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IoT Based Smart Battery Monitoring System Using NODEMCU and ThingSpeak

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Abstract

There are many research articles featuring the significance of batteries that require energy stockpiling for some reasons. Lead-Acid batteries are generally utilized in light of their dependability and strength. We chose Lead-Corrosive batteries since they are not difficult to screen and ordinarily accessible in Pakistan. This project will describe the Management System for Lead-Acid batteries, designed to monitor the battery's behavior. In order to accomplish this goal, the following system design objectives were initiated. Lead-Acid batteries are being used because of their increased cost-effectiveness compared to the other type of batteries available in the market all around us, domestically and commercially. They consist of two electrodes—a cathode and an anode—dipped in an electrolytic solution. The battery can withstand numerous charges and recharge cycles, but temperature significantly affects the battery's performance. High and low temperatures can impact the battery heavily in the long and short term. If not properly monitored, the extreme temperature will almost certainly result in battery failures. It would be easier to study the behavior of the battery and predict its lifecycle, charging, and discharging times, so we will deploy a mechanism to automate the log as mentioned above parameters to improve the battery payback period. The objective of this project is to provide different parameters of the lead acid battery, such that DoD (Depth of discharge), SoC (State of Charge), SoH (State of Health), current, voltage, time estimation (charging/discharging), temperature and water level. The project involves designing and developing a battery management System (BMS). It smartly monitors, controls, and manages battery health.

Keywords: Smart Battery Monitoring System; NODEMCU; Battery Health; Battery Management System (BMS).

1. Introduction

Many resources focus on renewable energy, like geothermal, hydro, solar, and wind energy, yet some renewable energy has some restrictions in producing energy. For example, Solar PV cell modules can only generate a limited amount of energy during the scorching sun. Smart microgrids are used to overcome these limitations (García Vera et al., 2019). Battery backups are also needed in smart microgrids when the source is not producing energy.

A systematic battery management system needs to be implemented to monitor the battery's performance continuously. The battery deterioration process should be diminished by molding the battery in an appropriate way by calculating its charging and releasing summary, much under different burden conditions. As a rule, the battery lifetime will be lessened whenever the battery is worked under a broad scope of warm conditions, especially in a high-beat current situation. Batteries are sheltered in spite of reports of blasts or disappointment. A battery monitoring system is required in order to monitor the operating system and performance of any Lead-Acid battery life, such as charge and discharge and many other processes. Battery monitoring system designed to measure device parameters

such as battery voltage, current, temperature, mixture solution level, etc. These parameters are allowed to be processed to monitor the two main states related to the health of any battery, the first is a state of charge, and the second is the depth of discharge of the battery. SOC gives the present state of the battery and gives powers to batteries to powerfully be charged and released at that level reasonable for battery life enhancement. In this way, SOC helps in the administration of batteries. The battery monitoring system is required to monitor the operational performances, system, and battery life, such as the discharge and charging process.

Human Machine Interface (HMI), the internet of things (IoT) based Battery Monitoring System, which is developed in this work, consists of a communication channel from and to the IED, data acquisition, Human Machine Interface (HMI). This Battery Management System aims to monitor the basic parameters to help gauge the battery's life and conditions. Incorporating Cloud and IoT into the Battery Management System will help analyze the data in real time. This could be best for the organizations to focus on the company's goals rather than self-monitoring the battery's parameters.

Problems Statement

Lead acid battery life and its usage is a threatening problem in Pakistan; Lead acid batteries are used domestically, commercially, and industrially. As solar energy is used widely, batteries are not monitored; they are usually broken and overused. The payback amount cannot be recovered in batteries. Batteries are hot; they can explode and also affect the charging and discharging cycles which could threaten the overall life of the battery. There's no correct methodology accessible to calculate its parameters.

Moreover, for UPS and solar panels installation, there is a requirement for a battery. According to the research, many electricity users partially and fully adopt renewable resources like solar energy. Most people are unaware of battery management protocols, so there may be issues that they cannot diagnose effectively. As indicated, the electricity shortfall is at its peak in the summer in Pakistan; many domestic users cannot use its power. There are the following fundamental problems:

- **Electrolyte Loss:** The electrolyte deficiency in a Lead acid battery occurs through gassing as hydrogen evades during charging and discharging. Venting causes the electrolyte to become more concentrated. Loss of electrolyte (Battery University, 2010) in Lead acid batteries is a recurring problem that is often caused by overcharging.

- **Sulphation:** Sulphation occurs when a battery is deprived of a full charge; it develops and stays on battery plates. Too much Sulphation can obstruct the chemical to electrical conversion and significantly impact battery performance (Crown Battery, n.d.). When your battery has a development of sulphates. The following can happen:

- better charging time
- excessive Temperature rise
- little running times for charge
- fully battery failure

- **Stratification:** Stratification occurs during discharge and recharges when the acid in the electrolyte neglects to blend in with the water and settles to the lower part of the battery case. Over time, the concentrated acid at the lower part of the cell can harm the battery plates and fundamentally (Bobby, 2014) diminish the Service life of the battery.

