Design and Analysis Of Battery Optimization in Electric Vehicles

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Abstract

The IoT-Based Battery Monitoring System for Electric Vehicles is developed to improve battery safety,performance, and longevityby integrating real-time sensing withI oT-enabled remote monitoring. The system uses an Arduino as the main controller, interfaced with voltage, current, and temperature sensors to continuously measure the battery's electrical and thermal parameters.A 12V battery powers the system,with relays controlling connected loads such as multiple mobile chargers and a DC motor, while LEDs indicate operational status. The Node MCU module uploads sensor data to a cloud platform, enabling users to remotely monitor battery health and performance through an online dashboard or mobile application.In the event of abnormal conditions, such as over-voltage, excessive current,or over heating,the system triggers a buzzer for immediate alerts, ensuring timely intervention to prevent damage and enhance electric vehicle reliability**.**

keywords: Baterry Monitoring, Electric Vehicles,Thermal parameters,Node MCU.

I. INTRODUCTION

Electric vehicles (EVs) rely heavily on the efficiency and safety of their batteries, making real-time monitoring of battery parameters crucial for optimal performance and longevity. Traditional battery management systems often lack remote monitoring capabilities, limiting the ability to quickly detect and respond to abnormal conditions such as over-voltage, overcurrent, or overheating. To address these challenges, an IoT-based battery monitoring system has been developed, integrating sensors and IoT technology for continuous supervision of battery health. Using an Arduino microcontroller as the central processing unit, the system measures electrical and thermal parameters via voltage, current, and temperature sensors.A Node MCU module enables real-time data upload to a cloud platform, allowing users to remotely track battery performance through a nonline dashboard or mobile application.The system also incorporates relays, LEDs, and a buzzer to manage connected loads, indicate operational status, and provide immediate alerts during abnormalconditions. This approach ensures safer battery operation, enhances the reliability of electric vehicles, and facilitates timely preventive maintenance.

