

DESIGN OF BATTERY OPTIMIZED ENERGY STORAGE SYSTEM FOR EV

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in Mechanical Engineering

By

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SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

**Accredited with grade "A" by NAAC | 12B Status by UGC | Approved by AICTE
JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **DIVYA PRAKASH V (39150703)** and **RAHUL SRIVATSAN A (39150710)** who carried out the project entitled **DESIGN OF BATTERY OPTIMIZED ENERGY STORAGE SYSTEM FOR EV** under our supervision from December 2022 to April 2023

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DECLARATION

We, **DIVYA PRAKASH V** and **RAHUL SRIVATSAN A** , hereby declare that the Project Report entitled **INVESTIGATION ON PERFORMANCE CHARACTERISTICS OF BATTERY OPTIMIZED ENERGY STORAGE SYSTEM FOR EV** done by under the guidance **Mr. S. VENKATESH., M.E., (Ph.D.)** at Sathyabama Institute of Science and Technology is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering

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ABSTRACT

In Recent year electric vehicles is attracting considerable and it has the development of battery technologies and advanced significantly the vehicle power consumption of the batteries electro chemical process, electric vehicle batteries tend to have accelerated degradation due to high peak power and harsh charging or discharging cycles during acceleration and deceleration periods, an electrochemical cell with similar architecture with higher capacity rate and better cycling ability the mass utilization of Internal Combustion engine vehicles in the transportation sector also increases pollution emissions, especially Greenhouse Gas emissions, which must be prevented for the sustainability of the planet and for life quality, new requirements for the electrical storage system are derived, including engine, dynamo, battery and motor, dynamo adds accuracy, speed of the system, that converts the mechanical energy to electricity.

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LIST OF ABBREVIATION

HEVS	HYBRID ELECTRIC VEHICLES
PHEVS	PLUGIN HYBRID ELECTRIC VEHICLES
EV	ELECTRIC VEHICLE
BMS	BATTERY MANAGEMENT SYSTEM
ICE	INTERNAL COMBUSTION ENGINE
KCP	KEY CONTROL POINTS
LIB	LITHIUM-ION BATTERIES

CHAPTER 1

INTRODUCTION

Electric Vehicles (EVs) have been gaining popularity due to their environmental friendliness, low operational costs, and increasing availability of charging infrastructure. However, the performance of EVs is highly dependent on the efficiency of their energy storage system, which is typically composed of lithium-ion batteries. To ensure optimal performance, it is necessary to design a battery optimized energy storage system that considers factors such as energy density, power density, charging speed, and thermal management. The design of a battery optimized energy storage system for EVs involves a multi-disciplinary approach that requires knowledge in materials science, electrical engineering, and mechanical engineering. It also involves the integration of advanced technologies such as machine learning and artificial intelligence to optimize battery performance and extend battery life. The ultimate goal of a battery optimized energy storage system for EVs is to provide reliable and efficient power to the vehicle while minimizing the size, weight, and cost of the energy storage system. In this context, this topic is of great interest to researchers, engineers, and manufacturers who are involved in the development and deployment of EVs. The development of hybrid energy storage systems that can improve the power and mileage of electric vehicles is gaining popularity. Batteries and ultracapacitors are critical components in a hybrid energy storage system. The advantages of ultracapacitors, such as high power density, quick charge and discharge, and multiple cycles, can be emphasised, compensate for lithium-ion battery shortages, resulting in increased battery life and better performance. Power performance At the same time, the battery's performance will be constantly monitored. attenuated as a result of electrochemical reactions and battery condition which will have an effect on battery life, and these factors will have a direct impact on the vehicle's power and economy performance. energy management system. With their advantages of high energy density, no memory effect, low self-discharge rate, and long life, lithium-ion batteries (LIB) have been widely used in electric vehicles (EVS), hybrid electric vehicles (HEVS), and plugin hybrid electric vehicles (PHEVS) in recent years, life of service Working as a temperature-

sensitive component The temperature of a lithium-ion battery must be 1540 C, and The maximum temperature difference is less than 5 degrees Celsius. Under Long and intense driving conditions, hot weather, and high operating temperatures will reduce battery life and Thermal runaway can even occur. As a result, a dependable and effective battery thermal management system is required, to keep the battery's operating temperature within to improve the specified range during charging and discharging. Electric vehicle (EV) industries are rapidly expanding. Despite the fact that numerous commercial batteries are used to power EVs, lithium ion (Li-ion) batteries have become one of the most popular battery technologies in EVs due to their high energy and power density, long life cycle, and low rate of self-discharge. However, the current charging strategies have severely limited the widespread deployment of Li-ion batteries in EVs. To address this issue, researchers have developed a new paradigm for providing an optimal charging method for Li-ion batteries, which has emerged as a new paradigm towards a smarter battery management system (BMS). EV lithium-ion battery systems are made up of hundreds to thousands of cells connected in series or parallel. The creation of an Power management is especially useful on loads with high peak-to-average power ratios because it lowers the rating of the main energy source and thus its costs. However, if not properly implemented, power management with an ESU may increase the cost and complexity of the vehicle. To implement power management or load levelling in a cost-effective manner, a design methodology capable of minimising the size and cost of both the main energy source and the ESU is required. Automotive battery requirements have been steadily increasing for several years, owing primarily to the integration of more and larger loads into vehicle electrical systems. Furthermore, fuel-saving measures that actively use the battery are being considered. On the one hand, these are energy management strategies that, at least partially, decouple electric generation and load operation during key-on. The battery serves as a buffer, preventing continuous overcharging Such measures, on the other hand, entail various levels of powertrain hybridization, such as micro, mild/medium, and power-assist/full hybrid electric vehicles (HEV). The requirements associated with any of these HEV system configurations necessitate a fundamental shift in the nature of the system. The mass utilization of Internal Combustion Engine (ICE) vehicles in the transportation sector also increases pollution emissions, especially Greenhouse Gas emissions,

which must be prevented for the sustainability of the planet and for life quality. The widespread use of Internal Combustion Engine (ICE) vehicles in the transportation sector also increases pollution emissions, particularly Greenhouse Gas emissions, which must be avoided for the planet's sustainability and quality of life. In terms of urban pollution, ICE vehicle emissions are a major source, particularly in medium and large cities. The rising prevalence of respiratory problems, allergies, asthma, and certain cancers is causing public health concerns, as air pollution is a proven contributor to mortality and morbidity. Electric machines, whether pure EVs or HEVs, are critical components to sustainable mobility and the world's future due to their high efficiency, no local emissions, silent driving, and ability to recover braking energy. A stage of transition Concerns about pollution, the rapid increase in fuel costs and the depletion of fossil fuel reserves have been the main drivers behind the automotive industry's drive to electrify transportation. Alongside research sectors in industry, universities have played an important role in researching electric vehicles (EVs) and hybrid electric vehicles (HEVs) and developing new topologies and ideas. Although EVs and HEVs have many advantages, there are some difficulties associated with this type of transportation. The main problem is the energy storage in the vehicle. Statistical analysis shows that consumers are reluctant to buy electric and hybrid vehicles unless the performance and reliability of these types of vehicles match or exceed. The key control points (KCPs) need to be set to ensure safety during the charging process. These KCPs can be voltage (rise) range, current range and temperature (rise) range. develop matching design. The implementation of an optimal charging strategy in the BMS requires well-designed hardware and software, data acquisition, high computation capability and suitable control and management system. integrate the optimized charging method into the intelligent BMS.

CHAPTER 2

LITERATURE SURVEY

2.1 Bin Wang a , Jun Xu a, Binggang Cao a , Xuan Zhou,2015- A novel multimode hybrid energy storage system and its energy management strategy for electric vehicles: Compared to the conventional HESS, the proposed multimode HESS has more operating modes and thus it could in further enhance the efficiency of the system. The rule-based control strategy and the power-balancing strategy are developed for the energy management strategy to realize mode selection and power distribution. Generally, the DC to DC converter will operate at peak efficiency to convey the energy from the batteries to the UCs. Otherwise, the pure battery mode or the pure ultracapacitors (UCs) mode will be utilized without the DC to DC converter. To extend the battery life, the UCs have the highest priority to recycle the energy and the batteries are isolated from being recharged directly during regenerative braking. Simulations and experiments are established to validate the proposed multimode HESS and its energy management strategy. Both the batteries and the UCs can provide power directly to the motor inverter. The DCtoDC converter will operate at peak efficiency to convey the energy from the batteries to the UCs or the motor inverter. In addition, the UCs have the highest priority to recycle the energy, and the batteries are isolated from being recharged directly during regenerative braking. Based on the proposed multimode HESS, the operating modes and energy flows have been categorized and analyzed to design the energy management strategy, including mode selection and power distribution. The rule-based control strategy has been developed for mode selection and the power-balancing strategy has been proposed to distribute the power between the batteries and the UCs.

