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A Review on Classification, Monitoring Systems and Parameters of Hybrid Electric Vehicles

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ABSTRACT:

Hybrid electric vehicles have been among the most impressive, fast-growing, and potentially game-changing technical developments of the previous decade (HEVs). The demand for green cars has been on the rise for some time now. Both future automobile buyers and current residents are considering the financial implications of pollution and environmental issues. Potential causes include the government's stricter laws concerning CO2 emissions and the continually increasing price of Brent oil. With a 48 percent rise, sales of hybrid and electric vehicles are booming. In this study, classification of HEV's are also discussed. Battery management systems (BMS) is one of the most important monitoring systems, batteries are used as the principal energy source in many different kinds of products and machines, such as portable gadgets and electric cars. Interest in EV batteries started to rise as the initial EV was developed in the midst of the nineteenth century. The automobile industry has once again begun to focus on EV batteries due to the fact that EVs may reduce fuel use by up to 75%. The primary concerns of consumers in expanding the EV and HEV industry are security and reliability. However, the battery technology and battery management system are also considerations for each of them. A battery management system (BMS) connects the battery to the vehicle and optimises both the battery's performance and the vehicle's safe and reliable operation. We also use this information to come up with a cheap way to keep track of electric and hybrid cars.

1. INTRODUCTION:

One of the most impressive, rapidly expanding, future-oriented technological trends of the recent decade is the rise of hybrid-electric vehicles (HEVs) and full-electric cars. Due to a number of factors, the market for eco-friendly cars has been growing steadily. Potential car purchasers must balance two competing priorities: reducing their impact on the environment by purchasing fuel-efficient vehicles and keeping their budgets in check. Some of the reasons could be that businesses have to follow stricter rules about carbon dioxide emissions and the price of Brent oil keeps going up because of European policies. The government incentive (quite frequent throughout many European countries) that can be earned upon purchasing an electric or hybrid car is another factor that may influence a user's choice to purchase an electric or hybrid vehicle. This means that the sales volume in the niche electric/hybrid car industry is always rising. There was a 33% year-over-year rise in the registration of small and medium-sized passenger cars with the ability to be charged electrically in EU and EFTA nations in 2018. Sales of hybrid and electric cars increased by 48%. (approximately 201,000 units). These days, batteries are the go-to power source for a broad variety of devices and machines, from cell phones to electric cars. The introduction of the first electric vehicle in the middle of the nineteenth century sparked widespread curiosity in battery technology. The resurgence of interest in EV batteries is largely attributable to the fact that EVs may cut gas use by up to 75%. Consequently, a battery-management system (BMS) is crucial for enhancing battery performance and optimising vehicle operation in a safe and dependable way since it serves as the link between the battery and the vehicle. There should be indications on the BMS that display the battery's current safety, consumption, performance, and lifespan. If a lithium-ion battery is overcharged, it might catch fire due to increases in volatility, flammability, and entropy. Since an explosion might result in a tragic accident, this is a particularly critical issue in EV as well as HEV applications. Over-discharge also produces permanent chemical changes that diminish the cell's capacity. As a result, battery packs feature safety circuitry that needs a BMS to monitor and manage the battery. When the BMS detects a problem, such as high voltage or high temperature, it should alert the user and then carry out the programmed corrective method. The BMS also connects with specific components and operators, and it controls the core temperature to give a brief real-time energy plan. Simply said, the following features are essential for a fully-fledged BMS:

- Acquiring information.
- Ensures security.
- Identifying and foreseeing the battery's condition-charge-discharge management capabilities.
- Restoring cellular equilibrium.
- Incorporating thermal management.
- Transmission of authentication and battery life information to a software.

- Interaction between all battery parts.
- Improved battery life.

At the outset, it's important to differentiate between traction and propulsion. The motor provides the vehicle with traction, while the various engine systems power the vehicle forward. An all-electric vehicle is one that relies only on its on-board battery pack to power its electric motor. For proper functioning of the vehicle, huge charging hubs must be located at every mile which is shown in Fig1.An automobile is classified as a hybrid if its electric motor receives power from both an internal combustion engine and a battery. This car is really a hybrid that runs on hydrogen and water. All-electric and hybrid EVs lower pollutants in their immediate vicinity; however, this is not the case for the global environment.

