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Cloud Based BMS Data Analytics System for EV using IOT

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Abstract: The electric vehicle market in India appears to be gaining traction. The automobile industry is shifting to EV manufacturing, as the fuel is expensive and there is global pressure to reduce carbon footprint. There is necessity to improve the current technology and performance of electric vehicles. The continuous monitoring of EV battery for customer safety against accident due to battery failure is vital. There is a need to improve battery analysis and monitoring to improve EV performance. The cloud based BMS system for EV data analysis using IoT is an ongoing monitoring system for battery performance analysis. Along with this the system provides performance analysis of each EV battery, supplied by battery manufacture. The EV manufacturing is at its early stage, in comparison with fossil fuel vehicles. This maturity in fossil fuel engine has come long way by experimentation, experience, and revolutionary inventions as well stringent norms of government authorities like Euro/Bharat stage 6 etc. The consistent improvement in battery technology is a way ahead for successful deployment of EV. Therefore, continuous monitoring of battery performance parameter is essential which should help battery manufacture to estimate accurately the battery model, state of charge, state of health etc. It will also help to correctly predict possibility of accidents due to improper charging and discharging of battery and estimate of EV.
Keywords: IOT, THINGSPEAK, EV, BMS, Euro/Bharat Stage 6

I. INTRODUCTION

The advancement in cloud computing along with internet of things (IOT) has provided a promising opportunity to resoluteness the challenges caused by the increasing transportation issues. Advancement in the field of Internet of Things and cloud computing has given an opportunity of continues monitoring of data of electric vehicles along with its analyzingand graphical visualization. This system is one of the realistic applications of cloud computing and IOT of monitoring and analyzing the performance parameter of electric vehicles battery.

Electric vehicles depend on the battery as a source of power. However, improper battery charging cycles (during lifetime) gradually reduce battery performance. This is a major concern for battery design in terms of taking full advantage of the potential battery life, and the best performance possible.

Improper battery handling can lead to permanent damage or deterioration of the battery. The plan proposes a concept to monitor battery performance, using IoT-cloud techniques, so that battery monitoring can be done using the thingspeak IoT Cloud channel that works for EV builder and battery manufacturer. The Cloud- based BMS data analytics system consists of two major parts: i) Collecting performance parameter of EV's Battery by communicating with BMS ii) Aggregating, uploading performance parameters data onto cloud, and analyzing data to identify best performing battery. Based on performance parameter analysis, the system is capable to detect degradation in battery performance [2]. Based on battery's overall performance the EV manufacture can rate the battery suppliers. This project presents the cloud computing & IOT based system designed for monitoring & sending the parameters of the EV, opportunistically to cloud, through the Wi-Fi Module. This system aims to provide safety to the customer along with analysis of batteries supplied by different battery supplier. The performance analysis finds the best battery supplier and improving performance of batteries supplier by other manufactures if needed.

Key Services provided by Cloud Based BMS Data Analytics System for EV using IOT:

1) Easy analysis of performance parameters of EV batteries of various suppliers
2) Convenient data accessibility on IOT Webpage
3) Avoid any kind of accidents/hazardous effect due to continuous monitoring of parameters
4) Secure data analysis on thingspeak IOT.
5) Continues monitoring of EV performance parameter such as voltage, current and temperature

II. EXISTING SYSTEM

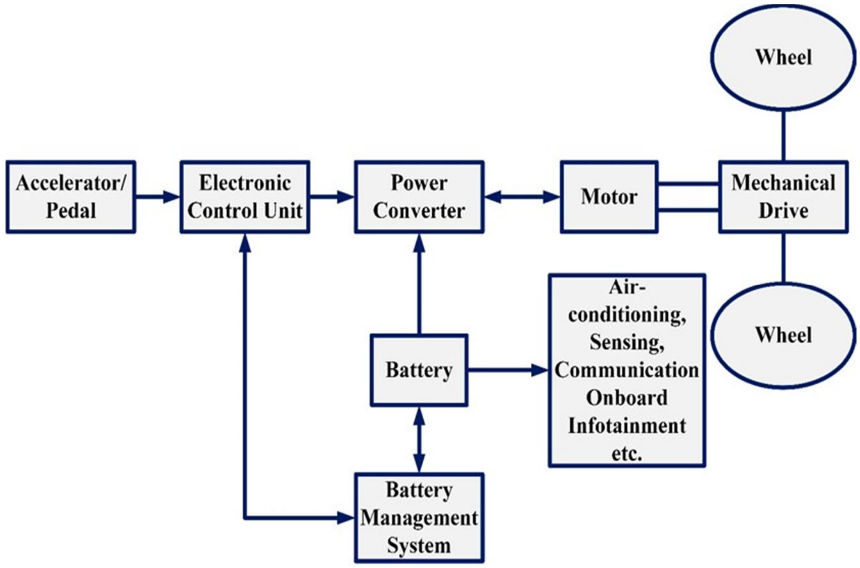

Figure 1: Current BMS operation inside EV [1]

BMS plays a vital part in an electric vehicle's general control, charging efficiency, safe operation, and energy usage optimization. The battery powered EV's power system topology is depicted in Figure [1]. The traction battery, which has a sizable capacity and strong power, is the only source of energy. It operates primarily in two different modes: charging and discharging. It operates electric motor that transforms electrical energy into mechanical energy (while in discharge mode). The vehicle's wheels receive rotational energy from the mechanical drive. Additionally, the battery meets the remaining onboard power needs for things like air conditioning, sensors, communication, infotainment, etc. There have been discussions on various hybrid power train configurations and design elements.