2.2 Cong Zhang , Dai Wang, Bin Wang and Fan Tong,2020- Battery Degradation Minimization-Oriented Hybrid Energy Storage System for Electric Vehicles: The battery and supercapacitor, the proposed system avoids using the large bidirectional DC/DC. Through the improved topology and two added controlled switches, the battery current can be managed flexibly. Based on the battery and supercapacitor voltage, seven operation modes of battery and capacitor cooperation are designed. The control strategy is redesigned to match

the modes, in which the key control parameters are calibrated based on three standard driving cycles. During driving, the proposed system calls the predefined parameter set by the cycle recognition technique. The objective of the cycle-related control is to maximize the harvest of the braking energy and minimize battery degradation in various driving styles. Taking the battery case solely as a benchmark and the infinite supercapacitors case as the largest battery degradation mitigation scenario, the battery degradation quantification of the proposed energy storage system shows more than 80% mitigation of the maximum theoretical battery, y . Using an independent driving cycle as the test cycle, the simulation result shows the battery degradation mitigation reached as high as 30%, larger than the majority of the prior HESS. This result indicates that the HESS topology and control strategy can be optimized together to realize a better battery degradation mitigation target. When comparing the battery degradation with other HESS, the proposed HESS does not need the bi-directional converter, and achieves a competitive battery degradation mitigation result than the majority of the prior HESS. Furthermore, the temperature is a complicated factor that affects the HESS system. The temperature is a complicated factor. For a car with the same configuration, the vehicle's mileage is not constant across the different driving situations, including the temperature. We prefer to use the security factor to determine the size of the power system. In this paper, we only use the energy required to configure the battery and SC size.

2.3 Diana Lemian and Florin Bode, 2022- Battery-Supercapacitor Energy Storage Systems for Electrical Vehicles: The current worldwide energy directives are oriented toward reducing energy consumption and lowering greenhouse gas emissions. The exponential increase in the production of electrified vehicles in the last decade are an important part of meeting global goals on the climate change. However, while no greenhouse gas emissions directly come from the operations of the electrical vehicles, the electrical vehicle production process results in much higher energy consumption and greenhouse gas emissions than in the case of a classical internal combustion vehicle; thus, to reduce the environment impact of electrified vehicles, they should be used for as long as possible. Using only batteries for electric vehicles can lead to a shorter battery life for certain applications, such as in the case of those with many stops and starts but not only in these cases. Despite significant advancements in battery

technology, available batteries at this time do not fully meet the energy requirements of EV electricity consumption. The principal issue is the battery discharge process where the non-monotonic power consumption is accompanied by frequent changes. This is extremely harmful to the battery's electrochemical process, and a viable solution is to combine the battery with a supercapacitor, which is essentially an electrochemical cell with a similar architecture but with higher speed capability and better cyclability. The study begins with a review of the batteries used in the electrified vehicle industry that points out the fact there have been substantial improvements in battery performance over the past few years, but the peak utilization is still the main issue. In the electrified vehicle case, this problem persists since several factors, including driving technique, the road, etc., produce abrupt variations in the power usage, and this will lead eventually to the irremediable deterioration of the batteries.

2.4 Eckhard Karden a, Serve Ploumen a, Birger Fricke a, Ted Miller b, Kent Snyder,2006- Energy storage devices for future hybrid electric vehicles:

Powertrain hybridization as well as electrical energy management are imposing new requirements on electrical storage systems in vehicles. This paper characterizes the associated vehicle attributes and, in particular, the various levels of hybrids. New requirements for the electrical storage system are derived, including: shallow-cycle life, high dynamic charge acceptance particularly for regenerative braking and robust service life in sustained partial-state-of-charge usage. Lead/acid, either with liquid or absorptive glass-fibre mat electrolyte, is expected to remain the predominant battery technology for 14 V systems, including micro-hybrids, and with a cost-effective battery monitoring system for demanding applications. Advanced AGM batteries may be considered for mild or even medium hybrids once they have proven robustness under real-world conditions, particularly with respect to cycle life at partial-states-of-charge and dynamic charge acceptance. For the foreseeable future, NiMH and Li-ion are the dominating current and potential battery technologies for higher-functionality HEVs. Li-ion, currently at development and demonstration stages, offers attractive opportunities for improvements in performance and cost. Hybrid electric vehicle markets are growing worldwide. As for conventional cars, different market conditions in Europe, America, and Asia will lead to differentiated products. For example, diesel full

hybrids can be attractive for Europe. Similarly, lower degrees of hybridization (from micro to medium) offer advantages under European conditions.

2.5 Fengyan Yi , Dagang Lu , Xingmao Wang , Chaofeng Pan , Yuanxue Tao Jiaming Zhou and Changli Zhao,2022- Energy Management Strategy for Hybrid Energy Storage Electric Vehicles Based on Pontryagin's Minimum Principle Considering Battery Degradation: the battery and ultracapacitor, can reduce the electric vehicle's power consumption and slow down battery degradation. Therefore, the purpose of this paper is to develop an EMS for hybrid energy storage electric vehicles based on Pontryagin's minimums principle (PMP) considering battery degradation. To verify the EMS, the hybrid energy storage electric vehicle model is first established. In the meantime, the battery cycle life trials are finished in order to develop a battery degradation model. Following that, a rule-based control approach and the PMP optimization algorithm are used to allocate power in a hybrid energy storage system (HESS) in a reasonable manner. An energy management strategy based on PMP for hybrid electric vehicles considering battery degradation is proposed, with the goal of determining the impact of battery decrease on the power and economic benefits of electric vehicles. Firstly, to verify the effectiveness of the strategy, the model of hybrid electric vehicle is established. The battery loss model is established, which provides a theoretical basis for formulating the energy management strategy by combining the two major factors that affect battery decline, DR and DOD, through nine sets of battery decay experimental schemes with different charge and discharge ratios and different discharge depths.

2.6 Lijun Zhang, Xiaohua Xia and Farshad Barzegar,2017- Control of a battery/supercapacitor hybrid energy storage system for electric vehicles:The controller is based on advanced model predictive control method and aims at smoothing the power flow from/to the battery to protect it from undesirable fast discharging/charging. The second objective of the controller is to control the electric vehicle to track a predefined speed profile. The dynamics of the vehicle and the supercapacitors are modeled from first principles to facilitate the controller design. It is assumed that the battery, as the primary energy source for the vehicle, is properly sized such that there is no need to control its state-of-charge. In addition, the controller is designed at the energy management level

instead of power electronics control level. Therefore, it serves to optimize the power flows of the hybrid energy storage system instead of controlling the power converters involved. r flow control of a hybrid energy storage system (HESS) consisting of batteries and supercapacitors for electric vehicles. The objectives of the controller are to track a given speed profile for the vehicle by proper power within the battery and supercapacitors of the HESS and to avoid abrupt variations in the power flow of the battery in order to protect the battery. The vehicle dynamics and supercapacitor dynamics are modeled from first principles to facilitate the controller design. The designed controller is tested with two standard urban driving cycles, one developed by the US and the other commonly used in the European countries. The results obtained verified that the controller is able to fulfill its objectives. In particular, the controller can track the speed profile and is able to split the low frequency and high frequency power demands of the vehicle to the battery and supercapacitor, respectively.

2.7 João P. Trovão Paulo G. Pereirinha, Humberto M. Jorge, 2009- Design Methodology of Energy Storage Systems for a Small Electric Vehicle: This strategy seeks to benefit from the best qualities of each available energy source, and is especially useful in urban driving. In this work, the need for multiple energy sources hybridization is addressed. A methodology to optimize the sizing of the ESSs for an electric vehicle taking as example the ISEC-VEIL project, using different driving cycles, maximum speed, a specified acceleration, energy regeneration and gradeability requests are presented. It is also studied the possibility of using a backup system based on solar energy, that may be considered in the design, or as an extra to cope with unforeseen routines and to minimize the recharge of ESS. The complete methodology is fast, objective, and quite accurate, since the simulations obtained for the proposed designs are within the minimum request results. It was also studied the possibility of using a backup system based on solar energy, that may be considered in the design, or as an extra to cope with unforeseen routines and to minimize the recharge of ESSs through the power network. The methodology can be improved by inclusion of techniques for multi-objective optimization, minimizing the initial cost, the cost of the ESSs recharges, and weight, maximizing the autonomy and life cycle of ESSs.

2.8 Junyi Shen, Serkan Dusmez- Optimization of Sizing and Battery Cycle Life in Battery/Ultracapacitor Hybrid Energy Storage Systems for Electric Vehicle: Urban driving conditions. Oversized energy storage system (ESS) meets the high power demand; however, in tradeoff with increased ESS size, volume, and cost. In order to reduce overall ESS size and extend battery cycle life, battery/ultracapacitor (UC) hybrid ESS (HESS) has been considered as a solution in which UCs act as a power buffer to charging/discharging peak power. In this paper, a multiobjective optimization problem is formulated to minimize the overall ESS size, while maximizing the battery cycle life according to the assigned penalty functions. An integrated framework for HESS sizing and battery cycle life optimization applied in a midsize EV, using an Autonomie simulation model, is described and illustrated in this paper. The main contribution of this work is to introduce a systematic approach and tool to optimize the HESS sizing and to estimate the battery cycle life. Following this framework, HESS design can be evaluated in terms of its sizing and battery degradation under various drive cycles without a long-term experimental test. To provide accurate evaluation of the HESS system, the MATLAB/Simulink vehicle models developed by ANL is adopted in the proposed framework, which has been verified by hardware-in-the-loop (HIL) vehicle testing. In addition, this optimization framework is very flexible and can be easily adapted to different optimization objectives, vehicle models, control strategies, and design variables. It is estimated that the optimized HESS under urban driving situations can effectively extend the battery lifetime by 76% with 72 UC cells.

