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Design of IoT based Smart Lamp Post System

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***Abstract*—Technology is changing very fast as the year passes and it is changing how we live, every electronic device is now connected to the internet and with this various types of data are being collected and stored in the cloud for analysis purposes. This advancement in technology has played an important role in smart cities. A smart city's main purpose is to provide more functionality while also improving our quality of life by using advanced technologies. Now, these cities will have street lights, now traditional street lights consume more electric energy instead we can use LED which will consume less electric energy and it will be economically beneficial. The system proposed is to completely power the hardware using solar panels and battery with other salient features including PWM control of LED, able to monitor and control the system remotely and display information. The work involved integrating the hardware and software for the selected components towards deployment of the system with PCB fabrication. The system was run for several days to evaluate proper functioning, power conservation and consumption towards proof of concept for installation in campus. The evaluation also included to verify if the system can be completely self-sustained based on battery getting charged from Solar PV and without any AC input. After several days of monitoring the energy conservation and discharge for the entire system, the average energy conserved during sunny days is 529 Watt-Hour, but it drops to 324 Watt-Hour during rainy days. When we look at the power discharged over the duration of a day, we find that the average is 428 Watt-Hour. We conserve more energy on sunny days, which can support us on rainy days when power conservation is low, so it is reasonable to conclude that the system is self-sufficient and that other system functions can run without error.**

***Index Terms*— Internet of Things, Global System for Mobile Communication, Transmission Control Protocol, Universal Asynchronous Receiver Transmitter, Serial Peripheral Interface, Attenuation Command.**

I. INTRODUCTION

The lighting system is the most basic electrical system that is required to illuminate light on the streets at night, but its power consumption is ignored. Traditional road lighting systems consume more energy and are not equipped with advanced technology that allows for automatic turn on and off with additional functions.

The system proposes an Internet of Things-based smart lamp post system controlled by an Arduino Uno microcontroller. Solar energy is used to power the entire system. Photovoltaic cells convert sunlight directly into energy, resulting in solar power (PV). Solar panels are kept outside so they can gather solar power and solar energy is conserved inside the battery. A total of 4 solar panels are used and a rechargeable lead-acid battery (12V & 150 Ah) for conserving the solar energy. The type of light that is being used is LED which consumes less power and saves money. The light's output is controlled by a microcontroller and a PWM circuit, which can

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control the intensity of the LED light to save more energy. As the name suggests it is a smart lamp post so different kinds of sensors are used and data is saved to the cloud. In addition, the temperature and humidity sensor's real-time data, as well as the date and time, are displayed in the P10 Red LED display. For detection of temperature and humidity DHT11 sensor is used. Solar and battery voltage and current are monitored using current and voltage sensors. Arduino UNO does not have any built-in RTC so to keep track of time one RTC module is used. The LED is turned on and off based on the time of day sunset and sunrise. Sunset and sunrise times for the entire year are saved in Arduino's Flash memory and can be accessed as needed. The entire Smart Lamppost system can be controlled via the cloud. It can be set to different modes for automatic turn on and off, as well as brightness control and other functions that can control the system remotely. The solar charge controller is also utilized in this project to manage power from the PV array, preventing overcharging or undercharging of the batteries, and preventing the battery from reverse-discharging to the array at night or when the sun is not shining. One GSM module is used to upload real-time sensor data to the cloud for system monitoring.

A. Objective

1) The primary objective of this project is to control and illuminate light according to the needs.
2) Automatic switching on and off of the LED light based on the sunset and sunrise times of the day.
3) PWM Control of the LED light to save more energy.
4) Monitor and display the temperature and humidity, as well as the current date and time.
5) Monitoring the voltage and current of the solar and battery.
6) Saving all useful data, such as current voltage, temperature, and humidity, to the thingspeak server for analysis.

II. Related Work

Traditional light sources, such as sodium vapor lamps and incandescent lamps, are still in use, but they are inefficient for economic growth. Some of the conventional lamps have been replaced with LED lamps. Non-Conventional sources of light such as solar-based lamps are now very popular shown in Figure 2.1. Wind-based lampposts are set up in Urmia, Iran as shown in Figure 2.2. In Asia, trials are going on by installing a camera on the lamppost to monitor people, cyclists and vehicles as shown in Figure 2.3. Now in Kolkata, they upgraded the lamppost with some the sensors like a rain sensor, and light sensor and are remotely monitored as shown in Figure 2.4. Europe was the first country to start a lamppost that detects the motion of objects or people based on that the lamp would turn on or off as shown in Figure 2.5. It’s so popular that the research based on motion detection is still being continued all over the world which would help save energy as well as develop one’s country.