In a hybrid-electric vehicle (HEV), at least two power converters are used together. These converters might be ICE engines, battery packs, hydraulic drives, etc. (HEV). The goal of the HEV is to provide the same level of performance as a conventional vehicle, as well as the same level of safety, while using less gasoline and emitting fewer potentially dangerous pollutants. Multiple advantages are possible with hybrid automobiles: greater efficiency, converting kinetic energy into future storable energy, high low-speed torque and reduced cruising-speed torque, eliminating transients and smoothing out the engine's idle time, allow the powertrain to be smaller and lighter, the engine may be turned off, lowering fuel consumption, emissions, and noise and vibration levels, Parasitic loads may be kept. **Drawback's of HEV:** Complexity has grown, the car became heavier because of the new parts, expense growth, reduce the dependability of systems.

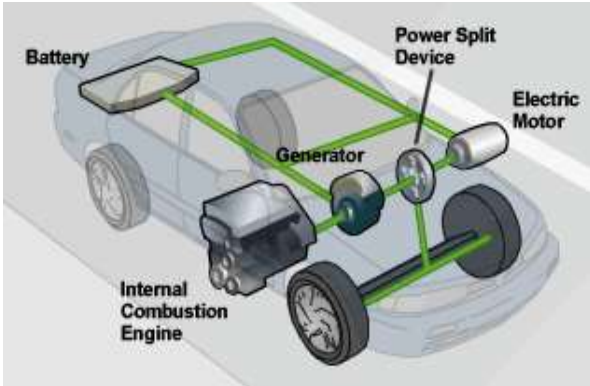

Fig1: Functionality of Hybrid cars

2. Classification of Hybrid Electric Vehicles

HEVs have traditionally been split up into three different types: series HEVs, parallel HEVs, and combination HEVs.

2.1 Configuration of Series HEV:

HEV components include an internal combustion engine (ICE), a generator, a power converter, a motor, and a battery as shown in Fig 2. Since the ICE and gearbox are not mechanically linked, the ICE can operate at peak efficiency by regulating the battery's output to meet the vehicle's needs. But there is additional energy loss during the transmission of electricity from the ICE, since it must first pass via the generators and then the engine. Since the engine is the only way to move the car, it has to be strong enough to match the vehicle's output. Because of this, it can almost store the braking force in the battery when the vehicle is stopped.

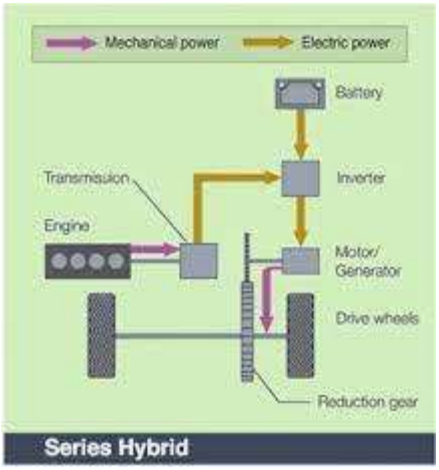

Fig 2: Configuration of Series HEV.

To replenish the battery storage system and the electric machine that drives the series HEV, an electric motor is linked to an internal combustion engine (ICE). The engine and vehicle speeds are separated, which is a major plus for the series. The engine will be operating at its optimum level, resulting in much less gasoline being used. However, this design contains a bulky energy storage system, electrical machine, and engine, increasing inefficiency and weight since the electrical generator is the only one attached to the axles and the engine/generator combination is designed for continuous power.

2.2 Configuration of Parallel HEV:

The electric vehicle and ICE may each produce power to move the car independently or in tandem with the parallel HEV. As shown in Fig 3, In contrast to the HEV series, there exists a mechanical connection between the ICE and transmission, so the ICE's rotating speed varies with the driving cycle; this allows the ICE to follow the optimal operating line by adjusting the battery's output power.

In parallel hybrids, the wheels are connected mechanically to both the electric drive and the engine. When accelerating, power may be distributed between the drive train and the engine because of their mutual connection to the wheels. As an added bonus, the engine and electric motor may be made smaller than in series hybrids. As the vehicle's speed determines the ICE's operating speed, this ICE can only run near its optimal efficiency curve under certain circumstances. Engine efficiency is improved in most situations when compared to a series system, even though both electrical and mechanical energy can be used directly to propel the vehicle.

