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Study on Energy Storage, Charging and Battery Management System for Electrical Vehicles

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Abstract: The demand of Electric Vehicle operating on batteries is rising globally. This is being driven by a number of factors, such as the need to lessen air ,noise pollution as well as our dependence on fossil fuels.The biggest disadvantage with modern EVs is their short range and the prolonged time needed to charge their battery banks. Pulse charging, as opposed to providing continuous current as well as voltage, have made tremendous advances in recent years in terms of shortening the time it takes to charge the battery of EVs. The most crucial step in determining the potential driving range of an EV is the assessment of the Electrical properties of batteries. It's vital to understand a variety of battery performance characteristics in order to understand battery behavior in diverse circumstances.

Key Words: Electrical Vehicles, Charging Systems, Battery Management Systems, Energy Storage Systems.

1. INTRODUCTION

An electric vehicle (EV) is a type of motor vehicle that is powered by one or more electric motors. Gustave Trouvé, Thomas Parker, and Andreas Flocken created experimental electric automobiles in the 1880s, but it was the 1890s that saw the first functional battery electric vehicles. In 1931, the number of battery-powered milk floats increased, and by 1967, the greatest network of EVs was in Britain. EVs emerged in the mid-1800s when electricity was among the preferred methods of powering automobiles, offering a level of comfort and ease of use unmatched by the gasoline cars of the time. For over a century, internal combustion engines dominated the way that cars and trucks were propelled, but electrical power was still widely used in other sorts of vehicles, including railways and all sizes of smaller vehicles.

Due to technology advancements, a growing emphasis on non-conventional energy, and the possibility to reduce the impact of transport on environmental pollution. EVs have had a renaissance in the twenty-first century. One of the top 100 modern options to combating climate change, according to Project Drawdown, is the use of electric automobiles. A lack of charging sites and expensive costs has slowed the growth of EVs. By 2030, the International Energy Agency predicts there will be 130 million EVs will be in use globally. Controlling of EV charging and discharge will become more challenging in a short amount of time as the number of EVs on the road increases. By controlling how EVs are charged and discharged, transmission lines and transformer overload can be avoided, preventing the network's equipment from deteriorating too quickly. EV charging station capacity can also be used to increase grid stability and recover critical loads. The efficiency of distribution networks can also be increased as a result of EV charging and discharging.

When a battery is charged, the chemical reaction that occurred during discharge is reversed. Batteries also play a key role in EVs. For getting the appropriate voltage and capacity in the final package, an EV battery is often consists of a network of parallel and series-connected tiny, individual cells. Batteries that can be recharged can be used to power a wide range of devices and platforms. The majority of these need a Battery Management System in order to assure the battery's secure and durable functioning, which includes precise SOC and SOH calculations.

From here on out, we'll discuss the SOC and SOH estimation methodologies that we employed while developing BESS projects. Regardless of how huge or complex your BMS is, the same strategies will work for it. A BESS is a rechargeable battery-based electrochemical energy storage system. With charge and discharge of batteries in correct times, the system may either store or supply power as needed.

A BMS manages the whole system.BMS keeps track of cells of batteries health also ensures that they are safe from harm. Developing a BMS is a multi-step process that necessitates the creation of a number of subsystems on both the hardware and software levels. The battery technology that your BESS will use is the first thing you should consider when creating a BMS.

There are many different types of battery chemistry, each with its own set of properties and features. The best option is to select a battery that meets all of the BESS requirements. Because battery chemistries have different thermal tolerances, the operating conditions of the system are crucial. As a result, lithium-ion batteries aren't resistant to severe temperatures; they only work correctly between 10 and 40 degrees Celsius.

A BMS controls charging and discharging by determining the state of charge, preventing premature capacity

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loss and extending the battery's lifetime. Another useful BMS feature that helps us to improve the working of batteries by estimating the state of health.

2. TYPES OF EV's CHARGING SYSTEMS

The three main charging procedures are

A. Battery swapping

B. Conductive charging. Pantograph (On-board and Off-board) and overnight charging are the two types of conductive charging.

