[1]*Israfil Hussain

[2] Rashel Sarkar

[3] Samarjit Das

[4] Spandan Kumar Borthakur

[5]Anupam Das

[6]Afsana Laskar

IoT-Driven Automation for Streetlight Monitoring and Fault Detection

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Abstract: - The proposed system is an IoT-based street lighting monitoring solution designed to manage lighting, detect faults, and enable immediate corrections. This paper introduces a system capable of monitoring streetlights in real-time through a server connected to multiple controller units. The system provides real-time monitoring of various parameters, which are displayed on a local debugging unit interfaced with a microcontroller. Additionally, vital data is posted to a web server for centralized monitoring. The system employs an STC12C5A60s2 single-chip microcontroller, interfaced with light sensors (LDRs) to measure the ambient light levels. Based on the analyzed light intensity, the microcontroller generates control signals to regulate the lighting. These control signals activate a transistor, which in turn energizes the relay coil to switch the streetlight on or off.For testing purposes, the system utilizes LED lamps. The proposed solution integrates multiple sensors and leverages IoT technologies along with a web server for data management. Furthermore, the system is designed to interface with a cloud server, enabling centralized data storage for future analysis and optimization.

Keywords: Street lights; Internet of Things; STC12C5A60s2; Wi-Fi technology; Database Management System.

I. Introduction

An indispensable part of cities and towns, streetlights illuminate the streets during the dark or nights, provides a better connectivity of the places where we live and work, reduces traffic casualties and crimes on road. Governments and municipalities around the world have accepted its importance and guarantees for its normal operations without faults and unnecessary drainage of power during off-peak period. At present, the technologies are switched from basic to advance direction. Under the smart city initiatives, every technology is being upgraded for a better cause of health and environment. As far as street lighting is concerned, the traditional streetlights are being replaced by the LED street lights. The LED lamps has better advantages over the traditional one for the energy saving capability, emits no harmful gases, decrease maintenance, servicing and time management cost. Traditional streetlamps such as high pressure sodium street lamps (HPS) had a better efficiency in 1970s. With due course of time, with technology advancement LEDs have granted us to be a better option. When this LED lamps are coupled to smart systems, it can save up to 75-80% of power consumptions. An improper operation of streetlamps leads to dissatisfaction and pose threat to moving vehicles and pedestrians too. Additionally, the manual supervision of the faulty streetlights by the respective maintenance authority will however cost precious time and money. The smart systems comprising of remote monitoring and controlling is now widely used, that provides real time centralized data management. Wireless sensor network (WSN) is a recent smart technology that connects an information world to a physical world. WSN comprises of sensor nodes, sink nodes, internet and a user computer [1]. The wireless sensor network is very economical. For the street light management (monitoring and control), it requires a huge cost and labor intensive. Using these networks of wireless sensors in street light monitoring and fault detection have left us with better choice.

The proposed street lighting system aims for the real time data acquisition and monitoring, for an autonomous operation, economically feasible and an immediate remedy on complaint. The errors due to manual operation can be eliminated. This system is implemented with smart embedded system which will control and monitor the streetlights based on detection of fault. The proposed lighting system is mainly dedicated to the integration of

[1] *Corresponding author: Royal School of Engineering & Technology, Royal Global University, Assam, India: Email: israfil.hussain@rgi.edu.in
[2] Dept. of CSE, Royal School of Engineering & Technology, Royal Global University, Assam, India
[3] Dept. of CSE, Royal School of Engineering & Technology, Royal Global University, Assam, India
[4] Dept. of CSE, Royal School of Engineering & Technology, Royal Global University, Assam, India
[5] Dept. of CSE, Royal School of Engineering & Technology, Royal Global University, Assam, India
[6] Dept. of CSE, Royal School of Engineering & Technology, Royal Global University, Assam, India

sensors technology and controlling mechanism. The system is an effective method for monitoring large area, from remote areas without visiting the location and centrally stores the data for future analysis.