A. Causes of battery fire as part of BMS safety function analysis [1]:

1) Mechanical Shock
2) No battery Monitoring
3) Product Quality Deficiency
4) Faulty mechanical & electrical design
5) Overcharge
6) Poor failure analysis
7) Unrealistic simulated environment
8) Service connects durability & cycling
9) Thermal shock
10) Short Circuit
11) Altitude
12) Humidity cycling
13) Cycle life due to charging, discharging

B. BMS Test Cases

Electric mobility is often regarded as the kind of transportation of the future. There is more support for expanding the usage of electric mobility while gradually phasing out fossil fuel-powered vehicles because of the increased worldwide concern for reducing emissions to combat climate change. BMS dangers and hazards can be considerably decreased by standardizing BMS for EVs and properly implementing the standards in EVs. The following table contains BMS test cases [1].

Table I: BMS Test Cases

No.	Test Case	Description	End-of-Test Criteria
01	Idle or Stand-by	BMS is configured and the fault criteria are defined in the BMS. The subsequent functions are evaluated in idle mode.	The whole process is evaluated in steady state.
02	Current, voltage, temperature sensing	The sensors are supposed to checked and calibrated. Then, the full-range accuracy test is carried out by keeping the BMS at various conditions.	All conditions tested.
03	Dynamic discharge	The battery pack is totally discharged at ambient temperature by considering a real dynamic discharge scheme.	BMS stops discharging to avoid over-discharge.
04	Overvoltage during regenerative braking	The battery pack is fully discharged during experiencing a high regenerative current. The battery is discharged by considering a real dynamic discharge scheme.	The BMS interrupts the regenerative charging current.
05	Over-temperature during discharge	The battery pack is fully discharged at high temperature considering a real dynamic discharge scheme.	Battery pack reaches the maximum temperature and BMS stop the discharge.
06	Short circuit	Short circuits are placed at different locations in the battery pack: Event I: Internal or external short circuit adjacent to the cell's tabs. Event II: External short circuit through fuses or shunt resistor. Event III: External short circuit through fuse and switch box.	Short circuit current is zero.
07	CC-CV * charge	Conventional CC-CV charging with active/passive balancing.	End of charge.
08	Charge test at low temperature	A charge is enabled, and battery temperature is kept below the threshold of charging. The temperature starts to increase gradually due to the heating system.	When the pack temperature reaches over the limit, charging starts.
09	Diagnosis	Event I: Emulate SOC vs BMS estimated SOC during real dynamic discharge scheme. Event II: New events based on the BMS diagnosis features.	End of charge or discharge.
10	Isolation monitor	Single isolation fault is introduced on the positive or negative terminal of the battery pack.	Isolation fault detected.
11	Global power consumption	Event I: Battery pack is fully discharged using a dynamic discharge scheme followed by CC-CV charge. Event II: Test on idle mode for a specific time span.	BMS power consumption is evaluated at all conditions.

* CC-CV = constant current constant voltage.

III. PROPOSED SYSTEM

In this project, the main objectives of the proposed work are to monitor performance parameters of the lithium-ion battery cells and to load the performance parameters onto thingspeak web page. The microcontroller is the heart of the system; we have used the Arduino UNO as a microcontroller. The main advantage of using Arduino UNO is it has inbuilt multichannel, 10-bit analog to digital converter (ADC). There are total four voltage sensor module and four temperature sensors along with one current sensor module.

As the output of the four voltages sensors and a current sensor is in analog form so it cannot be directly interfaced to the Arduino UNO digital input pins. Therefore, the output of the voltage sensors' module and a current sensor module are connected to 5 ADC input pins. The DS18B20 is a single-wire digital temperature sensor, so its output is directly connected to the Arduino UNO digital input line. Four temperature sensors are connected to a single wire and this single wire is further connected to microcontroller Arduino UNO digital input pins. To display the performance parameter of the lithium- ion battery cell the Arduino Uno is connected 20X4 LCD display. Wi-Fi module sends the parameters to the thingspeak cloud. This Wi-Fi module is interfaced to Arduino to collect the parameters. The ESP8266 is connected to the Internet for uploading performance parameter. The thingspeak is the IoT service we used which has 8 channels.