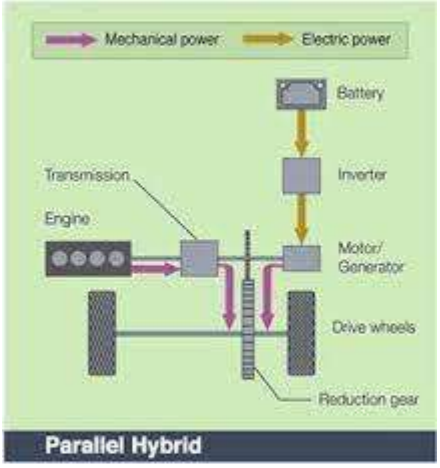

Fig 3: Configuration of parallel HEV.

2.3 Configuration of Combination HEV:

With the HEV combo, you get the best of both worlds: the best for both series and parallel hybrids; in the former, you get an extra mechanical connection between the ICE and gearbox; in the latter, you get an extra generator between the ICE and energy converter. Complexity in structure does increase manufacturing costs. Fig 4 shows the diagram of combination HEV.

The HEV mix combines the most advantageous features of parallel and series hybrids to create a very effective strategy. The method uses a mechanical gear set to transfer engine power to the wheels, while the generator generates energy. The series route is often avoided because of its low efficiency. The main extra feature is the decoupling of engine, generator, and motor speeds, which provides more power autonomy. A hybrid electric vehicle (HEV) transmission, two electric machines, and an engine make up the most common setup. This is called an input split.

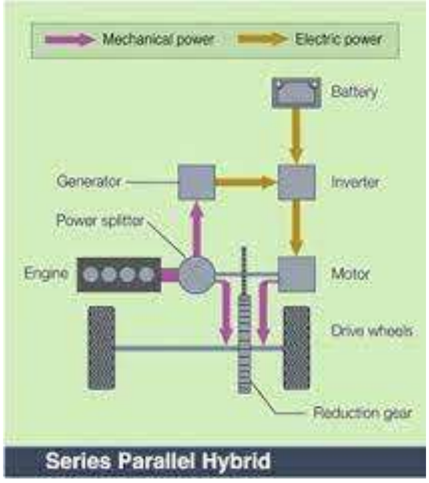

Fig 4: Configuration of Combination HEV.

3. Architecture:

When it comes to HEVs, the parallel powertrain design with a CVT is by far the most common. Discontinuously variable transmission provides an alternative to this technique (always in terms of parallel architectures). Although the parallel structure has been the most commercialised up to this point, innovations in power electronics and storage systems (Silicon carbide digital switches and supercapacitor storages), resulting in higher efficiency in various components, can put the current architectures to the test. Today, hybrid buses are the most common vehicles that employ the series design; therefore, these developments would be quite welcome.

Both designs have energy-related names; the former can send torque to wheels from both an ICE and an electric motor shaft at once, while the latter can only send torque from an ICE or an electric motor shaft. This means that all of the energy produced by the ICE is transformed into electrical form and then back into mechanical power by the electric motor, which is the only way that the latter can send power to the wheels. Fig 5 depicts the powertrains in both of their parallel forms (CVT and DVT). To achieve the correct transmission ratio in a CVT design, two electric drives are required, but in a DVT configuration, only one is needed thanks to the use of a planetary gear train (consisting of a sun gear, S, ring gear, R, and carrier gear, C). Full electric traction and regenerative braking are also possible with parallel architectures. In Fig3, the DC/DC converter is shown as a part of the connection between the storage system (B) and the DC-Link.

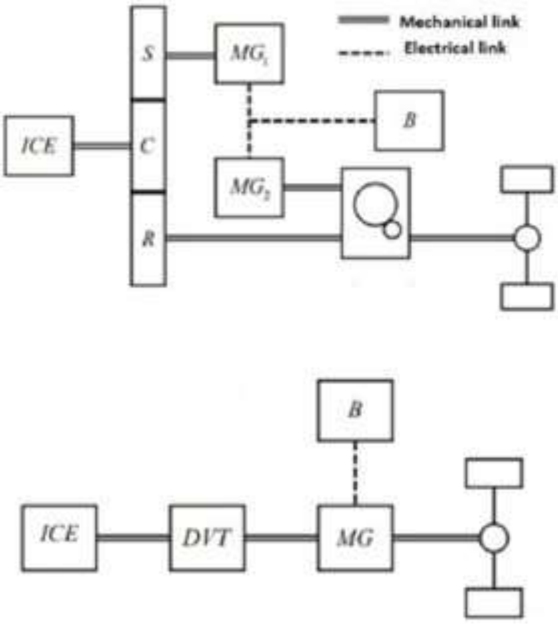

Fig 5: CVT parallel architecture (above) DVT parallel architecture (under)

