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A Comprehensive Study on Battery Monitoring System based on IoT

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A B S T R A C T

The Battery Management System may be remotely monitored and managed in real time by connecting it to the internet. Battery data analysis and the identification of battery cell behavior patterns in various locations and circumstances are made possible by the enormous amount of data storage that is available in the cloud, especially when compared to the storage that is available on an embedded device or a local server. No matter where they are physically located, devices and sensors can be monitored and managed thanks to the Internet of Things. IoT connectivity also makes it simpler to finish a software upgrade, enabling more rapid advancements in battery management applications. The evaluation and analysis of lead acid battery management and monitoring utilizing the Internet of Things are the main objectives of this paper.

Keywords:IoT, lead acid battery, Battery Monitoring System.

1. Introduction

Based on current experimental data, an analytical technique is used to forecast how Li-ion batteries will behave in the future. Empirical models can be parameterized without a complete understanding of the electrochemical cell structure. The lack of data quality and measurement inaccuracy are these techniques principal drawbacks. Counting Coulombs, an essential parameter that decreases as the battery ages is capacity [1]. Kong Soon Ng and others stated that, the Kalman filter and expanded Kalman filter concepts are employed for battery state estimation[2].When a suitable battery model is provided, the model-based KF and EKF processes produce increased accuracy.One of the problems with this method is how complicated the computations are. The EKF technique's lack of stability when the system is nonlinear is another issue [3].Fuzzy logic and artificial neural networks are powerful tools for modelling complex and non-linear physical processes. The fuzzy logic technique simply translates the input and output properties of the battery and treats it like a black box. The fundamental physicochemical processes are not physically described in it [4,5]. These battery models are based on equivalent circuit theory and include a variety of estimation techniques for model parameters [6,7].

To calculate battery ageing, internal battery measurements including battery impedance, temperature, current, and voltage are employed.Vapnik [8] invented the SVM methodology. SVM is a machine learning method that may be applied to both regression and classification. However, it is commonly used in classification problems. The fundamental idea is to create a probability density function (PDF) of the situation utilising all of the battery data that is available. A comprehensive description of SVM and RVM is given in reference [9]. A sort of non-linear filter called a particle filter produces precise state estimations with little processing burden by combining sampling and Bayesian learning techniques [10]. For statistical models, a lot of data is needed.These models don't need any formulations in chemistry or physics, nor do they need any analytical information on the ageing process [11]. The promped use of Autoregressive Moving Average (ARMA) for predicting battery health. A second order ARMA model's inputs are used to generate the battery prognostics. Electrochemical techniques are used to evaluate the battery's voltage, current, temperature, electrolyte content, corrosion, and other characteristics (physical models). They must be well conversant with the physical and chemical characteristics of the battery, such as the density, porosity, and electrolyte volume [13].The SPM makes clear incorporation of the effects of transportation events. A model of electrolyte transport and ion intercalation was built inside a single electrode particle. The concentration in the solution phase between the particles and the effects of the cell potential

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were not taken into consideration in this model. The SPM is a straightforward and efficient procedure. The only drawback is that it only works under specific circumstances, including tiny electrodes and low speeds [14]. The P2D model incorporates the Butler-Volmer equation, diffusion in the solid phase, and diffusion in the electrolyte. A P2D model based on concentrated solution theory was created to characterize the behavior of a Li-ion battery made up of porous electrodes with current collectors and a separator [15].

The difficult system modelling approach includes multi scale, multidimensional, and multi physics electrochemical connected models. These simulations completely capture all of the crucial events that take place while an electrochemical multiphysics system, like a battery, is operating [16]. DFT computations may be used to get analytical conclusions regarding the composition and operation of battery electrode materials. The electrical structure and lattice properties of graphite within the LiC_6 electrode were determined using DFT-based simulations [17]. Investigated the impact of lithium binding and Quinone property on positive electrode stability using DFT simulations. An IoT-based Battery Monitoring System based on the ESP8266 monitors battery charging/discharging status, battery voltage, and percentage.Since it powers the whole system, the battery is, as we all know, the most important component of any gadget [18]. Because improper or excessive charging or discharging might result in battery damage or system failure, it's crucial to monitor the battery's voltage level.