- **Separator Failure:** The initial function of the separator is to block physical contact between the anode and cathode. Separator Failure occurs when there is localized heat up, large-scale heat up, uncontrolled discharge, and penetration of the separator by foreign particles; thus, the separator is no more effective in preventing physical contact between anode and cathode. (Zhang et al., 2017).

In conclusion, while there are a few methods available that are as efficient as the one proposed in this

paper, they have not been innovative enough to identify and address the common problems faced in the power sector in Pakistan. Despite the gradual increase in power generation, administrative issues still pose a challenge. The proposed smart lead-acid battery monitoring system provides real-time monitoring of all parameters, unlike other systems that calculate them at once. Moreover, it allows users to access data anytime and anywhere, making it suitable for both domestic and commercial use in stabilizing the electrical shortfall in Pakistan.

2. Objectives

- Modeling of battery system using sensors.
- Programing of battery monitoring system using NodeMCU.
- Measuring the various parameters of the battery such as DOD (Depth of discharge), SoC (State of charge), maximum current and voltage, time estimation, acid temperature, and water level.
- Monitoring all the data with the help of ThingSpeak to aggregate, visualize, and analyze live data streams in the cloud.

3. Scope and Limitations

Lead acid batteries are made from abundant, low-cost materials and nonflammable water-based electrolyte that significantly minimizes environmental impact. Nevertheless, forecasts of the downfall of Lead acid batteries have focused on the health effects of lead. A large gap in technological progressions should be seen as an opportunity for scientific engagement to extensively diversify Lead acid batteries into power grid applications which currently lack a single energy storage technology with optimal technical and economic performance ("Forbes Search"), Lead acid batteries are widely used in our industries, markets, homes, etc., Solar energy is the cheap form of electricity, but it has its own demerits that it cannot produce electricity without solar radiations hence to compensate the issue there will be a need of a battery that can store enough solar energy for consumption in the absence of solar radiations. We need to monitor (EHS – Concordia, 2016) the parameters of the batteries that will help us maintain the battery, prolong the battery's lifetime, and save costs.

4. Significance

A quintessential design of the smart lead acid battery can facilitate its consumers as well as companies. The smart lead acid battery can track data of different parameters, and a user can check it anywhere in the world. The smart lead acid battery reduces human involvement in maintenance work. Commercializing the smart lead acid battery type is a step toward digitalizing the electrical power sector in Pakistan. The main advantages of the lead-acid battery (EHS – Concordia, 2016), are that it is a cheap power source, is almost fully recyclable, and is safe equipment.

5. Literature Review

Batteries are the most widely recognized electrical energy storage gadgets. Various academic projects revolve around the Lead Acid Battery. Lead-Acid batteries are being used because of their cost-effectiveness as compared to the other type of batteries available in the market (EHS – Concordia, 2016), all around us domestically and commercially. It is important to monitor the status of the battery and the other important parameters which can reduce the life of a battery. For this purpose, we read some research papers to learn how we will implement this in our project. We have taken help from YouTube to compare the sensors which we are using in our project for reliability and low cost. The followings are the important parameters:

- Temperature
- Water level
- State of charge, discharge, and health

For connecting each parameter, we have used Node MCU (ESP 32 module), which consists of 30 total pins and 12 Analog input pins, which is further connected with ThingSpeak, which is an IoT platform it collects data in the cloud ("ESP32 DevKitC Pinout," 2021) and analyzes and acts according to the given instructions.

Temperature of the Battery

The temperature has a major effect on the battery and its performance. High and low temperatures can impact the battery in the long and short run. If not properly monitored, extreme temperatures will almost certainly result in battery failures (Hutchinson, 2004). We picked up PT-100 (platinum-100) of three wires for temperature monitoring. The PT-100 of two wires has less accuracy (Process Parameters, 2019), which is why we have used the PT-100 of three wires, as we require high accuracy. Faults in a battery occur due to the connected circuit, which creates an impact on the battery's temperature (in degrees). Some of the common faults that cause in increasing the battery's temperature are poor ventilation, shorted cells, ground faults, and lost regulation of charging. To check the battery temperature ("How does a Pt100 sensor work?", n.d.), recognize a portion of these faults. Super-durable harm can happen if the battery temperature is not observed and appropriately controlled. In the best-case scenario, some mechanical mutilation or change in the synthetic arrangement will occur, bringing about an expensive battery replacement (Akcp.com). At most exceedingly terrible, the battery cell can detonate, spill synthetics, or cause a fire that could be amazingly destructive to the climate.

The other reason we choose this sensor is that it is waterproof and can work in the acidic nature of water. The size of the sensor is such that it can be used in batteries easily. It is also being used in the industry for temperature monitoring.

Other temperature measurement sensors are available in the market, such as thermistors, thermocouples, and RTDs. The comparison of the YouTube

videos shows that RTD gives the most accurate results. RTD slightly has the disadvantage of the cost as it is expensive compared to other temperature sensors. But we have neglected this factor to increase the reliability of our sensor (Resistance thermometer, n.d.)