4. BATTERY TECHNOLOGY:

There has been a fundamental change in the way people now live. Electricity generation and conservation are becoming more important as automation spreads across every industry. Nanowire batteries, which can survive a high number of charge and discharge cycles, are being considered as an alternative for solid-phase lithium ion batteries in order to fulfil the increasing need for electricity. Since nanowires have a high electron storage density and a quick rate of diffusion, they may be employed for operations that need high power sources, such as those found in metros and also in other automotive applications.

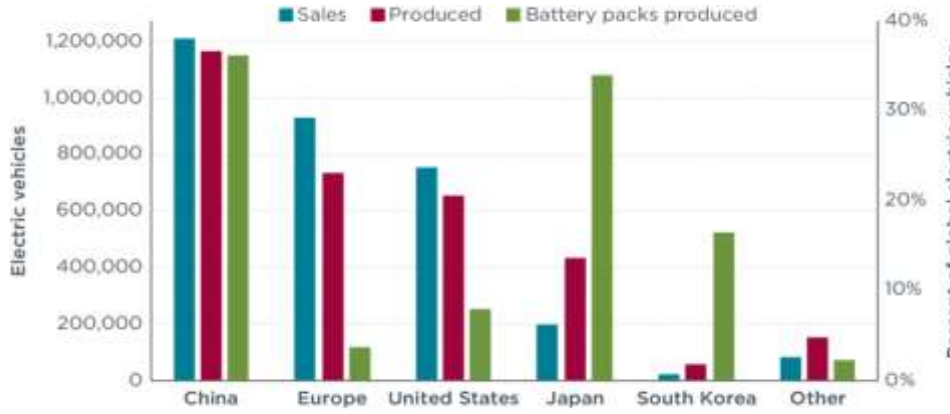

Fig 6: Electric vehicles manufacturing in world.

From Fig 6 we can observe the increase/ decrease in manufacturing of electric vehicles. The gold nanowires have been given a protective coating of manganese oxide and an electrolyte in the form of a gel. Large storage applications are made possible by the electrolyte gel's ability to bind the cables together and improve the metal oxide's surface so that it is smoother and less prone to breaking. It is also used in smart cards and the sensors in power remotes, which can be used in biomedical applications.