II. LITERATURE REVIEW

J Hill et al. [1] studied the system architecture analysis of wireless sensor network (WSN). They developed a small device that is representative of the class, design a tiny event-driven operating system, and show that it provides support for efficient modularity and concurrency-intensive operation. J.D Lee et al. [2] have designed a hardware for reducing uneasiness of handling and difficulty of maintenance in operating light control system using Zigbee communication technique. C Jing et al. [3] designed a system to study the control scope of each lamp, reduce electricity consumption and maintenance cost using wireless sensor network. C Lordache et al. [4] presented a paper on modern streetlight monitoring system, keeping control cabinets online all the time, the solution guarantees energy savings, due to the dimming option, traffic safety and lighting comfort. X. Shentu et al. [5] presented a paper on remote streetlight monitoring system based on wireless sensor network. The system automatically controls streetlights according to sunrise and sunset algorithm and light intensity. Cleland et al. [6] studied the methods for monitoring and control of street lamp that includes monitoring a light level and Voltage level and adjusting a light level, estimating power consumption. The methods may be performed in part at a streetlight, a local gateway or a central controller and database. D. Kapgate et al. [7] published a paper on wireless street light control system using a network of wireless sensors. This system provides an optimal costing for street light maintenance and cost. The paper also presented a comparison between current system and sensor control system. O Natu et al. [8] designed a GSM based streetlight monitoring & control system using 89C51 microcontroller which on setting of time delay switches on/off the street lamps and sends the data via message to the specified phone number. M. Karthikeyan et al. [9] designed a system for the cloud based automatic system that involves the automatic updating of the data to the lighting system using Zigbee device. S Siregar et al. [10] has presented a paper on solar panel and battery street light monitoring system using GSM wireless communication system. The system sends the data through a GSM to a server, via SMS. The server then processes the data from SMS and sends it to the web server. Hussain I et al. [11] in their paper presented simulated results of reactive power performance analysis using Genetic Algorithm (GA), Particle swarm optimization (PSO) and flower pollination algorithm (FPA), which reveals that FPA optimized controllers for AVR and SVC provide the improved dynamic performance of the dish-stirling solar thermal-hybrid energy system as compared with GA and PSO optimized controllers. Hussain I et al. [12] presented a simulated performance analysis of Grid rooftop PV system installed in GMCH using PVsyst software, and thus obtained a comparative result on tilted panel seasonal based with the fixed panel installed in the premises for better optimization.

III. SYSTEM DESCRIPTION

The IoT based street light monitoring and fault detection system is fully automated, that works on the principle of sensing of light (sunlight) intensity and flow of current through the circuit along with voltage monitoring.

Internet of things is used to connect the proposed model to the web-server through Wi-Fi technology.

Primarily, the LDR senses the environmental light from the sun. The Op-amp works in a differential mode provides 1 bit ADC input to the I/O pin of microcontroller. A potentiometer is connected to the inverting input of the Op-amp to adjust the threshold value. Based on this, the non-inverting output will be either high or low. The microcontroller provides some logic signals to the relay driver circuit. If the LDR is low, the relay will be activated or else if the LDR is high, the relay will not be activated. Based on this operation, the LED panel will be ON and OFF respectively. The microcontroller sends some sets of command to the LCD to display the data in real time. The LDR-2 is used to check if the LED panel is working or not working. If somehow, there is a fault in the panel then the microcontroller sends the command and the information to the Wi-Fi modem through the serial communication along with the unique identification number of the device. When the Wi-Fi modem is connected to the web-server through the network, it will send all the vital and required information.