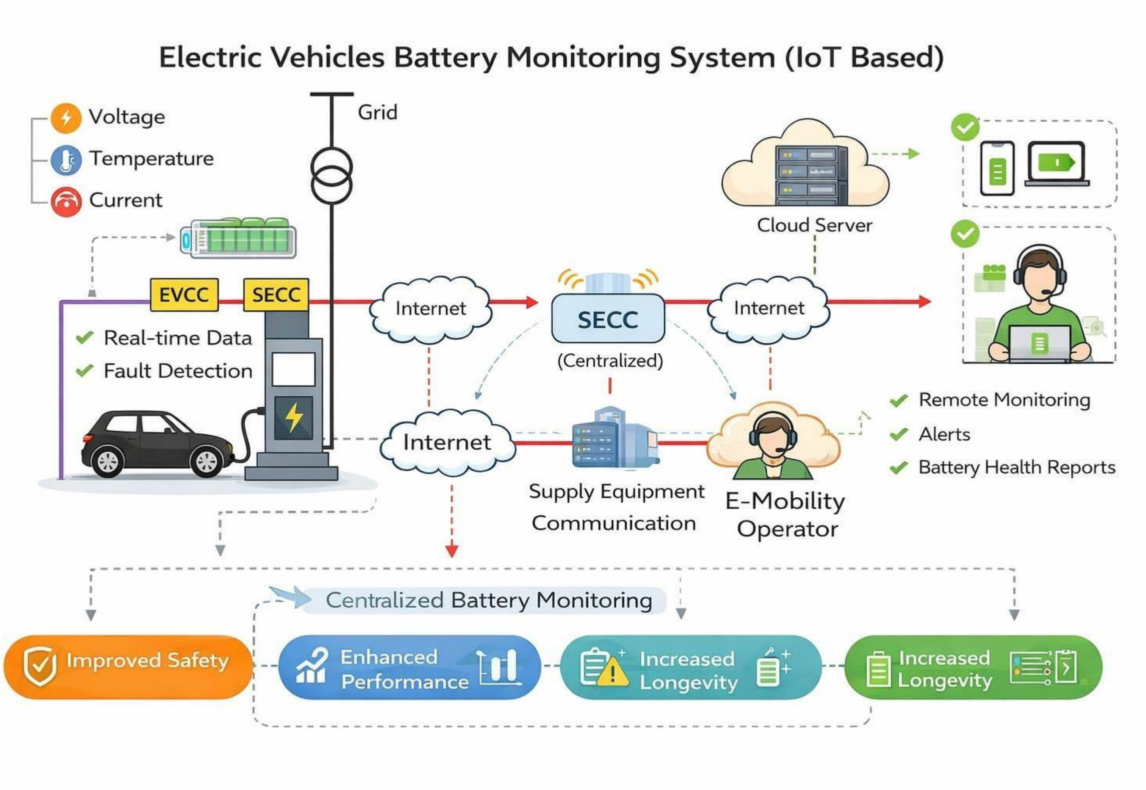


Fig.1.EV Battery Monitoring System

II. EXISTING METHOD:

Traditional electric vehicle battery monitoring systems often rely on manual inspection or basic onboard diagnostics, which provide limited real-time insights into the battery's condition. These systems may only alert the driver through dashboard indicators when a fault becomes severe, lacking early warning mechanisms. Additionally, they typically do not integrate IoT capabilities, making remote monitoring impossible. This can lead to delayed detection of issues such as overheating, voltage fluctuations, or overcurrent conditions, resulting in reduced battery life, unexpected breakdowns, and potential safety hazards.

Existing electric vehicle battery monitoring systems, commonly known as Battery ManagementSystems(BMS) ,are designed to ensure the safe and efficient operation of the battery pack by continuously monitoring key parameters such as voltage, current, and temperature. These systems use sensors and a microcontroller to collect and process data, while protection circuits safeguard the battery against conditions like overcharging, deep discharge, and short circuits. Additionally, basic functions such as cell balancing are implemented to maintain uniform charge levels across all battery cells, thereby improving battery performance and lifespan. However, traditional BMS models operate mainly within the vehicle and rely on limited onboard diagnostics, providing only basic information to the driver through dashboard indicators.They lack advanced features such as real-time remote monitoring, predictive fault detection, and IoT integration.

The existing battery monitoring systems used in electric vehicles areprimarily designed to provide basic safety and operational control of the battery pack.These systems continuously measure important parameters such as cell voltage, current flow, and temperature using embedded sensors, and the collected data is processed by acentral controlunit to ensure the battery operates within safe limits. In addition, conventional systems include protective mechanisms to prevent faults like overvoltage, undervoltage, overcurrent, and overheating. However, these traditional models have several limitations, as they are mostly confined to in-vehicle monitoring and do not support advanced communication technologies. The absence of IoT integration restricts real-time data sharing and remote access, making it difficult to monitor battery performance from external platforms. Furthermore, these systems generally lack intelligent algorithms for early fault prediction and advanced diagnostics, which reduces their ability to identify potential issues before they become critical. Consequently, this can result in inefficient battery usage, decreased lifespan, increased maintenance requirements, and higher risks related to safety and reliability.

