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Solar Powered Smart Lamp Post

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***Abstract*— This paper describes the design and implementation of a solar-powered smart lamp post that integrates advanced features such as intelligent light intensity control, speed detection systems and smart mailing technology. The system uses lead-acid batteries for energy storage and solar panels for power supply, making it an environmentally friendly and cost effective solution. An intelligent light control system adjusts light brightness according to the environment, providing an optimal lighting experience with minimal energy consumption. Integrate mailing technology and speed detection systems to improve public safety. The Raspberry Pi, used as the microcontroller provides a flexible and customizable platform for the system. This paper describes the design, implementation and experimental results of the system, showing its effectiveness and potential for future development. In addition, the use of solar-powered smart light poles in public areas such as parks, streets and public squares can enhance the aesthetics and atmosphere of the surroundings. The sophisticated design and energy-saving properties of the lamp post make it an attractive addition to the cityscape. Overall, the importance of solar-powered smart light poles cannot be overstated given their potential to improve public safety, conserve energy, and enhance street aesthetics. Demand for such systems is likely to increase in the future as interest in sustainability and environmental protection grows.**

***Index Terms*— Introduction, Related Work And Literature Survey, Motivation, Problem domain, Problem Statement, Design of PV Array-Battery circuit, Light Intensity Control, Vehicle Detection and Speed Estimation, Smart Mailing System, Results, Future Scope, Conclusion, References**

I. INTRODUCTION

In light of the growing urban population and rising energy consumption, developing sustainable urban infrastructure is essential. Reducing environmental effect requires combining smart technologies with renewable energy. An innovative solution to energy consumption and urban efficiency is the solar-powered smart light post. Cities must lower their carbon impact and deal with the issue of rising energy consumption. Conventional streetlights increase greenhouse gas emissions and are not sustainable. By using renewable energy, smart solar lamp posts reduce CO2 emissions and lessen reliance on fossil fuels. Around the world, a large amount of overall energy bills in cities are related to lighting. Stability depends on street lights, and LEDs increase energy efficiency and driver comfort. Inefficiency results from the lack of smart technology in many streetlights. Automatic streetlights use sensors to adjust to changes in ambient light levels and do away with human switching. Data is efficiently gathered by vehicle detection technology, improving management services. The goal of the Smart Solar Lamp Post project is to show that outdoor lighting systems are feasible and have the potential to be widely used.

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II. RELATED WORK AND LITERATURE SURVEY

[1] compares and discusses photovoltaic solutions for clean power with LED street lighting. In standalone solar systems, lead acid batteries are frequently utilised since they are affordable, long-lasting, and rechargeable. PV array design is covered in this publication as well. [2] Examines lead acid batteries in stand-alone solar systems, emphasising their range of capacities, cost, and robustness.[3] describes how motion sensors and LDR are used to control light intensity, and how a Raspberry Pi is used to alter LED voltage to save energy when traffic is light. The explanation of operational modes can be found in [4] and [5]. [6] uses intelligent street light control via power line carrier communication. [7] Creates a system that uses power grid resources efficiently. [8] enables vehicle recognition and speed estimation by using a Raspberry Pi as a base station for the collecting of sensor data.[9] Displays a prototype for a smart street lighting system powered by photovoltaic cells that has a charge controller for working both off and on the grid. [10] Uses solar energy to power autonomous street lighting that is microcontroller-controlled and reduces energy use by 30%.

III. MOTIVATION

The growing need for affordable, environmentally friendly outdoor lighting is being met by the Smart Solar Lamp Post project. Because they use fossil fuels, traditional lamps are expensive and have an adverse effect on the environment. As an affordable and environmentally friendly alternative, Smart Solar Lamp Posts employ solar energy that is renewable. Benefits like improved energy saving, safety, security, and remote monitoring are provided by intelligent features like energy management and wireless connectivity. The project intends to demonstrate the usefulness of this technology in a range of outdoor lighting applications, thereby promoting a more sustainable future.