2.9 JunyiShen,2016-ENERGY MANAGEMENT OF A BATTERY-ULTRACAPACITOR HYBRID ENERGY STORAGE SYSTEM IN ELECTRIC VEHICLES: An oversized energy storage system (ESS) can meet the high power demands; however, it suffers from increased size, volume and cost. In order to reduce the overall ESS size and extend battery cycle life, a battery-ultracapacitor (UC) hybrid energy storage system (HESS) has been considered as an alternative solution. In this work, we investigate the optimized configuration, design, and energy management of a battery-UC HESS. One of the major challenges in a HESS is to design an energy management controller for real-time implementation that can yield good power split performance. We present the methodologies and solutions to this problem in a battery-UC HESS with a DC-DC converter interfacing

with the UC and the battery. In particular, a multi-objective optimization problem is formulated to optimize the power split in order to prolong the battery lifetime and to reduce the HESS power losses. g EVs, deliver energy to the electric machine during propulsion and recover energy during regenerative braking. During urban drive cycles with frequent stop-and-go, the frequent high power exchange between the electric machine and the ESS results in accelerated battery aging. The battery aging decreases the battery capability of storing energy and providing power over the battery lifetime. One potential solution to this problem is to integrate highenergy density batteries with high-power density UCs as a battery-UC HESS. In this work, a systematic approach is presented to the energy management problem of battery-UC HESS for EVs. This energy management problem encompasses multiple energy storage resource planning and sizing, power distribution and an effective hardware design for the real-time system implementation. This complex and multidisciplinary problem of the battery-UC HESS development is decomposed into four stages. In the first stage, a comprehensive review of the previous and ongoing research in this area is provided to present an in-depth investigation of the state-of-the-art of the battery-UC HESS design, especially for vehicular applications.

2.10 Lia Kouchachvili Wahiba Yaïci, Evgueniy Entchev,2017-Hybrid battery/supercapacitor energy storage system for the electric: Electric vehicles (EVs) have recently attracted considerable attention and so did the development of the battery technologies. Although the battery technology has been significantly advanced, the available batteries do not entirely meet the energy demands of the EV power consumption. One of the key issues is non-monotonic consumption of energy accompanied by frequent changes during the battery discharging process. This is very harmful to the electrochemical process of the battery. A practical solution is to couple the battery with a supercapacitor, which is basically an electrochemical cell with a similar architecture, but with a higher rate capability and better cyclability. In this design, the supercapacitor can provide the excess energy required while the battery fails to do so. In addition to the battery and supercapacitor as the individual units, designing the architecture of the corresponding hybrid system from an electrical engineering point of view is of utmost importance. The present manuscript reviews the recent works devoted to the application of various battery/supercapacitor hybrid systems in EVs. the entire

electrical system should be subtly matched to build an integer power source. It is of important to decide when and how each electrochemical cell should be charged or discharged. This is accompanied by a complex usage procedure, which is different from regular testing of the electrochemical cells. Therefore, designing the future cells should be based on a close collaboration between the researchers working on the electrochemistry part of the power source and those who are designing the electrical system of the whole power source in the EV. There is still a huge gap between these two areas of research. Many of the hybrid systems tested for the EVs are based on commercial batteries and SCs, which have not been fabricated for this purpose. Instead, it is vital to design the batteries and SCs based on the requirements for the hybrid energy systems of the EVs. The critical important of this point lines in the availability of various electrode materials for both batteries and SCs, which might not be useful for the popular applications, but they provide new opportunities for the EV applications. A simple comparison between the size and performance of a laptop battery and the power source required for an EV reveals that entirely new types of electrochemical cells are required for the future EVs. However, most of the common candidates for the EV power sources are practically based on the scaled-up version of the same old battery systems. The present manuscript merely aimed to attract the attention of researchers working on different sides of this field to specifically focus on the opportunities for designing native battery/supercapacitor systems for the EVs. In this direction, the crucial differences between the performances of these electrochemical cells in a hybrid.

CHAPTER 3

AIM AND SCOPE

3.1 Aim:

Designing a battery-optimized energy storage system for an electric vehicle (EV) involves several considerations. Here are some key factors to keep in mind:

- **Battery Type and Capacity:** The first step is to choose the type and capacity of the battery that will power the EV. Lithium-ion batteries are currently the most popular choice for EVs due to their high energy density and relatively low cost. The battery capacity should be chosen based on the vehicle's power requirements and desired driving range.
- **Battery Management System:** A battery management system (BMS) is crucial for the safe and efficient operation of the battery. It monitors the battery's state of charge, temperature, and voltage to prevent overcharging, overheating, and over-discharging. A well-designed BMS can also help extend the life of the battery.
- **Charging System:** The charging system must be designed to support the battery's charging rate and voltage requirements. Fast charging can reduce the time needed to charge the battery, but it can also cause more heat and wear on the battery. Therefore, the charging rate and voltage should be chosen to balance charging time and battery life.
- **Thermal Management System:** The battery generates heat during charging and discharging, which can degrade its performance and shorten its life. Therefore, a thermal management system is needed to keep the battery within its optimal temperature range. This can include a combination of cooling and heating systems, such as air or liquid cooling.
- **Power Electronics:** The power electronics, including the inverter and DC-DC converter, are responsible for converting the battery's DC voltage to AC voltage for the motor and other electrical loads. These components should be designed to be efficient and reliable to minimize energy losses and ensure smooth operation.

- **System Integration:** Finally, all of these components must be integrated into a cohesive system that works together seamlessly. This includes the wiring, sensors, and control systems needed to monitor and control the battery and its associated components.

Overall, designing a battery-optimized energy storage system for an EV requires a deep understanding of the vehicle's power requirements, the battery's characteristics, and the interactions between various system components.

3.2 Scope:

The scope for designing a battery-optimized energy storage system for an EV is vast and growing rapidly as more and more people shift to electric vehicles. Here are some key areas where this technology can have a significant impact:

- **Range and Performance:** One of the biggest advantages of a well-designed battery storage system is the ability to extend the range and improve the performance of an electric vehicle. With a larger battery capacity and more efficient charging and discharging, EVs can travel further on a single charge and accelerate more quickly.
- **Cost Savings:** Electric vehicles have lower operating costs compared to traditional gasoline-powered vehicles, but the initial purchase price can still be a barrier for some consumers. A battery-optimized energy storage system can help reduce the overall cost of the EV by improving the battery's lifespan and reducing maintenance costs.
- **Environmental Benefits:** EVs are often touted as a more environmentally friendly alternative to traditional vehicles, but their impact on the environment is still dependent on the source of electricity used to charge the battery. By optimizing the battery storage system, the amount of electricity needed to power the vehicle can be reduced, leading to lower greenhouse gas emissions.
- **Grid Integration:** As more EVs are adopted, there is a growing need to integrate them into the electricity grid to balance supply and demand. Battery storage systems can be used to store excess electricity from renewable sources during times of low demand and feed it back into the grid during peak demand.

- **Energy Security:** In some regions, there may be concerns about energy security due to factors such as natural disasters or political instability. Battery storage systems can help provide a backup source of electricity for EVs, reducing dependence on external sources of energy.

Overall, the scope for designing a battery-optimized energy storage system for an EV is significant and can have a positive impact on multiple aspects of society, including transportation, the environment, and energy security.

3.3 Material And Process:

Designing a battery-optimized energy storage system for an electric vehicle (EV) involves selecting appropriate materials and processes to ensure efficient and safe operation. Here are some key considerations:

- **Battery type:** Lithium-ion batteries are commonly used in EVs due to their high energy density and long lifespan. Other types of batteries, such as nickel-metal hydride (NiMH) and lead-acid, may also be used but are less efficient.
- **Battery size:** The battery size should be chosen based on the energy requirements of the vehicle. This will depend on factors such as the weight of the vehicle, the desired range, and the power demands of the motor.
- **Battery management system (BMS):** A BMS is essential for monitoring the battery state of charge (SOC), temperature, and voltage, and for preventing overcharging and over-discharging.
- **Charging infrastructure:** The charging infrastructure should be designed to match the battery type and size. Fast charging is possible with some battery types, but may reduce the lifespan of the battery.
- **Thermal management:** A thermal management system is needed to control the temperature of the battery during charging and discharging. This can be achieved through passive or active cooling systems.

3.4 Applications:

For use with diesel engines, diesel-electric transmission. Mostly replaced petrol-electric transmission, capturing a large portion of the same markets. On railways, it is widely used in diesel-electric locomotives and diesel-electric

multiple units. In some road vehicles, such as buses and trucks, it is used in conjunction with a battery pack to store the energy required to power the electric motor in a hybrid electric vehicle. For use with steam turbine engines, turbo-electric transmission. Ships, particularly military ships, use it extensively. The main advantage of an electric transmission is that it eliminates the need for gear changes and allows for smoother acceleration. It can also provide significant benefits as it reduces the wasted energy generated in mechanical transmissions when the vehicle driver neglects to shift the vehicle's gears. This is especially true for heavier vehicles that require significantly more force than is required to maintain speed at launch. Therefore, this system is most commonly used on ships and railway locomotives. Most cars use mechanical transmissions instead because they are lightly loaded and lightweight. However, these cost savings are somewhat offset by the increased weight and initial cost of generators, wiring, and motors.