Figure 2.1.Solar Based Figure 2.2.Wind based Lamp Post Figure 2.3. Camera Based Lamp Post Lamp Post

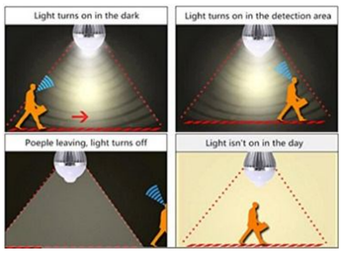

Figure 2.4 Sensor Installed in Lamp Post, Kolkata Figure 2.5.Motion Detection in Lamp Post

III. Hardware Architecture And Description

The hardware architecture and explanation of the proposed system are shown below

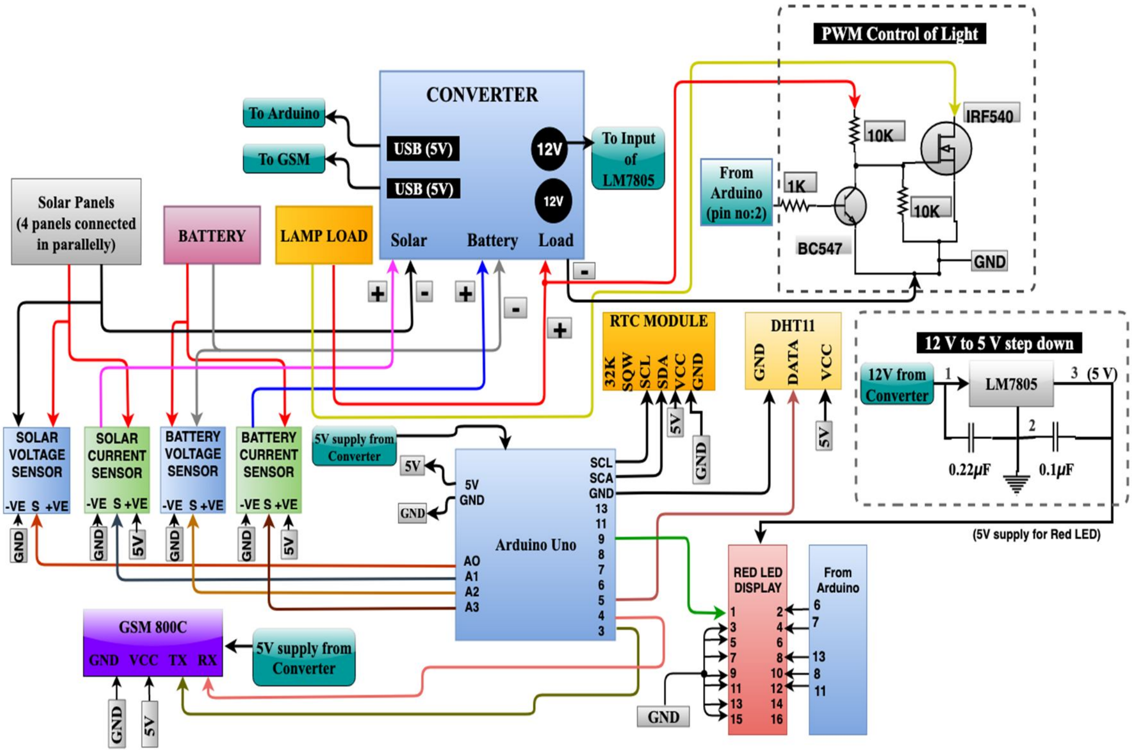

Figure 3.1. Hardware Architecture

Solar panel boards are gadgets that can produce electric energy from sunlight. In this system, we have used four 50W and 12V panels for a total of 200W. All the panels are connected in parallel with the solar charge controller. At midday, the maximum solar current is 8.9 amps.

A Light Emitting Diode (LED) is a semiconductor device, which can emit light when an electric current passes through it. In this system, a 30W LED light (12V, 2.5A) is used.

