IoT-Based Battery Management System for Electric Vehicle

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Abstract -This paper describes the appliance of Internet-of-things (IoT) in monitoring the performance of electrical vehicle battery. it's clear that an electrical vehicle totally depends on the source of energy from A battery. However, the quantity of energy supplied to the vehicle is decreasing gradually that results in the performance degradation. this is often a serious concern for battery manufacture. during this work, the thought of monitoring the performance of the vehicle using IoT techniques is proposed, in order that the monitoring are often done directly. The proposed IoT-based battery monitoring system is consists of two major parts i) monitor and ii) interface . supported experimental results, the system is capable to detect degraded battery performance and sends notification messages to the user for further action.

***Key Words*:**Arduino Uno, ESP8266 Shield, BMS, Lithium ions batteries

1.INTRODUCTION

Nowadays, electric vehicle (EV) is becoming popular since the fuel prices becoming costlier . thanks to these scenario, many vehicle manufacturer trying to find alternatives of energy sources aside from gas. the utilization of electricity sources may improve the environment since there are less pollution. additionally , EV produces great advantages in terms of energy saving and environmental protection. Most EVs used rechargeable battery which is lithium ion battery. it's smaller to be compared with lead acid. In fact, it's a continuing power, and energy's life cycle is 6 to 10 times greater compared with lead acid battery. Lithium ion battery life cycle are often shortened by some reasons like overcharging and deep discharges. On the opposite hand, EV usually has limited range of travelling thanks to battery size and structure . Now, a crucial reason that limits the appliance of EV is that the safety of existing battery technology [1]. for instance , overcharging battery not only could significantly shorten the lifetime of the battery, but also cause a significant safety accidents like fire [2-4]. Therefore, A battery monitoring system for EV which will notify the user about battery condition is important to stop the stated problems.

Previous battery monitoring system only monitor and detect the condition of the battery and alarmed the user via battery indicator inside the vehicle. thanks to the advancement of the planning of notification system, internet of things (IoT) technology are often wont to notify the manufacturer and users regarding the battery status. this will be considered together of the upkeep support procedure which will be done by the manufacturer. IoT utilizes internet connectivity beyond traditional application, where diverse range of devices and everyday things are often connected via the web, making the planet is at the user's finger tips.

M Motivating by the stated problems, during this work, the planning and development of A battery monitoring system using IoT technology is proposed. the rest of the paper is organized as follows. Section 2 reviews the varied wireless communication technologies and wireless battery monitoring systems for industries and EVs, section 3 presents design and implementation of the system, section 4 describes different tests performed, section 5 discusses the main issues faced and section 6 finally gives the conclusions of the work.

2. Related work

2.1. Technology Based on Wireless Communication

Wireless communication may be a sort of digital communication that's performed and delivered wirelessly. this is often a broad term that comes with all procedures and sorts of connecting and communicating between two or more devices employing a wireless signal through wireless communication technologies and devices. From the previous work there are several sorts of technology that are used for wireless battery monitoring system like ESP8266, ZigBee, GPRS, Android, WIFI and Bluetooth communication.

ESP8266 (. a plus of ESP8266 is that it's no problem with international roaming. it's also easy to be implemented and therefore the global subscribers create far better in network effect for ESP8266 handset maker's carrier and users. But note that, most of the technology are patented and will have license from QUALCOMM Corp. There are various literatures on battery monitoring and management using wireless communication.

GGlobal Positioning System (GPS) utilizes GPS satellite to transmit data that gives location and therefore the current time to a GPS receiver globally. It synchronizes the operation in order that these repeating signals are transmitted at an equivalent instant. The signals, moving at the speed of sunshine , reach a GPS receiver at slightly different times because some satellites are further away than others. the space to the GPS satellites are often determined by estimating the quantity of your time it takes for his or her signals to succeed in the receiver. When the receiver estimates the space to a minimum of four GPS satellites, it can calculate its position in three dimensions. The accuracy of an edge determined with GPS depends on the sort of receiver. Most consumer GPS units have an accuracy of about

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10m. Other sorts of receivers use a way called Differential GPS (DGPS) to get much higher accuracy [5]. a piece wiped out