C. wireless charging

A. Battery Swapping:

Battery swapping means replacing of a drained battery with fully charged battery. The owner can replace the battery with a fully charged one when it is discharged. This will handle the issue of installing charging stations as well as drivers' range anxiety. Furthermore, battery leasing can assist EV owners save money on battery purchases. In comparison to charging at a battery station, which might take hours, the service is faster and takes only a few minutes. It also necessitates the bare minimum of infrastructure.

This kind of Electric charging strategy can be more expensive than fueling the engine because of the high monthly rental rates imposed. This technique requires an enormous amount of pricey batteries as well as a sizable storage facility, it is expensive in real estate and high traffic area. In addition, the vehicles batteries might be of a different standard than the station's, which may have a particular battery model.

B. Conductive charging method:

The conductive charger is a standard gadget that generates electricity by contact. In this type of charging, the Electric Vehicle connector and charge input are directly in contact. A conventional electrical outlet or charging station can be used to power the cable. Because it simply uses plugs and sockets to convey electrical energy via actual metallic contacts, the conductive charger for electric vehicles offers the benefits of stability, ease, and low price. To transfer energy, conductive power transfer connects two electronic devices via a conductor. Conductive charging is classified into two types

Pantograph: On-board and Off-board overnight charging.

a. **Pantograph charging:**

Higher battery capacity and power demand applications, such as buses and vehicles, require this type of charging infrastructure. This charging method requires less expenditure in the bus battery, lowering the bus investment cost; nevertheless, the charging method requires more investment in the bus battery. This enables you to charge bigger fleets of electric buses overnight at 50kW to 150 kW per each vehicle and during the day at 150kW to 600 kW for charging. This is again classified into two types:

Off-board charging

On-board charging

b. **Overnight charging:**

The overnight depot charging system can be built to charge slowly or quickly. This option enables operators to charge eTrucks during the day using fast chargers and over the course of the night at the depot. Usually, this is done overnight at the depot. Because it takes 5-8 hours to recharge the bus's batteries, chargers in these applications can be either AC or DC, and they run at relatively modest power levels (10kW–150kW). Slow charging is thus the most advantageous choice because to the minimal effect on the distribution system.

C. Wireless charging method:

Wireless automobile charging is a more advanced version of Smartphone charging that differs in various ways. "Without the use of cords, wireless inductive charging allows an electric vehicle [EV] to charge automatically." An electric vehicle's wireless charging technology uses an electromagnetic field to charge the vehicle and transfer energy. This charging method for electric vehicles can be divided into two kinds.

a. Static Wireless charging Method

b. Dynamic Wireless charging Method

3. TYPES OF BATTERIES USED IN EV's

Battery is a device that uses one or more electrical cells to transform Chemical energy into Electrical energy. There are two sorts of electrochemical cells i.e batteries:

A .Primary Batteries

B .Secondary Batteries

A .Primary Batteries:

These are "single-use" and non-rechargeable. Once the electrolyte in it has been consumed, it cannot be reused. Once these batteries have been discharged, they are no longer useful and must be discarded. Primary cells can be found in remote controls, wall clocks, watches, and other small electrical devices. Some types of primary batteries are

Leclanche cell

Mercury cell

a . Leclanche cell:

In 1866, French scientist Georges Leclanche designed and patented the Leclanche cell, a type of battery. It is a non-rechargeable cell. The Leclanche cell, commonly known as the zinc-carbon battery, is a conventional general-purpose dry cell. The Leclanche cell was commonly used for telegraphy, electric bell, and signalling operations, as well as activities that required irregular intervals and low current.

Advantages:

1. This battery cell is inexpensive.
2. These cells come in a variety of shapes, sizes, and capacities.
3. Long traditional reliability.

Disadvantages:

1. It has a low energy density.
2. In cold weather, it provides poor service.
3. It has poor leakage resistance.
4. The voltage drops slowly when the battery is discharged.

b. Mercury Cell:

The Mercury cell, often known as "Mercury oxide battery," a non-rechargeable and non-reusable electrochemical cell. This type of cells were utilised in watches, hearing aids, and calculators as button cells, as well as in bigger forms for various devices such as walkie-talkies.

Advantages:

1. Long shelf time up to 10 years.
2. The output voltage is constant at 1.35V.
3. Mercury cells are economical with current technology.

Disadvantages:

1. The presence of hazardous mercury and concerns about its disposal in the environment.
2. This battery generates power by oxidising zinc with mercury(II) oxide.