To measure the voltage and current, we are using a 12-bit ADC MCP3202. It provides 1.22 millivolt per step if the reference voltage for ADC is considered to be 5 volt. The ADC is responsible to collect the analog data from the voltage and current sensor. For the voltage sensor we are using a simple voltage divider circuit which will reduce the input 12 volt into almost 5 volt DC. To calculate the input voltage accurately, a mapping system is implemented. Then we have ACS712 current sensor of 20Amp, which is based on the "Hall effect sensor. The manufacturers specify the conversion factor in the data sheet. Finally, for web-designing and database management we use the WAMP Server64. WAMP (Windows, Apache, Mysql and PHP) is a tool for testing the website in a localhost. ESP8266 Wi-Fi modem is used to connect the hardware data to the web server. Since, the system is based on IoT there will be multiple users and those who have valid id and password can login to the server to get the required information.

Refer to Fig. 1. we have used the following hardware listed below-

1. Microcontroller (STC12C5A60s2): It is a single chip microcontroller based on a high-performance IT architecture 80C51 CPU. It can execute an instruction in 1-6 cycle (much faster as compared to standard 8051). Additionally, it has two extra I/O pin, inbuilt 10 bit ADC, two UART, on chip crystal oscillator, SPI and a one-time enable Watchdog timer [13].
2. LCD (Liquid Crystal Display): A monochromatic 20×4 alphanumeric LCD is used with 20 characters and 4 line display.
3. LM358 Dual Op-amp IC comprising of two integrated comparators with 8 pins.
4. LDR or a photo resistor whose resistivity is a function of the incident electromagnetic radiation.
5. A 7A/250 V AC relay. A relay driver circuit consisting of NPN transistor switch and a flywheel diode.
6. LM7805 Voltage Regulator IC. For any value of input less than or equal to 35V, it will provide a constant output of 5V.
7. ADC MCP3202 IC for sensing and processing of input analog to digital signal.
8. ACS712 IC current sensor. The load is connected to its terminal in series.
9. Voltage divider circuit for voltage sensing. The input voltage (Vin) using Ohms law, we get:

   $V_{in} = I \times R1 / I \times R2 = I \times (R1+R2)$ [Since the resistors are in series, the current is same]

   $I = V_{in} / (R1+R2)$ ………(i)

   Similarly,

   $V_{out} = I \times R2$

   $I = V_{out} / R2$ ……………(ii)

   Equating (i) and (ii)

   $V_{out} / R2 = V_{in} / (R1+R2)$

   Thus, the output voltage we get, $V_{out} = V_{in} \times R2 / (R1+R2)$.
10. ESP8266 Wi-Fi modem for wireless data logging.

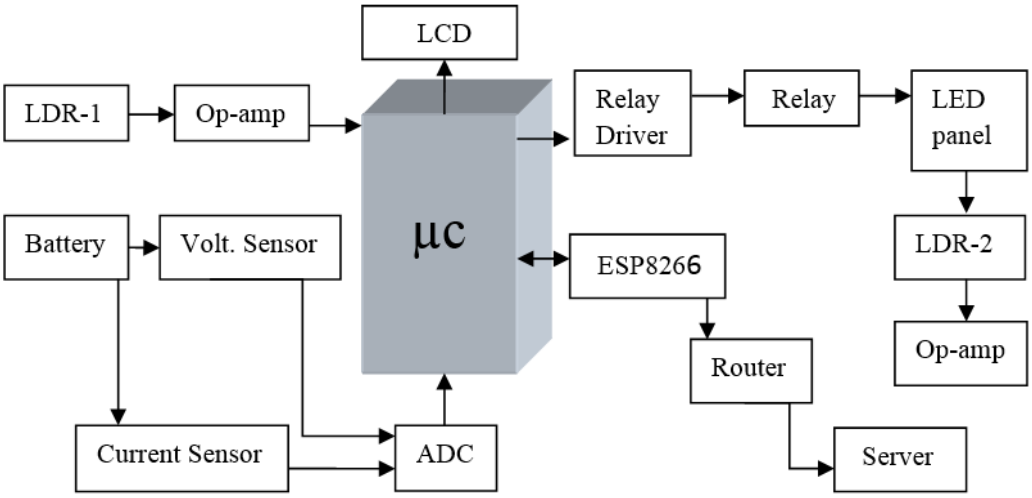

Fig. 1. Block diagram of the proposed hardware architecture.