[5] utilized ESP8266/GPS in monitoring and managing an EV battery. Android is an OS for mobile phones, tablets and a growing range of devices encompassing everything from wearable computing to in-car entertainment. Android may be a Linux-based software , and almost like Linux, is free and open source software. It are often developed by anyone because it is Linux-based open source. The OS is in a position to tell you of a replacement notification, SMS, Email or maybe the newest articles from an RSS Reader. Unfortunately, it always need a lively internet connection or a minimum of GPRS internet connection therein place in order that the device is prepared to travel online to suit people's needs. Furthermore, the OS features a lot of process within the background causing the wasteful of batteries.

2.2.Technology supported Wireless Battery Monitoring System

Reliable battery management is important for safety purposes. There are several reasons that cause battery breakdown like deterioration of battery and style defects. Manual battery monitoring system are like normal battery monitoring system which suggests that it doesn't save the info into the database. But only show the info collected in real time. Therefore, it's essential to remotely monitor battery systems using wireless technology. There are various battery monitoring system using wireless communication that are developed for the industry like uninterruptible power supply (UPS) which is vital to make sure continuity of power supply for domestic and commercial during power interruption. Suresh et al. proposed a PLC-based battery health monitoring system for an UPS using ESP8266 modules and SCADA by providing alert messages when batteries are in critical condition and temperature [6]. Sardar et al. also developed A battery monitoring system for UPS using ESP8266 [7]. The system could monitor voltage, current and temperature of the battery. Hommalai et al. developed battery monitoring system using wireless communication for UPS to detect dead battery cells [8]. There also are several studies associated with the event of battery monitoring system for EV using wireless communication. Dhotre et al. developed an automatic battery charging and engine system for EV using ESP8266 module [9]. SMS is shipped to the user when battery health goes below threshold value. Then, user can reply via SMS to auto-start the engine to charge the battery. Mathew et al. proposed a wireless battery monitoring system using 2.4GHz radio transmission scheme for EV [10]. The modular design consists of transmit module (monitors batteries) and controller module (receives batteries status). Bacquet et al. also developed A battery management system using 2.4GHz radio transmission for EV [11]. They demonstrated that radio transmission is feasible for EV's battery monitoring in harsh condition. Luo et al. developed A battery monitoring system for

EV supported GPRS communication consists of online monitoring terminal to live battery parameters (voltage and temperature) with GPRS data transmitter unit and a user

and temperature) with GPRS data transmitter unit and a interface for battery monitoring [12]. Rahman et al. proposed A battery management system for EVs using ZigBee communication and point-to-point wireless topology [13]. ZigBee was used thanks to its low power consumption, low-cost, high reliability and low data rates. They concluded that wireless battery management system is vital for EVs mainly to balance the charge to reinforce battery lifespan, but it's not efficient for controlling battery temperature. More recently, Menghua et al. presented a lithium-ion batteries monitoring system using WIFI communication for EVs that collects and displays voltage, current, temperature and other parameters of batteries on a smartphone [14].

Based on the described previous work, it shows that there are not any automatic monitoring system available to notify the user with reference to the performance of the battery. Therefore, the used of IoT technology that comes with together within the monitoring system can help in improving the preventive maintenance in ensuring the battery quality and increase the security of the user.