B. Secondary Batteries:

This batteries are rechargeable . It's a cell or a group of cells whose cell reactions are reversible. This indicates that by allowing current to flow into the cell, the original chemical conditions within it can be restored. Smartphones, electronic tablets, and autos all use these types of batteries.There are different kinds of secondary Batteries.

a. Lead Acid battery
b. Nickel Metal Hydride
c. Lithium ion battery
d. Nickel cadmium Batteries

a. Lead Acid Batteries:

They are invented in 1859 but are still in service, these batteries are the oldest. It can be recycled. This batteries have the benefit of being more affordable and having been around for a while. They store a mild solution of sulfuric acid and are a type of vexil battery. Although considered outdated, this battery technology is still reliable and fully developed. This battery type has a limited lifespan of three years and necessitates periodic electrolyte level checks because lead-acid batteries are heavy and provide enough energy to account for 25 to 50 percent of a vehicle's mass.

Working of Lead Acid Battery:

The accumulator, also called secondary cell, is a kind of battery in which Electrical energy stored as Chemical energy and transformed back into Electrical energy when needed. While charging a battery, electrical energy is transformed into chemical energy using an external electrical source. Discharging of secondary cell is process of converting chemical energy back to electrical energy for the purpose of powering an external load.

When a battery is charged, current is sent through it, causing chemical changes inside the battery. During the production of these chemical changes, energy is absorbed. While battery is connected to external load, chemical reactions occur in the opposite direction and the absorbed energy is released.

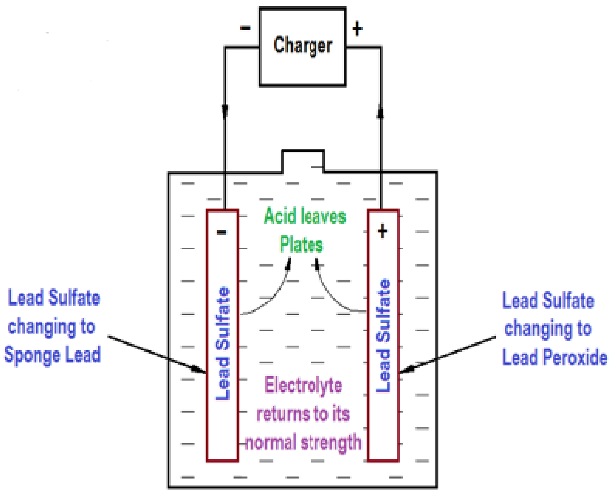

Fig.1: Lead Acid Batteries

Advantages:

1. It comes in a variety of shapes and sizes.
2. Lead can be recycled and reused in new batteries in approximately 97 percent of the time.
3. It performs well at both cold and high temperatures.

Disadvantages:

1. Cycle Life is Limited.
2. Charging is slow and inefficient.
3. energy squandered.

b. Nickel-Metal Hydride:

This was first used for commercial purpose in the early 1980's.The nickel-metal hydride battery's offer higher specific energy compared to the lead-acid batteries can operate at potential of 1.2 volts. The nickel-metal hydride batteries display the battery's internal energy level. These are recyclable even if their energy density is incredibly low in comparison with lithium-ion batteries. These batteries are proven for use in electric vehicles with a 5 to 7 year battery life and a distance of 1,00,000 miles.

Working of Nickel Metal Hydride:

Nickel-metal hydride batteries, like nickel cadmium battery uses nickel hydroxide as positive electrode. Hydrogen is stored in an aqueous solution containing mostly potassium hydroxide for the negative electrode and Hydrogen absorbing alloy for the positive electrode. Their charging as well as discharging responses are shown in the diagram below. It can be seen from overall response above, a nickel metal hydride battery's fundamental features, include the fact that hydrogen switches its direction when the electrodes are charged and discharged, without the electrolyte participating in the reactions, which means that there is no corresponding rise or fall in electrolytes.

