, 17V solar panels provide a capable source of clean energy reliable and renewable, contributing to sustainability efforts and reducing reliance on traditional fossil fuel-based energy sources.

e) Web Based Monitoring System:A internet-primarily based monitoring system is a digital platform designed to acquire, examine, and visualize information remotely from a variety of resources, imparting users with real-time perception and manipulate over system or gadget monitoring over the use of net technologies including HTML, CSS, JavaScript Easy Through over the internet interface providing an intuitive and clean to use interface, customers can view key overall performance indicators, view products a taking area, putting indicators, and tracking monitored assets or routes remotely. The machine generally integrates with sensors, IoT gadgets, databases, and different records resources to continuously acquire and aggregate information. Advanced records evaluation and visualization tools permit customers to interpret complicated information units and make knowledgeable choices. Web-based tracking structures discover packages in a whole lot of industries, inclusive of environmental monitoring, commercial automation, power management, and smart infrastructure.

VI. IMPLEMENTATION

The approach to the fault-detecting intelligent street lighting system has several options to ensure seamless integration of hardware components and software functionality

The implementation of an intelligent fault detection street lighting system begins with the selection and installation of the necessary hardware components. Hardware components used in this system include ESP32 microcontroller boards, PIR (Passive Infrared) sensors for motion detection, LDR (Light Dependent Resistor) sensors for ambient light detection, battery storage energy and solar panels for renewable energy they are skilled. Once the hardware components are in place, the software development process begins using Embedded C and the Arduino IDE (Integrated Development Environment).

The ESP32 microcontroller boards are designed using Embedded C, enabling various tasks such as collecting sensor data, determining, and monitoring external lighting functions The Arduino IDE serves as the primary development platform for authoring, compiling and installing firmware code on ESP32 boards is done The functionality of the

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software includes writing code to allow the ESP32 board to communicate with PIR and LDR sensors, capturing data on motion detection and ambient light levels The firmware includes algorithms for intelligent decision making contains, such as street lights based on environmental conditions and sensor inputs Automatic lighting Furthermore, fault detection algorithms are used to monitor the performance of street lights and detect abnormalities or any errors in real time.

In addition, software applications will include wireless communication methods and remote monitoring/monitoring of the street lighting system. The ESP32 boards are configured to communicate with a central monitoring station or cloud-based platform using wireless protocols such as Wi-Fi or Bluetooth. This allows supervisors to remotely monitor street lighting system performance, receive alerts for detected faults, and make necessary adjustments to improve performance.

In summary, the implementation of intelligent fault-finding street lighting systems requires careful integration of hardware components and software functionality Leveraging ESP32 microcontrollers, PIR and LDR sensors, batteries and solar panels, and Embedded C and Arduino IDE for software development the system can efficiently detect faults, improve energy efficiency, and increase the overall operational efficiency of the urban lighting system.

VII. SIMULATION RESULTS

In order to check the Software before launching a complete amount, a strategic prototyping approach turned into advanced to verify the purposeful components of the software for processing competencies and the performance evaluation and overall performance algorithm the opportunities of studying the shrewd student . The packages also served as researchers thru rigorous trying out and certifications of the packages and gained insights, which knowledgeable destiny research and changes.

With the prototype modified and progressed, the completely useful machine started out to be advanced. Months of rigorous trying out have been carried out to demonstrate the performance of the machine below real-international conditions. This segment of testing consists of deploying the smart road lighting system in carrier areas, along with city corridors or checkpoints for testing, and to look the way it works over the years.

In actual-time application, the gadget showed amazing fault detection accuracy, diagnosed problems in road lighting gadget fine Using advanced algorithms and sensor statistics, the machine can detect anomalies as lighting malfunctions, voltage fluctuations, or conversation disasters Enabling intervention and answers.

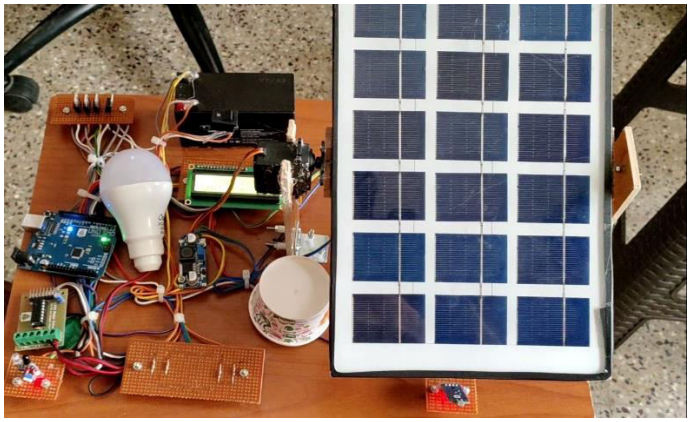

Fig. 3 Initial Stage of smart Street Light System

The primary achievement of the test phase changed into the large discount of energy intake thru the usage of ON/OFF controls for lighting fixtures By intelligently adjusting the quantity of light relying on the surroundings conditions and occupancy, the device optimized energy performance without compromising safety or visibility.