CRITERIA	RTD	THERMOCOUPLE	THERMISTOR
Sensing range	(-260 to 850)°C	(-270 to 1800)°C	(-80 to 150)°C
Accuracy	±0.01°C	±0.5°C	±0.1°C
Linearity	Best	Good	Worst
Stability	Best	Low	Moderate
Sensitivity	Moderate	Low	Best
Cost	(1100 to 1400)Rs	(600 to 1200)Rs	(1100 to 1500)Rs
Specifically for	High accuracy	High temperature	Point sensing

Table. 1. Comparison between temperature sensors

The above parameters target the performance of the temperature sensor, and according to all the research papers, we found that the RTD is the best fit for temperature sensing you can see clearly from the above table of comparison. Planar obstruction temperature locator, RTD, can be produced with microelectronics preparing methods. In any case, the fabricated planar resistor requires an additional progression for change of the R_{0} reference opposition, R_{0} . In this paper, we have assessed the creation of nickel-RTD transducers for shrewd temperature sensors. The obstruction change step is avoided by applying the brilliant sensor idea, as the alignment bend can be put away in the Transducer Electronics Datasheet (TEDS). The RTDs have been manufactured by warm dissipation of nickel onto an alumina substrate. Alignment bends have been estimated as an element of temperature, and high linearity is noticed. Two unique models for molding and handling gadgets are examined.

A thermocouple is a temperature-estimating gadget comprising two disparate conductors that reach each other in at least one spot, where a temperature differential is capable by the various conductors (or semiconductors) (Pandya, 2016). It creates a voltage when the temperature of one of the spots contrasts with the reference temperature at different circuit pieces. Thermocouples are a generally utilized sort of temperature sensor for estimation and control (O'Grady, 2019). The primary impediment with thermocouples is exactness; framework mistakes short of what one degree Celsius (°C) can be hard to accomplish.

Water Level of The Battery

Water-level of the battery is one of the most important parameters of the battery because the low water level of the battery will make the solution more acidic that will cause the cell of the battery to be damaged, and it will reduce the charging capacity of the battery ("Battery basics", 2020) For this purpose; we have used an Ultrasonic sensor (HSSR04) (Lastminuteengineers.com). High-

frequency sound (ultrasound) waves are generated by an ultrasonic sensor. Echo is reflected when the ultrasound wave hits the object which is sensed by the receiver. It is usually used to determine the distance of the objects. The ultrasonic sensors are easy to use and not hazardous during operation for nearby objects, persons, equipment, or material. We learned that HS-SR04 is used widely for academic projects by searching the internet. Radar sensors are the best sensors in the market. Still, they are costlier than the ultrasonic sensor and partially available in the market, so that is why we picked up HS-SR04 to monitor the water level of the battery (Dahl, 2013).

PARAMETERS	INFRARED SENSOR	ULTRASONIC	RADAR SENSOR
Range	(10 -80) cm	(2-10) cm	(100) m
Beam width	75° C	30° C	15° C
Frequency	353THz	40KHz	80GHZ
Unit cost	1500pkr	300pkr	2500pkr

Table. 2. Comparison between water level sensors

Depth of Discharge of the Battery

The depth of discharge of the battery is an important parameter. Depth of discharge means the fraction or percentage available from the fully charged battery. By monitoring it, we can calculate the battery cycle. And also, as the fast discharge of the battery causes the capacity of the battery to reduce, so by monitoring it, we can save the battery from being fast discharged. By taking help from the website, we see that if the depth of discharge is 20%, it can give 4000 cycles, and similarly, if the depth of discharge is 50% and 100%, it will give 1600 and 800 cycles, respectively. So, we can conclude from this why it is important to monitor the depth of discharge of the battery ("Characteristics of lead-acid batteries", n.d.)

State of Charge of the Battery

The state of charge (SOC) represents the current capacity of any battery. The state of charge acts like a fuel gauge in any vehicle. It lets users know how long they can operate the load or machine before it runs out of energy. The quick charging of the battery can cause a decrease in the battery's lifetime, and also it affects the cells of the battery. Fast charging of the battery can also cause the temperature of the battery to be increased. Many methods can estimate the state of charge; the first is coulomb counting, which is the quickest and easiest method. So, you have only to calculate what percentage capacity (Ah) you took from the battery during a period of your time (it doesn't matter if it's variable or not) (Chang, 2013).

Battery State Calculation

The battery position is utilized as an information variable for the electrical administration, and moreover, it is a significant variable for the client. So, the battery condition may be utilized to gauge the crossing over time or the normal lifespan of the battery. The condition of the

battery may be improved, portrayed by the accompanying two variables: SOC and DOD both variables are not autonomous and impact the battery execution (for example, accessible limit). The relationship has appeared in SOC assurance much of the time Ah checking, including charge misfortune estimation, is used (Yao & You, 2020). Two or three good working strategies are known and utilized for SOH assurance. It relies firmly upon battery innovation, and the sort of use which strategy is useable shows a technique utilizing an ideal channel calculation for SOC and SOH assurance (Chiasson et al., 2003). Different strategies like fluffy, bunching, and neural systems were additionally evolved and tried.