3. Methodology

3.1. System Overview

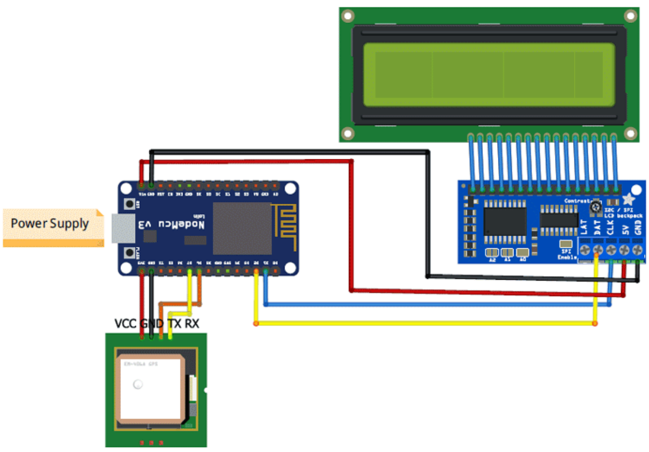

Fig. 1: Overview of the proposed system

Figure 1 depicts the overview of the proposed system. so as for the system to figure , initially, the voltage sensor measures the lithium-ion battery's voltage level. At an equivalent time, a ESP8266/GPS/GPRS shield reads the situation of the vehicle by using the GPS function. The battery's voltage level readings and site of the vehicle are conveyed to an Arduino Uno microcontroller for processing. As shown within the figure, the processed data are sent to A battery monitoring interface during a computer wirelessly using the shield. Once data transfer is successful, the battery monitoring interface on the pc will show the updated data of battery status. When the battery produced low voltage level, a notification email is shipped to notify the user. the web battery system not only can measure the voltage of the batteries but also communicate with the battery monitoring system to urge the parameter of batteries. The detail design of the system is described within the next sections.

3.2. System Flowchart

Figure 2 illustrates the ASCII text file flow of the system. Once the system is switched ON, it'll starts to initialize. Then, voltage sensor measures the battery voltage and conveys it to an Arduino microcontroller. Next, supported the received voltage data, the ASCII text file will verify the battery condition. If the battery voltage is above threshold, it'll still read battery voltage level. If the battery voltage level is low, a notification email is shipped to the supervisor using the ESP8266 module. The administrator can inform the customer about the critical battery condition.

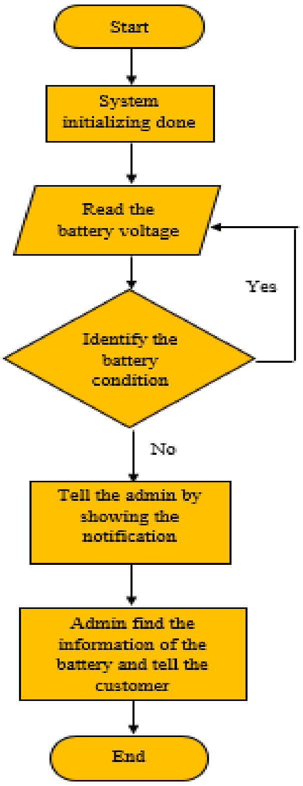

Fig. 2: System flowchart

3.3. Hardware Design

Initially, so as to verify the suitability of the hardware parts, the planning of the system was developed using Fritzing software. Figure 3 illustrates the circuit design of the system. The figure shows the system is consists of a voltage sensor, an Arduino Uno microcontroller, a ESP8266/GPRS/GPS module and a 9V battery for power supply. Figure 4 shows the particular hardware design of the proposed IoT-based battery monitoring system. As shown within the figure, the planning of the system is analogous to the circuit prepared using the Fritzing software.

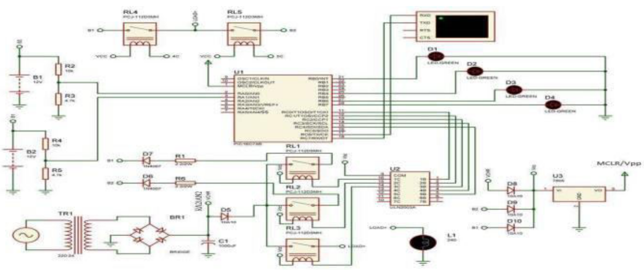

Fig. 3: The design of the circuit using Frizzing software

4. Experiments and Analysis

This section reports the experiments and analysis of the system. First, experiment steps and results on the characteristics of voltage sensor, ESP8266 module are going to be described. this is often to form sure the circuits are in fitness. Then, experiments and results to verify degradation of battery are going to be explained.

4.1. Voltage Sensor Experiment

In this experiment, the values of 5 (5) batteries was measured employing a multimeter as shown in Figure 5. Then, these values were compared with the values of an equivalent batteries that were connected to the voltage sensor circuit as shown in Figure 6. the aim is to point out the differences and accuracy percentage between both values. the chosen batteries were varied in voltage values. The batteries were a mixed of latest and used ones. The results of measurement will show these differences.