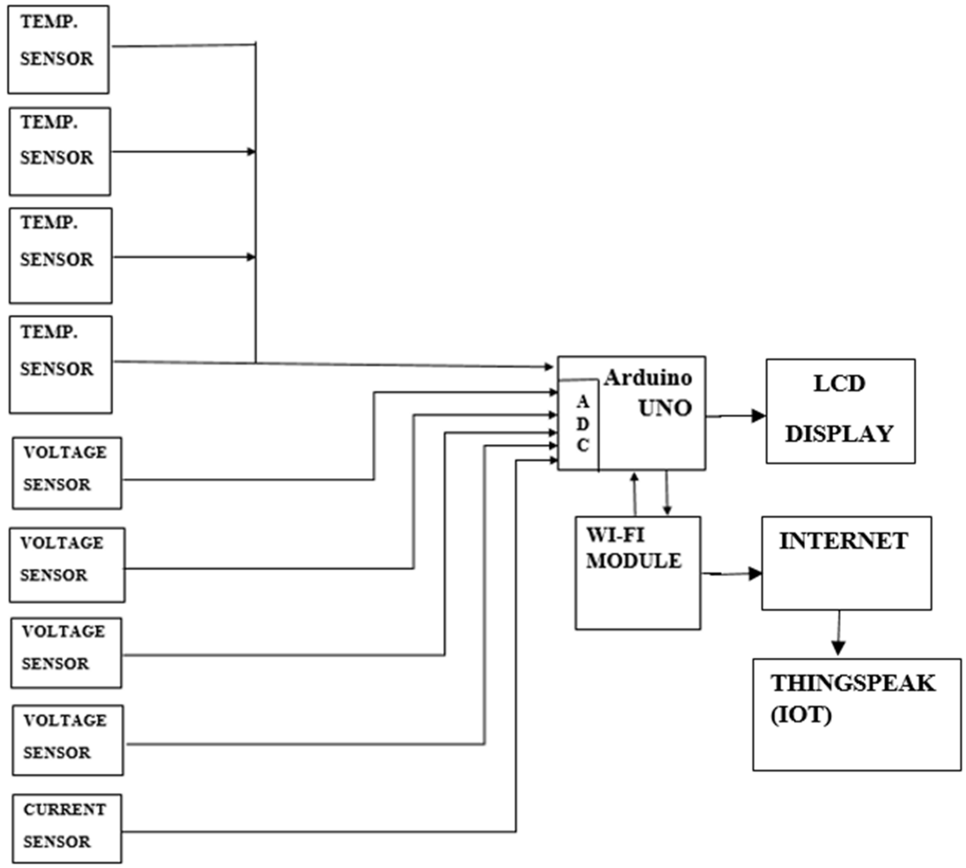

Figure 2: Proposed System Block diagram

1) *Arduino UNO:* The Arduino UNO is based on the ATMEL AVR processor. The Arduino programming language gives you access to microcontroller peripherals, including analog to digital converters, general purpose input/output pins, communication buses (including I2C and SPI) and serial interface.

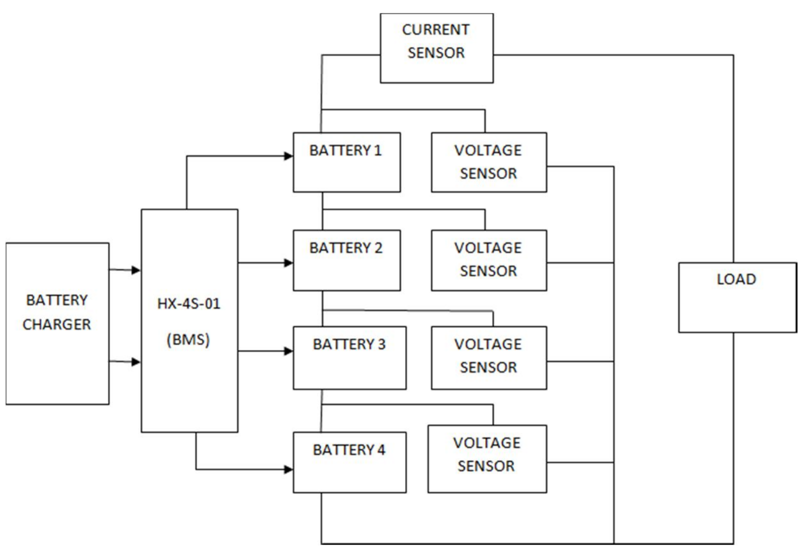

Figure 3: BMS and Lithium-Ion Cell Block Diagram

2) *Current Sensor:* This system uses the current sensor ACS172, which has analog output. The load (Bulb) is connected in series with the sensor. This sensor accurately calculates the current of lithium-ion cell. As this sensor output is analog so it is converted digital form by applying it to one of the ADC pins of Arduino UNO.
3) *Voltage sensors:* One of the performance parameters that we have calculated is voltage of lithium-ion cells; this is achievedby voltage sensor module. As there are total four lithium-ion cells used in this system, across each lithium-ion cell a voltage sensor is connected to measure operating voltage of each cell. This operating voltage output at each voltage sensor is then applied to ADC pins of Arduino to convert it into digital form. Then these parameters are uploaded on webpage.
4) *HX-4S-01 (BMS):* The HX-4S-01 is a battery management system/charge protection circuit. This charge protection circuit provides over-charge, over-discharge, short circuit protection, over current protection. This chip is connected to four lithium-ion cell in series to increase the life of lithium-ion cell by protecting their charging cycles. This chip is low cost, small size also this has high performance
5) *Temperature Sensor:* The temperature sensor used in this proposed work is DS18B20 which is 1 wire digital sensor. There are four temperature sensors, which are mounted on each lithium-ion cell to measure their temperature. As this sensor has digital output so it is connected to digital input pin of Arduino.
6) *Lithium-ion Cell:* The system battery is of 14.8v which is formed by connecting four 3.7v lithium- ion cells in series with each other. These cells are of 3.7v and 2200mAH current.
7) *Thingspeak (IOT):* The thingspeak is a service of IOT which is free of cost and provides analysis, monitoring in graphical format. With the help of Wi-Fi module Arduino can access internet, so Arduino transfer the performance parameter of each lithium-ion cell onto thingspeak webpage. This webpage has 8 data channels. The battery parametersare graphically represented on thingspeak webpage.
8) *LCD Display:* This system consists of 20X4 LCD display. This display is interfaced with Arduino to display performance parameter of lithium-ion cell.
9) *Wi-Fi Module:* This ESP8266 module is interfaced with Arduino with objective that Arduino can have internet access to transfer the performance parameters of the battery under monitoring to thingspeak data channels.

