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Development of a Real-Time Battery Monitoring solution with IoT Technology for Improved Safety and Performance in Electric Machines

Md.Robiul Islam[1], Musfikur Rahman[2], Tania Sarkar[2], Maisha Islam[3], Md. Asadullah[31]

Dept. of Electrical Engineering, Hohai, University, China

[2]Dept. of EEE, Bangladesh Army University of Engineering & Technology, (BAUET)

[3,4,5]Department of Electronics & Communication Engineering (ECE), Institute of Science, Trade & Technology (ISTT)

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ABSTRACT

The goal of the research is to demonstrate how an IoT-based battery performance monitoring system may be used for any machine, but especially for automobile batteries. By utilizing the most recent Internet of Things (IoT) technologies, this study proposes a concept for sharing battery state monitoring parameters. The battery life can be increased by taking corrective action after obtaining such metrics. This suggested framework can transmit battery parameter data to a cloud database by mounting sensors on the battery. Users can consult this database to keep track of the battery's overall health. This will increase battery usage effectiveness and lengthen battery life. As it powers the entire system, the battery is, as we all know, the most crucial part of any device. So, it's essential to keep an eye on the battery's voltage level because improper or excessive charging or discharging might cause battery damage or system failure. Building an IoT-based battery monitoring system for this research project will enable us to track the battery's charging and discharging status as well as its voltage and percentage. Battery Management System (BMS), a separate system in electric machines, keeps track of all the characteristics of the battery pack, including voltage, current, temperature, etc. It also assures the handling and safety of lithium batteries. Earlier, the Battery Monitoring System just kept track of the battery's health and alerted the user via the machine's battery indicator. Thanks to technological advancements, the Internet of Things (IoT) can now be utilized to remotely alert about the battery status.

Keywords: Internet of Things, Sensor, Lithium Batteries, Electric Machine, Cloud Database

INTRODUCTION

The necessity for sustainable fuel and energy sources, along with growing awareness of global warming, has resulted in a persistent trend toward electric and hybrid vehicles. Temperature, charging strategy, and depth of discharge (DOD) are a few examples of variables that affect battery performance. This study aims to provide an Internet of Things-based battery voltage and current metering. Numerous applications can be powered effectively by lead-acid batteries [1]. They are cheap, readily available, and provide whatever they are hooked on a lot of power. Unfortunately, if the charge is not monitored, the battery will eventually run out of power. The battery's current voltage is also required in order to calculate the battery's charge. It is possible to estimate the battery's approximate charge based on its output voltage [4-5]. Through the use of a

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smartphone application, users can obtain accurate location data for the buses that are closest to the bus stop [17]. Because of its architectural design, the system can forecast the sensor sleep interval based on data accuracy, historical usage trends, and the amount of battery life left. After that, this microcontroller uses a short message service (SMS) to send the data to a server over a GSM communication system [14]. The purpose of this study is to support the creation and use of learning mechanisms and data analytics to enhance the energy efficiency of IoT and low-overhead mobile devices. Our area of expertise is middleware that makes energy-efficient data analytics implementation safe [10].

LITERATURE REVIEWS

It was determined that reading through the many papers, books, and other relevant literature and guidelines for the essential pathway was necessary before moving on to the designing portion of the system. So, to understand the situation, the following literature was studied. The research on Battery Monitoring System has been conducted by the researchers listed below. By [1] Anif Jamaluddin A Wireless Battery Monitoring System (WBMS) for electric vehicles has been devised in this researcher's work to track the voltage, current, and temperature of the battery. Hardware (sensors, a micro controller, a Bluetooth module, and an Android smartphone) and software make up this system. It was created using the inexpensive micro controller AT mega 328 (Arduino UNO).