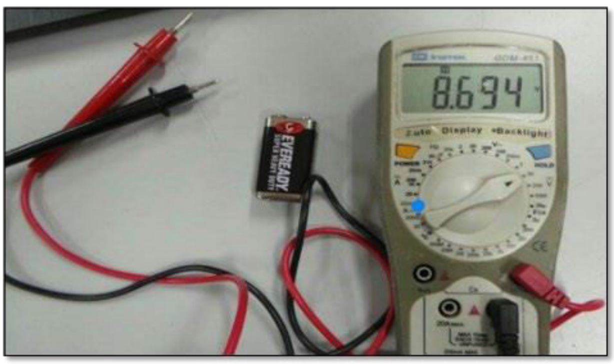

Fig. 5: Battery voltage measurement using multimeter

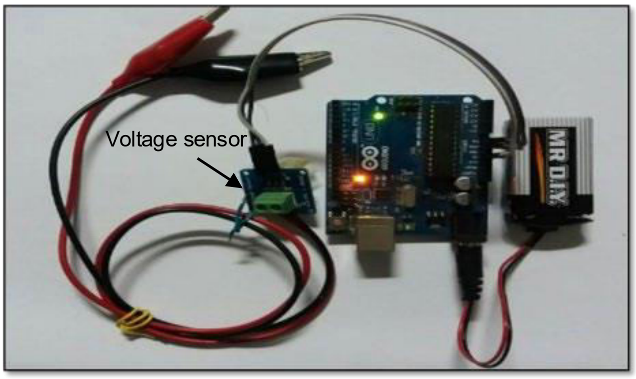

Fig. 6: Battery voltage measurement using voltage sensor circuit

Table 1: Voltage measurements results

Battery	Voltage measurement results		Accuracy percentage (%)
	Voltage sensor	Multimeter	
1	12.81	12.79	99.47
2	12.98	12.91	99.29
3	12.70	12.55	98.27
4	12.25	12.23	98.40
5	12.81	12.79	99.48

Table 1 shows the results of the experiments. As shown within the table, since the batteries were a mixed of used and new batteries, the values are different from one another . From the results, it shows that the accuracy of the voltage measurements taken from voltage sensor are quite almost like the measurements taken using multimeter. The accuracy percentage for all of the measured batteries are above 99%. Therefore, it are often concluded that the voltage sensor provides valid measurement values of the batteries.

4.2. GPS Module Experiment

In this subsection, the characteristic of the ESP8266/GPRS/GPS module was verified to work out the accuracy of the GPS coordinate. Furthermore, this experiment also will determine the functionality of the module. Figure 7 shows the experimental setup of the module. The experiments were done at five (5) different target locations, where the coordinates of every location were collected via GPS. These GPS coordinates were then compared with the coordinates derived from Google Maps website

Table 2: Coordinate measurements results

No.	Place	Coordinates from Google Maps	Coordinates from module	Accuracy percentage (%)
1	Jalgoan	1.852154, 103.073998	1.852150, 103.073798	99.99
2	Nashik	1.856250, 103.084588	1.856240, 103.084580	99.99
3	CBS	1.848993, 103.075913	1.848980, 103.075920	99.99

Table 2 shows the results of the experiment. As shown within the table, there are five (5) different target locations. The table shows the coordinates of all target locations taken from Google Maps and module. From the results, it shows that the accuracy of the coordinates taken from module are quite almost like the coordinates derived from Google Maps. The accuracy percentage for all of the measured coordinates are near 100% accurate.

Therefore, it are often concluded that the module provides valid coordinates which will be utilized in the proposed Battery Monitoring System. Figure 8 shows an example of the output from module showing the situation of a target position.

4.3. Battery Monitoring System

The proposed battery monitoring system during this work is consists of a voltage sensor and module. Experiments and analysis to point out the characteristics and usefulness of the sensor and module are presented within the previous subsections. Therefore, during this subsection, the battery monitoring system usefulness is demonstrated.
Figure 9 shows the developed hardware circuit of the battery monitoring system. within the figure, the voltage sensor is connected to the module. The system has been verified to display voltage values and coordinates simultaneously. The voltage values and coordinates are updated in real time with a 1 (1) minute delay. The marker will bounce when the battery voltage value is less than 2.8V with duration but 2.4 hours.