The majority of electrical and electronic equipment have a unique system known as the Battery Management System (BMS). The BMS monitors the battery's voltage, current, temperature, and auto-cut-off system.This ensures the safe and proper handling of lithium-ion or lithium-polymer batteries. Previously, the BMS did little more than keep track of the battery's condition and notify the user through a battery indicator. However, we can now immediately alert consumers from a distance because of the Internet of Things. They may check the battery level on their cellphones or computer dashboards from anywhere in the globe. In this Internet of Things-based Battery Monitoring System, we'll use a Wemos D1 Mini with an ESP8266 chip to transmit data about the battery's state to the ThingSpeak cloud. The Thingspeak will show the battery voltage and battery % in both charging and discharging modes.

2. Review on Battery Management System

BMS is defined differently depending on the application. BMS, in general, refers to a management strategy that keeps an eye on, regulates, and improves a person's performance or the performance of several battery modules in an energy storage system. In the case of abnormal circumstances, BMS can regulate the disconnecting of the module(s) from the system. With the right safety precautions in place inside a system, it is utilized to enhance battery performance. BMS is used in a power system application to track, manage, and supply the battery's power at its most effective level (battery life is also considered here). BMS is used in automotive applications to manage energy at various system interfaces and to protect the system from dangers.BMS is composed of several useful structural components. The functional blocks of the BMS are linked to the batteries and every other element of the structured system, including controllers, a grid, and other dispersed resources, as seen in Figure 1. With the correct architecture, practical building blocks, and cutting-edge electronics, the system battery life may be extended. There are several commercial BMSs available. For instance, NUVATION Energy provides a flexible, reliable, module-based, and BMS for mobile and stationary energy storage applications.