A. *System Operation*

1) First step is to turn on the power supply. After turning on power supply the LCD will display the general details of the project. Then the system connects the ESP8266 Wi-Fi module to the internet so that it can transfer the parameter to thingspeak IOT webpage.
2) The four-temperature sensor are mounted on lithium-ion cell. So that the temperature of battery cell can be measured accurately. All temperature sensors bus slaves are connected to a single digital input pin of Arduino which is bus master using 1-wire bus protocol of DS18B20 (1-wire digital temperature sensor).
3) Each voltage sensor connected across lithium-ion cell; this will measure the voltage of each cell. The voltage is calculated in programmatically form by subtracting the previous cells voltage from overall battery voltage.
4) The current sensor module is connected in series with four lithium-ion cells and theload (bulb). A switch is connected to turn on-off the bulb. According to load conditions the current value will vary.
5) All the values of voltage and current sensor module is in analog form so it is given to the ADC of Arduino UNO, it will convert all analog parameter in digital values. The temperature sensor is bydefault digital, so it directly interfaced digital input pin of Arduino UNO.
6) The Arduino UNO is interfaced with LCD and ESR8266 Wi-Fi module. The Arduino UNO will transfer the performance parameter to both LCD and Wi-Fi module as they are output devices.
7) The LCD will display voltage, current and temperature of each lithium-ion cell.
8) After every 20 sec the data will be transferred to IOT thingspeak webpage, and the data is represented in graphically manner.

IV. IMPLEMENTAION

1) *Step 1*- Install thingspeak libraries on PC.
2) *Step 2*- Create a new account on Thingspeak. For the purpose, go to thingspeak.com and create user account.

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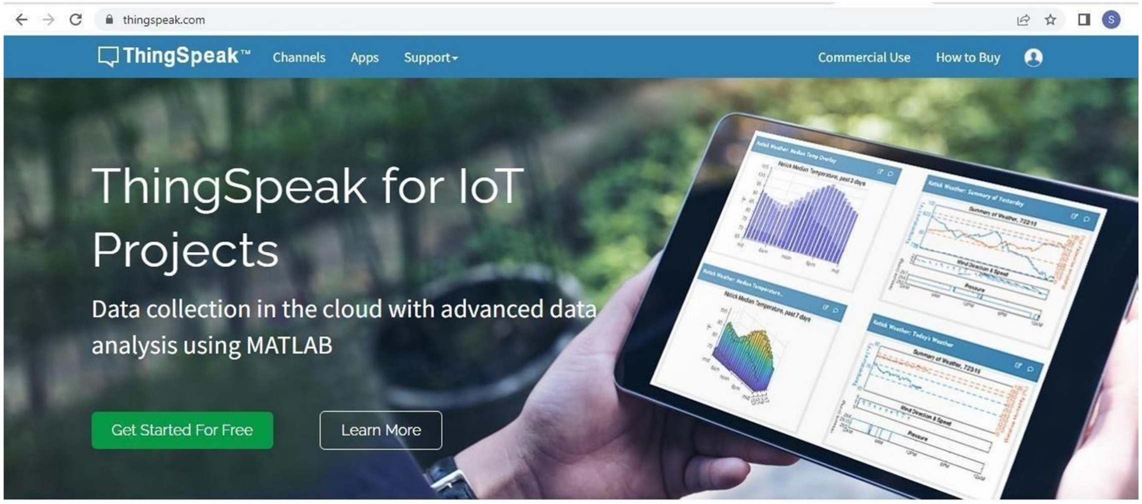

Figure 4: Sign up on thingspeak

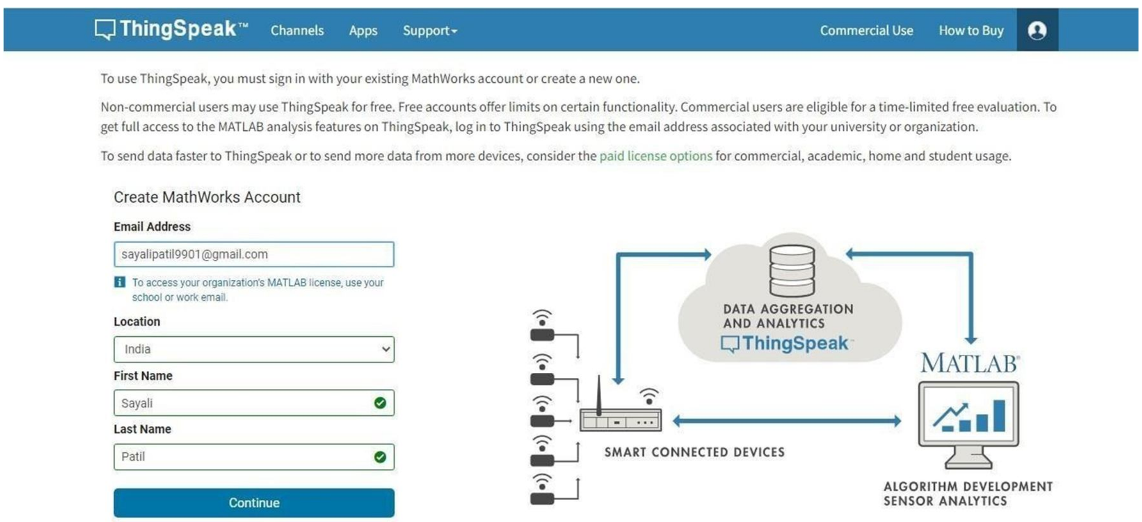

Figure 5: Sign up with email address

3) *Step 3*- Create a channel for data by clicking “NEW Channel” button. After creation the user can enter name of data in fields and save the channel.