III. PROPOSED METHOD

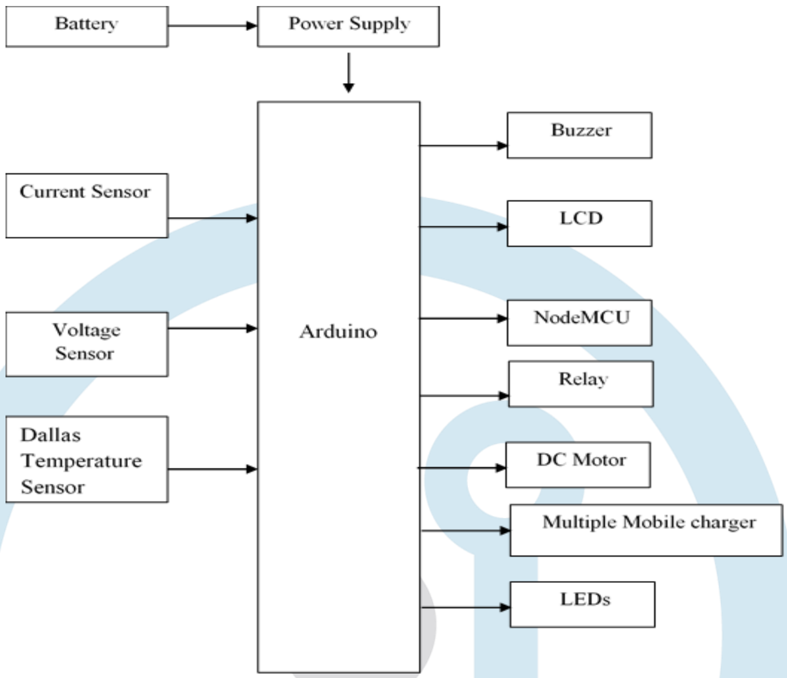


Fig.2.Proposed Method

The proposed IoT-Based Battery Monitoring System enhances battery safety and performance by integrating advanced sensors with cloud-based remote monitoring. Using an Arduino as the central controller,voltage,current,and temperature sensors continuously track battery parameters, while a NodeMCU module uploads real-time data to a cloud platform for remote access via a web or mobile interface. In the event of abnormal conditions like overheating, high current, or low state-of-charge, the system triggers a buzzer for instant alerts, enabling timely intervention. This approach ensures proactive maintenance, improved battery longevity, and enhanced operational reliability of electric vehicle.

IV.Hard ware Components:

Arduino:

Arduino Uno is a very valuable addition in the electronics that consists of USB interface, 14 digital I/O pins, 6 analog pins, andAtmega328 microcontroller. It also supports serial communication using Tx and Rx pins.There are many versions of Arduino boards introduced in the market like Arduino Uno, Arduino Due, Arduino Leonardo, Arduino Mega, however, most common versions are Arduino Uno andArduino Mega. If you are planning to create a project relating to digital electronics,embeddedsystem,robotics,orIoT,thenusingArduinoUnowouldbethebest, easy and most economical option.