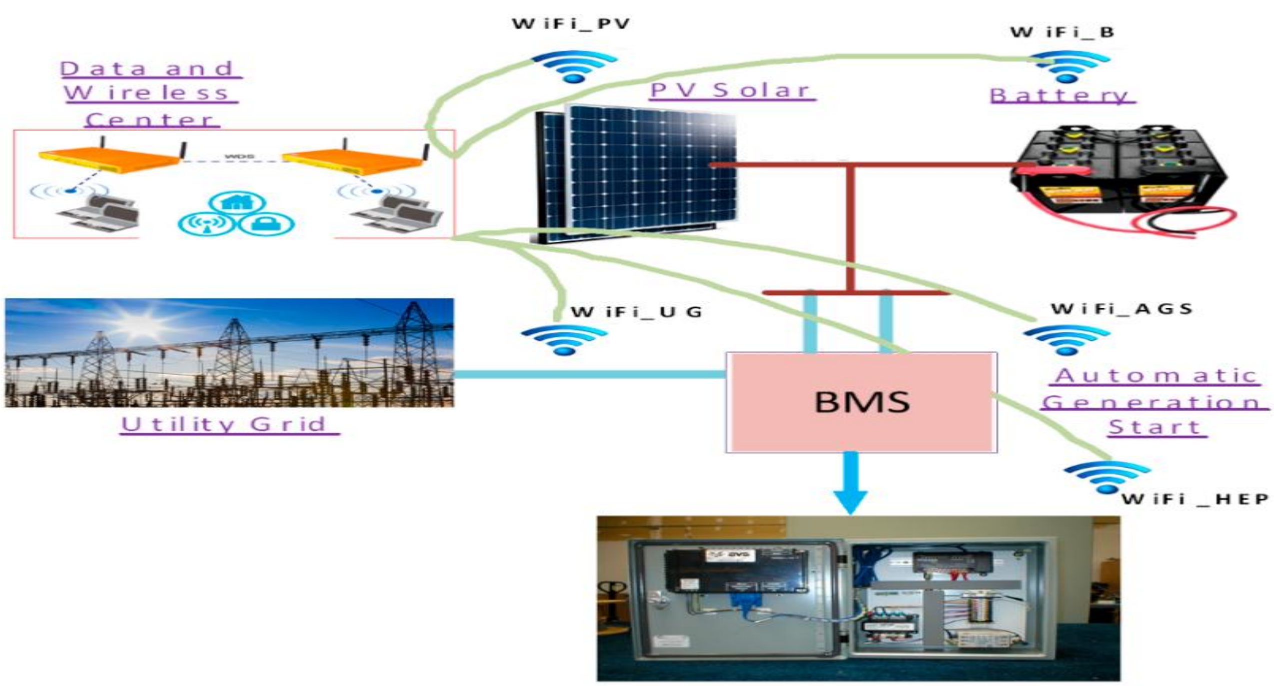

Figure 1: BMS Connections

2.1. Basic Structure of BMS

The battery management is an essential tool that combines computer technology, wireless communications, and embedded measuring technology to enable online battery system monitoring and management. The fundamental idea is that the battery unit's voltage, current, temperature, and other characteristics are directly or indirectly measured by the data acquisition circuit. The control unit (MCU, microprocessor) evaluates the battery's level of charge and its state of health (SOH) using the appropriate algorithm in conjunction with the external parameters that have been gathered.And to regulate the battery pack's external circuit's on and off states in order to accomplish the equalization of the battery pack's individual cells. Real-time battery state monitoring and battery equalization are the major features. Control over charging, thermal management, data transfer, and other auxiliary tasks are among them. Distinct situations place a different focus on the battery management mechanism. Real-time detection of the battery's external characteristics enables the execution of all functions.

2.2. Components and topologies

A BMS cannot be used independently inside a system infrastructure. It is integrated with other system elements to accomplish the system's objectives. An intelligent energy automation system could have a battery management module (BMM), a battery interface module (BIM), battery units, and a battery supervisory control, for instance. The system protects the battery pack, extends battery life, manages power usage, and interacts with several networks.Three implementation topologies are available on the BMS market: centralized, distributed, and modular. In a centralized architecture, many wires connect a single control unit to a collection of battery cells. Each control unit is linked to a particular battery cell by a single communication connection in a scattered design. Finally, a single battery cell is managed by a number of connected control units in a modular design.The most affordable and least extensible BMS is the one that is centralized. Although the distributed BMS is the most expensive, it is also the easiest to install and provides the cleanest assembly of the three. The features and issues of the other two topologies are in conflict with each other in the modular BMS, which requires additional hardware and programming work. BMS implementation architecture is shown in Figure 2.