CHAPTER 4

EXPERIMENTAL SETUP

4.1 Methodology

The system is been working on this overview, Engine is running in the ideal condition. The engine is a four stroke petrol engine, the engine has the flywheel in the flywheel disc the frictionless dynamo is connected in it, the power is transmitted to the dynamo. Dynamos convert external power to electrical power to get power out there first has to be power in. Electrical generators (magnetos, dynamos and alternators) and motors (DC and AC) are all based on electromagnetism. Magnetos are not covered in the following description but are based on permanent magnets to generate the magnetic field rather than the electromagnet in a dynamo. When a wire moves through a magnetic field it generates a current proportional to the strength of the magnetic field and the speed of movement through that field. The dynamo power is transmitted to the battery . the power is been saved in the battery, the battery is been connected with motor.it is the detailed process for the experiment. By this experiment we can save the energy for the battery from the ideal engine, it is more efficient in hybrid vehicles, the efficiency is more in the system, by the dynamo the process will be smooth and the more efficiency is been converted.

4.1.1 Hybrid Technology :

It combines two or more power sources, typically an internal combustion engine (ICE) and an electric motor, to achieve better fuel efficiency and lower emissions. The experimental setup for hybrid technology would depend on the specific application and goals of the study. However, some general components of a hybrid experimental setup are:

- **Powertrain:** The powertrain is the heart of a hybrid system and consists of an ICE, an electric motor, and a transmission. The ICE can be connected to the transmission directly or through a generator. The electric motor is connected to the transmission through a power electronics module, which controls the power flow between the battery and the electric motor.

- **Battery:** The battery is the energy storage system for the electric motor. It can be a lithium-ion battery or any other type of battery that meets the power and energy requirements of the system.
- **Control system:** The control system is responsible for managing the power flow between the ICE, electric motor, and battery. It uses sensors and algorithms to optimize the system's performance, including fuel efficiency, emissions, and overall performance.
- **Data acquisition system:** The data acquisition system records the performance of the powertrain, including engine speed, electric motor speed, battery voltage, current, and temperature. This data is used to evaluate the system's performance and make improvements.
- **Test vehicle:** The test vehicle is used to evaluate the performance of the hybrid system. It can be a prototype vehicle or a production vehicle that is modified to accommodate the hybrid system.
- **Testing environment:** The testing environment should be designed to simulate real-world driving conditions, including road conditions, speed, and temperature. This can be achieved through a test track or a chassis dynamometer.
- **In summary,** the experimental setup for hybrid technology consists of a powertrain, battery, control system, data acquisition system, test vehicle, and testing environment. The setup should be designed to evaluate the system's performance under real-world driving conditions and collect data for analysis and improvement.

4.1.2 Hub Motor:

A hub motor, also known as an in-wheel motor, is an electric motor that is integrated into the hub of a wheel. This type of motor can be used to power electric bicycles, scooters, and even cars. Hub motors offer several advantages over traditional electric motors that are mounted separately from the wheels:

- **Simplified drivetrain:** With a hub motor, there is no need for a chain or belt drive to transfer power from the motor to the wheel. This reduces the number of moving parts, making the system simpler and more reliable.

- Better efficiency: Hub motors offer better efficiency compared to traditional motors because they can transmit power directly to the wheel without any losses from the drivetrain.
- Regenerative braking: Hub motors can be designed to provide regenerative braking, which allows the motor to act as a generator when the vehicle is slowing down, converting some of the kinetic energy of the vehicle into electrical energy that can be stored in the battery.
- Improved handling: By placing the motor in the hub of the wheel, the weight distribution of the vehicle is improved, which can lead to better handling and stability.
- There are two types of hub motors: direct-drive and geared. Direct-drive hub motors have a large diameter and a low RPM, which makes them suitable for high-speed applications. Geared hub motors have a smaller diameter and a higher RPM, which makes them better suited for low-speed applications.

In summary, a hub motor is an electric motor that is integrated into the hub of a wheel. It offers several advantages over traditional electric motors, including a simplified drivetrain, better efficiency, regenerative braking, and improved handling. A hub motor, also known as an in-wheel motor, is an electric motor that is integrated into the hub of a wheel. This means that the motor is placed directly inside the wheel, eliminating the need for a transmission or other drivetrain components. Hub motors are commonly used in electric bicycles, scooters, and even cars. They offer several benefits, including improved efficiency, simplified drivetrain, regenerative braking, and improved handling. Direct-drive and geared hub motors are the two main types of hub motors, with each offering specific advantages and disadvantages depending on the application. Hub motors are electric motors that are designed to be compact and lightweight, making them a popular choice for electric vehicles. They are typically brushless DC motors that use permanent magnets to generate the magnetic fields needed to spin the rotor. The motor can be placed either in the front or rear wheel hub of the vehicle, or both in the case of all-wheel-drive vehicles. The direct-drive hub motor is the simplest and most common type of hub motor. It has a large diameter and a low RPM, which makes it suitable for high-speed applications. However, the large size of the motor can make it heavy and difficult to integrate into the wheel. The geared hub motor is a more complex type of hub motor that uses a

reduction gear to increase the torque output and reduce the size of the motor. This makes it better suited for low-speed applications, such as electric bicycles and scooters. Geared hub motors are typically smaller and lighter than direct-drive hub motors but require more maintenance due to the additional moving parts. Hub motors are a popular choice for electric vehicles because they offer several advantages over traditional drivetrains. By placing the motor directly in the wheel hub, the drivetrain is simplified, reducing the number of moving parts and increasing overall efficiency. Additionally, hub motors offer regenerative braking, which allows the motor to act as a generator when the vehicle is slowing down, converting some of the kinetic energy of the vehicle into electrical energy that can be stored in the battery. Overall, hub motors are a reliable and efficient way to power electric vehicles. In addition to the advantages and disadvantages mentioned earlier, there are some other aspects to consider when using hub motors. One of the benefits of hub motors is their ability to regenerative brake, which means that they can convert kinetic energy into electrical energy and store it back into the battery. This feature helps to extend the range of electric vehicles and reduces the wear and tear on the mechanical brakes. Another advantage of hub motors is their ability to offer different levels of torque, depending on the model and type of motor used. This allows for greater flexibility in designing the electric vehicle's powertrain and can improve the performance and efficiency of the vehicle. One potential drawback of hub motors is their susceptibility to damage from road hazards and potholes. Because the motor is integrated into the wheel hub, it can be more vulnerable to damage if the wheel hits a pothole or other obstacle. This can lead to expensive repairs and replacement cost. Additionally, hub motors may require a larger wheel size in order to accommodate the motor, which can limit the available wheel and tire options. This can affect the ride quality and handling of the vehicle, especially if the wheels are too small or too large for the motor. Overall, hub motors are a viable option for electric vehicles and can offer numerous advantages in terms of efficiency, simplicity, and performance. However, they also have their own unique set of drawbacks that must be considered when designing and building electric vehicles with hub motors.

4.1.3 Alternator:

The alternator converts mechanical energy into electrical energy. When you turn on your engine, it powers a drive belt that rests on a pulley connected to the

alternator. The pulley rotates the alternator's rotor shaft, which spins a set of magnets around a coil. The battery is recharged and accessories are powered by the alternator. It converts the crankshaft's mechanical energy into electrical energy. As a traffic cop the computer or the regulator in older cars regulates the alternator's output. Using an alternating current, your alternator transforms mechanical energy into electrical energy. Alternators produce alternating electricity by rotating stator and rotor, which function as magnets. The battery is then charged after the alternating current (AC) is changed into a direct current (DC). Electromagnetic induction is the basis for how alternators function. This law states that in order to generate electricity, we need a conductor, a magnetic field, and mechanical energy. every device capable of rotating and regenerating alternating current.