Software description-

a. Keil uVision3: Keil uVisison3 tool is used for debugging and testing the programs written in C language before the hardware is available.
b. Proteus ISIS (Intelligent schematic input system) is used for drawing schematic circuit for the proposed model and simulates it in a real time (shown in fig.2).
c. WAMP (Windows, Apache, MySQL and PHP) is used for web designing and then testing and configuring it in the localhost. MySQL is used for storing the data, for the database management system. It is used in client site scripting.

On the other hand, PHP (Hypertext pre-processing) is a server site scripting used to process the data. Using POST method, the data are transferred from client to the server in HTTP protocol.

IV. IMPLEMENTATION

Most of the component used in the circuit need +5V except the Wi-Fi module ESP8266 (which need 3.3 V). For regulated power supply we are using LM780. Pin 1 of 7805 is input where we can give 7-18V. We are using +12V in our circuit from a step down transformer with Rectifier Bridge. Pin 2 is ground and pin 3 is regulated output. Irrespective of input voltage, the output will be +5V only. To reduce any harmonic noise in the power section, two 100nF ceramic capacitors are connected across pin 1& 2 and pin 2 &3 of 7805 IC.

STC12C5A60s2 microcontroller is the heart of the circuit and the entire system. According to datasheet the microcontroller can operate at 0-35MHz, but we are using oscillator of value 11.0592 MHz, this odd number is necessary to generate error free BAUD rate for serial communication. Pin 18 and 19 of microcontroller are XTAL2 and XTAL1 where we have connected the crystal oscillator. At 18 and 19 we have used two 33pF ceramic capacitors connected to ground. Pin 9 is the reset pin. For normal operation pin 9 must be pulled down hence a 10K resistance (R1) is connected from pin 9 to ground. Pin 31 is EA. As we have used internal 8K of the microcontroller, pin 31 is connected to +5V in our circuit.

To display the relative information status of the system, we are using a 20×4 LCD module. The module has 16 pins. Pin 1 is GND, pin 2 is VCC which is connected to regulated +5V (pin 3 of 7805). Pin 3 of LCD module is contrasting control pin where we have connected the center terminal of 10K variable resistance. One terminal of the POT is connected to VCC and other to GND. This POT is used as a voltage divider. By setting different voltage level at pin 3 we can set the contrast level.