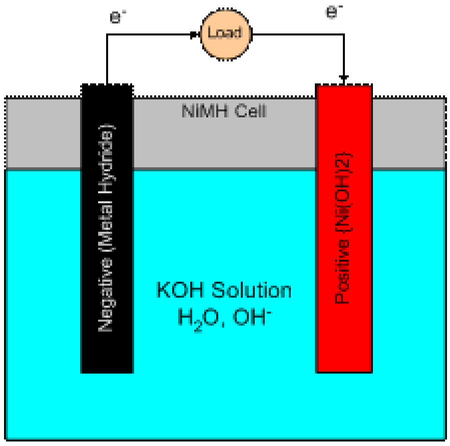

Fig.2: NiMH Batteries

Advantages:

1. 30% greater capacity than a typical NiCad battery.
2. Exercise cycles that occur on a regular basis must be completed less frequently.
3. There are less harmful metals. The NiMH has been designated as "environmentally friendly."

Disadvantages:

1. It has reduced charging effectiveness.
2. At room temp, a self discharging of 12.5 percent per day, and the rate at which heat is produced during rapid charging and discharge.
3. The NiMH's recommended discharge current is significantly lower than the NiCad's.

c. Lithium-ion batteries:

Lithium batteries, that have a higher energy density than other batteries but were not commercially available until the 1990s, were introduced. While not being used, they almost never lose its charge. This characteristic is known as self discharge. Innovation is the development of science, and many experts agree that Lithium-ion batteries are the most technologically advanced rechargeable batteries to date. The greatest option for supplying electric automobiles with power in the near future is this kind of battery. Despite being outrageously expensive, these batteries are nonetheless the ones that are utilised in EV the most frequently.

Working of Lithium-ion Battery:

During the charging process, lithium ion migrate from positive electrode through the electrolyte to the negative electrode. Around outer circuit, the electrons move from positive to the negative electrodes. Lithium is deposited at the negative electrode by the combined action of ions and electrons. When there are no more ions left to flow, the batteries are completely charged and available for use.

When the battery is discharged, the ions return through the electrolyte. The current flows backwards from negative to positive electrodes, ions not only move from the negative to the positive electrode, but also throughout surrounding electrical circuit. This procedure gives your device its power.

The battery is considered fully charged if every ion has moved back to its previous location.

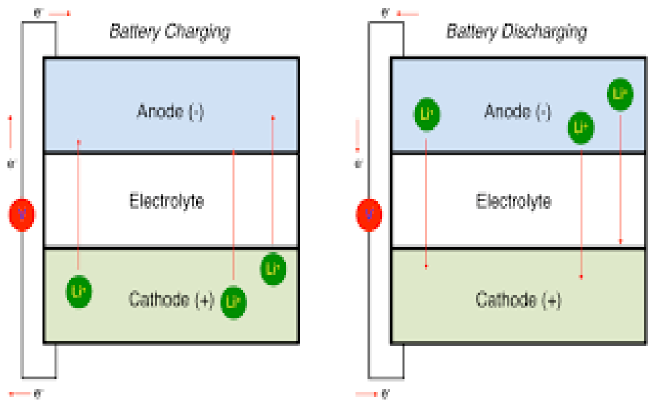

Fig.3: Lithium-Ion Batteries

Advantages:

1. The rated open voltage is 3.6V, compared to 1.2V for Ni-MH and Ni-Cd batteries.
2. Lithium is a highly reactive metal that can both release and retain a lot of energy.
3. Maintenance is low.

Disadvantages:

1. It only lasts two to three years after the manufacturer's warranty expires.
2. High temperatures make it vulnerable.
3. The battery can no longer be recharged once it has been totally discharged.
4.

d. Nickel-Cadmium Battery:

After Waldemar Junger's invention of the Nickel cadmium rechargeable battery in Sweden in 1899, the first of these products was introduced in 1900s. Portable computers, drills, camcorders, and other small battery-powered devices employ Nickel-Cadmium batteries, which are rechargeable. NiCd utilise nickel oxide hydroxide electrode, metallic cadmium and electrolyte of potassium hydroxide.

Working of Ni-cd batteries:

In this type of battery there is one more positive plates than negative plates. This battery's positive plates are electrically linked to the battery's containers. In completely charged, the cell positive plate is made of $Ni(OH)_4$ and the negative plate is made of cadmium . Potassium Hydroxide (KOH) ions are separated into K^+ & OH^- ions as cell discharges. The cathode receives hydroxyl ions while the anode receives potassium ions.