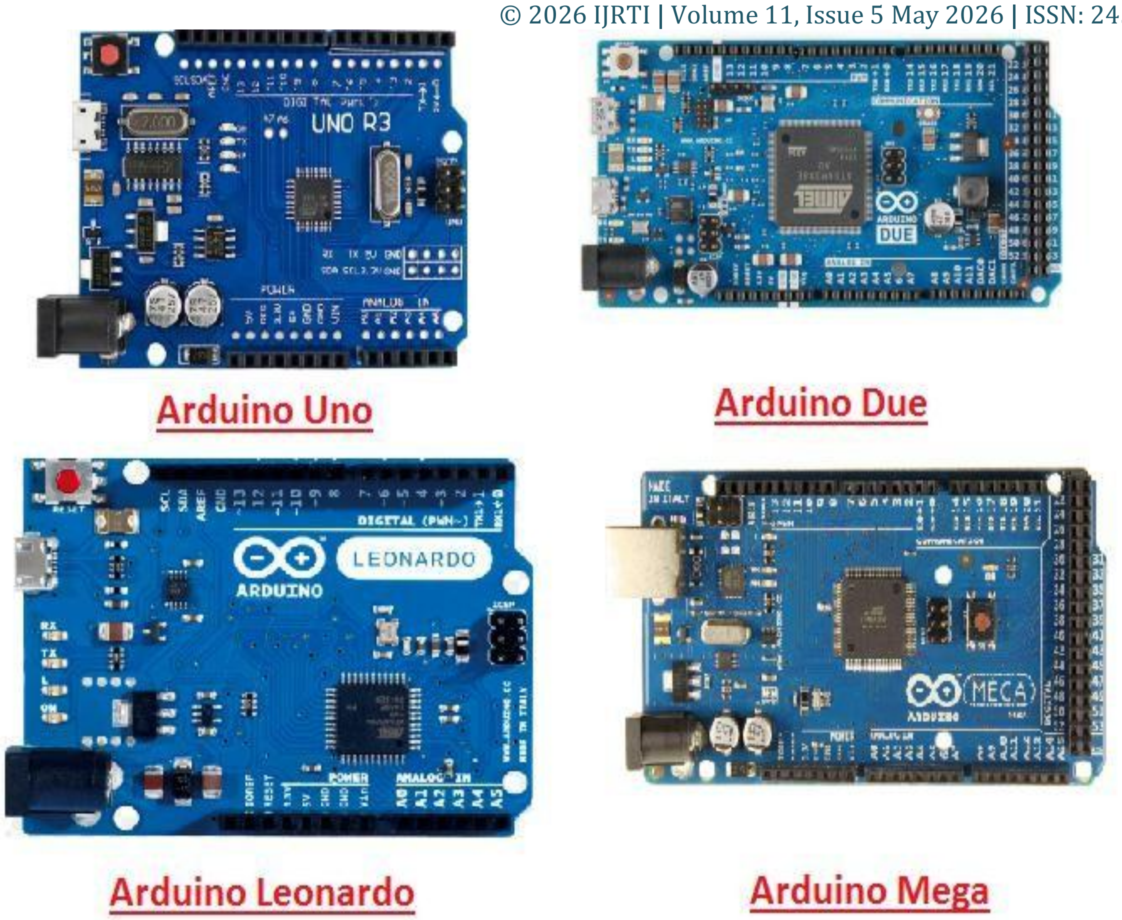


Fig.4.ArduinoMicrocontroller

It is an open-source platform, means the boards and software are readily available and anyone can modify and optimize the boards for better functionality.The software used for Arduino devices is called IDE(IntegratedDevelopmentEnvironment) which is free to use and required some basic skills to learn it. It can be programmed using C and C++ language.

Atmega328 microcontroller is placed on the board that comes with a number of features like timers, counters, interrupts, PWM, CPU, I/O pins and based on a 16MHz clock that helps in producing more frequency and number of instructions per cycle.

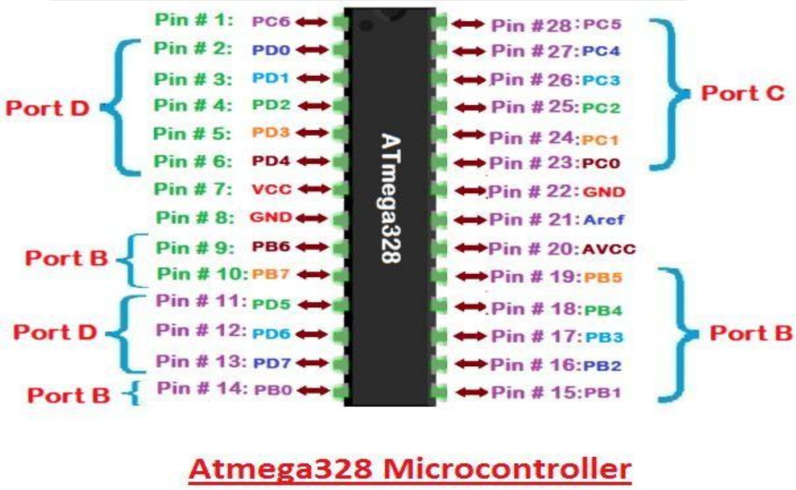


Fig.5.Atmega328 Microcontroller

It is an open source platform where anyone can modify and optimize the board based on the number of instructions and task they want to achieve.

This board comes with a built-in regulation feature which keeps the voltage undercontrol when the device is connected to the external device.Reset pin is added in the board that reset the whole board and takes the running program in the initial stage. This pin is useful when board hangs up in the middle of the running program; pushing this pin will clear everything up in the program and starts the program right from the beginning.There are14 I/Odigital and 6 analog pins incorporated inthe board that allows the external connection with any circuit with the board.These pins provide the flexibility and ease of useto the external devices that can be connected through these pins. There is no hardand fast interface required to connect the devices to the board.Simply plug the external device into the pins of the board that are laid out on the board in the form of the header.

The 6 analog pins are marked as A0 to A5 and come with are solution of 10bits.These pins measure from 0 to 5V, however, they can be configured to the high range using analog Reference () function and AREF pin.Arduino Uno is based on AVR microcontroller called At mega 328.This controller comes with 2KB SRAM, 32KB off lash memory,1KB of EEPROM. Arduino Board comes with 14 digital pins and 6 analog pins. ON-chip ADC is used to sample these pins. A16 MHz frequency crystal oscillator is equipped on the board. Following figure shows the pinout of the Arduino Uno Board.