Data on voltage, current, and temperature are sent to the micro controller, and subsequently data from the battery is sent through Bluetooth to the display.[4]. Data from the battery monitoring is shown in this study on a personal computer (PC) and an Android smart phone. The monitoring system was able to display voltage, current, and temperature data in real-time on an Android smart phone and a computer at the same time. [17] On a smartphone application, the user is given specific information about the precise location of the closest buses that are approaching the bus stop. Technologies like 3 G network and SMS-based services in the current mobile phones can be used with easily accessible Android APIs to lower the cost and size of hardware needed and produce better results [2] Judith N. Carpio in the Philippines, a car battery can only be expected to last 6 to 12 months on average. When a battery is six months old, it begins to exhibit undesirable behaviors including erratic startup and rapid drain. When the condition of the car is important, such as in an emergency, these reactions should be avoided. The researcher came up with a device to automatically check the temperature, load current, voltage level, number of hours before reaching a critical voltage level, and state of charge of a car battery using wireless technology in real time using a mobile application with a dedicated storage for recording data every predetermined period as a solution. To boost its dependability, the system interacts utilizing GSM, the internet, and Bluetooth. The device can be programmed to "auto-off" mode to automatically turn the loads off if communication is lost and the vehicle is reaching critical level.[3] Simon Siregar. For his research paper, he developed a GSM wireless communication system-based solar panel and battery street light monitoring system. [7,8,10]

The batteries and solar panel can be monitored using the ACS712 current sensor and voltage sensor with voltage divider circuit and GSM communication system. A microprocessor then processed the data from the voltage and current sensors.[14] The architectural layout enables the system to anticipate the sensor sleep interval depending on the battery life remaining, their usage patterns in the past, and the accuracy of the data. This micro controller then delivers the data through a GSM communication system to a server, using short message service (SMS). The information from the SMS was subsequently processed by this server, which then sent the data to a web server database. The internet can then be used to access this information. [10] The purpose of this study is to argue for the design and implementation of data analytics and learning mechanisms to increase energy efficiency in IoT and minimal overhead mobile gadgets. We concentrate on middle ware that allows for the robust insertion of energy-efficient data analytics-driven solutions and optimizations without modifying the OS or application code.

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PARAMETERS IN ELECTRONICS

A huge network of linked objects and individuals, collectively known as the Internet of Things (IoT), collect and share data about their surroundings and usage patterns. Devices make up the majority of the real physical objects connected to the system. The components of Asset Control Systems' device connectivity layer are sensors. There are a few components in the figure 1.