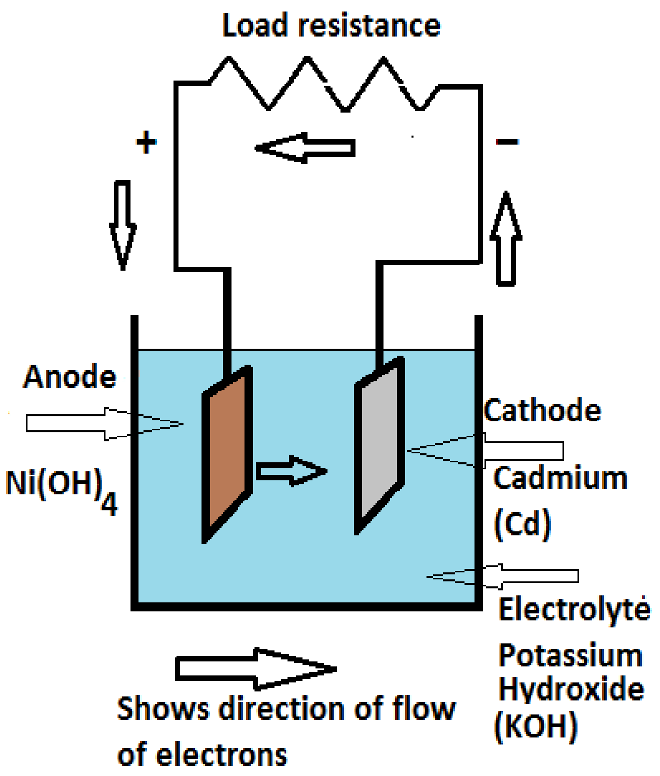

Fig.4: Nickel-Cadmium Battery

Advantages:

1. They are more durable and has high energy densities (50 to 75 Wh/kg) (2000 to 2500 cycles)
2. Delivers a large amount of current.
3. Overcharging tolerance is relatively high.

Disadvantages:

1. Cadmium has a negative impact on the environment.
2. There is a noticeable memory effect when charging.
3. The battery has a low capacity and a short life expectancy.

4. BATTERY MANAGEMENT SYSTEM

A rechargeable batteries operation is monitored and managed by an electronic device known as a battery management system (BMS). Monitoring of temperature, voltages, and current is covered, as well as maintenance planning, battery performance improvement, failures detection and/or avoidance, data collection, and analysis are included. Battery protection in order to avoid operations outside its safe operating region are the major purposes of a BMS for electric vehicles. During charging and discharging, battery packs are monitored by assessing their State-Of-Charge (SOC) and State-Of-Health (SOH).

In electric vehicles, a BMS extends the life of the battery cells. This is an efficient mechanism for measuring and controlling the voltage of the cell. It provides stability and reliability.

BMS can be used in single or multi cell lithium ion battery applications. In a Lithium-Ion battery, a BMS is necessary. This device monitors temperature and voltage, determines state of charge, connects to external devices, operates every battery cell in real-time, and performs a variety of other functions. BMS prevents the battery from being overcharged or overdischarged.nd voltage, and so on. It is not safe to use a lithium ion battery without a BMS. Overcharge protection is available for one cell. However, 2 cell (7.4 V) and 3 cell (11.1 V) packs require a BMS to completely charge the battery.

Basic Structure:

One of the most essential components of an electric car is the battery pack, which accounts for 40% of the entire vehicle cost. Lithium ion cells are used in battery management and are monitored by a BMS system. It has a control unit. Each cell's current voltage and temperature are measured and processed using control algorithms, which result in outputs such State-Of-Charge (SOC) ,State-Of-Health (SOH),temperature control, and power optimization. all this information is communicated with other ecus also it is sent to the display unit. first one cell monitoring if the charging as well as the discharging of the battery cells need to be monitored so it involved in the form of SOC and SoH of a cell. State-Of-Charge is indicator of power in the battery . State of Health (SOH) indicates overall health of the battery so this information is useful for battery maintenance and lifespan management. Power management SOC and SOH parameters must be maintained under the specified limit.During charging BMS Determines current permitted in each cell.And during discharging BMS makes sure the voltage doesnot go much low. Electric Vehicle Safety there can be a leak or thermal runaway which can result in hazard so voltage temperature and current data.Diagnostics:BMS diagnostics identifies faults stores these issues as trouble code to fix later.