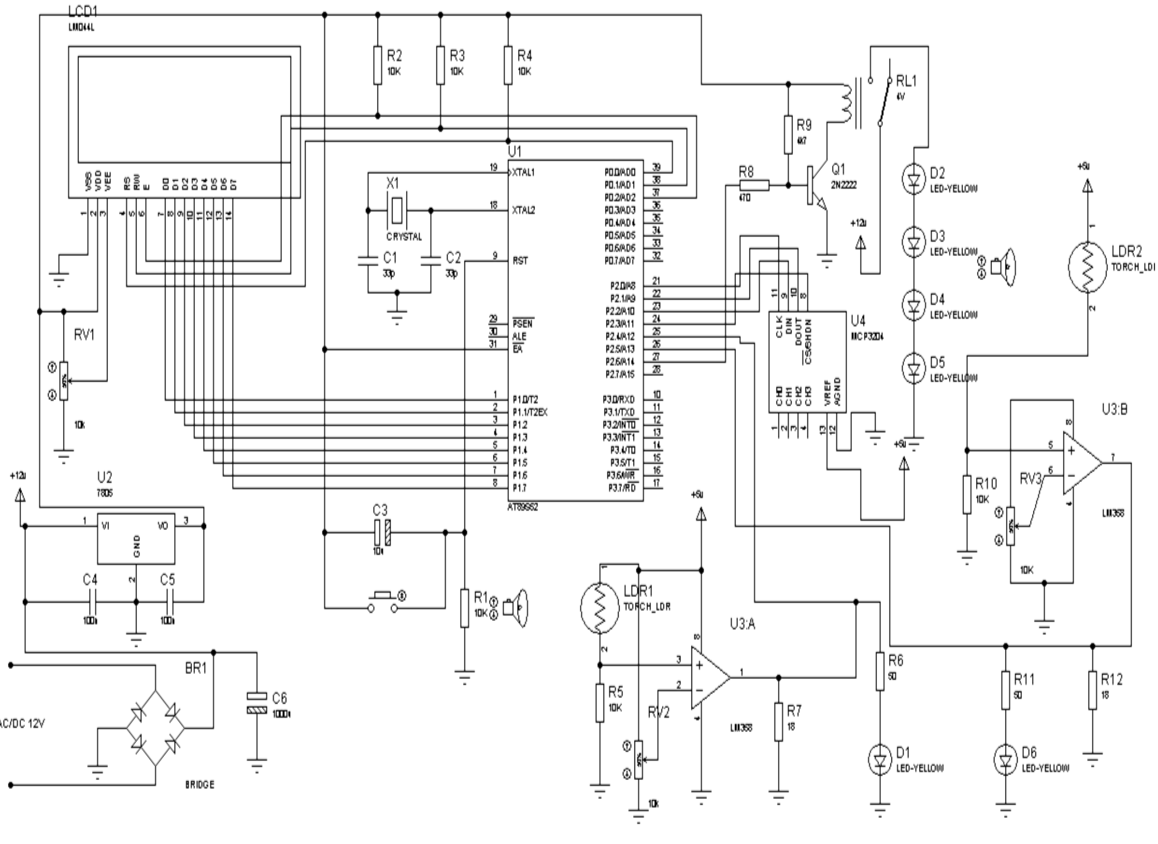

Fig. 2. Schematic circuit diagram of the proposed system.

Pin number 4, 5, and 6 of the LCD modules are the RS, RW and E respectively. At the time of sending command from microcontroller to LCD, RS pin must be pulled down (RS=0). At the time of sending data from microcontroller to LCD, RS pin must be pulled up (RS=1). The RW pin (Read/Write) is used to specify the read and write mode. 98% of the time, the RW pin is set to low.

The E or Enable pin is used to provide a high to low pulse after or during providing data or command from microcontroller to LCD. From Pin 7 to pin 14 we have provided data/command from microcontroller to LCD. They are bidirectional bus. Pin 15 and 16 of the LCD modules are used for providing power supply to the backlight of the LCD. We are using port 1 of the microcontroller to provide data/command to the LCD, hence pin 1 to pin 8 of the microcontrollers is connected to pin 7 to pin 14 of the LCD. The RS, RW and E pin of the LCD module is connected to pin 39, 38 and 37 of the microcontrollers, i.e. P0.0, and P0.2 respectively. The microcontroller has 4 ports P0, P1, P2 and P3. The internal pull up of port 1, 2 and 3 are activated but internal pull up of port 0 is not activated. Hence, we have used external pull up with I/O pin of port 0 if they are used in circuit. As we are using P0.0, P0.1 and P0.2 for RS, RW and E of LCD we have used three pull up resistance of value 10K (R2, R3, R4) from VCC to pin 39, 38 and 37.

To identify whether the sunlight is present or not we are using LDR as sensor. The internal resistance goes high and low depending on light intensity fall on the LDR. We are using OPAMP LM258 IC in differential mode (comparator). Pin 1, 2, and 3 of LM358 is not-inverting output, inverting input and non-inverting input of first comparator. Pin no. 4 is ground. Pin no. 5, 6 and 7 are non-inverting output, inverting input and non-inverting input of the second comparator. Pin no.8 is directly connected to the microcontroller input, we are using +5v power supply to pin no.8 (VCC).

To set the input voltage at inverting input we are using 10k potentiometer which is using as voltage divide circuit. The central terminal of the potential is connected to inverting input of the comparator, i.e, pin no.2 and pin no.6 of LM358. The LDR is connected to non-inverting input of the comparator, i.e, pin no.3 and pin no.5 of the OPAMP.