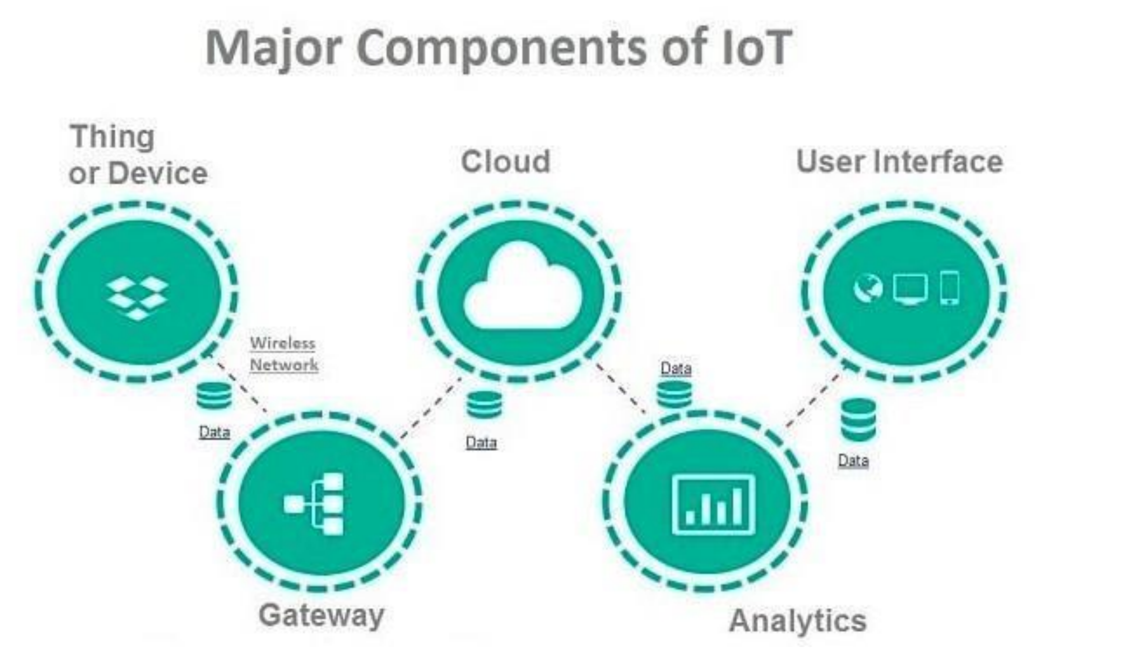

Fig. 1: IoT Components

First, we employ: MCU Node Board Model: ESP 8266-12E Based on the ESP-12E Wi-Fi Module, Node MCU is a well-liked and extensively used development board that combines features of easy programming with the Arduino IDE (C\C++) and Wi-Fi functionality. IOT applications are growing in popularity nowadays, and object connectivity is becoming more and more crucial. There are numerous methods for connecting items, including the Wi-Fi protocol. . Based on the ESP 8266, Node MCU is an open-source platform that allows data transfer over the Wi-Fi protocol and allows things to be connected. Furthermore, we might offer some of the most crucial micro controller functions, including GPIO, PWM, ADC, etc. Many of the project's requirements can be met by it alone [1-2]. The second is the DHT22 Humidity and Temperature Sensor. A digital sensor for both temperature and humidity are the DHT 22. It measures the ambient air using a thermistor and a capacitive humidity sensor before emitting a digital signal on the data pin (no analog input pins are required). Although it is easy to use, grabbing data requires precise timing. Sensor readings from this sensor can be up to two seconds old when using the library because the user can only receive new data from it once every two seconds. Thirdly: 0.96? I2C OLED Display: This tiny OLED display module has a diagonal measurement of just 0.96? and is composed of 128×64 individual blue OLED pixels, each of which is independently controlled by a controller chip. OLED display is higher than LCD display; it functions in a dark environment without a back light. This module connects to Arduino and other micro controllers using I2 C. Fourth: TP 4056 Charging Module: This lithium-ion battery charger is a linear design. Single-cell batteries can be charged by this module. The fact that it supports both constant voltage and constant current charging modes is crucial. Both modalities are available for selection by users. This module has a charging current of one amp. Because of its 4V to 8V operational input voltage range, we may use it to directly charge batteries from a USB port. A USB port's maximum current is 500 mA. And lastly:

Development of Apps: With the aid of the Blynk IOT app, which is produced by Blynk Inc. and is accessible on the Google Play Store, we can view our battery performance directly. [3]

Fig. 2: Node MCU ESP 8266

Fig.3: DHT 22 Temperature & Humidity Sensor

Fig.4: 0.96? I2C OLED Display

Fig.5: TP 4056 Charging Module

SYSTEM DESCRIPTION

It seems that we are explaining a system that gathers data and uploads it to the open-source cloud service Thing Speak using an Arduino UNO board and a DHT 11 sensor. To accomplish this, you have connected the Arduino UNO to the internet via the ESP 8266 Wi-Fi module, which is then used to transmit the sensor data to Thing Speak. For your project, here is the description of the system:

1) Instrument DHT 11: This sensor provides data to the Arduino UNO. This project's environmental monitoring system uses a DHT 11 composite sensor to measure humidity and temperature at the same time. It provides reliable and trustworthy environmental data and is intended for a range of applications, such as industrial monitoring, climate control, and home automation. The DHT library for Arduino is integrated by the system to read sensor data and compute humidity and temperature values. Digital readings of the current temperature and humidity are sent; these can be viewed on a linked device or examined further on a computer. The system gathers and updates environmental data continually, giving users the ability to track, evaluate, and decide based on data or act when circumstances change. All things considered, the Environmental Monitoring System with the DHT11 sensor is an affordable and approachable environmental monitoring system that makes it easier to respond quickly to changing environmental conditions in a variety of applications.