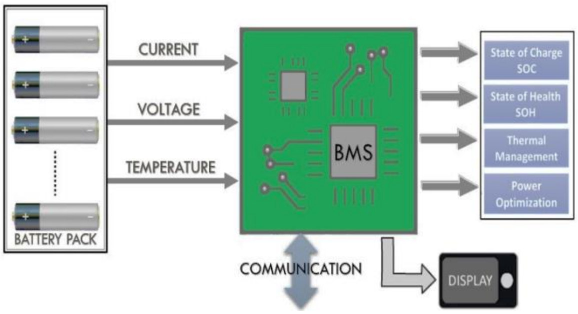

Fig.5: Basic structure of BMS

Structure Of Battery Management System:

Depending on the complexity and functionality of the system, MCUs and BCUs can be arranged in a variety of ways. They differ in terms of price and simplicity.

There are different types of configurations,They are

A. Single-Board Configuration
B. Smart Modules Configuration
C. Light-Intelligent Modules Configuration
D. Full-Intelligent Modules Configuration

i. Functions of Battery Management:

The Multi-point Control Unit comprises measurements of voltage, temperature, and current. Protection and performance management, are mandatory for all BMSs

A. Performance Management:

a. Voltage, Current and temperature monitoring:

These three primary quantities which can be monitored directly. But temperature is indirectly calculated. Most measurements are conducted in the centre of a cell casing or on top of the anode collector.

b. Cell balancing:

Cell balancing is a technique for extending the life of a battery pack by increasing the capacity of numerous cells connected in series and ensures that all of the energy is available for use. Higher capacity cells are charged and discharged completely during balancing. The cell with the smallest capacity is a weak point without cell balancing. Cell balancing, along with temperature monitoring, charging, and other characteristics that help extend the life of a battery pack, is one of the basic activities of a BMS. Cell balancing methods are divided into active and passive categories as a starting point for classification. Energy is transferred between neighboring cells when active balancing is used.

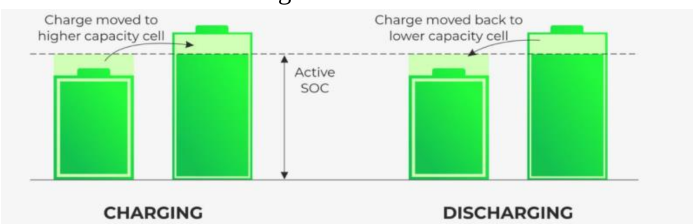

Fig.6: Active balancing

A switching resistor is generally used in passive balancing methods for the most charged cell in a battery string.

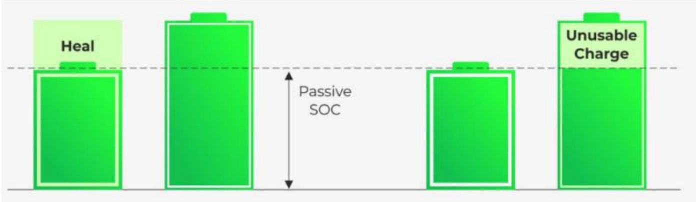

Fig.7: Passive balancing

c. Power save mode:

Lithium-ion batteries can't be discharged any further than a certain point. When a battery is left entirely depleted over an extended period of time, the BMS should detect this and enter power-saving mode.

B. Protection:

The Safe Operating Area (SoA) is critical to the safe operation of a battery pack. It is described as the voltage, current, and temperature settings at which the device will run without self-damage. An intelligent BMS must protect its battery pack from external threats like overheat and thermal protection. These circumstances may result in failure and damage. BMS ensures that the battery is performing in a safe operating area to avoid such situations.

C. Auxiliary functions:

a. Precharge function:

If the battery is linked to a system with a high input capacity, this function is required. A large inrush current may flow into the load, potentially damaging the input capacitors or the high-power relay. Two relays are connected in parallel to lower current peaks. The precharge relay, for example, has a series resistor that reduces the peak current. The input capacitor gets charged after sometime, allowing the main switch to be closed without causing excessive currents.

b. Cooling control:

A battery used in high-power applications may experience significant heat dissipation inside the cells on a regular basis.To maintain the safe operation of the battery,it must be provided with active cooling system under the control of BMS.