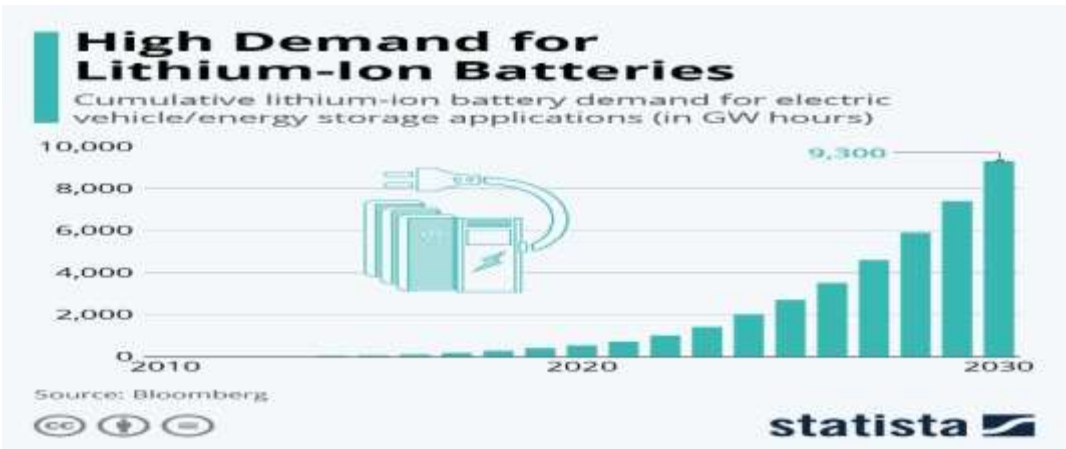

Fig 7: Demand for Lithium-Ion Batteries

There is a need to improve the specified rechargeable batteries for improved efficiency and longer run times. The diverse applications of rechargeable battery technology such as Pb-Acid (lead acid), Ni-Cd, and Ni-MH are extensive. In the recent decade, its use has grown steadily. Their utility is limited by the fact that the materials used to create them have their own set of constraints, which prevents them from being employed in any kind of massive storage system. Using them safely is the primary issue. There are, however, other issues related to their use, such as low cost, long lifespan, sustainable power efficiency, and supportability. The widespread availability of charging stations is another major challenge for the widespread adoption of electric vehicle battery technology. As an additional eco-friendly measure, batteries should be recycled once they have reached the end of their useful life. About 85% of all the lead in the world is used to make lead acid batteries, but only about 60% of lead is made from recycled lead. We can also observe the comparison in between specifications of various batteries in Table 1.

Table 1: Comparison of specifications of various batteries.

Type	Energy Density (Wh/kg)	Energy Efficiency (%)	Power Density (W/Kg)	Cycle Life (Cycles)	Self Discharge (%/Month)
Lead-Acid	30 - 40	70 - 90	180	200 - 2000	3 - 4
Li-Ion	100 - 250	75 - 90	1800	500 - 2000	5 - 10
Li Polymer	130 - 200	70	3000	>1200	4 - 8
Ni-MH	30 - 80	70	250 - 1000	500 - 100	30
Ni-Cd	40 - 60	60 - 90	140 - 180	500 - 2000	10 - 15
NaS	150	80 - 90	120 - 150	2500	-
VRB	25 - 40	80	100 - 150	>16,000	<1
Zinc Bromide	70	70	-	1000	-

4.1 TYPES OF BATTERIES:

4.1.1 LEAD ACID:

Gaston Planté conceived the basic design for a lead acid battery in 1860, and ever since then, the technology has evolved and been refined to meet the changing needs of consumers. There have been several notable advancements in lead acid batteries that have been integrated into modern automobile batteries. The vast majority of lead produced in the world is used to make batteries. The current design for lead acid batteries uses lead peroxide (PbO2) at the cathode and lead metal at the negative terminal (Pb). The electrolyte is a sulfuric acid solution with a specific gravity between 2.12 and 1.30 (or 28% and 39% by weight). The electrolyte of a lead-acid battery generally consists of a mixture of sulphuric acid (36%) and water (64%). Hydrogen gas from these electrolytes vaporises, creating extremely combustible vapours, which are dangerous during battery charging. The battery's typical weight of 30–60 pounds is increased by the weight of the electrode plates that are dipped within the electrode.

4.1.2 NICKEL CADMIUM:

In 1899, Swedish inventor Waldemar Jungner created the first practical nickel-cadmium (Ni-Cd) battery. In the early days of nickel-cadmium batteries, alkaline electrolytes were employed, and the battery's positive and negative electrodes were made of nickel hydroxide and cadmium hydroxide, respectively. When disposed of improperly, Ni-Cd batteries may be dangerous since they contain a poisonous element (cadmium). As a result, several countries have outlawed the use of such a material mix. Ni-Cd batteries need a high voltage charger, which is expensive to purchase. Predicting the battery's actions is a challenging task. The memory effect of these batteries is most noticeable when charging when the battery's charge is still above the minimum. With regards to battery life, this is a disaster.

4.1.3 LITHIUM ION:

M. Stanley Whittingham, a British scientist at Binghamton University who worked for Exxon in the 1970s, suggested lithium batteries. Fig 7 shows the demand for Lithium-Ion Batteries. He thought of using titanium sulphide and lithium metal as anodes. Positive electrodes in modern Li ion batteries are made of metal oxide, whereas negative electrodes are made of carbon; lithium salt serves as the electrolyte. The manufacturing cost is expensive, and the use of safety monitoring circuits is required for safe battery operation. High temperatures may occur when a battery is overcharged and begins to overheat. After a certain number of charge-discharge cycles, performance degrades. Even while not in use, the battery gradually loses its capacity. Lithium Ion batteries have a lower self-discharge rate than other types of batteries, but when they are overcharged, they undergo a deep discharge and become useless.

Due to the buildup of internal pressure caused by the breakdown of the electrolyte, the battery may explode if overcharged or overheated. This is because the gases made by this reaction cause the battery to get bigger, which could cause it to catch fire.