Lead-acid batteries are among the most reliable and long-lasting rechargeable batteries. We used a lead-acid battery to store solar energy in this system.

Two P10 Red LED Displays are connected to display useful information such as temperature and humidity values from the sensor, which is controlled by an Arduino UNO microcontroller. To connect Arduino and the display, we have used a 3m long Flat cable. To send data to the red led display, Arduino uses the SPI protocol.

A solar charge controller, which is an electronic device, is used in this system to regulate the amount of solar power that enters the battery bank. It prevents the batteries from overcharging during the day and returning power to the solar panels overnight, which drains the batteries.

We are currently using Arduino as the controller, and GSM is used for communication. Sensors for temperature, humidity, current, and voltage are used for measurement. We created a Real-time Database that contains all sensor data.

Arduino UNO is a free and open-source platform for creating electronic projects. It uses the C programming language for the coding part. We have used the GPIO pins to interface the sensors and GSM module. Also, the P10 Red Led display is powered by a separate 12V to 5V converter circuit and controlled by Arduino.

In the proposed system, DHT11 is used, which is compact, inexpensive, and consumes little power while displaying accurate temperature and humidity values.

The ACS712 Module uses the Hall Effect concept and the well-known ACS712 IC to measure current. The ACS712 modules can measure AC or DC currents ranging from +5A to -5A, +20A to -20A, and +30A to -30A. These sensors measure voltage, which is then divided by the sensitivity value to calculate the current.

This voltage sensor module can detect voltages as high as 25V DC. A resistive voltage divider circuit represents this device. It provides a matching analogue output voltage by reducing the input voltage signal by a factor of 5.

The DS3231 RTC is a 32Kbit EEPROM Precise Real-Time Clock Module with a built-in 10-bit temperature sensor with a 0.25C resolution. Arduino doesn't have RTC inbuilt which is why to use the RTC module to keep track of time.
We used a GSM Module to enable the system to connect to the internet. "GSM" is a shortened form for "Global System for Mobile Communications." The module is powered by the solar charge controller's USB port.
In this system, we communicated with the GSM using AT commands. Some features are used to send, receive, and send data to the server.

IV. PCB FABRICATION OF THE SYSTEM

PCB fabrication is done for system deployment in college. The PCB board contains all of the sensors, including the current sensor, voltage sensor, dht11, RTC ds3231, and 12v to 5v converter circuit, as well as the PWM circuit. The PCB schematic is shown below, and the entire PCB design is done in fritzing software. The PCB schematic includes the Arduino UNO with PWM circuit and 12V to 5V DC to DC converter, all current and voltage sensors, DHT11, RTC, and MicroUSB to USB extended ports for future component addition.