LCD:

LCD (LiquidCrystalDisplay) is the innovation utilized in scratchpad shows and other littler PCs. Like innovation for light-producing diode (LED) and gas-plasma, LCDs permit presentations to be alot more slender than innovation for cathode beamtube (CRT). LCDs expend considerably less power than LED shows and gas shows since they work as opposed to emanating it on the guideline of blocking light.

A 16x2 LCD implies 16 characters can be shown per line and 2 such lines exist. Each character is shown in a lattice of 5x7 pixels in this LCD.There are two registers in this LCD, in particular Command and Data.

The directions given to the LCD are put away by the order register.An order is a direction given to LCD to play out a predefined assignment, for example, introducing it, clearing its screen, setting the situation of the cursor, controlling presentation, and so forth. The information register will store the information that will be shown on the LCD. The information is the character'sASCII incentive to show on the LCD.Two types of signals are accepted by LCD,one is data and one is control.The LCD module recognizes these signals from the RS pin status. By pulling the R/W pin high,data can now also be read from the LCD display. Once the E pin has been pulsed, the LCD display reads and executes data at the falling edge of the pulse, the same for the transmission case.

There are two RAMs for LCD displays, namely DDRAM and CGRAM. DDRAM registers the position in which the character would be displayed in theASCII chart. Each DDRAM byte represents every single position on the display of the LCD.

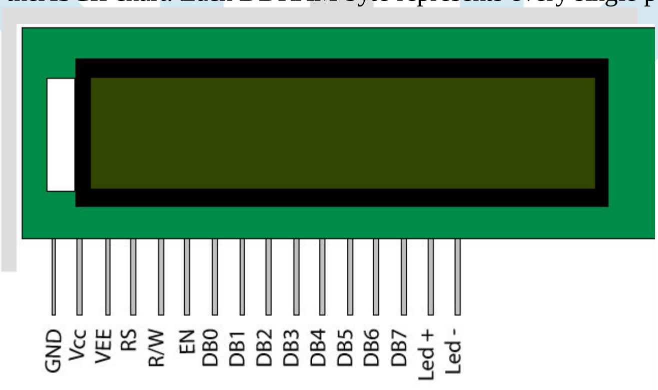


Fig.6. LCD Pin Diagram

VOLTAGE SENSORS

Thissensorisusedtomonitor,calculateanddeterminethevoltagesupply.This sensor can determine the AC or DC voltage level. The input of this sensor can be the voltage whereas the output is the switches, analog voltage signal, a current signal, an audible signal, etc. Some sensors provide sine waveforms or pulse waveforms like output & others can generate outputs like AM (AmplitudeModulation), PWM (PulseWidthModulation) or FM (Frequency Modulation).

Table.1.Voltage sensors

InputVoltage(V)	0to25
VoltageDetectionRange(V)	0.02445to25
AnalogVoltageResolution(V)	0.00489
Length(mm)	28
Width(mm)	14
Height(mm)	13
Weight(gm)	4

CurrentSensor:

Current flowing through a conductor causes a voltage drop.The relation between current and voltage is given by Ohm's law. In electronic devices, an increase in the amount of current above its requirement leads to overload and can damage the device.

Measurement of current is necessary for the proper working of devices. Measurement of voltage is Passive task and it can be done without affecting the system. Whereas measurement of current is an Intrusive task which cannot be detected directly as voltage

Table.2.Current Sensors

Currentsensorchip	ACS712ELC-20A
OperatingVoltage(V)	4.5V~5.5VDC
MeasureCurrentRange	-20~+20A
Sensitivity	100mV/A
Length(mm)	32
Width(mm)	13
Height(mm)	13.5
Weight(gm)	5

DC MOTOR

A direct current (DC) motor is a type of electric machine that converts electrical energy into mechanical energy. DC motors take electrical power through direct current, and convert this energy into mechanical rotation. DC motors use magnetic fields that occur from the electrical currents generated, which powers the movement of arotorfixed within the output shaft.The output

torque and speed depends upon both the electrical input and the design of the motor.