Microcontroller (NODEMCU ESP-32)

We have used NODE MCU ESP-32 instead of another micro-controller chip to extract our information from the sensors and show the result on the result window or screen (Veit & Johra, 2021). By comparing it with another microcontroller like Arduino, we found that Arduino doesn't have a Wi-Fi chip built-in, we can add an external Wi-Fi module ("The Internet of Things with ESP32", n.d.), but it will increase the complexity of the circuit Arduino was originally made for the professional users. At the same time, the ESP32 module is done for DIY projects because it is easy to use, and the most critical factor is its cheaper than Arduino. There are products with ESP32 and ESP8266 inside. And it also doesn't have more analog pins as we required, so by looking at all of these things, we have chosen NODE MCU ESP-32. There are also other models of NODE MCU ("NodeMCU ESP32", n.d.), like ESP-8266; we have considered ESP-32 because ESP-8266 has only one analog input pin. It will link our information from the screen to the cloud. For this purpose, we are using ThingSpeak, which will show the parameters information of the battery on the cloud or on a website that can be accessed from anywhere and at any time (Kumar et al., 2020)

CRITERIA	ESP32	ESP8266	AURDUNIO UNO	RASPBERRY PI
Core count	Single/dual-core	Single-core	Single-core	Dual-core
Arquitectura	32 BITS	32 BITS	32 BITS	32BITS
Clock	160MHz	80MHz	16MHz	133kHz
Wi-Fi	Built- in	Built-in	Not supported	Not supported
Ram	512KB	160Kb	2Kb	264kb
Gpio	36	17	14	26
Ade	18	1	6	3
Dac	2	0	0	0
Mcu voltage	3.3VDC	3.3 VDC	5VDC	3.3VDC

Table. 3. Comparison between microcontrollers

Internet of Things (ThingSpeak Platform)

The ThingSpeak platform is a service that provides IoT analytics capabilities. We have utilized this platform due to

its ability to store data in the cloud, analyze and visualize it, and act upon given instructions. By using this software, we are able to instantly visualize data collected by devices on ThingSpeak, such as the ESP8266 daily task (2018).

IoT devices and sensors have the potential to manage a network of physical objects and can provide observations across multiple layers of the network and infrastructure utilized by customers. With the help of data hardware version, code version, and location, one can collect information beyond what can be obtained from an on-site monitor alone. It is important to look beyond just the sensor data and consider how the data is captured and transferred, including timestamps and error logs, in order to enhance network performance (The role of cloud computing, n.d.).

PCB Designing and Dip Trace

For our circuit planning and carrying out the reason, we have utilized PCB (printed circuit board). First and foremost, we were attempting to carry out the hardware in Vero board; however, it has some marginal inconveniences, so to ad-lib our work as suggested by (Agarwal, 2017), we need to embrace PCB, yet it was a simple assignment at all it is on the grounds that we need to plan our PCB format on a product. Likewise, the disarray became which is to choose which programming we picked for our plan. We have analyzed a lot of programming; however, the interface of the plunge follows was intriguing and simple to utilize ("Dip Trace", n.d.). We have seen numerous recordings of the plunge following and working on the PCB plan on YouTube (Hamilton, 2013).

Liquid Crystal Display (LCD 20*4)

There are 20 characters for each line and 4 such lines in a 20x4 LCD. Each character is shown in a 5x7 pixel grid in the LCD. There are two registers in this LCD, Command, and Data. This is a standard HD44780 regulator LCD. I2C Module has an inbuilt PCF8574 I2C chip that changes I2C sequential information to resemble information for the LCD show. These modules are, as of now, provided with a default I2C address of either 0x27 or 0x3F. To figure out which adaptation you have, check the black I2C connector board on the underside of the module.

Efficiency of Battery

Battery efficiency is the measure of energy you can get out of a battery relative to the amount of energy that is put into the Lead-Acid battery is not always 100% at storing electricity - you may by no means get out as tons as you install while charging. Overall, a performance stage of 85% is frequently assumed. The performance will depend upon different factors; however, we are mainly focusing on the charging or discharging of the temperature. The better the charge of fee or discharge, the decrease in the performance of the battery. The country of fee of the battery will likewise have an impact on fee effectiveness. With the battery at ½ of the fee or

less, the fee performance can be over 90%, losing closer to 60% while the battery is above 80% charged. However, it has been observed that if a battery is best partly charged, performance can be decreased with every fee. If this case persists (the batteries by no means attaining complete fee), the battery's life can be reduced.

In this project, we are trying to monitor SOC, SOD, and temperature with immediate effect with rightly distributed intervals and the intensity from under controlled situation to the alarming situation; we are incorporating buzzers and lead for effective human interactive indications; hence we can counter the problems earlier, and by this way, we can ensure prolong battery's life and efficiency.

