1) **What is a BMS? Types of BMS and differentiate the types of BMS.**

 In order to ensure the safety of electric vehicles, a battery management system is essential. It controls the electronics of a rechargeable battery pack. By ensuring that the cell runs within its safe operating limitations, it protects both the user and the battery. BMS tracks the battery's State of Health (SOH), gathers data, manages external elements that affect the cell, and balances them to maintain uniform voltage across cells. A smart battery pack is a battery pack that has a BMS connected to a data bus or an external communication data transmission system.In order to provide details about the battery's power status, it may also include additional features and functions like fuel gauge integration, smart bus communication protocols, General Purpose Input Output (GPIO) options, cell balancing, wireless charging, embedded battery chargers, and protection circuitry. The device can use this information to intelligently preserve power. Key variables including voltage, current, internal resistance, and ambient temperature will be continuously monitored by the BMS. The BMS's monitoring system will safeguard the device by sending a signal to the alarm generator and instructing it to disconnect the load or charger. Every BMS will be used in a distinct application, leading to the variety of BMS.A BMS may protect its battery by preventing it from operating outside its safe operating area, such as:[citation needed] Over-charging Over-discharging Over-current during charging Overcurrent during discharge Over-voltage during charging, especially important for lead–acid, Li-ion and LiFePO4 cells Under-voltage during discharging, especially important for Li-ion and LiFePO4 cells Over-temperature Charging while under low temperature Overpressure (NiMH batteries) Ground fault or leakage current detection (system monitoring that the high voltage battery is electrically disconnected from any conductive object touchable to use like vehicle body) The BMS may prevent operation outside the battery’s safe operating area by: Including an internal switch (such as a relay or mosfet) which is opened if the battery is operated outside its safe operating area Requesting the devices to which the battery is connected to reduce or even stop using or charging the battery. Actively controlling the environment, such as through heaters, fans, air conditioning or liquid cooling

BMS is classified into hardware BMS and software/smart BMS;

* Hardware BMS

All BMS have at least all the function of hardware BMS. Mainly the functions are

Over voltage cutoff

Under voltage cutoff

Continuous current

Over current detection

Over temperature cutoff

The BMS will also manage the battery's recharging by directing the energy that has been recovered (through regenerative braking) back into the battery pack (typically composed of a number of battery modules, each composed of a number of cells).

The cooling medium for battery thermal management systems can be air, liquid, or some other type of phase transition, and they can be passive or active. The simplicity of air cooling is a benefit. Such systems can be active, utilizing fans for airflow, or passive, depending merely on the convection of the surrounding air. Commercially, the battery systems of the Honda Insight and Toyota Prius both utilize active air cooling. [2] The main drawback of air cooling is its lack of effectiveness. To function, a lot of electricity must be utilized.

* Software BMS

It includes every feature of a hardware BMS. In addition, they have data control capabilities, a monitor for data storage, and the ability to communicate data through Bluetooth and CAN. Benefits of a smart BMS include the ability to monitor battery status information such as internal temperature, impedance, voltage, and current online. While lowering the cost of human maintenance, round-the-clock monitoring enables prompt action in the event of potential battery accidents.

The system can also automatically appraise and analyze uploaded data thanks to real-time alarms and online balancing. For instance, you can establish a custom alert threshold, and if the uploaded data is anomalous, the system will send a server-based alarm to maintenance.Because of all the historical data that is gathered, stored, and analyzed, a smart BMS might be considered a BMS data center. At the same time, you can get real-time battery information via a certain system. Additionally, it is straightforward to set up and operate due to the friendly user interface design of the smart BMS.Due to its numerous benefits, the smart BMS is applied as an assistant in various industries. To summarize, there are mainly six application areas with a wide array of use at various levels.

 These include:

 Data centers

 Power utility like substations

Transportation such as railway transport

Base transceiver station sites

Energy storage stations Financial institutions like banks.

Most of the battery monitoring suppliers normally provide common solutions for these industries. Therefore, DFUN provides a targeted solution for different industries that meet the needs of professional customers.

Types of battery management systems

1. Centralized BMS Architecture

consists of a battery pack assembly with a single central BMS. Direct connections have been made between the central BMS and each battery package. Figure 6 depicts a centralised BMS's construction. There are various benefits to the centralized BMS. Since there is only one BMS, it tends to be more compact and more affordable. But there are drawbacks to a centralised BMS. Since every battery is directly connected to the BMS, the BMS requires a large number of ports to connect with every battery package. Large battery packs consequently have a lot of wires, cabling, connectors, etc., which makes maintenance and troubleshooting more difficult.

1. Modular BMS Topology

The BMS is separated into numerous replicated modules, much like a centralised implementation, each with a specific bundle of wires and connections to a neighboring designated area of a battery stack . These BMS submodules might occasionally be supervised by a main BMS module, whose job it is to keep track of their status and interact with ancillary hardware. Duplicated modularity makes troubleshooting and maintenance simpler, and it makes it simple to expand to larger battery packs. The drawback is that total expenditures are a little greater, and depending on the application, there can be redundant, unneeded functionality.