EXPERIMENT to work out DEGRADED BATTERY

Analyses has been administered to work out degraded batteries by measuring the discharge rates of the battery against the clock . Basically, EVs utilize lithium ion batteries in bulk quantity. Therefore, during this project an experiment has been conducted to work out battery degradation by using two (2) 12VV Li-ION batteries, where one (1) battery was during a new condition and another one was a degraded battery. Figure 10(a) shows a picture of the 12VV Li-ION battery.
When a 12VV Li-ION is discharged, there's a coffee cut-off voltage value that determine the battery is fully discharged. When it reaches the cut-off value, it means the battery is at 0% discharged or 100% Depth-of-Discharge (DOD). during this experiment, so as to work out the degraded battery, the duration of the discharge battery per time was calculated. If the speed of the discharge state to succeed in the cut-off value is approximately 30% or but from the speed of the healthy battery, it means the battery is categorized as degraded battery. Usually, a 12VV Li-ION battery takes 8 hours to completely reaching the minimum voltage of discharge state. Table 2 shows the grading of condition of the battery supported the duration taken to succeed in the stop .

The time taken for A battery to discharge is depends on the capacity of the battery. The capacity of the battery is reduced because the maximum cycles are reached. thanks to this reason, the time taken to finish the discharge state are shorten. From Table 3, it shows that if the duration takes 2.4 hours to

finish the discharge state, it means the battery is almost degrading condition.
An experiment has been administered to check the degrading condition of batteries using electronic cigarettes or vape. Figure 10(b) shows a picture of the vape. Two (2) 12VV Li-ION batteries (one (1)

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

Table 3: 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

Table 4: Battery for time taken to reach the cut off

4.4. Battery Monitoring System User Interface

The developed battery monitoring system is additionally consists of a web-based interface . The interface is capable to watch multiple battery monitoring devices' locations, and therefore the conditions of batteries. Therefore, the thought of the interface has taken into consideration things where there's a requirement to watch multiple batteries conditions.
Figure 11 shows the most page for the web-based interface . A user must login before use the interface. The login page is made for a secure data handling, where user is required to key-in username and password.
Once the user has successfully login into the interface , the battery monitoring interface is displayed. The interface shows a map supported Google Maps application of the situation of registered battery monitoring devices marked by red markers. If the battery voltage condition of a tool is approaching cut-off discharge state, the red marker will bounce continuously at the situation . Clicking the bouncing red marker will show the knowledge of the device like location (latitude and longitude), battery voltage reading and measured time as shown in Figure 12. This information are often used for the user/admin to tell the users/clients about their battery condition especially during critical battery condition or degraded battery.
Furthermore, supported Figure 12, the upper left of the interface (red box) shows a variety window where the user/admin can choose Logout, View customer and Add customer. The user can prefer to sign off safely by clicking Logout. View customer is to look at the list of battery monitoring devices that are being monitored. Add customer is employed to feature new battery monitoring devices to be monitored. When View customer is clicked, the interface shows the list of battery monitoring devices as shown in Figure 13. The list

battery monitoring devices as shown in Figure 13. The list shows detail information about the registered battery monitoring devices, like user name, telephone number and users' address. Furthermore, the user can view battery information for every device. A registered data are often deleted by clicking Delete.
The developed battery monitor interface is meant to help user/admin monitoring degradation of batteries in order that notification are often sent to the user of A battery monitor .

3. CONCLUSIONS

The paper described the planning and development of an IoT-based battery monitoring system for electric vehicle to make sure the battery performance degradation are often monitored online. the target is to proof that the concept of the thought are often realized. the event of the system consists of the event of the hardware for the battery monitor and a web-based battery monitoring interface. The system is capable to point out information like location, battery condition and time via internet by incorporating GPS system to detect the coordinate and display it on the Google Maps application
Further modification are often done to enhance the system by adding more functions into the system. The system are often utilized in smartphones by developing smartphone application which will help user to watch battery and as A battery degradation reminder. so as to reinforce the web connection, Ethernet are often wont to get a far better internet connection compared to GPRS

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