IV. PROBLEM DOMAIN

Solar Powering of the lamp post is one of the main challenge and hence topic of this article. It belongs to the domain, Smart Power Control. With the usage of sensors, the involvement of Internet Of Things domain can also be considered.

V. PROBLEM STATEMENT

There is a growing need for cities to reduce carbon emissions and meet their energy demands. Since they utilise a lot of energy and produce greenhouse emissions, traditional lamps are not sustainable. Inefficiency and maintenance problems result from the lack of smart technology in many. An intelligent light post that runs on solar power is suggested as a solution to these issues. Utilising sophisticated technology to regulate light intensity, it lowers carbon emissions while increasing efficiency and lowering maintenance costs. It also produces renewable energy. Enhancing safety are extra elements including speed detection and a vehicle number plate mailing system.

VI. DESIGN OF PV ARRAY-BATTERY CIRCUIT

As the project includes Solar cells, Figure 1 shows the connection and working of PV(Photo Voltaic) Array model. Figure 2 is the real time connection of the system.
The size and configuration of a PV array depend on the amount of energy required, the available space, and the location. PV arrays can range from small rooftop systems for residential use to large utility-scale power plants.

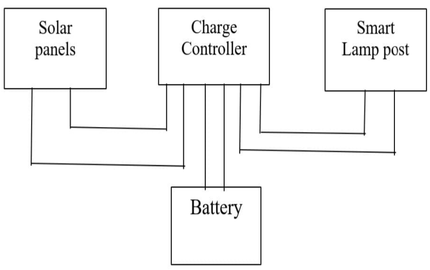

Figure.1 Panel-Battery connection

Figure.2 PV array arrangemen

A. Calculation of PV panel numbers and arrangement

TABLE I lists the loads that the system uses, with each of their power and energy consumption. This data is used to calculate the total load energy required by the system.

TABLE. I LIST OF LOADS AND THEIR RESPECTIVE POWER AND ENERGY CONSUMPTION

Components	Power consumed (Watts)	Energy (W-hr)	Total Energy (W-hr)
LED Lamp	30W	30Wx6hr=180W 15Wx6hr=90Whr	270 Whr
Camera	5W	5WX24hr=120Whr	120 Whr
Raspberry pi 4	7.5W	7.5Wx24hr=180Whr	180 Whr
Miscellaneous	1W	1Wx24hr=24Whr	24 Whr
Total energy consumed-			594 Whr

Total Load: 30+7.5+1+5 = 43.5 Watts ~50W
Energy consumption=power*time in W-hr
Total energy consumed- 594 Whr ~600Whr
Say charge controller efficiency = 95%
Input energy of charge controller = 600/0.95 = 631.57 Whr.
Input energy of charge controller = Output energy of solar panels = 631.57 Whr
Let peak sun hours be = 5 hours
Output power of panels = 631.57/5 = 126.315 W
Panel rating = 50 W
Number of panels required = 126.315/50 = 2.526 ~3 panels
Therefore 3 panels connected in parallel are required for our system.

B. Solar Charge Controller

The solar charge converter uses the logic of a Buck Convertor and MPPT(Maximum Power-point tracking) Controller. DC-DC Buck Convertor is used since PV Array voltage is higher than battery voltage, it helps in the regulation of the input voltage from PV Array while maintaining power delivery to charge battery.
MPPT (Maximum Power Point Tracking) Algorithm is necessary to keep a track of maximum output power. This algorithm investigates relation of the input voltage from PV Array while maintaining power delivery to charge battery.
However, the functions of MPPT and DC-DC conversion, are successfully performed by the Solar Charge Controller, that is connected to both the solar panel array and the battery as shown in the above figure.