Temperature	Life of the battery with monitoring(Years)	Life of battery without monitoring(Years)	Comments
25°C	8<x<12	5<x<9	Optimum Temperature of the battery
33°C	4<x<6	2.5<x<4.5	Should be monitored by sensors
41°C	2<x<3	1.25<x<2.25	This indicates there is a fault in battery
49°C	1<x<1.5	x< 1 year	Battery should be replaced

Table 4. Life of batteries with and without monitoring

Human Machine Interface

HMI is used in ventures and forces plants to control and screen machines. An exceptionally normal HMI that you frequently experience is ATM. It is hard to have a nice, robotized measure in organizations without an HMI; usually, HMI is in a sort of screen like a PC contact screen. It tends to be put in charge boards where the Maintenance faculty can work without much of a stretch work and screen it. HMI shows different boundaries on screen at a time, where it can show an extremely exact degree of temperature, water level, and the ostensible voltage of the battery. The engineering professional has to design each parameter and do the coding parts; we only can utilize it where a large need of batteries is required to become economical for the overall production.

The GLG Toolkit incorporates the GLG Graphics Builder - a graphical editorial manager with a point and snaps interface for making dynamic HMI and SCADA screens and charts. With the Graphics Builder, engineers can make elaborate interaction control and framework observing drawings, characterize dynamic conduct, and append continuous information sources. Various pre-assembled parts and ranges are accessible as building blocks in the Builder. A discretionary GIS Map part is additionally accessible.

Block Diagram

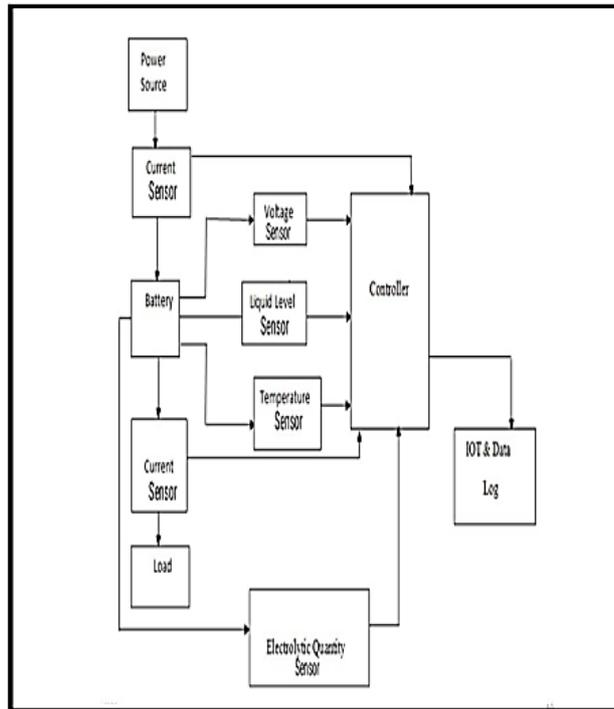


Fig. 1. Block Diagram

6. Methods

Gathering information from the literature review and utilizing the PT100 RTD temperature sensor, we have created a circuit diagram to connect it to the NodeMCU (esp-32). Secondly, a circuit diagram was drawn on Dip Trace software to obtain the schematic diagram, which was then converted into a PCB design for routing and printing. The third step consisted of imprinting.

the PCB design onto the PCB board, drilling the holes, inserting the components, and then soldering them to the board. Our next task was to acquire data through the Arduino IDE, connecting the circuitry to the NodeMCU and programming it accordingly. After the PT100 measured the battery's temperature, we observed the increment in temperature. The objective flow diagram of our process is given as follows:

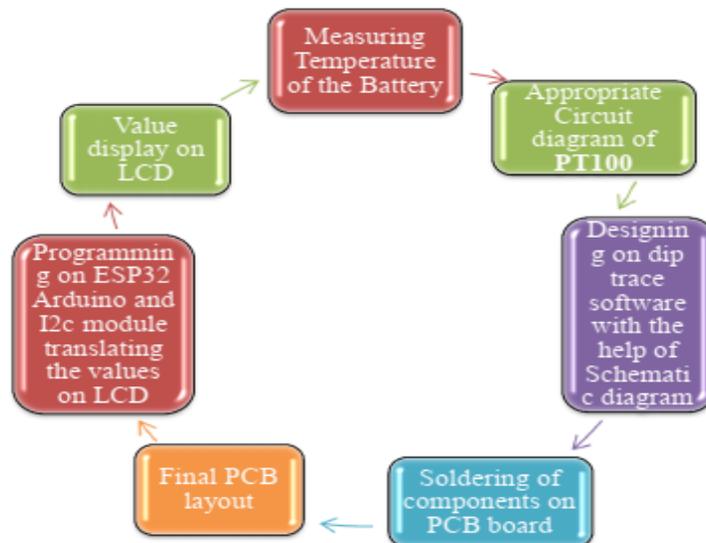


Fig. 2. Process Flow Chart

Circuit Diagram

Creating a circuit diagram to connect the PT100 (RTD) temperature sensor to the NodeMCU (EPS-32) to enable

digital visualization of the analog data is necessary. Using the necessary components, the circuit can be designed to connect the sensor and NodeMCU.