2) Node MCU ESP 8266: The system's internet connection is made possible by the ESP 8266 module. It uses TCP/IP to communicate with Thing Speak. An adaptable Wi-Fi module that makes Internet of Things (IoT) applications possible is the ESP 8266. Because of its integrated micro controller, it offers a small and affordable wireless communication option. The ESP 8266's ability to connect to Wi-Fi networks facilitates data transmission and reception. Sensor networks, smart gadgets, and home automation are among its frequent uses. It can read sensors, control devices, and send data to servers or mobile apps when programmed with the Arduino IDE or other platforms that are compatible. Due to its compact size, low power consumption, and community support, it is a well-liked option for integrating wireless functionality into a range of electronic projects.

*3) TP 4056 Charging Module:*The TP 4056 module is a lithium-ion battery linear charger. Single-cell batteries can be charged by this module. The fact that it supports both constant voltage and constant current charging modes is crucial. Both modalities are available to users. This module has a charging current of one amp. Its functioning input voltage range is 4V to 8V, therefore we may use a USB port to charge batteries directly. A USB port's maximum current is 500 mA.

Configuration and Software

1) Arduino IDE: The Arduino UNO is programmed using the Arduino IDE. To read data from the DHT11 sensor and transfer it to the ESP8266 module, we will need to write code.

2) AT Instructs: AT commands are used to configure and manage the ESP8266 module. By using these commands, you can configure the module to connect to your Wi-Fi network as a client and submit data to Thing Speak.

3) IoT Cloud: IoT cloud services gather, store, and analyze data from linked devices to enable Internet of Things applications. They provide a platform for data insights, control, and real-time monitoring. Data-driven decision-making is made feasible by the ability for users to remotely access and manage Internet of Things devices via web interfaces or mobile apps. When the battery is charged or discharged, the battery voltage and percentage will be shown on the IoT Cloud Dashboard.

4) Thing Talk: Sensor data can be stored, visualized, and analyzed via Thing Speak, an open IoT platform. To receive and show your sensor data, you must create a channel one Thing Speak and register for an account.

System Operation

1) The DHT22 sensor provides temperature and humidity readings to the Arduino UNO on a regular basis.

2) This data is transmitted over a serial connection to the ESP8266 module. The ESP8266 module is set up

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to use AT commands to establish a connection with your Wi-Fi network.

3) The ESP8266 module connects to the internet and creates a TCP connection with the Thing Speak server.

*4)*Through the internet, it transmits the sensor data to the Thing Speak server.

*5)*In addition to storing the data, Thing Speak offers you tools for analysis and visualization so you can keep an eye on and monitor real-time sensor data.

Data Visualization and Analysis

1) We can see real-time data from your DHT22 sensor in the form of graphs, charts, and other visualizations by logging into your Thing Speak account.

2) To build a complete IoT solution, you may combine Thing Speak with other platforms and services, set up alarms, and examine past data.

METHODOLOGY

Depending on the state of the Node MCU ESP 8266, the DHT 22 Temperature & Humidity Sensor charges and dissipates. Inching closer to the core is the TP 4056 Charging Module. As a result, the Wi-Fi chip may frequently connect to the Wi-Fi network and send data to it. The flowchart shows how we switch on the system originally. After the system has finished initializing, we examine the battery voltage. We also assess how well the charge is doing. If the requirement is met, we will recheck the battery voltage; if it is not, we will inform the user and stop the process. [

System Analysis

We will design a system to monitor DHT 22 temperature & Humidity, battery voltage along with charging and discharging status. For the micro controller, we use Node MCU which has an ESP 8266 Wi-Fi-enabled chip. This Wi-Fi chip can connect to the Wi-Fi network and uploads the data regularly to the server.