C. Battery Design

The intensity control of a street lamp can be achieved using a battery in several ways. One common method is to use a battery to power a solar panel, which in turn powers the street lamp. During the day, the solar panel charges the battery, and at night, the battery powers the street lamp. Another method is to use a battery as a backup power source in case of power outages. In this scenario, the street lamp is normally powered by the electrical grid, but a battery is installed to provide power when the grid is down.
Given below are the calculations to decide on the rating of the battery for the given system
Total energy consumed- 594 Whr ~600Whr
Final battery capacity:
Battery Capacity in Ah=600/12=50Ah
DoD=50%
DoA=1.5 days
Final Capacity of battery=(50/0.5)*1.5= 150Ah
Hence the use of a 150Ah battery with 12V rating is feasible.

VII. LIGHT INTENSITY CONTROL

Setting up responsive and adaptive lighting environments is possible due to the advancement of sensor technology. With an emphasis on the intelligent control of light intensity through sensor integration, this paper explores the field of smart lighting.

A. Hardware Architecture for Smart Light intensity control

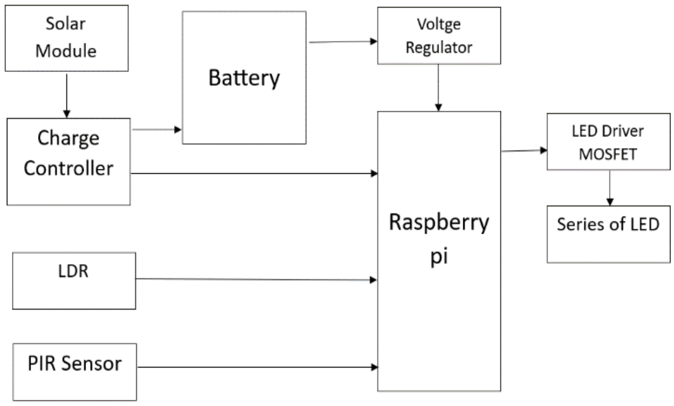

Figure.3 System Circuit Arrangement

Figure 3 represents the circuit connection used for the purpose of light intensity control in a flowchart format. The components used in Figure 3 have been listed in TABLE II with their respective description and specifications.

TABLE. II COMPONENTS USED AS HARDWARE

Component	Description	Specifications
Solar module	Converts sunlight into electrical energy	4 panels, each rated at 50W and 12V (200W total)
Battery	Stores electrical energy	12V, 150Ah
Charge controller	Regulates battery charging	
LDR sensor	Detects light intensity	Operating voltage: 3.3V-5V
PIR sensor	Detects infrared radiation for presence detection	Operating voltage: 12V Detection range: 180 degrees Distance measuring range: 15m
Voltage regulator	Maintains stable voltage output	
LED driver	Regulates power to LEDs	
LED	Light source	30W, 12V, 2.5A
Raspberry Pi	Single-board computer	Broadcom BCM2711 CPU, 4GB RAM, Gigabit Ethernet, Wi-Fi, Bluetooth

B. Working of the circuit

Using a solar panel to transform sunlight into electrical energy, this solar-powered lighting system charges a battery via the solar charge controller. The Raspberry Pi receives electricity from the charged battery, which functions as the power source of the system. The Raspberry Pi receives data from the LDR sensor, which measures the amount of sunshine. The Raspberry Pi then processes the LDR value and compares it to a preset threshold. The Raspberry Pi turns on the relay and illuminates the LED if the measured value is less than the threshold. On the other hand, the LED is automatically turned off if the value over the threshold and the relay is turned off.
The algorithm mentioned above, is briefly explained in Figure 4.