1. Primary/Subordinate BMS

Conceptually similar to the modular topology, however, in this case, the slaves are more restricted to just relaying measurement information, and the master is dedicated to computation and control, as well as external communication. So, while like the modular types, the costs may be lower since the functionality of the slaves tends to be simpler, with likely less overhead and fewer unused features.

1. Distributed BMS Architecture

The electronic hardware and software in these topologies are contained in modules that connect to the cells through bundles of attached cabling, which is significantly different from the other topologies. A control board located on the cell or module being monitored houses all the electronic hardware in a distributed BMS. As a result, the majority of the wiring is reduced to a few sensor wires and communication cables connecting nearby BMS units. Each BMS becomes more independent as a result and manages calculations and communications as needed. Although it appears straightforward, this integrated form could make maintenance and troubleshooting difficult because it is tucked away inside a shield module assembly. As there are more BMSs in the total battery pack construction, costs also tend to be greater.

2) **What are the technical parameters to keep in mind while procuring a BMS for assembling a battery pack?**

Mainly, there are 6 components of the battery management system.

1. Battery cell monitor

The voltages for battery systems are primarily monitored via a battery cell monitor. For high voltage measurements, it is a fast system with a reasonable total cost.Monitoring individual cell voltage in relation to the predetermined voltage level is the simplest technique to assess the battery pack charge.The charging automatically stops when the first cell's voltage hits the voltage limit. It serves as a warning that the battery charge cap has been exceeded.The least charged cell will approach the limit first and the remaining cells will be left partially charged if the battery pack has a lower charge than the average cell.

2. Cutoff FETs

The battery pack's load and charger must be connected and kept separate by the FET driver. Voltage, current, and real-time detecting circuitry readings are used to forecast behavior.They can be attached to either the low or high side of a battery pack.To enable high-side connection, NMOS FETs must be activated, which calls for a charge pump driver. For the remaining circuitry, a high-side driver is used to set a reference for the solid ground.Since a charge pump is not required in integrated systems, we use a low-side FET driver to cut expenses. In such circumstances, high voltage devices are not necessary.Using low-side cut-off FETs, the battery pack's ground connection floats. The IC's performance may be impacted, increasing its sensitivity to insinuated noise measurement

3. Monitoring of Temperature.

With the increase in product requirements, the batteries have been on a constant surge in delivering currents at fixed voltages. The continuous operation processes may cause a catastrophic event such as fire or explosion. We can identify whether battery charging or discharging is desirable using temperature measurements. Temperature sensors monitor the energy storage system or cell grouping for compact portable applications. The circuit temperature is monitored by the internal ADC voltage-powered thermistor. Employing the internal voltage reference helps reduce the temperature inaccuracies and improves the overall measurement system.

 4. Cell voltage balance

It is essential to ascertain the battery pack's condition. To make sure that the cells are functioning properly in order to achieve a long battery life, cell voltage monitoring is carried out as a result. In a lithium-ion battery, the operating voltage ranges from 2.5V to 4.2V. When battery operations are performed outside of the voltage range, the battery life is dramatically impacted. A cell's lifespan is shortened as a result, perhaps rendering it useless. While connecting the battery pack in series raises the total voltage, connecting it in parallel increases the overall drive current.

5. BMS Algorithms

To act quickly and wisely in the present based on the knowledge acquired. A microcontroller for the battery management system is required for this task in order to gather, arrange, and evaluate the data from the sensing circuits. The most well-known application of a battery management system algorithm is the Rennes ISL94203. It is a digital standalone solution that is integrated onto a single chip and has programmable features. These stand-alone methods can be used to clean the memory and microcontroller for battery management system clock cycles.

6. Real-Time Clock (RTC)

The real-time clock functions as a "black box" device for time-stamping and memory storing, letting the user know the battery pack's behavior prior to any alarming incident. Battery authentication prevents the BMS electronics from syncing with a different battery pack. Through a voltage reference/regulator, the peripheral power circuitry is employed around the battery management system's components.

3) **What is the purpose of BMS with communication? What are the various protocols of communication used in a BMS?**

 In terms of voltage, current, and temperature, the fundamental objective of BMS is to keep the battery within the safe operating range while it is being charged, discharged, or in some circumstances, when it is open circuit. You often utilize a BMS IC while working with a BMS. You might need to link to an external microcontroller or another external IC, depending on the BMS IC being used to control your BMS.

To send and/or receive information from one another, these ICs must be able to communicate with one another. You might not be able to measure current with your BMS IC, for instance. As a result, you employ an external IC for current measurement. The BMS IC must then receive this current data.The BMS IC may also be coupled to a microcontroller, which reads data from the IC and uses it to make choices about the BMS. Therefore, for a battery management system with numerous ICs to be able to communicate with one another, communication protocols are essential.