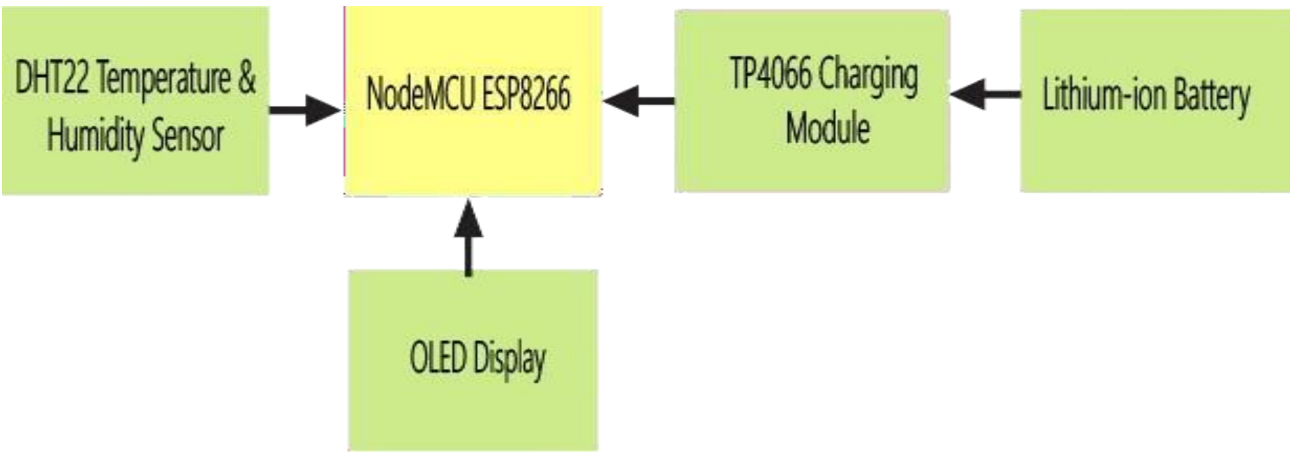

Fig.6: System analysis

Flow Chart

Itis a type of diagram that represents a workflow or process. A flow- chart can also be defined as a diagrammatic representation of an algorithm, a step-by-step approach to solving a task.

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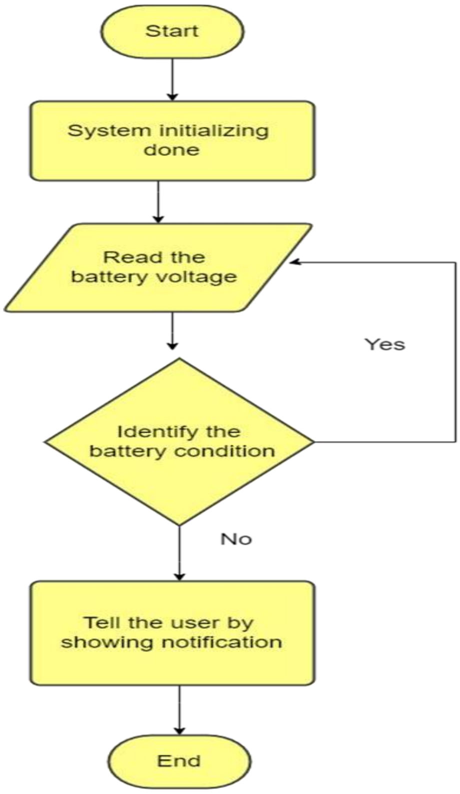

Fig. 7: Flow Chart

HARDWARE IMPLEMENTATION

This section displays the prototype and implementation. Figures depict the basic configuration. A system to track DHT 22 temperature and humidity, battery voltage, and charging and discharging conditions will be designed. We use Node MCU, a micro controller with an ESP 8266 Wi-Fi-enabled chip, as the micro controller. A smaller board, such as the Wemos D1 Mini, is an additional option. This WiFi chip has the ability to connect to a network and routinely uploads data to the server. The D4 pin of the Node MCU is linked to the Out pin of the DHT 22 sensor. Pins D1 and D2 are linked to SCL and SDA pins. The GND and VCC pins of the DHT 22 sensor and OLED are linked to the respective GND and 3.3V pins. Since the TP 4056 module is designed primarily for Battery Management Applications, you can use it to charge the battery. The maximum analog input voltage that the ESP 8266 Chip can handle is 3.3 V. However, the battery voltage rises to 4.2V. Therefore, in order to reduce the input voltage, we must create a voltage divider network.