To create the voltage divider circuit, we have connected 10k resistance as pull-down resistance (R5). When the light falls on LDR, it changes the voltage level at the non-inverting input of the comparator, and the comparator compares this value with the inverting input of the comparator. If it crosses the threshold value (pin no.2), the non-inverting output goes high which is connected to the input pin of microcontroller. To display the status visually an LED is connected to the output of the comparator though 470 ohm resistance. The program executing in the microcontroller is responsible for monitoring the status of the first LDR. If LDR1 is high, it will consider that environment has enough sunlight, but if first LDR is low, it will consider that the environment is not having enough sunlight and need to activate the relay driver circuit. Now it will activate the relay trough a switching transistor 2n2222 from Philips. The emitter of the transistor is connected to ground, the base is connected to pin no.21 of the microcontroller through a 470 ohm resistance and the collector id connected to first terminal of the relay coil and the other terminal of the coil to +12v. As 2n2222 is an n-p-n transistor, we need a positive power to activate the switching, i.e, the internal resistance between emitter and collector is high. In absence of positive voltage at base and it will not allow to flow the current but when the base is connected to positive power, the internal resistance between emitter and collector goes low and it completes the circuit. As 8051 cannot provide us enough the power to activate the transistor we are using a pull up resistance of value 4.4k (R8).

A freewheeling diode is connected between the relay coil terminals to stop the reverse flow. A LED is also connected between the relay coils through a 470 ohm resistance to indicate the status of the relay.

Then the ACS712 module has two phoenix terminal connectors through which the wire has to be passed. In this case we are measuring the current drawn by the LED panel so the wire that is going to the load is passed through the ACS 712 Module in series with the load. From the other side we have three pins where Vcc is connected to +5V to power the module and the ground terminal is connected to the ground of the controlling unit. Then the analog voltage given out by the ACS712 module is read by the ADC and finally the converted signal is feed to the I/O pin of Microcontroller. After calculating the current, the value is stored in the local variable so that it can be sent to the web-server.

V. EXPERIMENTAL RESULTS

The hardware setups are tested with several experiments conducted in various timestamps under both cases during light and dark period to gather the real time status of LED panel, fault status, current and voltage values, all stored for future analysis.

Refer to Fig. 3, from the left, 1st case when the sun is high, LED is OFF. 2nd case when the sun is low, LED panel is ON. 3rd case when the sun is low but the LED is OFF meaning that the LED panel is not working or faulty. Table below shown the power readings (V×I) based on the above experimental setup.

Table 1. Power consumption readings of the proposed streetlight monitoring system.

SL No.	Time (pm)	Current (Amp)	Voltage (V)	Power Consumption (Watt)
1	2.30	10.10	8.60	86.86
2	3.50	9.80	8.20	80.36
3	5.15	11.90	7.60	90.44
4	7.45	10.70	8.40	89.88

For accessing real time data of each node or the system remotely, a website has been designed in the localhost of WAMP server. Refer to Fig 4, shows the device list, user list, the number of working and faulty devices in a region, and a device status in (Real Time). Multiple users can login to the site to view and update the data, unless they provide a valid user-id and password. The IoT (Internet of Things) is incomplete without the wireless communication between the device and Wi-Fi module (ESP8266). ESP8266 works on access mode. First, we configured it in the hyperterminal; we get the IP address of my local network as (192.168.43.197) of my system. Finally, we browse this IP address; we get the transmitted data on web page.