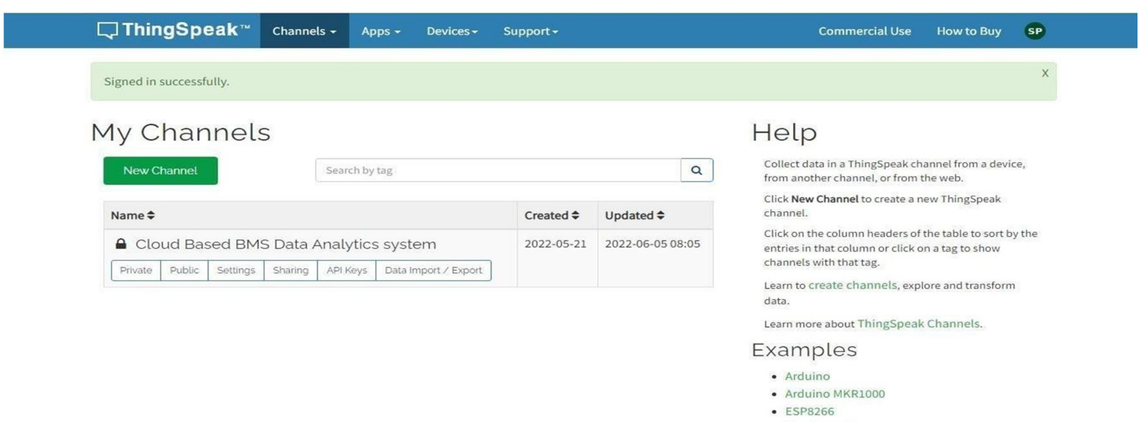

Figure 6: Channel Connection

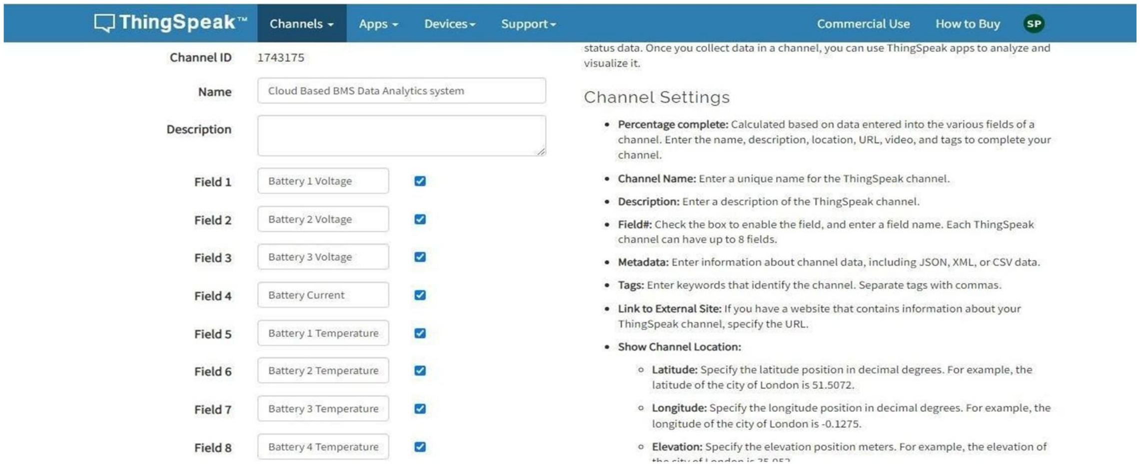

Figure 7: Creation of fields for data

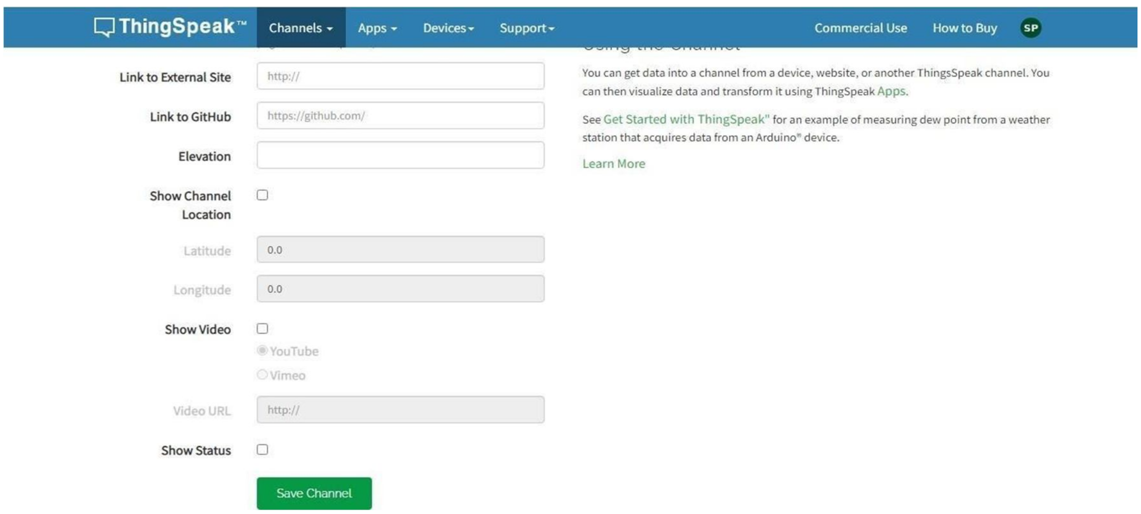

Figure 8: save Channel

4) *Step 4*- To upload data, it needs API key which will be used in the code to upload sensor data to thingspeak website. Get an API key.

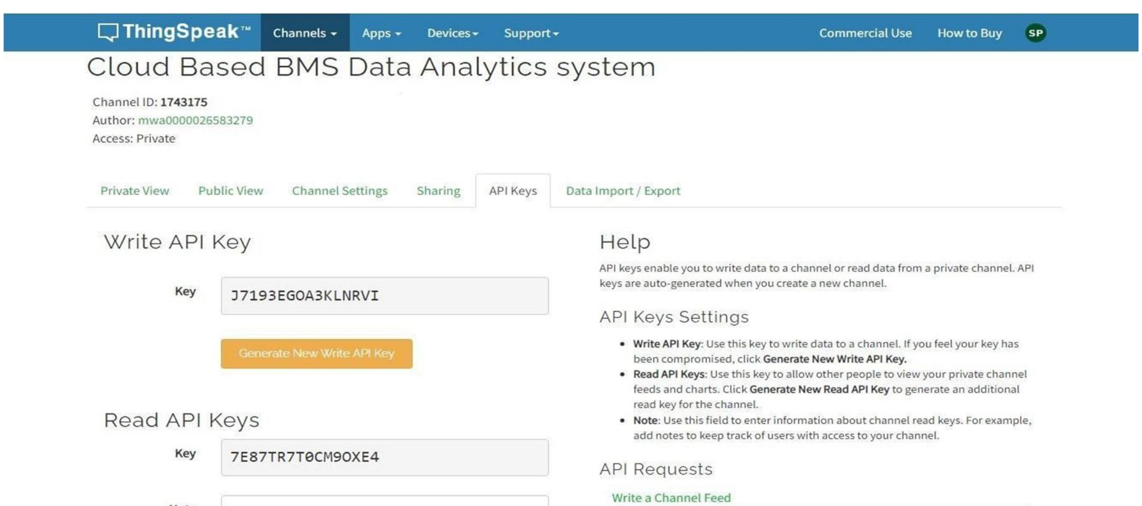

Figure 9: Get API Key

A. MQTT Protocol:

Thingspeak uses the MQTT API to update Thingspeak channels. The Thingspeak IoT platform enables clients to update and receive updates from channel feeds via the Thingspeak MQTT broker. MQTT is a publish/subscribe communication protocol that uses TCP/IP sockets or Web Socket. MQTT over Web Socket can be secured with SSL. A client device connects to the MQTT broker and can publish to a channel or subscribe to updates from that channel.

Publish

Publish to a Channel Feed	Publish message to update multiple channel fields simultaneously with MQTT
Publish to a Channel Field Feed	Publish message to update single channel field with MQTT

Subscribe

Subscribe to a Channel Feed	Subscribe to updates from channel feed with MQTT
Subscribe to a Channel Field Feed	Subscribe to channel updates from specific field of channel with MQTT