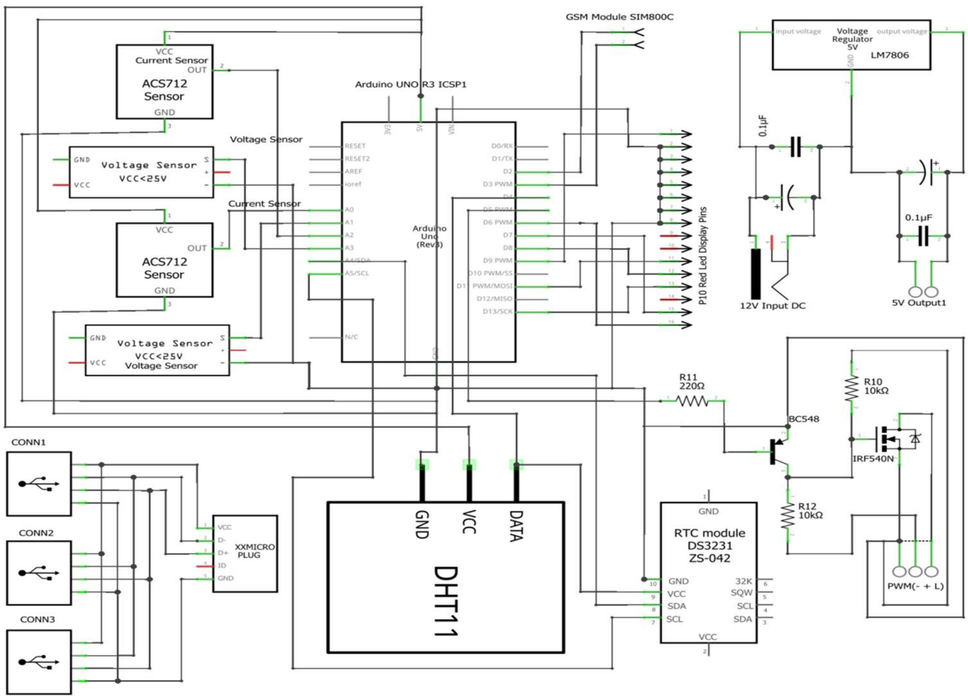

Figure 5.1. System's Schematic

Figure 5.1 shows the finished PCB after soldering the components. This is a two-layer PCB board measuring 12.8cm X 12cm.

V. SYSTEM DEPLOYMENT

Figure 5.1 depicts the overall hardware connection of the deployed system. The Arduino UNO microcontroller is connected with a variety of sensors, including solar and battery voltage and current sensors, DHT11 sensor, P10 red LED display, RTC module, and PWM circuit.
In the PWM Circuit MOSFET (IRF540N) and Transistor (BC547B), two 10KΩ and 1KΩ resistors are used. MOSFET is used because Arduino can't provide more than 5V of supply for Lamp load to control PWM that is why we are using MOSFET. Transistor is used because MOSFET is going to draw more current from the Arduino which can only provide 500mA if it draws more current it might damage the Arduino. That is why we used a transistor as a protective circuit for Arduino and to control the PWM. It uses inversion logic, when logic 1 is supplied by Arduino, the lamp is turned off, and vice versa.
The solar charge controller's USB port provides power for GSM and Arduino, which each requires 5V. More USB ports have been added to the PCB board to allow for more component connections. GSM's Transmit and Receive pins are connected to Arduino's Receive (pin 2) and Transmit (pin 3) pins. Various sensors like voltage

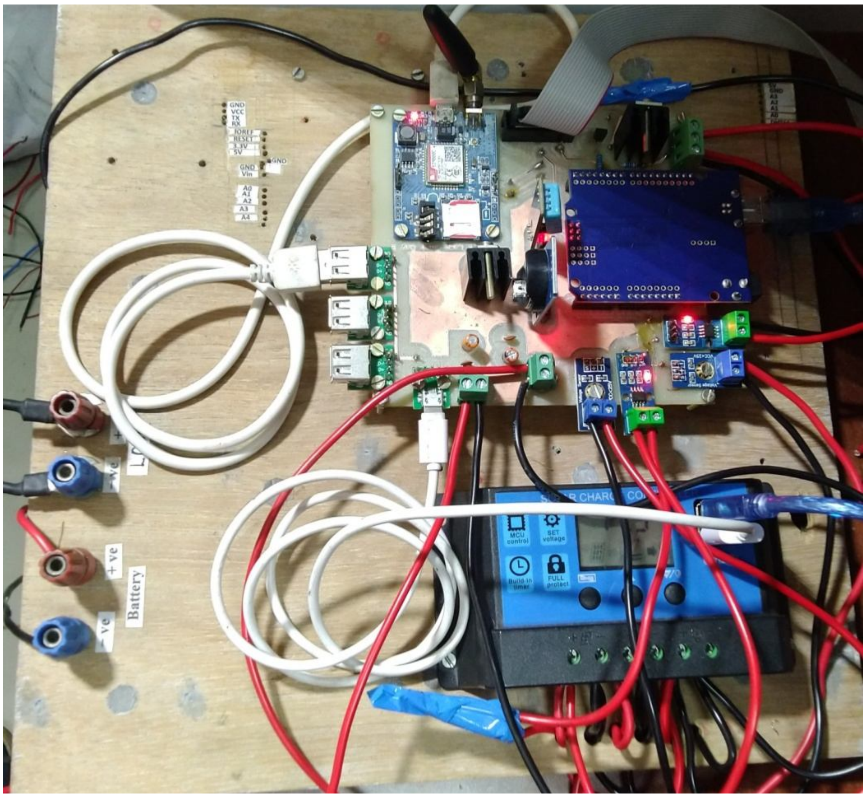

Figure 5.1 Overall Hardware Connections

and current sensors of both Solar and Battery, DHT11 sensor, P10 red LED display, RTC module and PWM connections are given to Arduino. A 12V to 5V converter with an LM7805 IC is also used to power up the P10 red led display.