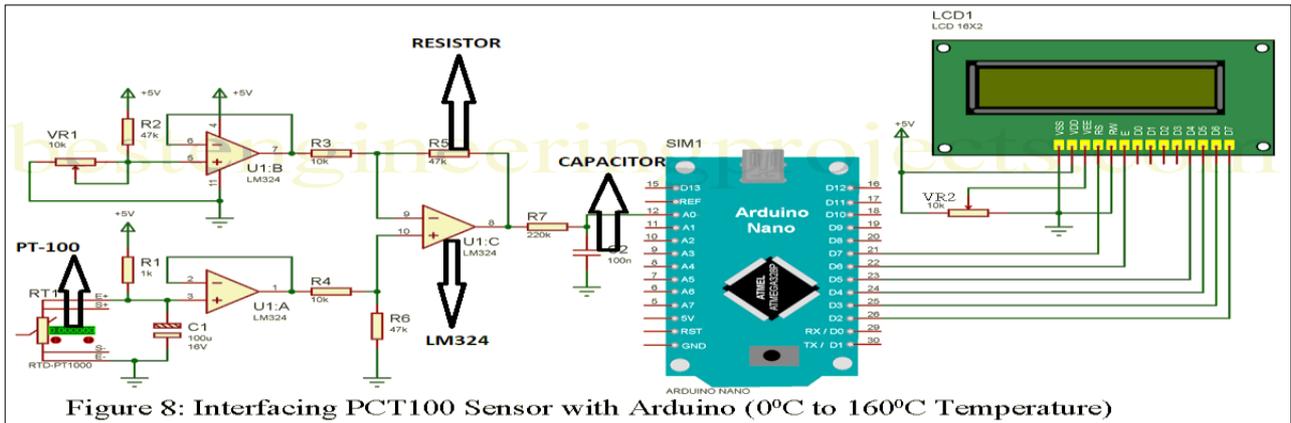


Fig. 3. Modelled Test System

Measuring the Acid Level of the Battery

Measuring a battery's acid level requires using an ultrasonic sensor, such as the HCSR04. Table 2 of the literature review shows that this sensor is the most suitable for our project due to its size and cost. The ultrasonic sensor works by sending out a sound wave at a frequency above the range of human hearing. The sensor's transducer acts as a microphone to receive and send the sound signal. The four pins of the HCSR04 (ground, trigger, VCC, and echo) are connected to the Node MCU through jumper wires to digitally represent its results on the screen, allowing the user to monitor the acid level of the battery easily.

Measuring The State of Charge of The Battery

The State of Charge is the third most essential metric (SoC). The percentage of a battery's rated capacity is known as the SOC. In other words, SOC is the ratio of the energy saved in the battery to the entire amount of energy that can be saved. If the rated capacity is expressed in coulombs or Ah, the RC should also be calculated in those units. SOC can be calculated using the energy storage capacity when the remaining or rated energy content is measured in watt-hours. The SOC indicates the battery's present state and allows it to be charged and drained safely at a level that extends its life. The battery becomes less efficient as the temperature rises, and the cells become damaged. SoC gives the user access to functionality that isn't present in the battery or that might be required in a fully negative feedback circuit to ensure optimal charging control. There are multiple estimation methods SoC; the first is coulomb counting, Which is the quickest and most straightforward method. So, all you have to do now is figure out what percentage capacity (Ah) you drained from the battery over a while (varying or not).

Measuring the Depth of Discharge of the Battery

A battery's depth of discharge (DOD) defines the charge remaining in the battery. Depth of Discharge can be

stated as the ratio between the capacity that is discharged from a fully charged battery and the total battery capacity. The DOD is expressed in percentage. This is because each battery always provides more volts when the battery is 100% charged and low voltage when the battery is empty. A fully charged 12-volt lead-acid battery usually provides 12.7V power. If the lead-acid battery is only 20% left, it will only deliver 11.6V. The batteries we used in the voltage range have lower electrical power than lithium-ion batteries (HABdi et al., 2017). The life cycle is the number of charge/discharge cycles that any battery can maintain in its useful life. If you regularly discharge batteries at a lower percentage, there will be more efficient cycles than when you discharge the battery to its higher DOD. A standard lead-acid battery offers 200 to 300 discharge cycles ("What is Depth of Discharge", 2020).

The second thing that affects an acid-powered battery's useful life is how you look at it. Batteries in a tropical area (above 30 degrees C) may be extremely hot, reducing the overall battery life. Extremely cold temperatures also have a negative effect on the battery, as it has to work hard and have a high charging capacity. So the conclusion of the above statement is to place batteries at room temperature to help maximize the useful life of the Lead-Acid battery.