V. TESTING RESULT

A. EV Parameters on Thingspeak IOT Webpage

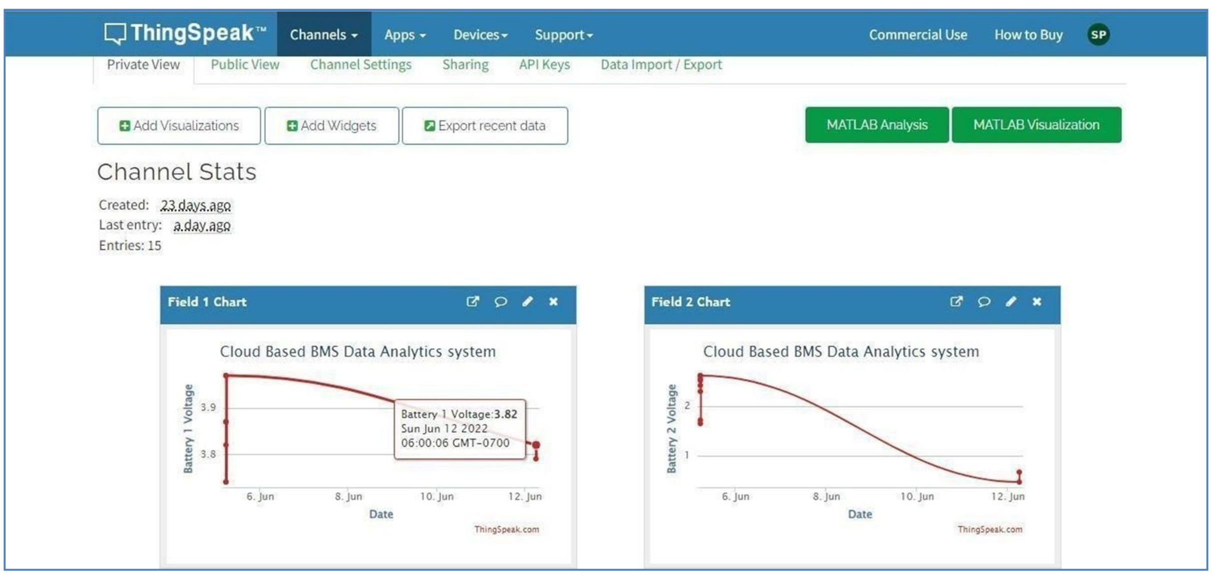

Figure 10: Graphical Representation of voltage of Lithium-ion cells

The above screenshot represents graphical representation of the voltage parameter of lithium-ion cell. The x-axis represents date and y-axis represents the battery voltage. This voltage is the real time voltage of lithium-ion cell calculated by voltage sensor and BMS. By continues monitoring of this voltage the lithium-ion cell can be protected from hazardous effect and increase their lifetime.

Figure 11: Graphical Representation of temperature of Lithium-ion cells

The above screenshot represents graphical representation of the temperature parameter of lithium-ion cell. The x-axis represents date and y-axis represents the battery temperature. This is the real time temperature of lithium-ion cell measured by temperature sensor and BMS. By continues monitoring of this temperature the lithium-ion cell can be protected from overheating and hazardous effect which will increase their lifetime.

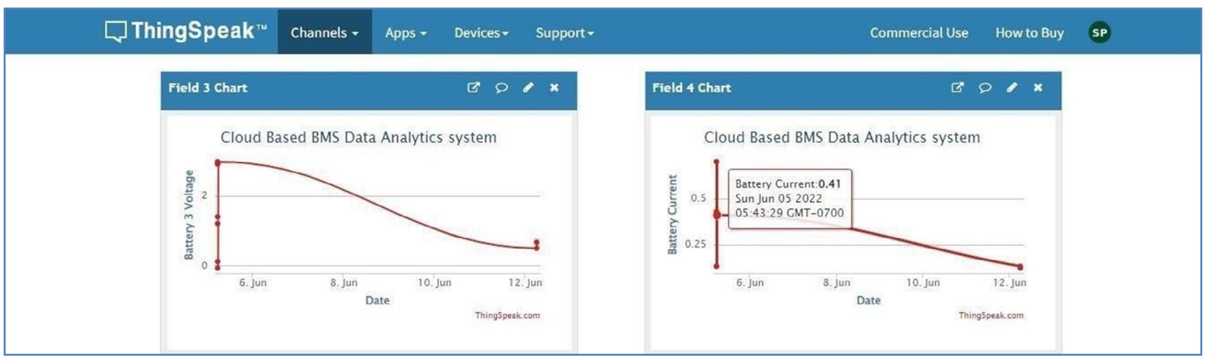

Figure 12: Graphical Representation of current Lithium-ion Cells

The above screenshot represents graphical representation of the current parameter of lithium-ion cell. The x-axis represents date and y-axis represents the battery current. This is the real time current of lithium-ion cell measured by current sensor and BMS. By continues monitoring of this current the lithium-ion cell can be protected from hazardous effect which will increase their lifetime.

B. EV Parameters on Project Hardware

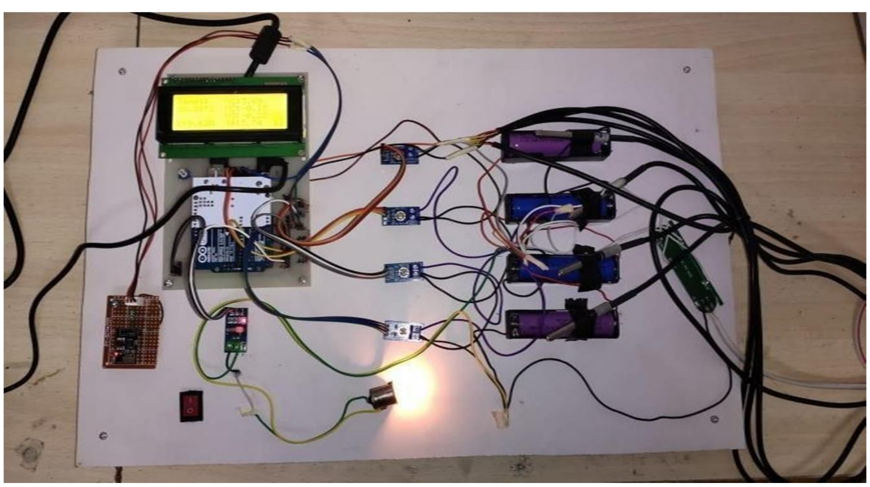

Figure 13: Main circuit diagram of project (When load is connected)

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Figure 14: LCD display showing Project name

Figure 15: LCD display showing performance parameter

Figure 16: Sending Data to Thingspeak Server

The figure 14 contains the main circuit diagram of the project when the load is connected. As shown in the figure four lithium-ion cells are connected to BMS. The figure 15 represents the LCD display showing the project name. Figure 16 contains LCD display is showing the performance parameter, after that the figure 10 contains sending data to thingspeak server. From above figure it is clear that the real time performance parameters are transferred to the Thingspeak IOT server.