Fig.4.1: Alternator

A group of coils arranged in a magnetic field is called an armature winding. The engine control unit of the vehicle is in charge of these systems (ECU). The ECU signals the alternator to begin charging as the load on the vehicle increases. The alternator must modify its charge rate to accommodate changing electrical loads. Simply put, the battery powers your vehicle's electrical dash components and starts your engine. Your battery starts the alternator, which then produces electricity to power your battery continuously. When the engine is idle, a decent alternator should generate 13.5 to 14.5 volts. Low voltage readings (12.5 volts or below) suggest a charging issue but do not provide any additional information. Interesting fact: The term "alternating current," or AC, is how the automotive alternator received its name. The alternator converts mechanical energy into electrical energy, which is sent to the battery and used to power every electrical component in your car. Higher ratings

are becoming more frequent, especially since there is more strain on the vehicle's electrical system due to the presence of air conditioning, electric power steering, and other electrical systems. Standard passenger car and light truck alternators are rated between 50 and 70 A. The Stator, Rotor, and Diode are the alternator's three primary parts, along with a voltage regulator. A long charging cable is necessary for high-output alternators. The wire attached to the alternator is 10 gauge, which is the minimum size, while the narrow 12 gauge wire at the top is too tiny. The fat wire, which is 6 AWG wire, would be ideal. The battery won't recharge while the engine is running if the alternator starts to malfunction. Here's how to identify a bad alternator. If the car dies after a jump start, that is one of the most evident indicators. Even with a weak battery, the alternator ought to be able to keep the car going. If an alternator is going to be used in a system using 12 volt batteries, it needs to be able to produce more than 12 volts. A 14 volt alternator may be used instead of a 12 volt alternator because the actual voltage regulator set-point is often between 13.5 and 14.5 volts. Alternators are superior to direct-current generators in a number of ways (dynamos). An alternator is lighter, less expensive, and tougher at idle speed, can give a meaningful charge. Employ slide rings instead of a commutator since they dramatically extend brush life (Or completely brushless designs) An alternator's brushes only transport DC excitation current, a negligible amount compared to a DC generator's brushes, which carry the generator's whole output current. To convert AC to DC, a diode bridge (set of rectifiers) is needed. The pole-pieces of the rotor are shaped and a polyphase winding is employed to generate direct current with little ripple (claw-pole). Automobile alternators are typically belt-driven at speeds that could blow a commutator apart in a generator, which is 2-3 times the crankshaft speed. Compared to a sine wave, the AC waveform produced by the claw pole configuration is more effectively corrected. Despite their names, "alternators" and "DC generators" both first create alternating current. This AC current is produced in the rotating armature of a so-called "DC generator," and the commutator and brushes convert it to DC. In a "alternator," the stationary stator generates the AC current, which is then changed to DC by the rectifiers diodes. Alternators for light trucks and cars typically use a Lundahl or 'claw-pole' field design. With the use of a shaped iron core on the rotor, a single coil winding can create a multi-pole field. The rotor's poles have the appearance of two hands' fingers clasped together. Earlier cars with less lighting might have had an alternator that could only produce 30 amps. Although greater

ratings are increasingly prevalent, especially when there is more load on the vehicle's electrical system with air conditioning, electric power steering, and other electrical systems, most passenger car and light truck alternators are rated around 50-70 A. Buses, heavy machinery, and emergency vehicles may employ very powerful alternators that can generate 300 A. Typically, the alternators in semi-trucks produce 140 A. Oil- or water-cooled very large alternators are also possible. The voltage drop in the diode bridges, bearing loss, iron loss, copper loss, and fan cooling loss all reduce the efficiency of automobile alternators. At high speeds, efficiency drastically decreases, primarily because of fan resistance. An alternator is a device that converts mechanical energy into electrical energy. It is a type of generator that is commonly used in vehicles to produce electricity for charging the battery and powering the electrical systems. Alternators are also used in many other applications, including power generation and industrial machinery. The basic components of an alternator include a rotor, a stator, and a rectifier. The rotor is the rotating part of the alternator, while the stator is the stationary part. The rectifier is used to convert the alternating current (AC) produced by the alternator into direct current (DC) that can be used by electrical systems. When the engine of a vehicle is running, it drives the alternator through a belt or other mechanical connection. As the rotor rotates, it creates a magnetic field that interacts with the magnetic field in the stator. This interaction creates a voltage difference between the two ends of the stator, which produces an AC current. The rectifier then converts the AC current into DC current that can be used by the electrical systems. Alternators are generally more efficient than traditional generators because they use slip rings and brushes to maintain a constant magnetic field in the rotor, which reduces the amount of energy lost due to friction. They also have the advantage of producing a more stable output voltage than generators, which can be important for sensitive electrical systems. In addition to their use in vehicles, alternators are also used in power generation and industrial machinery. They can be used to produce electricity from a variety of sources, including wind, water, and steam, and can be configured in a variety of ways to meet specific power requirements. Overall, alternators are an essential component of many modern technologies and play a critical role in generating the electricity needed to power a wide range of electrical systems.

4.1.4 Battery Management System (Bms)

Any electronic device that controls a rechargeable battery (cell or battery pack), such as by safeguarding it from operating outside of its safe operating range, monitoring its condition, calculating secondary data, reporting that data, controlling its environment, authenticating it, and/or balancing it, is referred to as a battery management system (BMS). A smart battery pack is one that was constructed along with a battery management system and an external communication data channel. A smart battery charger is required to recharge a smart battery pack. A BMS may keep track of the battery's condition as shown by several things, including Voltage overall voltage, individual cell voltages, or periodic tap voltage Temperature: overall temperature, the temperature of the coolant being injected into or removed from the system, or the temperature of each individual cell For liquid-cooled batteries, coolant flow,

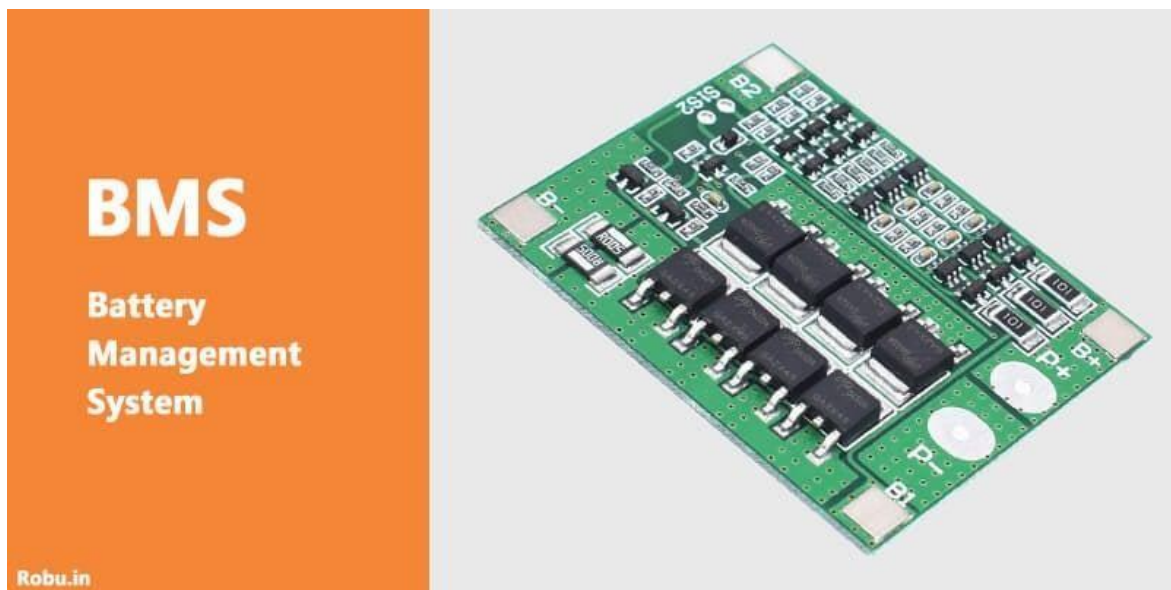


Fig.4.2: Battery Management System

In addition to the basic functions mentioned above, a BMS may also include other advanced features such as:

- Cell balancing: The BMS can balance the charge between individual battery cells to prevent overcharging of some cells and undercharging of others, which can lead to reduced battery performance and lifespan.

- Fault detection and protection: The BMS can detect faults in the battery, such as short circuits, overvoltage, and undervoltage, and take corrective actions, such as disconnecting the battery from the load or charger.
- Predictive maintenance: The BMS can analyze the battery performance data over time to predict the remaining useful life of the battery and schedule maintenance accordingly.
- Data logging and analytics: The BMS can store and analyze battery performance data, which can be used to optimize the battery usage and improve the overall efficiency of the system.
- Remote monitoring and control: The BMS can be connected to a remote monitoring system, which allows for real-time monitoring and control of the battery performance, even from a remote location.

Overall, the BMS plays a crucial role in ensuring the safe and efficient operation of the battery, which is essential for the reliable and long-term operation of battery-powered systems.

BMS will also regulate 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, utilising 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 utilise active air cooling. The main drawback of air cooling is its lack of effectiveness. To function, a lot of electricity must be utilised. A BMS's central controller can interface with low-level hardware working at the cell level or high-level hardware operating externally, such as laptops or an HMI. Further information required. Both distributed and modular BMSes require some form of low-level internal controller-controller or controller-controller communication.