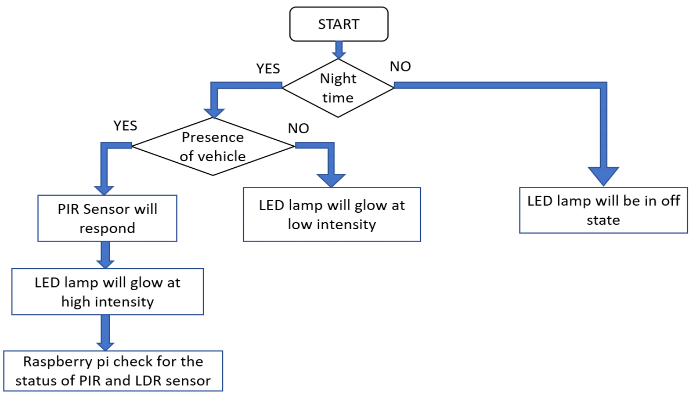

Figure.4 Flow Chart of Intensity control Algorithm

VIII. Vehicle Detection And Speed Estimation

The fundamental task is to determine the speed of a vehicle. Developing an effective method to identify and measure the speed of moving vehicles is the goal of the paper. To examine the video feed that the camera has recorded, OpenCV—a popular computer vision library—is used. System control and algorithm execution are handled by a Raspberry Pi microcontroller.

A. Working of the speed detection algorithm

The first step is to capture a video stream of the road using a camera. Then to define the region of interest, plot mark-1 and mark-2 for the calculation of speed of the vehicle. In this step, the detected foreground regions are segmented and filtered to identify regions that are likely to contain a vehicle. Once a vehicle is detected, its position and trajectory are tracked over two successive marks to estimate its speed.
The speed of the vehicle is estimated by calculating the displacement of the vehicle between successive frames and dividing it by the time interval.
Figure 5 explains the algorithm used by the python code to achieve the above working.

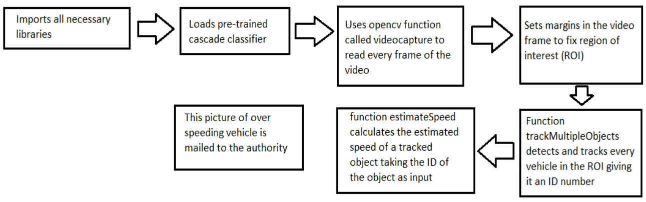

Figure.5 Flowchart representation of the algorithm used in the code for speed detection

Finally, the results of vehicle detection and speed estimation are displayed on a monitor along with the id of the vehicle and it is stored in a file along with the date and time.

IX. Smart Mailing System

Smart mailing system uses SMTP. The standard technique for delivering and receiving email messages between servers is called SMTP (Simple Mail Transfer technique). It is a client-server protocol based on text, with the mail server serving as the main hub for sending and receiving emails. SMTP is used for smart mailing system because it is reliable, secure and scalable. The code used for the purpose of smart mailing system, follows the algorithm as shown in Figure 6.

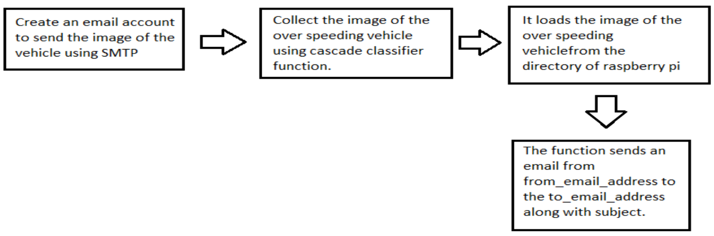

Figure.6 Flowchart representation of the algorithm used in the code for smart mailing system

Here the from_email_addr is: eeecapstoneproject@gmail.com and the to_email_addr is the Gmail address of the receiver. On entering the appropriate password under from_email_pass, the algorithm successfully sends an image of the over speeding vehicle to the receiver.

X. Results

A. Light intensity control results

On connecting the circuit as shown in Figure 3, the following results were observed:
SYSTEM OFF : during daytime
SYSTEM ON : when dark

- light switches on with 50% intensity as shown in Figure 7.

- when PIR sensor is triggered, light switches on with 100% intensity as shown in Figure 8.
- when there is no motion, it returns to 50% intensity.

SYSTEM OFF: presence of natural light as shown in Figure 9.