Light Emitting Diodes (LEDs)

The Light emitting diode is a two-lead semiconductor light source. In 1962, Nick Holonyak has come up with an idea of light emitting diode, and he was working for the general electric company. The LED is a special type of diode and they have similar electrical characteristics of a PN junction diode. Hence the LED allows the flow of current in the forward direction and blocks the current in the reverse direction.

Node MCU:

Node MCU is an open-source firmware and development kit that plays a vital role in designing your own IoT product using a few Lua script lines. Multiple GPIO pins on the board allow you to connect the board with other peripherals and are capable of generating PWM, I2C, SPI, and UART serial communications.

•The interface of the module is mainly divided into two parts including both Firmware and Hardware where former runson the ESP8266 Wi-Fi So Candlateris based on the ESP-12 module.

The firmware is based on Lua–A scripting language that is easy to learn, giving a simple programming environment layered with a fast scripting language that connects you with a well-known developer community.And opensource firmware gives youthe flexibility to edit, modify and rebuilt the existing module and keep changing the entire interface until you succeed in optimizing the module as per your requirements.

•USB to UART converter is added on the module that helps in converting USB data to UART data which mainly understands the language of serial communication.

Instead of the regular USBport, Micro USBport is included in the module that connect sit with the computer for dual purposes: programming and powering up the board.

•The board incorporates status LEDthat blinks and turns offimmediately, giving you the current status of the module if it is running properly when connected with the computer.The ability of module to establish a flawless WiFi connection between two channels makes it an ideal choice for incorporating it with other embedded devices like Raspberry Pi.

Node MCU Pinout:

NodeMCUcomeswithanumberofGPIOPins.FollowingfigureshowsthePinoutofthe board. There is a candid difference between VIN and VU where former is the regulated voltage that may stand somewhere between 7to12V while later is the power voltage for USB that must be kept around 5 V.

V.RESULTS

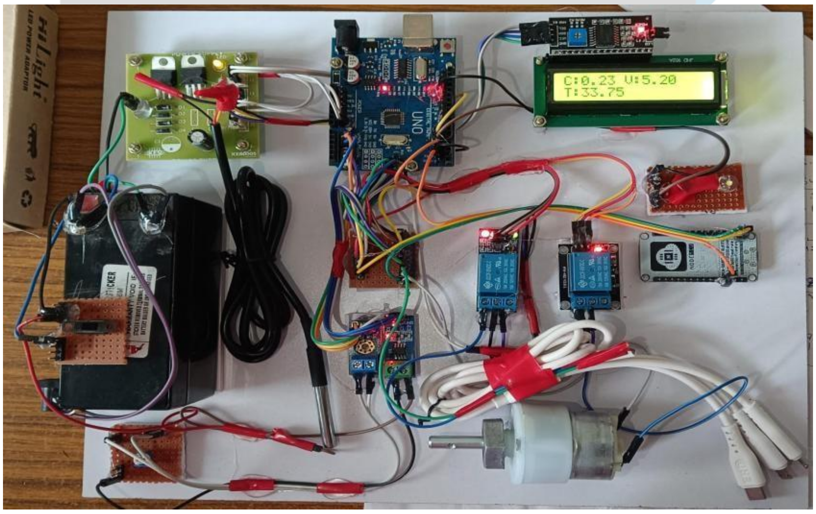
Thesystemsuccessfullymonitorsbatteryvoltage, current, andtemperatureinrealtime.

SensordataisdisplayedontheLCDscreencorrectly.Dataisalsosenttothecloudusing NodeMCU,andcanbeviewedonmobileorcomputer.Whenabnormalconditionsoccur Buzzer gives alert Relay disconnects the load. The system responds quickly to changes in battery condition.

“The system successfully monitors voltage, current, and temperature in real time and sendsdatatothecloud.Itgivesalertsduringabnormalconditionsandprotectsthebattery. Temperature monitoring is very important because high temperature can damage the battery, so the system detects overheating and prevents failure.”