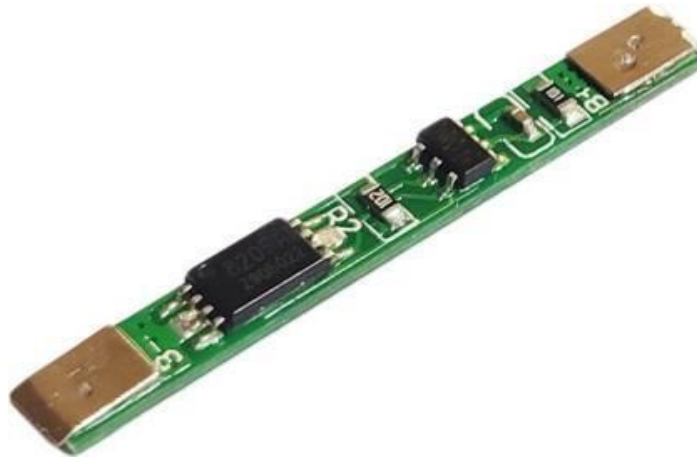


Fig.4.3:Bms Circuit Board

These communication methods are challenging, particularly for high voltage systems. Voltage shift between cells is the issue. The difference between the ground signals from the first and second cells could be hundreds of volts. In addition to software protocols, optical-isolator and wireless communication are two further methods of hardware communication for voltage shifting devices. The maximum number of cells is an additional limitation for internal communications. The majority of hardware for modular architecture is capped at 255 nodes. Another limitation for high voltage systems is the searching time of all cells, which reduces minimum bus speeds and limits some hardware alternatives. The price of modular systems is crucial because it. The most popular communication protocols utilised in mobile phone chargers for negotiating an elevated voltage are Qualcomm Quick Charge and MediaTek Pump Express. These protocols were created to circumvent the power restrictions of current USB connections caused by heat from electrical current. In order to reduce heat generated in the device when converting an elevated voltage down to the battery's terminal charging voltage internally, Oppo's "VOOC" (also marketed as "Dash Charge" with "OnePlus") increases the current instead of voltage. This, however, renders it incompatible with existing USB cables and requires the use of special high-current USB cables with correspondingly thicker copper wires. The USB Power Delivery standard, which was just developed, intends to create a universal negotiating procedure for devices that can use up to 240 watts. battery to load circuit connection Moreover, a precharge system may be included in a BMS, providing a secure means of connecting the battery to various loads and obviating the need for excessive inrush currents while loading capacitors. Typically,

electromagnetic relays known as contactors are used to control the connection to loads. Until the capacitors are charged, the precharge circuit may consist of power resistors connected in series with the loads. As an alternative, it is possible to charge the voltage of the load circuit up to a level sufficiently close to the battery voltage to enable shutting the contactors between the battery and load circuit using a switched mode power supply connected in parallel to loads. Before precharging (due to overload), a BMS's circuit may be able to determine whether a relay is already closed. A battery management system (BMS) is an electronic system that manages the charging and discharging of rechargeable batteries, such as those used in electric vehicles, renewable energy systems, and portable electronic devices. The main function of a BMS is to protect the battery from damage by monitoring and controlling various parameters, including:

- Voltage: The BMS monitors the voltage of each battery cell and ensures that it does not exceed or fall below safe limits.
- Current: The BMS regulates the charging and discharging current to prevent overcharging or over-discharging of the battery.
- Temperature: The BMS monitors the temperature of the battery and takes measures to prevent overheating or overcooling, which can cause damage to the battery.
- State of Charge (SOC): The BMS estimates the SOC of the battery and ensures that it is charged and discharged within safe limits.
- State of Health (SOH): The BMS tracks the SOH of the battery over time, which helps determine the remaining useful life of the battery.

The BMS typically consists of a microcontroller, sensors, and communication interfaces, which work together to monitor and control the battery. The microcontroller processes the sensor data and makes decisions based on the pre-programmed algorithms. The communication interfaces allow the BMS to communicate with other systems, such as the battery charger, motor controller, and vehicle management system. Overall, a BMS is an essential component of any battery-powered system as it ensures the safe and efficient operation of the battery, maximizes its lifespan, and minimizes the risk of damage or failure.

4.1.5 Electric Motor:

An electric motor is a device that converts electrical energy into mechanical energy to produce motion. Electric motors are widely used in a variety of applications, including industrial machinery, household appliances, and transportation, such as electric cars, trains, and boats. Electric motors work on the principle of electromagnetism, where a magnetic field is created by an electric current flowing through a coil of wire. The magnetic field interacts with a stationary magnetic field, either produced by a permanent magnet or an electromagnet, to create rotational motion. The direction of the motion is determined by the direction of the electric current flowing through the coil. There are different types of electric motors, each with its own advantages and disadvantages. The most common types are: DC (direct current) motors: DC motors are simple and efficient, making them ideal for low-power applications such as toys, small appliances, and electric vehicles. They require a DC power supply, which can be a battery or a power converter that converts AC (alternating current) to DC. AC (alternating current) motors: AC motors are widely used in industrial machinery and large appliances. They are more complex than DC motors, but they are more efficient and can handle higher power levels. AC motors require an AC power supply, which is readily available in most households and industrial settings. Brushless DC (BLDC) motors: BLDC motors are similar to DC motors but use electronic controls instead of brushes to switch the direction of the electric current. This makes them more efficient and reliable than DC motors and ideal for high-power applications such as electric cars. Electric motors have many advantages over traditional combustion engines, including lower maintenance costs, reduced noise and vibration, and zero emissions. They also offer more precise control over the speed and torque of the motor, making them suitable for a wide range of applications.

The working of an electric motor can be explained in the following steps:

- **Power Source:** The electric motor needs a source of electrical energy to operate. This is usually an AC or DC power supply.
- **Magnetic Field:** The motor has a fixed magnetic field, called the stator, and a rotating magnetic field, called the rotor. The stator is made up of a series of

electromagnets, while the rotor is made up of a permanent magnet or an electromagnet.

- Interaction of Magnetic Fields: When electricity is supplied to the motor, it creates a magnetic field in the stator. This magnetic field interacts with the magnetic field in the rotor, causing it to rotate.
- Commutator or Electronic Controller: In DC motors, a commutator is used to reverse the polarity of the current in the rotor as it rotates, which keeps it rotating in the same direction. In AC motors, an electronic controller is used to change the frequency of the current supplied to the stator, which changes the speed of the rotating magnetic field.
- Output Shaft: As the rotor rotates, it drives an output shaft that can be used to power a variety of applications.

The key components of an electric motor include:

- Stator: The stator is the stationary part of the motor and is made up of a series of electromagnets.
- Rotor: The rotor is the rotating part of the motor and is made up of a permanent magnet or an electromagnet.
- Commutator: The commutator is a component of DC motors that helps to reverse the polarity of the current in the rotor as it rotates.
- Electronic Controller: The electronic controller is a component of AC motors that helps to change the frequency of the current supplied to the stator, which changes the speed of the rotating magnetic field.
- Bearings: Bearings are used to support the rotating shaft of the motor and reduce friction.
- Enclosure: The motor is typically enclosed in a housing to protect it from damage and prevent it from causing injury.

Overall, electric motors are an essential component of many modern technologies and are used in a wide range of applications. They offer many advantages over traditional combustion engines, including higher efficiency, lower emissions, and quieter operation

4.2 Batteries:

Because of their ability to convert a chemical energy source into electrical energy and the other way around, EV batteries are the most well-known and widely used application for power systems. The energy and power of the batteries are evaluated capacities, as a result, the most important characteristics to consider when battery capacity is measured in ampere-hours (Ah) when designing a HESS. The amount of energy stored in a battery ranges between 0.02 and 40 depending on the type of BEV. Watt-hours (Wh) are measured, with specific energy ranging from 30-180 Wh/kg, and the battery's usable state-of-charge (SOC), which indicates the percentage of the battery currently contains energy. There are numerous battery types available on the market, each with its own chemical composition structure. Currently, lead-acid batteries[4]. Batteries made of lead-acid, Lead-acid batteries are rechargeable electrochemical products that have been used in both residential and industrial applications. Lead-acid batteries have several advantages, including low capital costs, high energy efficiency >80%, fast response times, and low self-discharge rates of only 2% of rated capacity per month (at 25°C). Lead-acid batteries, on the other hand, have a low specific energy density of 30-50 Wh/kg and a maximum cycle life of 1500 cycles. Because the use of lead-acid batteries is increasing, so is the disposal of the parts. Lead is hazardous and has negative consequences, environmental consequences. Nickel-Cadmium Batteries Nickel-based batteries are classified into four types: Nickel-iron and nickel-cadmium alloys Nickel cadmium (NiCd), nickel metal hydride (NiMH), and nickel zinc (NiZn) [18]. All three varieties make use of The positive electrode is nickel hydroxide, and of a battery pack (up to 25% after approximately eight years or approximately 140,000 km). The number of battery cycles considered practical in the literature ranges between 1000 and 3000 cycles, implying that the battery should last a long time. The range's lower value (1000 cycles) for an EV with a 200 km electric driving range is easily achieved by manufacturers nowadays, and the car could still be driven 200,000 kilometres before breaking down. The battery's life had expired. People in Europe anticipate a driving range of around 300 miles km, which is difficult to achieve solely with batteries. The EV driving range is one of them,

one of the major impediments to consumers' adoption of sustainable transportation transportation.

4.2.1 Battery transmission system:

Electric transmission eliminates the need for a gearbox by converting the mechanical force of the engine into electrical energy (via dynamo or alternator) and using the electrical energy to drive traction motors, which mechanically propel the vehicle. The traction motors can be driven directly or via a rechargeable battery in some cases; if rechargeable batteries are used, the vehicle is considered a hybrid vehicle. Electric transmission is typically classified as multiple separate transmission methods based on engine type; for example, a vehicle powered by a petrol engine that uses electrical transmission is typically classified as having petrol-electric transmission, despite the fact that the petrol engine is part of the engine and the transmission is a separate component. Petrol-electric transmission for gasoline engines. Significantly used in many industries in the early twentieth century, but died out around the time of World War II due to the greater popularity of diesel engines. Use today as a hybrid electric vehicle in conjunction with energy stored in a battery pack.