URAT

The most popular communication protocol used in battery management systems is UART, which stands for Universal Asynchronous Receiver/Transmitter. In serial communication, like UART, bits are transferred sequentially one after the other as opposed to simultaneously in parallel communication, when several bits are sent. A microcontroller and the BMS IC in a BMS frequently communicate using the UART protocol. Additionally, it is employed for interfacing the microcontroller with the GSM, Bluetooth, or WiFi modules. When a BMS's firmware is being developed, it is frequently used for debugging to examine specific portions or lines of code. UART allows code output to be printed and displayed on a screen. UARTs send data asynchronously, which means there is no clock signal to synchronize the output of bits from the transmitting UART to the sampling of bits by the receiving UART. In UART communication, two UARTs communicate with each other directly. Instead of using clock signals to run, UARTs use baud rates. The pace at which data is transferred during communication, measured in bits per second, is known as the baud rate. For communication to function, the baud rates on the transmitting and receiving sides must be adjusted to be equivalent. Before there is too much of a difference in the timing of the bits, the baud rates can only change by roughly 10%. To communicate data between two UART devices, only two cables are required.

For example, if we have 2 devices, device 1 and device 2, each device has 2 connections, Rx and Tx. The Tx of each device connects to the Rx of the other device. This way the transmitting data of one device goes to the receiving end of the other device, thus, establishing communication.

12C

The IC-to-IC protocol is known as inter-integrated circuits communication (I2C). I2C is primarily designed for close-proximity communication between two integrated circuits on the same printed circuit board (PCB). Multi Master - Multi Slave topology is supported by I2C. In order to connect with slave devices, the I2C standard bidirectional interface employs a controller known as the master. Things like an RTC clock, an EEPROM, flash memory, or SD card memory are examples of slave devices.All other devices are slave devices, while the clock-generating device is the master device. To distinguish one device from another on the same I2C bus, each I2C bus device has a unique device address. A device may have one or more registers for storing, writing, or reading data. The serial clock (SCL) and serial data (SDA) lines make up the physical I2C interface. A pull-up resistor must be used to link the SDA and SCL lines to VCC. The SDA line may transmit and receive data because it is bidirectional.

SPI

A master-slave protocol known as SPI, or serial peripheral interface, offers a straightforward and inexpensive interface between a microcontroller and its peripherals. The SPI protocol synchronizes the transmitter and receiver, or Master and Slave, using a dedicated clock signal generated by the master device. All other devices, such as peripheral ICs or even additional microcontrollers, are referred to as slave devices since only one device—typically a microcontroller—is designated as the bus's master. Along with other peripheral devices that support SPI communication, the microcontroller can connect with the BMS IC via this protocol.These applications make use of memory devices like SD cards, MMC, EEPROM, or Flash, sensors like pressure or temperature sensors, control devices like ADC, DAC, digital POTs, and audio codecs, as well as other devices like touch screens, LCD devices, RTCs, or gaming controllers. Each device in SPI communication utilizes 4 lines. To determine which slave device the master is attempting to interact with, there are chip select lines, input data lines (receiving data), output data lines (transmitting data), clock lines, and output data lines. The chip pick line serves to choose the specific slave device to either transmit data to or receive data from if there are numerous SPI slave devices attached to the master.MOSI (Master Out, Slave In), MISO (Master In, Slave Out), SCLK (Serial clock), and CS or SS are the specific pins of an SPI bus (Chip Select or Slave Select). The master device reads data from a slave device using the MISO, while the slave device transmits data to the master using the MOSI. Full-duplex communication takes place at extremely high speeds during SPI. Full duplex refers to the simultaneous operation of data transmission and reception. In contrast to UART or I2C connection, where data can only be sent or received at a certain time and not both at once, this has advantages.The disadvantage of SPI is that 4 wires are required instead of 2 for UART and I2C.

CAN

In the automobile sector, the most popular communication protocol is called CAN, or Controller Area Network. Because CAN communication eliminates all signal disturbances like electromagnetic sounds, it is frequently used in automobile applications. Additionally, it gets rid of a lot of wire harnesses from a system. One of the strongest and most dependable communication protocols is this one. Applications utilizing CAN can range from being very simple to being quite complicated. They are used in both electric and gasoline-powered cars. A chip that supports CAN communication is used in conjunction with the CAN protocol. One company that produces CAN chips, which enable CAN communication between devices, is Texas Instruments.

One example of this is the TCAN1042-Q1 Automotive Fault Protected CAN Transceiver with CAN FD.

The CAN chip links to the microcontroller, and the CAN chip then connects to the external devices. TXD and RXD pins on the CAN chip enable communication with the microcontroller. The TXD pin is used for data transmission, whereas the RXD pin is used for data reception. Thus, these are the battery management systems' most popular and widely utilised communication protocols