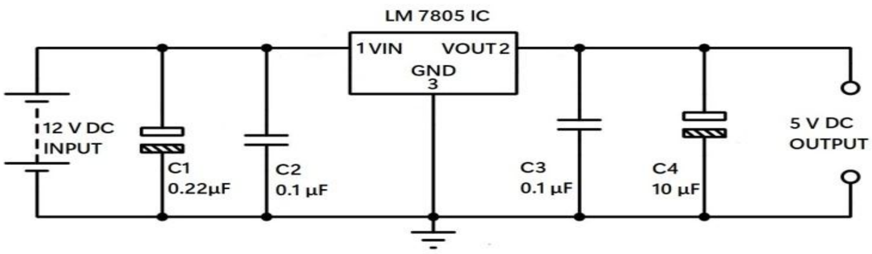

Figure 5.2.12V to 5V Converter Circuit

The 7805 voltage regulator IC is used to convert 12 volts to 5 volts and is a common circuit for most applications. It has three terminals and is built with op-amp and transistor properties. However, the power dissipated by this regulator component is greater than the power supplied to the output load. This circuit is more efficient than resistor-based and Zener based circuits because excess current generated in the circuit is consumed by circuit components. In addition, the 7805 regulator IC has additional systems that protect the circuit from short circuits and the power source from any causes. The capacitors are present to smooth out certain spikes caused by increased current demands.

VI. System Programming

The entire system is programmed in C, and an Arduino microcontroller is used. As previously stated the LED turns on at precisely sunrise and off at sunset. So the sunrise and sunset times for an entire year are saved in Arduino's program memory and can be accessed as needed.

As previously stated, the system's behavior can be monitored and controlled through a server, and the ThingSpeak server is used for this purpose. The control parameters that can be used to control the system are listed below in the tabular form. The system responds to these control modes in less than 30 seconds. The UART protocol is used for communication between the Arduino Uno and the GSM module, and AT commands is used to control the GSM module.

TABLE 6.1.LED CONTROL MODE

Name of the Control Mode	Value to be sent to configure the system	Description of the control mode
Season Wise RTC Automatic Mode	114 and LED Brightness Value[0-1 Float]	LED will be turned on and off based on the time of sunrise and sunset. LED brightness can also be controlled via the cloud.
RTC Manual Mode	115 and [LED On & Off Time]	The LED can be turned on &off at specific times, and ThingSpeak can be used to provide time input.
LED On (Max Brightness)	1.100	To turn the LED on to its maximum brightness.
LED On (50% Brightness)	1.50	To turn on the LED at a brightness of 50%.
LED Off (0% Brightness)	1.00	To turn the LED off.

Figure 6.1 represents the entire system program flow chart. The entire code is written in Arduino, and the void loop function runs indefinitely, so there is no end block in the flow chart. We used a GSM module (SIM800C) with an Arduino to establish a wireless internet connection. AT commands are used to control the GSM module. At the end of the loop execution, the program sends data to the ThingSpeak server every 2 minutes .Although the loop execution time can vary depending on the signal strength or the GSM module's slow response.