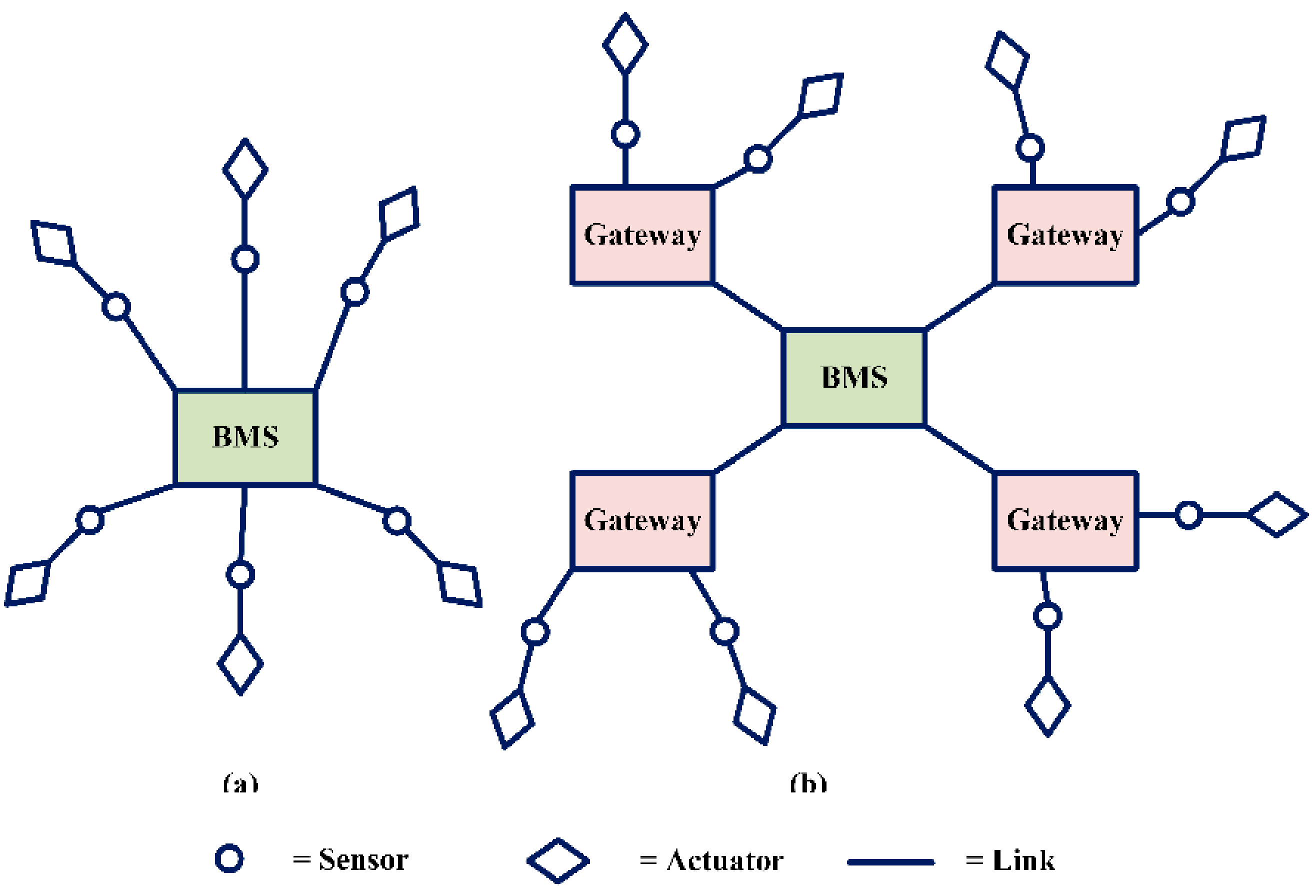

Figure 2: BMS implementation topology: (a) centralized, (b) distributed.

2.3. Architecture

Multitasking is possible with the BMS software architecture. Previously, it was not feasible to carry out two jobs concurrently; one task had to be put on hold in order to do the other. Various activities may now be completed concurrently and without interruption thanks to the new BMS software design. To ensure BMS safety, the first responsibilities of a BMS software architect, such as voltage/current measurement, over current/voltage protection, temperature monitoring, and protective relay actuation, must be completed quickly. To carry out real-time activities, the real-time operating system (RTOS) is incorporated in the BMS software architecture. The BMS software's architecture is depicted in Figure 3.