VI. ADVANTAGES

A. It provides easy analysis of performance parameter of lithium-ion battery of different battery supplier.
B. Continuous monitoring of performance parameter of electric vehicle
C. Convenient data accessibility on Thingspeak webpage
D. Avoid any kind of accidents, hazardous effect due to continue monitoring of EV parameters

VII. FUTURE SCOPE

A. To make system more reliable and accessible to owner of Electric Vehicle create a simple database that can be analyzed, and the previous data can be accessed at any time on cloud.
B. Create mobile application that displays the analysis of the performance parameter of each cell of EV and also sends notification/alerts for further preventive action.
C. Analysis of each EV battery, supplied by battery manufactures to find best battery supplier, amongst all and locate improvement areas for rest of battery suppliers so they can correct their products.

VIII. CONCLUSION

The main objective of the system is, continues monitoring of EV performance parameters through thingspeak IOT webpage. This is achieved by using Arduino UNO. We can easily interface the different sensors connected to lithium-ion cells to build in ADC of Arduino. These parameters are essential for analyzing the performance of electric vehicle. That's why it is necessary to continuously monitor the parameters.

This continuous parameter monitoring is achieved with the help of internet of things (IOT) and Wi-Fi module. Then with the help of Arduino UNO this parameter will get uploaded on webpage of IOT. The IOT webpage graphically represents the performance parameter of each lithium- ion cell.

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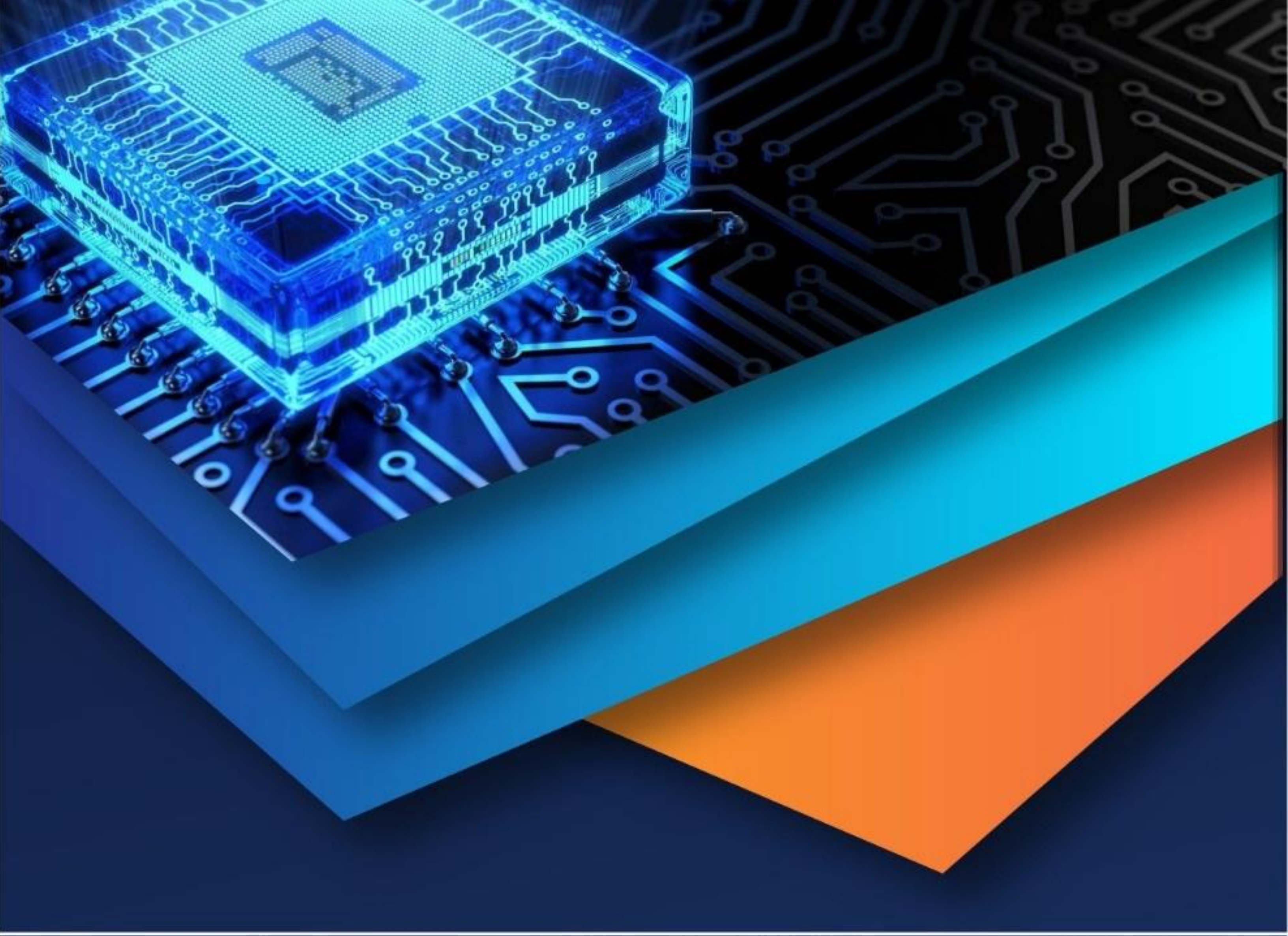

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