4.2.2 Lead-Acid Batteries

Lead-acid batteries are a type of rechargeable battery that have been widely used since the 1850s. They are commonly used in a wide range of applications, such as backup power supplies, uninterruptible power supplies (UPS), electric vehicles, and renewable energy systems. The basic construction of a lead-acid battery consists of two or more lead plates immersed in an electrolyte solution of sulfuric acid. The plates are usually made of lead or lead alloys, while the electrolyte is a dilute solution of sulfuric acid. The plates are separated by a porous material, which allows the electrolyte to flow between the plates but prevents them from touching each other. When a lead-acid battery is charged, the lead sulfate on the plates is converted back into lead and lead oxide, which produces electrical energy. When the battery is discharged, the lead and lead oxide on the plates react with the sulfuric acid to form lead sulfate and release electrical energy. Lead-acid batteries have several advantages and disadvantages. Some of the advantages include:

- Low cost: Lead-acid batteries are relatively low-cost compared to other types of batteries, making them a popular choice for many applications.
- High discharge rate: Lead-acid batteries can deliver high levels of current, which makes them suitable for high-power applications, such as starting an engine.
- Robustness: Lead-acid batteries are rugged and can withstand harsh operating conditions, such as extreme temperatures and vibration.
- Some of the disadvantages of lead-acid batteries include:
- Low energy density: Lead-acid batteries have a lower energy density compared to other types of batteries, which means that they have a lower energy-to-weight ratio.
- Shorter lifespan: Lead-acid batteries have a shorter lifespan compared to other types of batteries, which means that they need to be replaced more frequently.
- Maintenance requirements: Lead-acid batteries require regular maintenance, such as topping up the electrolyte and equalizing the charge between the cells.

Despite their disadvantages, lead-acid batteries remain a popular choice for many applications, particularly those that require high levels of power and reliability at a lower cost. A sort of rechargeable battery called a lead-acid battery was initially developed in 1859 by French physicist Gaston Planté. It is the original rechargeable battery design ever made. Lead-acid batteries have a lower energy density than contemporary rechargeable batteries. Despite this, the cells have a reasonably high power-to-weight ratio due to their capacity to produce significant surge currents. These qualities make them appealing for use in motor vehicles to supply the high current needed by starter motors, in addition to their inexpensive price. Due to "double sulfation" in the depleted state, lead-acid batteries have relatively limited cycle longevity (often less than 500 deep cycles) and overall lifespan. Even when surge current is not crucial and other designs could offer higher energy densities, lead-acid batteries are frequently employed because they are less expensive than more modern technology. In 1999, lead-acid battery sales made up 40–50% (excluding China and Russia) of the total value of batteries sold worldwide, amounting to a market value of nearly \$15 billion USD. In stand-alone power

systems, high-availability emergency power systems like hospitals, and backup power supply in cell phone towers, large-format lead-acid designs are frequently employed for storage. To increase storage times and lower maintenance needs for certain functions, customised versions of the regular cell may be employed. In these applications, gel-cell and absorbed glass-mat batteries, often known as VRLA (valve-regulated lead-acid batteries), are frequently used.



Fig.4.4:Lead Acid Battery

Lead and lead dioxide make up the negative and positive plates, respectively, in the fully charged state. The majority of the chemical energy is stored in aqueous sulfuric acid, which is present in higher concentration in the electrolyte solution. By electrolyzing water at high charging voltages, oxygen and hydrogen gas are produced, but the water bubbles out and is lost. Some lead-acid battery models have a mechanism that enables the electrolyte level to be checked and topped off with pure water to replenish any that has been lost in this manner. charge level's impact on freezing point Low charge and similarly low sulfuric acid concentrations in the battery increase the likelihood that the electrolyte will freeze in a cold environment due to freezing-point depression. While HSO_4 is consumed at both plates during discharge, H^+ generated at the negative plates goes into the electrolyte solution and is then consumed at the positive plates. During the charge,

the opposite takes place. Proton flow that is electrically driven, Grotthuss' mechanism, diffusion across the medium, or the flow of a liquid electrolyte media are all examples of this motion. The liquid will typically flow via convection because the electrolyte density is larger at higher sulfuric acid concentrations. As a result, a liquid-medium cell often discharges and charges more quickly than an otherwise comparable gel cell. When using sheet lead plates as the two electrodes, the lead-acid cell can be demonstrated. Nevertheless, such a setup only generates about one ampere for a few minutes, and for roughly postcard-sized plates. A way to offer a substantially greater effective surface area was discovered by Gaston Planté. The positive and negative plates in Planté's invention were made from two lead foil spirals that were coil-up, separated, and wrapped in fabric. As the cells' capacity was initially limited, a slow "formation" procedure was necessary to corrode the lead foils, produce lead dioxide on the plates, and roughen them to increase surface area. This procedure was initially powered by electricity from primary batteries; however, the cost of making batteries significantly decreased once generators were made accessible around 1870. Lead-acid batteries have variable capacities that change based on how quickly they are discharged. Peukert's law is the name for the empirical link between discharge rate and capacity. Just the reactive chemicals, which are at the interface between the electrodes and the electrolyte, are initially impacted when a battery is charged or drained. The charge that is typically referred to as "interface charge" or "surface charge" that is stored in the chemicals at the interface spreads over time as a result of the diffusion of these chemicals throughout the volume of the active material. Think about a battery that is fully dead (such as occurs when leaving the car lights on overnight, a current draw of about 6 amps). The battery plates only charge close to the interface between the plates and the electrolyte if it is then given a quick charge for just a few minutes. In this scenario, the battery voltage may increase to a level that is comparable to the charger voltage, which results in a large reduction in the charging current. This interface charge spreads over the electrode and electrolyte volume after a few hours, resulting in an interface charge that may be too low to start the automobile. As long as the charging voltage (about 14.4 volts) remains lower than the gassing voltage.

4.2.3 Lithium-Ion Batteries (Lib):

Lithium-ion batteries (Li-ion) are a type of rechargeable battery that are commonly used in portable electronic devices, electric vehicles, and renewable energy systems. They have a high energy density and are known for their lightweight, long cycle life, and low self-discharge rate. The basic construction of a lithium-ion battery consists of a positive electrode made of lithium cobalt oxide or other lithium-based materials, a negative electrode made of graphite or other carbon-based materials, and an electrolyte solution that allows the lithium ions to move between the two electrodes. When the battery is charged, the lithium ions are attracted to the negative electrode, where they are stored as lithium atoms. When the battery is discharged, the lithium atoms move back to the positive electrode, releasing electrical energy. Some of the advantages of lithium-ion batteries include:

- High energy density: Lithium-ion batteries have a higher energy density compared to other types of batteries, which means that they can store more energy in a smaller size and weight.
- Long cycle life: Lithium-ion batteries can undergo many charge and discharge cycles without losing their capacity, which means that they can last for many years.
- Low self-discharge rate: Lithium-ion batteries have a low self-discharge rate, which means that they can hold their charge for a longer time compared to other types of batteries.
- Some of the disadvantages of lithium-ion batteries include:
- Safety concerns: Lithium-ion batteries are known to be prone to thermal runaway and can catch fire or explode if not designed, manufactured, and used properly.
- Expensive: Lithium-ion batteries are more expensive compared to other types of batteries, which makes them less accessible to some consumers.
- Aging: Lithium-ion batteries can experience capacity loss over time, particularly if they are exposed to high temperatures or overcharged.

Overall, lithium-ion batteries are a popular choice for many applications due to their high energy density, long cycle life, and low self-discharge rate. However, their

safety concerns and higher cost must be taken into account when considering their use in various applications.



Fig.4.5:Lithium Ion Battery

A lithium-ion battery, often known as a Li-ion battery, is a type of rechargeable battery that stores energy by the reversible reduction of lithium ions. A standard lithium-ion cell's anode (positive electrode) is typically constructed of the carbon-based material graphite. Typically, a metal oxide serves as the cathode (negative electrode). Typically, a lithium salt in an organic solvent serves as the electrolyte. It is the most common kind of battery used in electric vehicles and portable consumer gadgets. Also, grid-scale energy storage as well as military and aerospace applications make major use of it. Li-ion batteries feature high energy densities, low self-discharge, and little memory effect in comparison to other rechargeable battery technologies (however a minor memory effect discovered in LFP cells has been linked to subpar cells). The different varieties of lithium-ion batteries have different chemistry, performance, cost, and safety properties. Intercalation compounds are used as active ingredients in the majority of commercial Li-ion cells. Graphite is typically used as the anode or positive electrode, while silicon-carbon is becoming more popular. It is possible to construct cells that emphasise power density or energy. The majority of handheld gadgets employ lithium polymer batteries, which have a high energy density when combined with a lithium cobalt oxide (LiCoO_2) cathode and a graphite anode as the electrolyte. Lithium nickel

manganese cobalt oxide (LiNiMnCoO_2 or NMC) and Li_2MnO_4 spinel, or Li_2MnO_3 -based lithium rich layered materials, may provide longer lifetimes and/or improved rate capability. NMC and its offshoots are widely used in Electric Vehicles (EVs), Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) with their advantages of high energy density and no storage effect, low self-discharge and long service life.