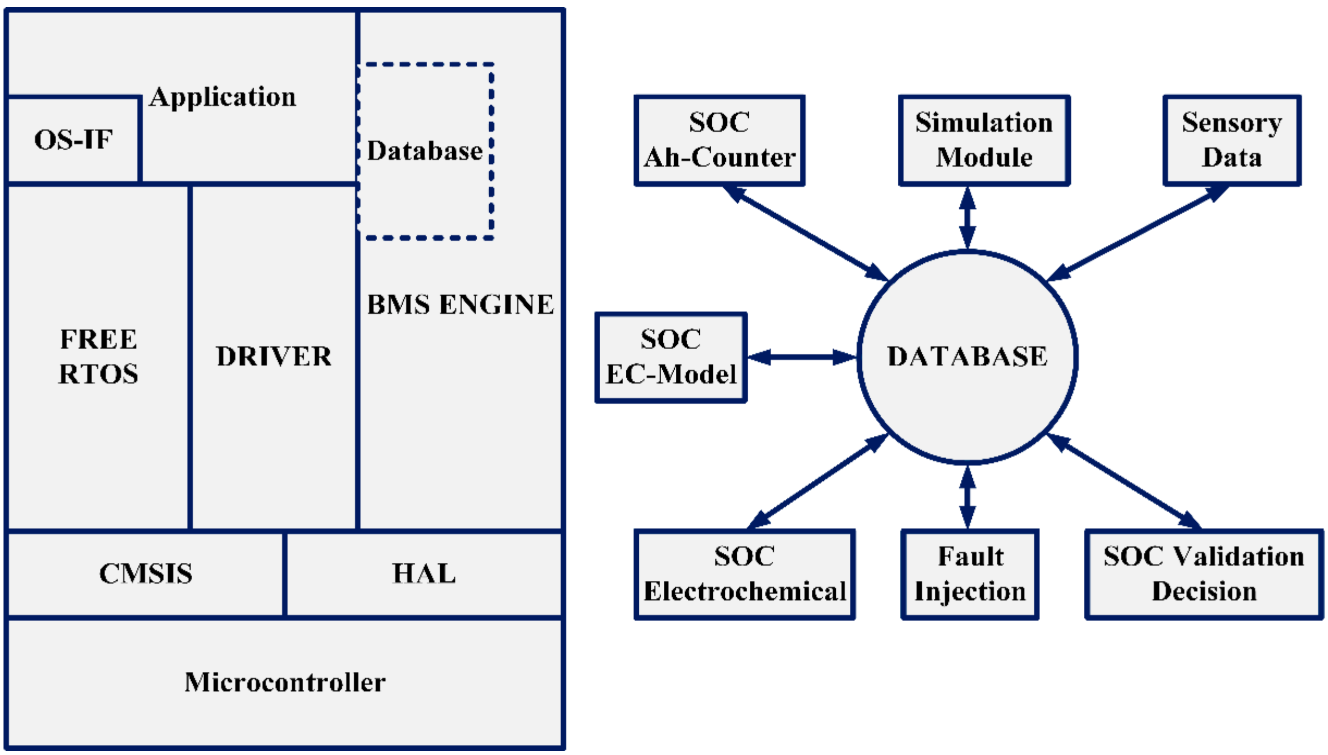

Figure 3: BMS Architecture

3. Lead-acid Battery management System

Over a century has passed since lead-acid batteries were first created. Lead-acid batteries offer better high-low temperature tolerance and high-current discharge performance than lithium-ion and nickel-cadmium batteries, as well as less expensive electrode materials. The communications and UPS power industries, the automobile sector, industrial and mining companies, and weapon systems all benefit greatly from the assembly environment, sophisticated charging mechanism, and excellent security. Lead-acid batteries are rechargeable, but they also have drawbacks such a limited lifespan, trouble balancing battery packs, and difficulties calculating battery power.in order to monitor battery state in real-time, guard against overcharging and over discharging, and prolong battery life. The battery management system has been the subject of technical research and development in the battery business in an effort to increase the battery's usage rate.

3.1. Parameters detection system

A. Detection of Voltage

The most fundamental battery parameter is voltage. Numerous measuring techniques exist. Common mode measurement is the most basic. The voltage of each point is measured by proportional attenuation of the precision resistor, and the voltage of each individual cell is then produced by successively subtracting. The common mode measurement is related to the same reference point. The method's circuit is straightforward, but it is vulnerable to drift voltage caused by significant resistance and is only appropriate when the series battery is small and the accuracy is low.Only differential mode measurement may be employed when there are several batteries connected in series and the precision is great. Differential mode measurement involves using a switching circuit to directly measure each individual cell. A multi-channel voltage loop sampling technique is typically used as the measuring strategy. The dynamic loading circuit, in other words, is utilized to time-separate the voltages of the different battery pack cells. Some individuals choose the voltage to be monitored using a mechanical relay array. The mechanical relay switching time, which affects measurement speed, and the sophisticated relay control logic need a lot of driving current. Some individuals then substitute analogue switch chips for mechanical relays.

B. Detection of Current

The dc current acquisition circuit is identical to the voltage acquisition circuit, except the current cannot be measured directly. Precision resistance, shunt, and current sensor technologies are primarily employed in industrial production and scientific research activities. The hall effect concept, magnetic modulator principle, magnetic amplifier principle, fibre optic measurement principle, and others are all used in the current sensor. Shunt and hall current sensors are the primary current detection devices used in battery monitoring systems due to the unique nature of the operating conditions of battery systems, taking complexity, power consumption, cost, volume, and other considerations into consideration.The Hall current sensor is based on the hall effect principle, composed of sensor parts, and is divided into direct detection (open loop) and magnetic balance (closed loop). It can measure current information without having to make contact with a high-voltage circuit, avoid high-voltage interference while removing an isolation device, and have quick conversion speeds. However, it has the drawback of being difficult to guarantee linearity at the low end of the measuring range. Examples of well-known manufacturers are Swiss LEM, American Honeywell, and others.