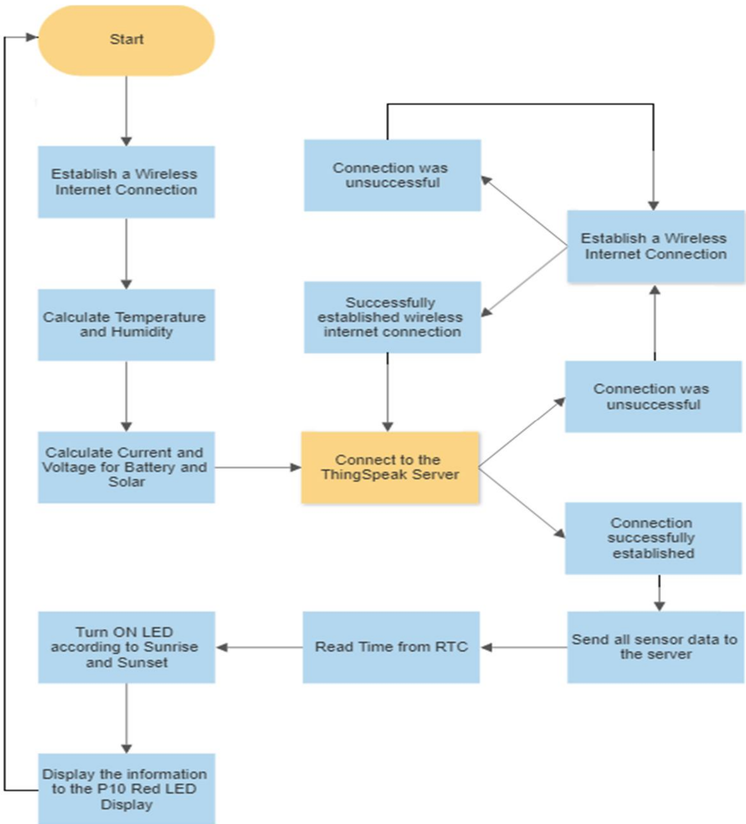

Figure 6.1 Flow Chart

VII. THEORETICAL POWER CALCULATION

A. Theoretical Power Conserved in a Day

The worst-case power conservation is calculated using the assumptions listed below

1. For 10 hours, solar energy will be available.
2. Changes in power conservation during sunny and rainy days are not considered.

3. The solar panels' efficiency is approximated to be 40%.

However, more solar panels could be added to increase power conservation. The theoretical power conserved of the system for an entire day is shown below.

TABLE 7.1 THEORETICAL POWER CONSERVED IN A DAY

Component	Voltage(V)	Current(A)	Power (Watt)	Time(Hour)	Energy(Watt.Hour)
PV Array	12 Volt	16.67 Amp	200 Watt	10 Hour	2000 Watt-Hour
		Efficiency = 40%	200*.4=80Watt	Total=	800 Watt-Hour

B. Theoretical Power Consumption in a Day

The worst-case power consumption is calculated using the assumptions listed below.

1. The LED light will be turned on for 12 hours.
2. The Arduino Uno will run for 24 hours.
3. The GSM module's power consumption is calculated over a 24-hour period. Even though the upload takes place only once every two minutes
4. We also assumed that the P10 Red LED display would be on all of the time.
5. The current consumption values are from the datasheet, but they've also been validated with measurements.

It should be noted that the system can further reduce power consumption by changing the brightness of LED lights late at night and turning off the p10 red led display during the night. The theoretical power consumption of the system for an entire day is shown below.

TABLE 7.2 THEORETICAL POWER CONSUMPTION IN A DAY

Component	Voltage(V)	Current(A)	Power(Watt)	Time(Hour)	Energy(Watt.Hour)
Arduino UNO	5 Volt	0.2 Amp	1 Watt	24 Hour	24 Watt-Hour
GSM Module (SIM 800C)	5 Volt	0.416 Amp	2.08 Watt	24 Hour	49.92 Watt-Hour
LED Light	12 Volt	2.5 Amp	30 Watt	12 Hour	360 Watt-Hour
P10 Red LED Display	5 Volt	0.3 Amp	1.5 Watt	6 Hour	9 Watt-Hour
				Total	442.92Watt-Hour