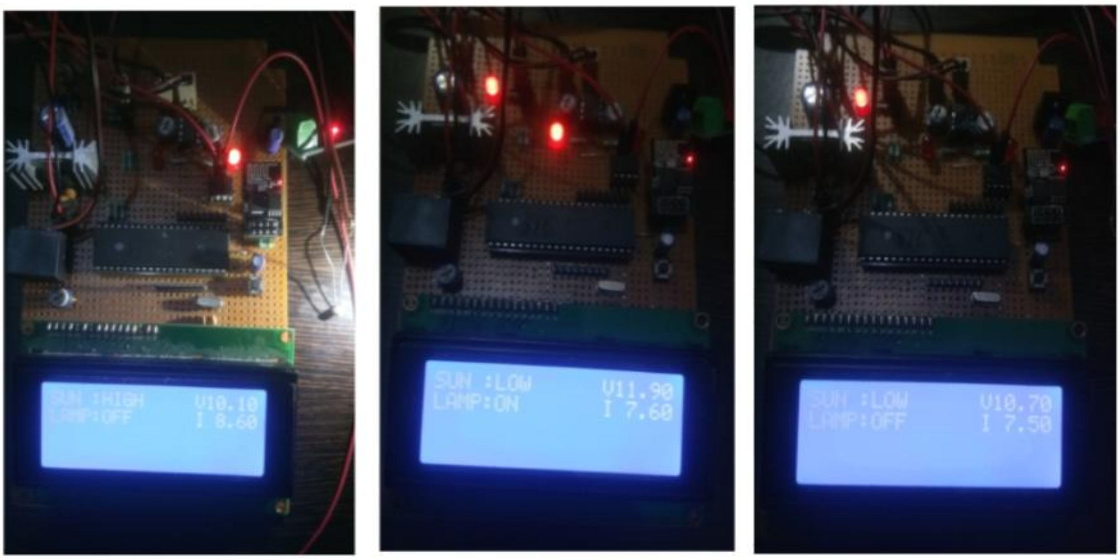

Fig. 3. Hardware experimental setup under low light and no light condition.

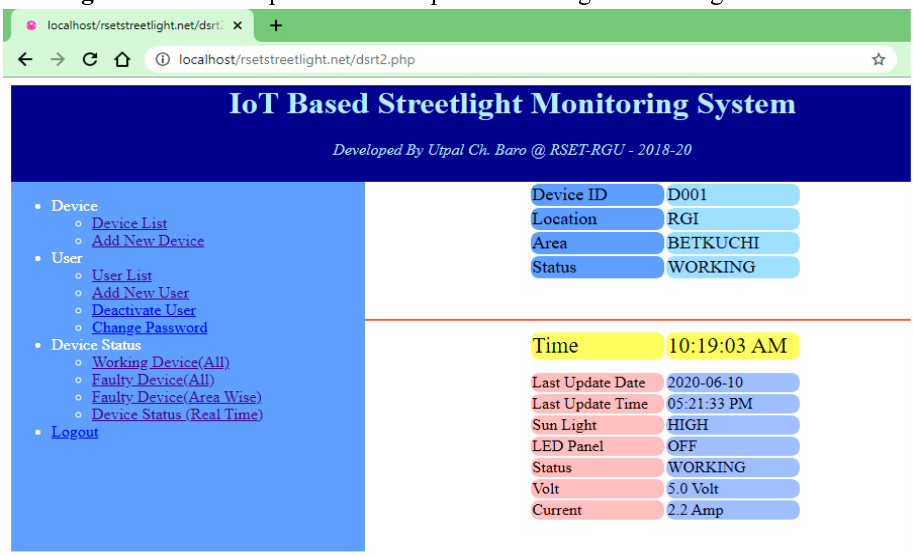

Fig. 4. Device status displayed in the webpage of the website.

VI. CONCLUSION

This paper presents an efficient automatic streetlight monitoring system based on Wi-Fi technology. Using the Internet of Things (IoT), the system enables remote monitoring of streetlights from a centralized location. This intelligent street lighting solution introduces advanced technologies that simplify maintenance and fault detection, offering enhanced operational efficiency. The proposed system successfully detects the status of LED lights, identifies faults, and measures power consumption using voltage and current values. This research is a modest contribution to the advancement of smart technology, with the hope that IoT will play a pivotal role in establishing the framework for future smart cities.

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