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Fig. 4 Luminosity 100% when vehicles cross the street light

Ongoing tracking and performance evaluations for the duration of the trying out and certification technique diagnosed any closing troubles or regions for improvement Data from area testing and user critiques informed system design, software program deployment put into effect, and document on the reviewed marketing strategy. Resource utilization meets or exceeds overall performance expectancies.

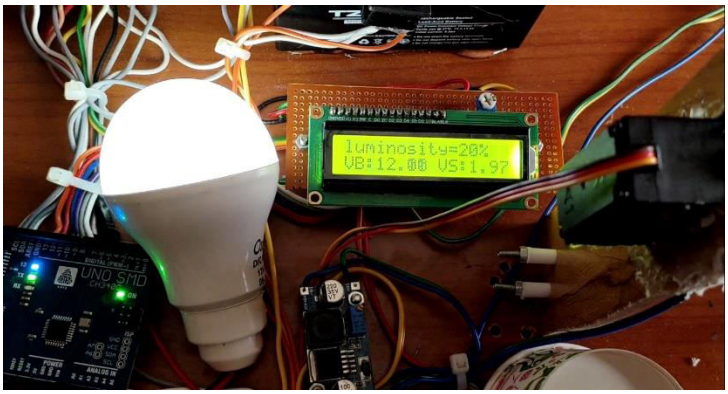

Fig. 5 Luminosity 20% when pedestrians cross the street light and voltage also displayed

Overall, the progression from prototype development to full implementation required a systematic approach to trying out, validation and refinement. By carefully reading the software settings and hardware additives of this tool, the researchers were able to offer a sturdy and dependable smart streetlight with excessive accuracy in fault detection and power a brilliant maintenance turned into given.

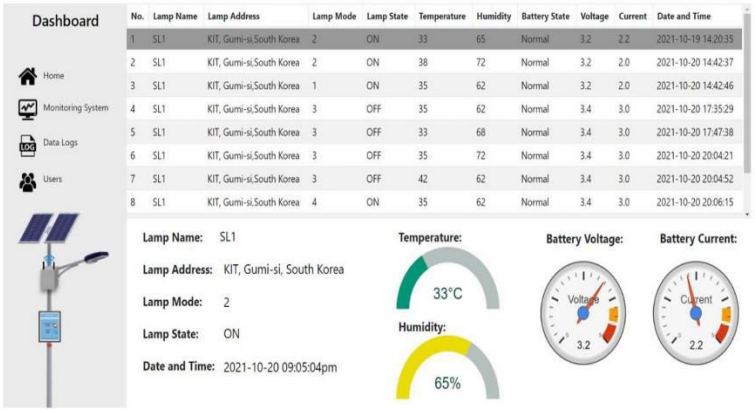

Fig. 6 Data monitored in webpage

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VIII. CONCLUSION AND FUTURE WORK

In conclusion, high-performance IoT-enabled smart street lighting for fault diagnosis leads to significant improvements in urban infrastructure utilization Through IoT technology, renewable energy and methods a through fault finding integration, this system increased energy efficiency, reduced operating costs Ni provides many benefits municipalities with the deployment of smart street lights Energy consumption can be made efficiently by changing the number of lights with energy depending on environmental conditions and traffic This not only reduces electricity consumption but also contributes to environmental sustainability through carbon also by reduction. In addition, the integration of renewable energy sources such as solar energy further increases system efficiency and reduces reliance on traditional grid-based electricity If options are adopted so detect faults including being able to monitor and resolve issues in a timely manner, ensuring that the street lighting network is smooth and manageable, so that relaxation times Reduce and provide order the overall reliability is improved Additionally, remote sensing and control capabilities enable operators to better manage street lighting systems, optimize infrastructure, and improve service Overall, high-performance intelligent street lighting systems with fault detection through IoT represent a transformational solution. Its ability to intelligently manage energy consumption, detect faults and adapt to changing conditions underscores its strengths.

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