Measuring Voltage of the Battery

Voltage in any battery is defined as one of the most important parameters for monitoring. It tells the user that any cell of the battery is getting damaged, and it will cause the other cells of the battery to be damaged as the cells of the lead-acid batteries are connected in series; other if anyone cell gets damaged, it will cause the other cells of the battery to be damaged too and it led the battery to lose its capacity of storing electricity. Every battery comes with a certain voltage and capacity rating. There are cells inside each battery that are connected in series to create voltage levels, and that battery-rated voltage is the nominal voltage at which the battery is supposed to operate. The unit for measuring battery capacity is ampere-hour, denoted as

(Ah). The energy capacity is the battery rated voltage in volts (v) multiplied by battery capacity in ampere-hours resulting in total battery energy capacity in watt-hours.

7. Results

Temperature of the Battery

The result shows the temperature variation given by the heating material by us to ensure that the PT-100 sensor is working perfectly or not. It provides the temperature in (OC).

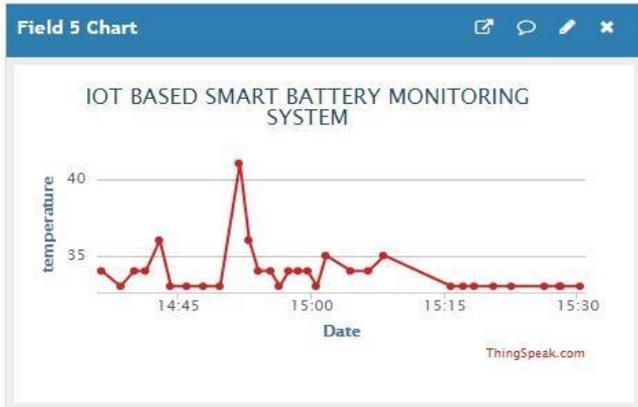


Fig. 4. Temperature of the battery

Liquid Level of the Battery

The demonstration gives the result of our ultrasonic sensors; here, we do the same job as before to ensure the proper working of the sensor. We move our sensor up and down with the reference ground to check it.

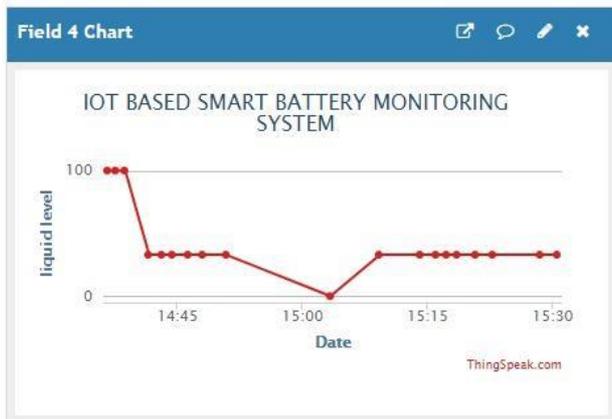


Fig. 5. Liquid level of the battery

State of Charge of the Battery

Here SOC means the state of charge where the graphical reading determines the charging of a battery with charging current provided by the power bang. The below battery is slightly aged, so the results vary, but you can see from this figure that the SOC graph increases with the charger's increase, and the SOC decreases with the increase in time due to the load.

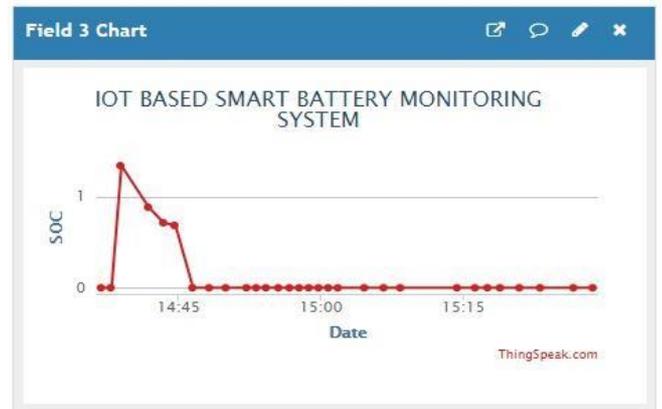


Fig. 6. State of charge of the battery

Depth Of Discharge of the Battery

DOD forms this figure varying because of the change of the loads [note: here we have used filament bulb and light stick as a load to observe the behavior of the DOD of our battery]. And it is totally the opposite of the above-stated SOC.

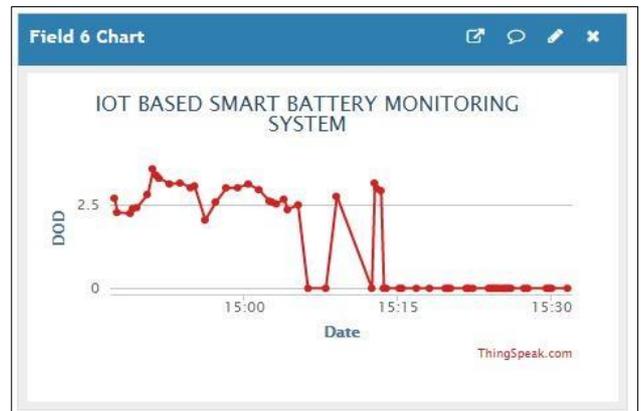


Fig. 7. Depth of discharge of the battery

Voltage of the Battery

The voltage here revolves around the 12v analog values, which you can refer to in Appendix B (Battery specification). We have programmed it to take some average values of the battery and display them on LCD.