C. Internal Resistance of battery

Battery outward measurements do not include battery internal resistance. Internal resistance is technically one of the battery's fundamental properties. There are battery management systems on the market that use internal resistance as the primary parameter to estimate battery SOC and SOH, however the majority of battery management systems use internal resistance characteristics as auxiliary factors for battery status calculation.The internal resistance of the battery is determined by applying a low-frequency ac current signal to the battery and measuring the low-frequency voltage at both ends, the low-frequency current flowing through it, and the phase difference between the two. The ac technique is appropriate for online use since it doesn't call for discharge, static, or offline operation, which minimizes the influence on equipment safety.A battery equivalent circuit model, which uses recorded voltage and current to determine a battery equivalent circuit of resistance in real-time, was developed by someone else as a theory for estimating battery internal resistance. With accuracy defined by the equivalent circuit order time and heavily impacted by the estimation methodology, this method is used to indirectly estimate battery internal resistance.

D. Temperature Measurement

Battery temperature measuring techniques including the thermistor method, thermocouple bridge method, and temperature sensor method are frequently used for lead-acid batteries since the electrode material and electrolyte activity are highly influenced by temperature.The typical way to detect temperature is to design a circuit using discrete components like a thermistor, an integrated operational amplifier, and an AD sampling chip. The resistance value of a thermostat or, a type of semiconductor thermally sensitive element, increases exponentially with temperature. It has a low cost and great sensitivity, but its stability and interchangeability are poor, and the resistance value varies linearly with temperature.Due to the incorporation of a conventional signal amplification circuit, sampling circuit, and AD conversion circuit, the analogue signal from the temperature sensor may be instantaneously transformed into a digital signal and supplied to a CPU for data processing. When compared to other methods of monitoring temperature, digital temperature sensor chips have the advantages of a straightforward peripheral circuit, good expansibility, and high accuracy.

2.3 Battery operating Conditions

According to their working circumstances, lead-acid batteries may be loosely categorized into four groups. The following is a description of the usual traits of a battery management system under the four operating circumstances.

A. Starter Battery

The starter battery is primarily used for gasoline engine lighting, ignition, and starting in vehicles, motorcycles, and weapon systems. Due to its excellent low temperature, high current discharge capabilities, and safety, the lead-acid battery is still the primary component of automobile starting batteries. In contrast to using a lithium battery to start a car, lead-acid battery automobile starters typically use a single 12v battery or two monomers connected in series. There is no battery protection board similar to that found in lithium battery cells, and the only device that can accurately estimate the amount of power left in the battery is the car's instrument.Typically, a single 12V motorcycle starting battery serves as both a power source and a voltage regulator. The number of single units connected in series is minimal, and the battery is replaced periodically, much like a fuel oil producing set. No unique beginning battery management mechanism exists. Currently, just a single battery monitoring device will be installed under a few specific operating situations, and most lead-acid batteries used for startup do not have battery management systems.

B. Power Battery

Electric bicycles, electric special vehicles (electric tour vehicles, police vehicles, forklifts, forklifts), low-speed electric passenger vehicles, and hybrid electric vehicles are the principal uses for power batteries. These batteries are mostly employed to power vehicles for transportation. They typically have a tiny dimension, a small installation footprint, frequent charging and discharging, and a wide range of voltage, current, and other parameter fluctuations. Unlike electric bicycles powered by lithium batteries, unique electric vehicles and electric bicycles typically lack battery management systems.The on-board monitoring module does not balance between separate batteries and solely records real-time battery voltage characteristics, which has a substantial impact on accuracy. The vehicle's battery life is significantly impacted by the compatibility of the electric drive system, notably the charger.A current focus of study is BMS (battery management system) for low-speed electric cars and hybrid electric vehicles. These are some of its characteristics. BMS frequently needs driving speed and other factors in addition to collecting battery voltage, current, temperature, and other metrics to forecast changes in battery parameters. Electric car operating circumstances are complicated, current variations are severe, and a high level of sampling and computation power is required of BMS.The battery's capacity and the available space in the car have an impact on the sensor's size and power requirements. Since the accuracy of the estimated battery SOC and the balance of the battery pack directly affect the range, electric cars have high requirements for dynamic battery detection and battery balancing. A distributed battery management system with two layers or a centralised management system with one layer commonly make up the topological structure (DBMS). The ev Management System now communicates using the CAN protocol.