D. Communication functions:

Because of the communication between them, all of the key duties of a Battery Management System are performed on time, including monitoring, collecting information about cell parameters, and related circuitry diagnostics. The communication medium chosen is determined by the application's requirements. Information on the battery and vehicle performance is also given to the driver in electric vehicles so that they can take appropriate action.

E. Diagnose functions:

a. SOC determination:

State of charge (SOC) indicator of power in the battery. The ratio of the available capacity to the maximum possible charge that may be held in a battery is known as the State-Of-Charge.

b. SOH determination:

State-Of-Health (SOH) indicates overall health of the battery so this information is useful for battery maintenance and lifespan management. This helps us to study the variations between tested battery and new battery,taking cell aging into account.SOH is the ratio of the maximum battery charge to the nominal capacity of the battery.

ii. State of Charge(SOC) controller:

It is defined as the quantity of electric charge that can be drained from a battery. It's commonly measured as a percentage of the battery's maximum charge capacity.There are a range of percentages used to express charge levels, from 0-100. The state-of-charge indicator allows users to see what resources are available and then when the battery has to be recharged. The following parameters can be used to assess the SOC: Potential difference, current, capacity, impedance, charging and discharging rate, and temperature are all factors

a. Open Circuit Method:
b. Coulomb counting (Current Integration)
c. Kalman filter
d. Alternative estimators of SOC
    a. Terminal voltage method
    b. Impedance method:
    c. Neural networks

iii. State of Health:

The capacity or current condition of a battery is referred to as its state of health (SOH) when contrasted to its ideal state. SOH can assist you figure out how much battery life you have left. As a result, when computing the SOH, you can rely on: Inbuilt resistance, number of cycles, Strength, and Aging, Energy output, temperatures, rate of self-discharge , and voltage. The SOC is a more general feature connected to the strength, age and degree of wear of the battery.Although the SOH battery parameter cannot be directly measured, it can be calculated by measuring related physical parameters..

a. Internal resistance Method
b. Internal impedance method
c. Counting charge/Discharge

iv. Safe Operating Area:

A BMS ensures that batteries are used safely and reliably. It can, for instance, safeguard a battery against overheating or under heating, as well as overcharging or over discharging. The temperature and voltage should always be within a safe operating area (SOA), as seen in the voltage versus temperature graph below. Because multiple systems are available, the value in the graph should always follow the BMS manufacturer's data sheet. An over-temperature condition occurs when the battery's temperature surpasses the SOA owing to very warm or hot conditions. It's dangerous since it can melt cells and circuits. Cold or freezing temperatures can induce an under-temperature state, affecting the battery's ability to provide power. Overcharging occurs when the voltage surpasses the battery's ideal state limitations and increases over the SOA, causing the battery to be damaged and rendered useless. It's called an under-charge when the voltage falls below the state limit. A trustworthy BMS monitors each cell in the circuit and protects the battery by stopping its charge if any of the ideal states are exceeded.

v. Temperature:

The temperature range of 25°C to 40°C is excellent for Li-ion batteries, whereas temperatures beyond 50°C are hazardous to the batteries' lifespan; Even a single immature cell can significantly impair the overall performance and efficiency of the battery pack. Temperature has a considerable impact on lithium-ion battery performance and also restricts their use. The range of electric vehicles (EVs) is temporarily reduced by cold weather. The chemical and physical interactions that make batteries work, particularly conductivity and diffusivity, are slowed by cold temperatures, resulting in decreased battery performance. The rate of Li battery degradation is known to be influenced by temperature. Temperature impacts the rate and effectiveness of chemical processes inside a battery, which is one of the main reasons it is so important. Higher temperatures (or higher voltages - but that's a topic for another essay) result in faster responses. At greater temperatures, the "unwanted" chemical interactions that cause batteries to breakdown occur more quickly.

5. CONCLUSION

Electric vehicle charging trends will primarily focus on fast charging, contactless charging, and charging from sustainable or renewable energies. Although it is estimated that electric vehicles will become the main means of transportation in the future due to their environmental benefits, the proportion of EVs is now low in Australia and around the world. The BMS supports longer battery life, lowers the rate of damage, and maximises the capacity, effectiveness, durability, and dependability of battery stacks.

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