A temperature sensor (like DS18B20) measures battery temperature It sends data to Arduino

Arduino checks whether temperature is within safe limit. System gives buzzer alert, Relay may disconnect load, Prevents battery damage.



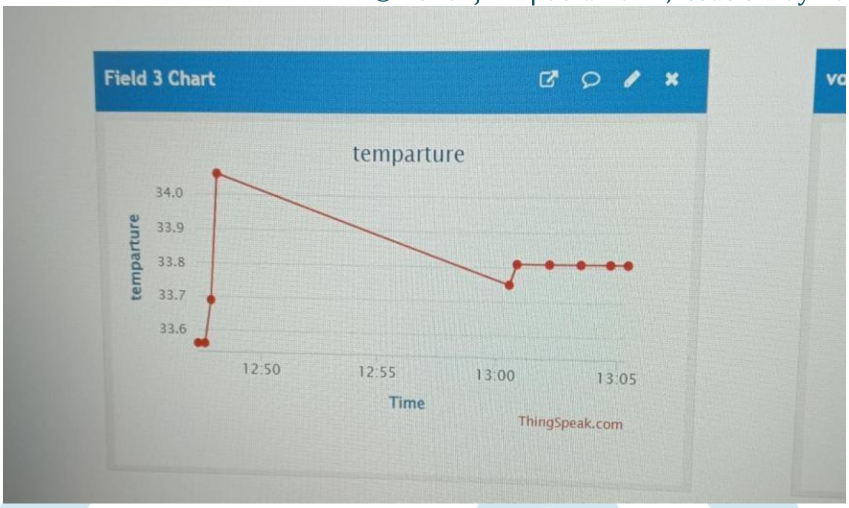


Fig .7. Graph(temp)

A graph displays temperature levels plotted against time provides a powerful visualization for understanding the dynamic behaviour of a system. The x-axis represent the progression of time, while the y-axis accommodates the varying scale of temperature.

TIME(minutes)	TEMPERATURE
0	33.79
1	33.75
2	33.75
3	33.75
4	33.75

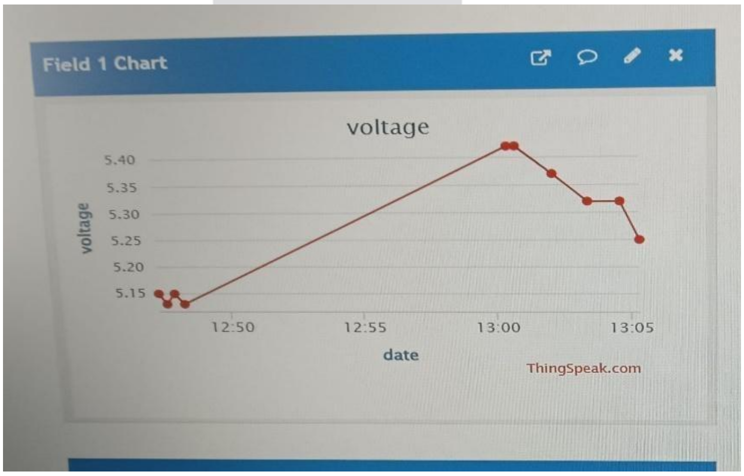


Fig. 8.Graph(vtg)

Show in the table since the batteries where a mixed of used and newbatteriesthe values or different from each other from the result it shows the accuracy of the voltage measurement taken from voltage sensor are quite similar to the measurement taken using multimeter the accuracy percentage for the all the measured value are above 99% therefore it can be concluded that the voltagesensor provide valid measured value ofthe battery.