C. Energy Storage Battery

An energy storage battery is a type of storage battery used in micro grids for solar, wind, and other renewable energy sources. Its main job is to control output power fluctuations and provide a steady and consistent electrical load. Because of their low cost, great efficiency, and durability, lead-acid batteries are among the best technologies for energy storage. However, they significantly impede its early usage and growth because to its short cycle life, low energy density, and higher single cycle expenses. Lithium-ion batteries, a novel variation on lead-acid batteries, are now the industry standard for energy storage because of their stability, safety, and large capacity.In an energy storage system, the battery typically functions in two states: first, it interacts with the energy storage converter (PCS, Power Conversion System), which then transmits the energy to the ac grid as alternating current. Second, the battery pack powers the converter. Features of power station level energy storage batteries (ESBMS, energy storage battery management system). Power facilities with energy storage must be able to balance their management systems. The size of the energy storage battery module is rather large due to the series connection of numerous strings of batteries. With a greater single voltage difference, the capacity of the entire box will drop, and the more series batteries there are, the more capacity they will lose.

D. Backup Power Battery

The backup power battery is mostly used for uninterruptible power supplies (UPS), emergency lighting power supplies, and other backup power supply batteries. In many major scenarios, such as petrochemical reactors, its reliability is linked to computer systems, telecommunication systems, safety, and stability as a backup power source that supplies energy to the load in unusual circumstances. Systems for storing backup power often feature set application scenarios, centralized management, and a floating charge state. There are few limitations on battery monitoring systems, and there are no size, power consumption, or other constraints on sensor modules. Online real-time monitoring of all of their parameters is also possible.

4. IoT based battery monitoring system.

The IoT-based Battery Monitoring System consists of a communication channel to and from the IED, data collecting, a cloud platform, and a user interface (HMI). An embedded system has been developed as an IoT to enable communication from and to the IED, for data collection, and as an internet gateway for all battery systems. The IoT-based battery monitoring system uses the TCP/IP-based digital connection in JSON format as a data collection to obtain battery measurement parameters from the IED. Data is sent to the database and web server of the cloud system via the Internet gateway.The data in the cloud system is processed and analyzed to deliver information that consumers can easily comprehend. The ExtJS/HTML5 framework is then used to display this data in a Human Machine Interface (HMI), which can be accessed via desktop or mobile devices as illustrated in Fig. 4.

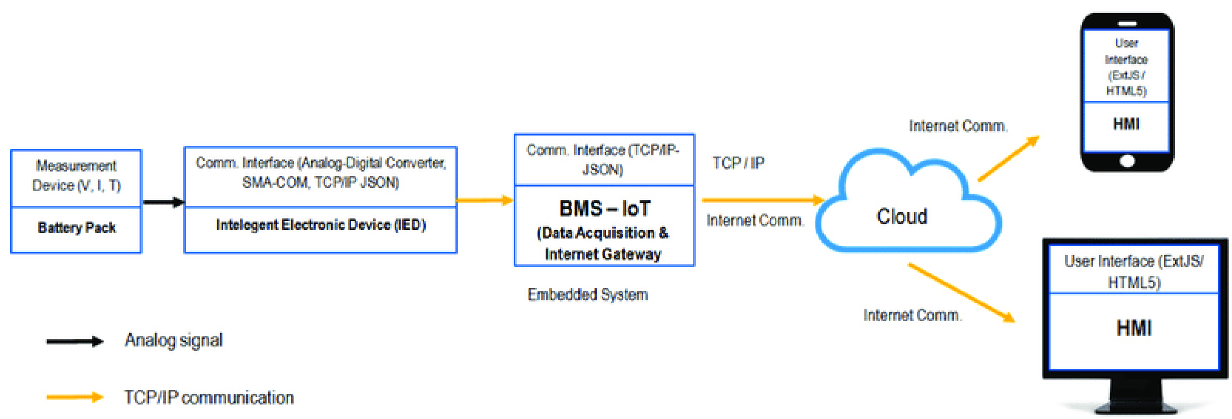

Figure 4: IoT based BMS

4. Conclusion

The main objective of this study is to priorities lead-acid batteries while having a full discussion on BMS and IoT-based BMS. The BMS parameters for the new BMS standard are compiled, examined, and stated in this article. The BMS is one of the core elements of electrical energy storage systems. Since BMS responds to both internal and external events, an electrical system must have a safe BMS on both fronts. The next development of the storage system is the IoT-based BMS.

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