4.2 BATTERY MANAGEMENT SYSTEM:

In EVs and HEVs, the battery management system (BMS) is essential. The BMS is there to ensure that the batteries always work in a secure and trustworthy manner. BMS features such as status monitoring and assessment, charge regulation, and cell balancing help ensure the battery's continued security and dependability. A battery's electrochemical makeup means it will respond differently depending on the context in which it is being used. The execution of these features is complicated by the unpredictability of a battery's performance. The main job of a BMS is to check a battery's charge, health, and remaining life. The battery management system (BMS) does more than just control the current, voltage, and power of the battery to make it last longer. It also gives accurate estimates of the battery's State of Charge (SOC) and State of Health (SOH) so that it can be used in a smart way. If the system is installed in a car, the BMS must additionally monitor the temperature of the coolant that surrounds the battery pack. This aids in supplying enough electricity to all parts of the system. some of the important parameters of BMS are:

4.2.1 State of Charge (SOC):

What is meant by the term "state of charge" is the total amount of power in a battery. Improved functionality and reliability of the BMS are possible thanks to SOC estimates. Estimating the release of arsine from lead-acid batteries, cadmium from nickel-cadmium batteries, and fluoride gas from lithium-ion batteries during charging and discharging cycles is challenging. Consequently, a reliable evaluation of the SOC is problematic due to the wide range of possible operational contexts. Some LIBs on the market, such as those made from LiFeO4, lithium polymers, and LiCoO2, have a high rate of power emission from the battery, and their battery cells have a complicated topology, making SOC calculations time-consuming. SOC estimate precision has been the focus of a lot of recent development and study.

1) The Coulomb keeping count or ampere-hour (Ah) method is one of the most common ways of estimating.
2) Voltage measurements taken with the open circuit. 3) Method for Estimating Impedance.

4.2.2 State of Health (SOH):

An individual battery's "State of Health" describes its general condition. Age and charging cycles are major factors that reduce a battery's SOH. After one thousand charges, the SOH of a typical Li-ion battery drops to 80%. Alternating current SOH estimation often calls for a costly hardware component. SOH estimation through monitoring a battery's full charge and discharge cycles is a time-consuming alternative that does not need any special technology. Genetic algorithm techniques are one way to figure out SOC and SOH with as few sensors and as little money as possible. In order to complete the procedure, the genetic algorithm method takes into account the battery's terminal voltage and current. The state-of-charge assessment may even be performed while the battery is already being used.

4.2.3 Cell Balancing:

Blocks of cells are linked in parallel to meet the high capacity needs of EVs and HEVs, as well as many blocks (or cells) in series, connected to deliver a high voltage. The chemical and manufacturing offsets result in each cell being unique. In a series of cells, therefore, the voltage will be varied but the current will be the same for all of the cells. If a battery quickly reaches full charge, capacity fading might pose a risk during the charging process. So, while the other cells are filling up, it will be overcharged and damaged. Likewise, the weakest cell in the pack may experience overdischarge and fail before the others. Due to the nature of a series network, the risk of failure increases for batteries made up of many cells connected in series. An efficient cell balancing method that would maintain the SOC values of individual cells in a battery pack as close to each other as possible should be developed to mitigate this impact and extend the battery life.

Generally speaking, there are two types of cell balancing techniques used today: dissipative and non-dissipative. Both approaches are aimed at correcting the voltage imbalance inside a cell. However, resistors' dissipative equalisers allow for inefficient heat dissipation of surplus energy or current. Transformers, inductors, and capacitors are often used to create non-dissipative equalisers. In comparison to dissipative equalisers, they are more effective. But their charge-discharge profile is more intricate than typical profiles because of the way cells exchange charge or energy with one another. For these balancing methods to work, you must know the SOC of each battery cell.

5. CONCLUSION:

This study set out to investigate the various methods used to keep tabs on electric and hybrid cars, as well as to categorise these vehicles. The need for creating a cheap architecture for tracking a vehicle's operational characteristics has also been highlighted, since this is essential for gauging the battery's endurance. Our long-term goal is to improve how batteries are managed by making an EV monitoring system that works better. Previous research was used to show the unique difficulties of BMSs and potential answers to these difficulties, laying the groundwork for the next round of study. Real-world applications provide a wide variety of problems; therefore, a cookie-cutter answer seemed undesirable. To make BMSs work better in EVs and HEVs of the future, many different approaches should be thought about and used.

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