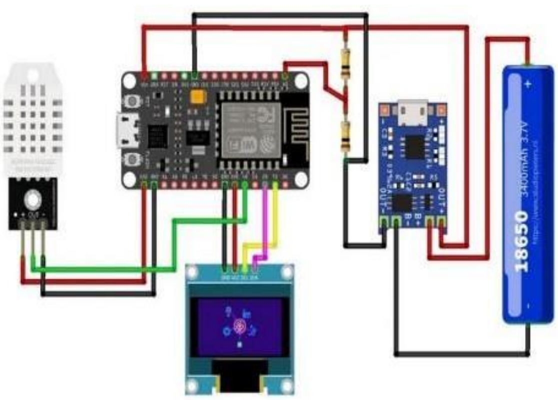

Fig. 8: Connection method

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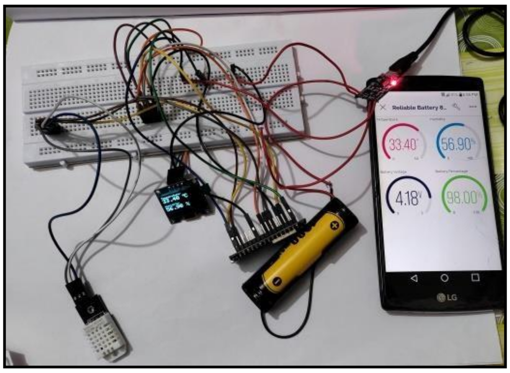

Fig. 9: Hardware implementation view

RESULT

We may see our result in our android mobile phone. The android apps will show the charging conditions, batteries lifetime, batteries connections procedures by various colors identifications. This indication shows our research result, and it will be the better real time battery monitoring system in electric vehicles.

Fig. 10: Result using mobile phone

COST COMPARISON

The systems in [22],[23],[24],[25],[26] are not cost efficient at all. Where we created this Real-Time Battery Monitoring solution with IoT Technology for Better Safety and Performance in Electric Machines System at very low cost in Bangladesh. Also, our is the long lasting one and has more accuracy than those systems of [22],[23],[24],[25],[26].

Table I. Cost Comparison Result

Existing systems	Cost in BDT	Tasks they can perform
System 1 [22]	56,100 BDT	1. Monitors cloud-based platform. 2. Faults diagnosis platform for large-scale Li-ion BESSs. 3. Can accurately estimate individual battery cells.

System 2 [23]	30,000 BDT	1. Addresses forecast error. 2. Stores stationaries. 3. Employs stored energies.
System 3 [24]	46,500 BDT	1. Estimates of the value of market grid storage. 2. Operates expenses energy storage system. 3. Increases the value of energy storage.
System 4 [25]	40,000 BDT	1. Stores grid electricity generated at off-peak hours. 2. Uses car batteries for grid energy storage. 3. Stores electricity.
System 5 [26]	12,500 BDT	1.Reduces both oil imports and greenhouse gas emissions. 2.Offers maximize potential sales. 3.Considers the maximum frequency of charging events.
Our proposed system	10,500 BDT	1. Detects battery failure in time. 2.Developsbattery monitoring and management system. 3.Enhances high-quality vehicles services.