Fig. 8. Voltage of the battery

Battery Percentage

The below result shows how much the battery is charged.

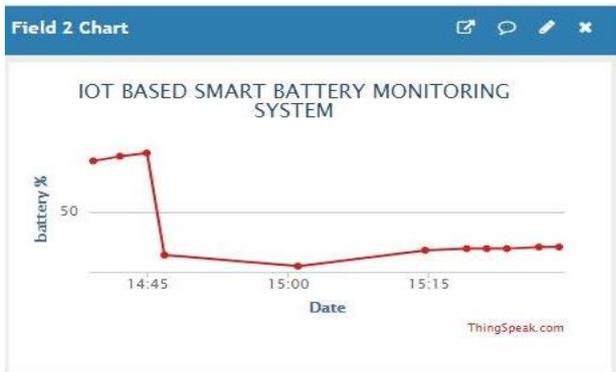


Fig. 9. Battery charging discharging percentage

All Parameters of the Battery



Fig. 10. All parameters of the battery

8. Conclusion

(IoT-based smart battery monitoring system using NodeMCU and ThingSpeak) the intent to provide a much-

protected atmosphere around the battery, which can help in having a battery. Therefore, it becomes essential for the detection of basic problems like Electrolyte Loss, Sulphation, Stratification, Separator Failure, and many others; now we have to counter these problems, so we implemented objectives as follows DOD (Depth of discharge), SoC (State of charge), maximum current and voltage, time estimation and acid's temperature and water level. To solve the above-stated problems, we have found a solution. If we consider Pakistan's high demand for battery monitoring systems, it is BMS. In our BMS, we incorporate all the factors that can be hazardous for human life or the environment. We used a temperature sensor (PT-100 three wired), and an ultrasonic sensor (HCSR04), to measure the state of charge, depth of discharge, and the battery's nominal voltage. But to convert it to a single monitoring system, we choose PCB, in which we select dip trace software because of its easy interface and configurations. It is free software best for academic work. Now, we have used ESP 32 microcontroller; to conclude all the above parameters result in a single platform, we select ThingSpeak; it is an IoT-based software used to aggregate, envision, and investigate live information streams in the cloud. We likewise empower putting away these values in the cloud, with the goal that it tends to be recovered later for investigation and can be seen whenever on our cell phone.

9. Future Recommendations

Battery Cell Damage

Subsequently carrying out this proposed idea, we realized that there is further room for modifications in IoT-based smart battery monitoring systems. In the future, it very well may be useful to recognize the specific cell harmed substitution due to if any one cell is harmed, it will cause the whole battery to be squandered. We can do this by observing the voltages of every battery cell, and by noticing the voltage of the cell, we can ensure what cell there is a voltage drop, and the cell is getting harmed; by replacing it, we can make our battery keep going long as the cells in the battery are in series with one another so that if one cell gets harm, its effect can create the other cell can harm as well.

GSM Module

Utilizing a GSM Modem, we can gather this raw information and send it as an SMS message to cell phones. With the assistance of cell phones, information can be gathered and seen even from distant areas where Internet association is powerless. This model can likewise be stretched out for different battery observing frameworks. We likewise empower putting away these values in the cloud, so they very well may be recovered later for investigation and can be seen whenever on our cell phone.

Additionally, by using the GSM (Global System for Mobile Communications) module, we can free our battery from any Wi-Fi relationship in the region as GSM (Global System for Mobile Communications) module can give the

organization associated with it. The disadvantage with the GSM is that we need to make it PTA embraced to get it into the working condition in Pakistan. The cost of the Initial License Fee from PTA support is about PKR 5000 for each module, and Annual License Fee is around 1.5% of yearly gross income with the exception of where a ban is allowed ("Fee Schedule.", n.d.). Regardless, in the wake of getting it upheld from the PTA we can enjoy many benefits.

Human Machine Interface (HMI)

We use HMI in industries and power plants to control and monitor machines. A very common HMI that you often encounter is ATM. It is difficult to have a decent robotized measure in businesses without an HMI. Ordinarily, HMI is in a type of screen similar to a PC contact screen. It can be placed in control panels where the Maintenance personnel can easily operate and monitor it.

HMI shows various parameters on screen at a time, showing a very precise temperature, water level, and the battery's nominal voltage. From this, you can easily analyze the data and make appropriate decisions. They can even connect to the PLCs to exclude laptop use. HMI consists of two main parts: an operation panel and a monitoring screen (Friansa et al., 2017), but it's not easy as you think; firstly, the engineering profession has to design each parameter and do the coding parts we only can utilize it where the large need of batteries are required to become economical for the overall production.

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