VIII. RESULTS

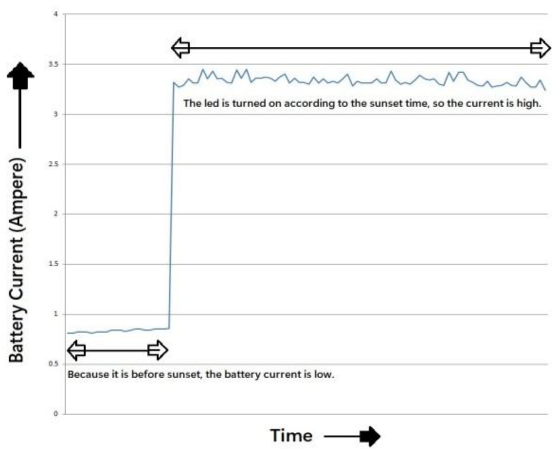

Figure 8.1 Battery Current during Daytime

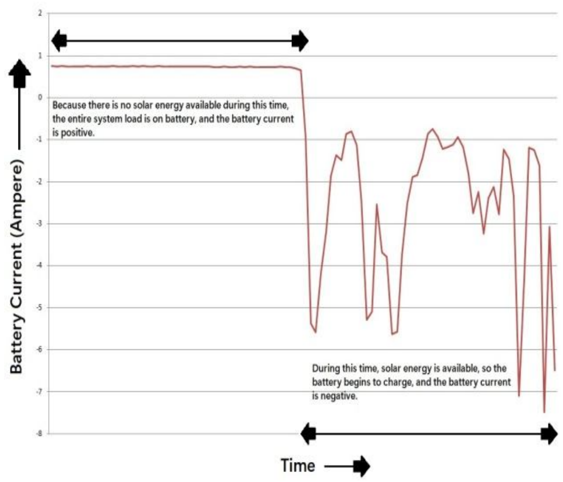

Figure 8.2 Battery Current during LED On

A. Power Calculation during sunny day

TABLE 8.1 POWER CALCULATION DURING SUNNY DAY

Date	Average Temperature	Average Humidity	Average Battery Voltage	Average Battery Current During Daytime	Average Battery Current After Sunset	Average Solar Voltage	Average Solar Current During Daytime	Total Energy Conserved	Total Energy Discharged
14th May 2022	31.51 C	68.06 %	13.12 Volt	-3.23 Amp	3.07 Amp	13.09 Volt	3.90 Amp	477 Watt-Hour	423.66 Watt Hour
15th May 2022	32.03 C	66.22 %	13.48 Volt	-4.79 Amp	3.16 Amp	13.44 Volt	5.46 Amp	581.46 Watt-Hour	436.21 Watt-Hour

B. Power Calculation during rainy day

TABLE 8.1 POWER CALCULATION DURING SUNNY DAY

Date	Average Temperature	Average Humidity	Average Battery Voltage	Average Battery Current During Daytime	Average Battery Current After Sunset	Average Solar Voltage	Average Solar Current During Daytime	Total Energy Conserved	Total Energy Discharged
14th May 2022	31.51 C	68.06 %	13.12 Volt	-3.23 Amp	3.07 Amp	13.09 Volt	3.90 Amp	477 Watt-Hour	423.66 Watt Hour
15th May 2022	32.03 C	66.22 %	13.48 Volt	-4.79 Amp	3.16 Amp	13.44 Volt	5.46 Amp	581.46 Watt-Hour	436.21 Watt-Hour

1) 28 to 34 degrees Celsius is the average temperature.
2) 50 to 70 % is the average humidity.
3) The average load current varies from 3.2 Amp to 2.3 Amp.
4) The average battery voltage varies from 12.8Volt to 11 Volt.
5) The average solar voltage varies from 14.5 Volt to 11 Volt
6) The maximum solar current during sunny weather is 8.7 Amps.
7) The average solar current during sunny weather is 3 Amps
8) During rainy weather solar current drops to average of 2 Amps
9) Average 430 Watt-Hour of energy is saved from solar panels to battery during sunny days
10) However, when it rains, the energy stored is 300 Watt-Hour

IX. CONCLUSION

1) It is a dependable system that can provide street lighting at night and other useful features such as information display.
2) The server can configure the system's behavior.
3) Server data can also be used to analyze system behavior.
4) It is possible to power the entire system using renewable energy.
5) Energy conserved during the day is greater than energy discharged at the night, also we can store more energy in the battery and that can be used as a backup source of energy on rainy days.
6) Due to the efficiency of solar panels and weather changes, there is a significant difference between both theoretical and practical power conservation analyses.

X. FUTURE SCOPE

This smart lamp post system has a lot of possibility of future development. This smart lamp post system can be improved by adding security cameras that detect vehicles also monitors traffic. A motion sensor can be included so that when a pedestrian or a car approaches the led, it increases its brightness, allowing more energy to be saved. When it comes to energy conservation, wind turbines can be installed in the future to save even more energy. More sensors, such as a rain sensor and a pollution sensor, can be added in the future, and the data from the sensors can be uploaded for analysis. A Wi-Fi network with mobile charging and an emergency calling facility can be added for public access to the system. An android app for configuring the system with a website can be added to the system.

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