EXPERIMENTAL VERIFICATIONS

Table II. Voltage Measurement Result

Battery	Voltage measurement results		Accuracy percentage (%)
	Voltage sensor	Multimeter	
1	3.81	3.79	99.47
2	9.98	9.91	99.29
3	8.70	8.55	98.27
4	1.25	1.23	98.40
5	3.81	3.79	99.48

The experiments' results are displayed in Table II. The values differ from one another as the table illustrates since the batteries were a combination of new and used batteries. The findings demonstrate that the accuracy of the voltage measurements made using a voltage sensor and a multi meter are quite comparable. All the batteries that were measured have accuracy percentages greater than 99%. Thus, it can be said that the voltage sensor offers reliable battery measurement readings. [24,25]

Table III. Coordinate Measurements Result

No.	Place	Coordinates from Google Maps	Coordinates from TP4056 Charging Module	Accuracy percentage (%)
1	ISTT Campus	1.852154, 103.073998	1.852150, 103.073798	99.99
2	ISTT Cafeteria	1.856250, 103.084588	1.856240, 103.084580	99.99
3	CUST Campus	1.848993, 103.075913	1.848980, 103.075920	99.99
4	OGSB Hospital	1.859067, 103.088704	1.859073, 103.088704	99.98
5	BN School	1.862602, 103.089685	1.862638, 103.089680	99.96

The experiment's results are displayed in Table III. There are five (5) possible target sites, as the table illustrates. The coordinates of every target site, obtained from Google Maps and the TP 4056 Charging Module, are displayed in the table. The findings demonstrate that the coordinates obtained from the TP 4056 Charging Module and those obtained from Google Maps are fairly accurate. All of the measured coordinates have accuracy percentages that are almost 100% accurate.

Table IV. Battery Grading Based on Duration to Reach Cut-Off voltage Value

Duration taken to reach the cut off (hour)	Percentage of time taken to reach the cut off (%)	The condition of the battery
8	100	Good
4	50	Moderate
2.4	30	Bad

According to Table IV, if it takes 2.4 hours to finish the discharge stage, the battery is almost at the point of degrading.

Table V. Battery for Time Taken to Reach the Cut-Off

Duration taken to reach the cut off (hour)	Voltage readings for new battery (V)	Voltage readings for degraded battery (V)
0	3.79	3.20
1	3.68	3.04
2	3.45	2.80
3	3.20	2.80
4	3.01	2.80
5	2.93	2.80
6	2.90	2.80
7	2.85	2.80
8	2.80	2.80

The voltage measurements for both batteries are displayed in Table V. The data indicates that it takes 8 hours for the fresh battery to reach the fully discharged state. Additionally, the battery's cut-off voltage is 2.8V.

FURTURE WORKS

Wireless communication is a kind of data transmission that is provided and carried out wirelessly. This is a generic term that covers all connections, setup procedures, and usage of wireless technologies and devices to transfer data back and forth between two or more devices. Using a range of technologies, including GSM, WiFi, Bluetooth, ZigBee, GPRS, and Android connectivity, a wireless battery monitoring system has been constructed. One popular wireless communication method is the global system for mobile communication or GSM. It uses frequencies in the 900 MHz–1800 MHz band to function. Because of its low cost, low power consumption, high reliability, and sluggish data rates, Zig Bee was selected. They came to the conclusion that while wireless battery management devices are essential for EVs to increase battery lifespan, battery temperature cannot be effectively regulated by them. A lithium-ion battery monitoring system for electric vehicles (EVs) was recently introduced by Menghua et al. It gathers and displays voltage, current, temperature, and other battery parameter data on a smartphone via WiFi connectivity. [20–21] This illustrates the deficiency of automated monitoring systems that could notify the user about the state of the battery.[19] sends alert messages when the batteries are at room temperature and in severe condition using GSM modules with SCADA. [24]

CONCLUSIONS

The design process of Reliable Battery Adviser System of machines using IoT is useful to detect battery failure in time, so that timely action can be taken on battery problem which will increase the life of battery and prevent from damage. In this study the vehicles battery monitoring and management system has been developed. It will enhance high-quality vehicles services, identify faults, and reduce road accidents. [4]. A wireless transmission device is used for GPS/GSM positioning and vehicles status acquisition and data will be sent to an android mobile phone as used as data monitoring center. [25,26]

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