Table.3.Voltage Measurements Results

Battery	VoltageSensor	Multimeter	Accuracy Percentage(%)
1	5.42	5.39	94.44
2	9.98	9.93	99.49
3	10.24	10.18	99.41
4	2.43	2.39	98.32
5	1.25	1.23	98.37

Table.4.VoltageMeasurements

ationtakentoreach the cut off (min)	eadingfornew battery	agereadingfor degrading
0	5.42	3.20
1	5.40	3.04
2	5.25	2.80
3	5.23	2.80
4	5.22	2.80
5	5.20	2.80

CONCLUSION

The IoT-Based Battery Monitoring System for Electric Vehicles effectively demonstrates a smart and reliable approach to enhancing battery safety, efficiency, and lifespan. By integrating real-time sensing of voltage, current, and temperature with IoT-enabled cloud monitoring, the system enables continuous tracking of battery health and performance. The use of Arduino and NodeMCU ensures low-cost implementation while maintaining scalability and flexibility for future upgrades. Safety mechanisms such as relays, LEDs, and buzzer alerts provide immediate response to abnormal conditions like over-voltage, over-current, and overheating, thereby reducing the risk of battery damage and operational failure. Overall, the proposed system improves electric vehicle reliability, supports preventive maintenance, and contributes to the advancement of intelligent and sustainable transportation solutions.

REFERENCES

1. M.A. Hannan, M. M. Hoque,A. Mohamed, andA.Ayob, "Review of energy storage systems for electric vehicle applications: Issues and challenges," Renewable and Sustainable Energy Reviews, vol. 69, pp. 771–789, 2017.
2. A. Khaliah and Z. Li, "Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles," IEEE Transactions on Vehicular Technology, vol. 59, no. 6, pp. 2806–2814, 2010.
3. S.M.Lukic,J.Cao,R.C.Bansal,F.Rodriguez,andA.Emadi,"Energystoragesystems forautomotiveapplications,"IEEE Transactions on Industrial Electronics,vol.55,no. 6, pp. 2258–2267, 2008.
4. Taher M. Ghazal ," Lithium-Ion Battery Management System for Electric Vehicles:Constraints, Challenges, and Recommendations "MDPI
5. AnjaliVekhande,AshishMaske,"Iot-BasedBattery Parameter Monitoring System For Electric Vehicle"
6. M.A.Hannan, M.M.Hoque, A.Mohamed, and A.Ayob,"Review of energy storage systems for electric vehicle applications: Issues and challenges," Renewable and Sustainable Energy Reviews, vol. 69, pp. 771–789, 2017.
7. Khaligh and Z. Li, "Battery, ultracapacitor, fuel cell, and hybrid energy storage systemsforelectric,hybridelectric,fuelcell,andplug-inhybridelectricvehicles," IEEETransactions onVehicularTechnology, vol. 59, no. 6, pp. 2806–2814, 2010.

8. S. M. Lukic, J. Cao, R. C. Bansal, F. Rodriguez, andA. Emadi, "Energy storage systemsforautomotiveapplications,"IEEETransactionsonIndustrialElectronics, vol. 55, no. 6, pp. 2258–2267, 2008.
9. D.S.Suresh,SekarR,MohamedShafiullaS.,"BatteryMonitoringsystemBasedon PLC", International Journal of Science and Research, vol. 3 issue 6. pp. 128–133, 2012.
10. S. Dhotre, S. S. Gavasane,A. R. Patil, and T. Nadu, "Automatic Battery Charging Using Battery Health Detection"International Journal of Engineering &Technology, Innovative science vol. 1, no. 5, pp. 486–490, 2014.
11. S.A.Mathew,R.Prakash,andP.C.John"Asmartwirelessbatterymonitoringsystem for electric vehicles," Int. Conf. Intel. Syst. Des.Appl. ISDA, pp. 189–193, 2012.
12. S.Bacquet,M.Maman,"Radiofrequencycommunicationsforsmartcellsinbattery pack for electric vehicle", Electric Vehicle Conference (IEVC) 2014 IEEE International, pp. 1–4, 2014.
13. M.Luo,Y.Xiao,W.M. Sun,andZ.Wang,"Onlinebatterymonitoringsystembased on GPRS for electric vehicles" Proceedings - 2013 5th International Conference on IntelligentHuman-MachineSystemsandCybernetics,IHMSC2013,Vol.1,pp.122–125, 2013.
14. W.MenghuaandX.Bing,"AReal-timeAndroid-basedMonitoringSystemforthe Power Lithium-ion Battery Used on EVs," 2017 10th Int. Conf. on Intelligent Computation Technology and Automation, pp. 245-249, 2017.