Figure 10 showcases the visual of the lamp post

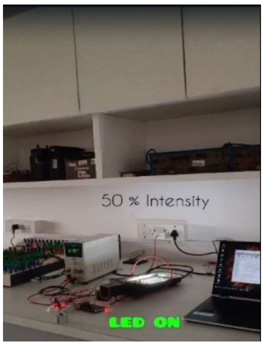

Figure.7 LED glowing with 50% intensity

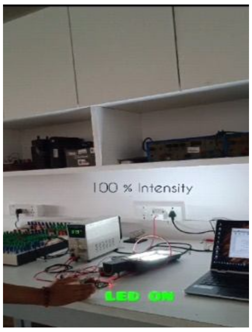

Figure.8 LED glowing with 100% intensity

Figure.9 LED in OFF state due to the presence of natural light

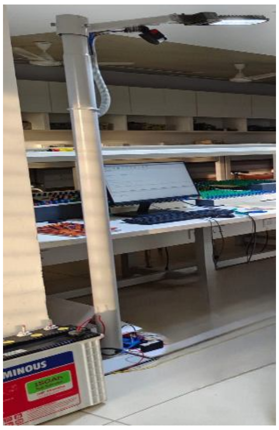

Figure.10 Solar Powered Smart Lamp Post

Hence the results obtained, successfully manifest the desired objective of smart light intensity control.

B. Speed detection results

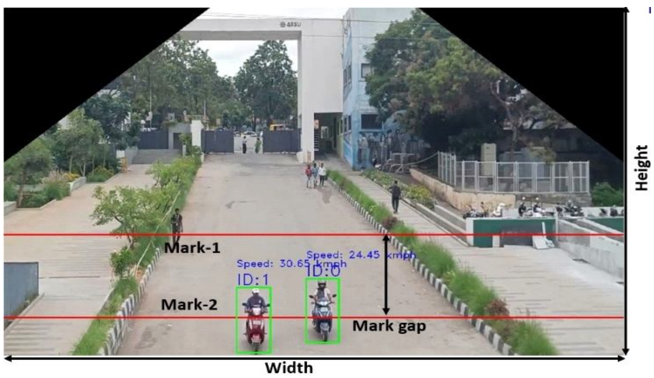

Figure.11 Output of the speed detection algorithm

The output of the code clearly mentions the ID number of the vehicle along with its speed in the terminal as well as the video as shown in Figure 11. The algorithm allows the code to capture the picture of the over speeding vehicle and store it in the pi. This picture is sent to the authorities with the date and time of over speeding, with the help of the smart mailing system. Hence successfully detecting the vehicle as well as estimating the speed.

XI. FUTURE SCOPE

In order to maximise the effectiveness of this project, it is suggested that its scope be expanded to include a wider range of urban and rural locations by incorporating intelligent infrastructure. Additionally, it is advised to look into additional features and functionalities that could be added to the smart lamp post. This involves the incorporation of sensors meant to track variations in temperature and humidity, monitor air quality, and enable weather tracking. Moreover, the addition of a Wi-Fi booster is advised to improve the reliability of Wi-Fi connections, particularly in areas with poor network signals. Ultimately, this chapter aims to provide a comprehensive overview of the project, outlining its current implications and explaining its possible future development path.

XII. CONCLUSION

In summary, the paper presents a Solar-Powered Smart Lamp Post and highlights a variety of developments in the field of urban illumination infrastructure. Equipped with a complex system that leverages solar energy and Raspberry Pi technology, the integration of smart light intensity management guarantees energy-efficient illumination customised to the specific requirements of the surrounding environment. By automatically modifying light intensity in response to vehicle movement, the addition of a vehicle speed detecting system improves the lamp post's functioning and increases road safety. An additional layer of adaptability is provided by the smart email system, which makes it possible to communicate easily and provide updates for maintenance or community announcements. The relevance of lamp posts in promoting smart and connected urban environments is highlighted by their comprehensive integration of intelligent lighting control, road safety features, sustainable energy, and communication capabilities. The Solar-Powered Smart Lamp Post is a testament to the potential of integrated systems in improving efficiency, safety, and communication within urban landscapes as we move towards more technologically advanced and sustainable cities.

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