Fig.4.6:Lithium Battery Cell

As a temperature-sensitive component, the operating temperature of lithium-ion battery must be $15\sim 40^{\circ}\text{C}$, and the maximum temperature difference is less than 5°C . Under the long and intense driving conditions and in hot weather, the high operating temperature leads to a reduction in battery life and even thermal runaway. Therefore, it is necessary to develop a reliable and effective battery thermal management system "BTMS". to keep the battery operating temperature within the specified range during charging and discharging to improve battery life, efficiency and safety. Currently, the cooling strategies applied to LIB can be classified as active cooling, passive cooling and hybrid cooling. Active cooling includes air cooling and liquid cooling. The main purpose of air cooling is to lower the battery temperature by optimizing the air duct design. However, air cooling has obvious limitations that cannot meet the heat dissipation requirements in extreme environments and harsh working conditions. Liquid cooling works more stable and efficient than air cooling. Researchers performed parameter analysis and optimization studies on the liquid cooling system from the perspective of the number

of liquid channels, inlet flow and outlet flow directions . Although the performance of the liquid cooling system has improved dramatically, the water pump consumes a large amount of parasitic energy, resulting in a reduction in the vehicle's range, which is one of the main shortcomings of this thermal management strategy. In passive cooling systems, phase change material (PCM) can absorb a large amount of generated heat. Voltage ranges outside of the safe range between 2.5 and 3.65/4.1/4.2 or 4.35V can damage lithium-ion batteries (depending on the components of the cell). Due to the reactive components in the cells, exceeding this voltage range causes premature ageing and safety issues. Long-term storage may cause the protective circuitry's tiny current demand to drain the battery below its shutdown voltage, rendering regular chargers ineffective since the battery management system (BMS) may keep track of this charger or battery "failure." Many different types of lithium-ion batteries cannot be charged safely below 0 °C due to the risk of lithium plating on the anode, which could lead to issues including internal short-circuit routes. The cathode or anode of an electrode is taken out, repaired, and then reused in a new battery. This process is known as direct recycling. With almost any modification to the crystal morphology, mixed metal-oxides can be introduced to the new electrode. In order to replace the lithium that is being lost in the cathode due to degradation from cycling, new lithium is typically added during the process. The cathode strips are taken from the disassembled batteries, immersed in NMP, and then subjected to sonication to remove any extra deposits. Before to annealing, it receives hydrothermal treatment with a LiOH/Li₂SO₄ solution. As the raw ingredients do not account for the majority of the cost, this technology is incredibly cost-effective for batteries that are not cobalt-based. In the realm of rechargeable batteries, nuclear magnetic resonance has traditionally not been a common characterization tool. Yet, there has recently been a lot of interest in the capacity to selectively address the interfaces via chemical or spatial selectivity. The measurement of in situ NMR studies of Li or Na plating as well as ex situ Magic Angle Spinning NMR (MAS-NMR) investigations of the SEI was one of the key resources utilised in recent years. Although this ability is strong, it should only be used sparingly because a number of requirements must be met in order for the measurements to be precise. Further advancement of NMR implementation in the battery should be a result of the development of Dynamic nuclear polarisation

(DNP) for sensitivity and Magnetic resonance imaging (MRI) for spatially localised information.

4.2.4 Wire

An assemblage of one or more wires that are bunched together or run side by side to convey electric current is known as an electrical cable. A cable assembly can be created from one or more electrical cables and the accompanying connections; this is not always necessary for connecting two devices, but it can be a partial product to be soldered onto a printed circuit board with a connector mounted to the housing. In order to connect numerous terminals together, cable assemblies might also take the form of a cable tree or cable harness. In the context of electrical wiring, the term "cable" originally referred to submarine telegraph cables that were armoured with iron or steel wires. Due of their susceptibility to damage, early attempts to install the armouring was produced in different factories from those that produced the cable cores. These businesses specialised in producing the wire rope used in nautical cables. The finished armoured cores became known as cables as a result. Later, the phrase was used to refer to any collection of electrical wires even just one encased in an outer sheath, whether or whether it was armoured. Telecommunications cables having fiber-optic cores inside the outer sheath are now also referred to by this term. In order to carry electrical signals or power from one device to another, electrical cables are used to link two or more devices. Undersea communication cables are used for long-distance communication. Power cables are utilised, particularly high-voltage wire, for the bulk transmission of alternating and direct current power. Electrical cables are widely used in building wiring for circuits that are permanently fixed in buildings such as lighting, power, and control. Installation labour is reduced compared to some other wiring methods since all the circuit conductors needed can be put in a cable at once. An assembly of one or more conductors with their own insulations and optional screens, individual coverings, assembly protection, and protective coverings makes up an electrical cable (s). Wire stranding can increase the flexibility of electrical cables. To create larger, more flexible wires that are comparable in size to solid wires, smaller, individual wires are twisted or braided together in this procedure. The most flexibility is added by bundling tiny wires before concentric stranding. A cable's copper conductors may be exposed or coated with a thin layer of another metal, most

frequently tin, but sporadically gold, silver, or another substance. Tin, gold, and silver are far less likely than copper to oxidise, which may increase the lifespan of wire and make soldering simpler. Each conductor that can carry current, including cables, emits an electromagnetic field. Any conductor or wire will also absorb energy from any nearby electromagnetic fields. These effects are frequently undesirable; the first involves the unintentional transmission of energy that could harm nearby equipment or other components of the same piece of equipment; the second involves the unintentional pickup of noise that could obscure the desired signal being carried by the cable or, if the cable is carrying power supply or control voltages, contaminate them to the point where equipment malfunctions. Since pick up and transmission are essentially related to cable length, the initial answer to these issues is to maintain short cable lengths in structures. The second remedy is to direct cables away from danger. Also, there are specific cable designs that reduce electromagnetic transmission and pickup. Shielding, coaxial geometry, and twisted-pair geometry are three of the main design methods. The Faraday cage's electrical theory is used in shielding. The entire length of the cable is covered in foil or wire mesh. In particular, if the shield is connected to a point of constant voltage, like earth or ground, all wires running inside this shielding layer will be largely disconnected from external electrical fields. A neighbouring power transformer's magnetic "hum" is one example of a low-frequency magnetic field that simple shielding of this kind is not very efficient at blocking. In cables operating at 2.5 kV or above, a grounded shield collects leakage current and capacitive current, preventing electric shock and balancing strain on the cable insulation. Further reducing low-frequency magnetic transmission and pickup is made possible by coaxial architecture. With this design, the inner conductor is exactly in the centre of the foil or mesh shield, which has a circular cross section. This results in two voltages of almost identical magnitude that cancel each other out between the shield and the core conductor when a magnetic field is applied. Two cable wires that have been twisted around one another form a twisted pair. This can be shown by inserting one wire from a pair into a hand drill and spinning it while keeping a light stress on the line. When the wavelength of the interfering signal is greater than the pitch of the twisted pair, alternate lengths of the wire create opposing voltages.

4.3 Power Supply Management (Psm):

Control of the on-board electric generation, i.e. control of the alternator setpoint in conventional electrical systems, aiming at optimizing all of the following: electrical function availability, battery life, vehicle performance (e.g. reduced alternator load when maximum acceleration is demanded), or fuel consumption (e.g. reduce alternator output at idle to allow for lower idle speed). Whereas many of these functions can be considered state-of-the-art in modern voltage regulation, particularly the latter has garnered growing attention recently. Electric generation contributes significantly to fuel consumption, at least in real-world conditions. An average alternator output of 1 kW involves as much as 1–1.4 l gasoline fuel consumption per 100 km, depending on vehicle parameters and driving conditions. Decoupling the electric generation from the loads' demands can significantly reduce this specific fuel consumption contribution by optimizing the system efficiency of engine and alternator at any point in time. This will introduce supply voltage fluctuations into the electrical system and systematically exploit the battery as a short-term energy buffer. Significantly more advanced strategies of PSM are of course needed for HEVs, where electric generation plays a more vital role.

4.3.1 Power Distribution Management (Pdm):

It is used to schedule the allocation of available power and energy to electric loads on a subsystem or component level. Effectively, it must ensure the controlled function delivery of individual electric features by prioritization. Whenever a power deficiency occurs, the PDM algorithm aims at ensuring rail voltage stability, charge balance and robustness, as well as minimizing battery charge throughput in the case of peak loads. Depending on the definition of electric feature priorities, a PDM strategy can dictate a temporary functional degradation under appropriate conditions. Here, a careful balancing of priorities is required, especially for functions that are directly perceivable by the customer. Advanced PDM algorithms will schedule electric feature functionalities dynamically rather than statically. Electric energy management actively uses the energy storage system (battery, supercapacitor, etc.) and hence relies on precise status information about this device. A battery monitoring system (BMS) has to deliver these essential inputs to the energy management control system.

4.4 Powertrain Hybridization:

In recent years, a number of new hybrid electric vehicle propulsion systems for passenger cars and light trucks have been developed and brought to the market by automotive manufacturers. By adding an electromechanical component to the driveline, improvements in propulsion efficiency and reduced exhaust gas emissions could be shown. Different levels of hybridization can be distinguished, implementing the following hybrid functions to different extents, cf. and engine stop/start operation, regenerative braking, modification of engine operating points and various levels of hybrid electric propulsion assist. shows Ford examples, a Micro-HEV technology demonstrator and a full hybrid in series production. The lowest level of hybridization, the Micro-HEV, combines automatic engine stop/start operation with regenerative braking. Several electrical drive systems can deliver the stop/start function, e.g. an enhanced starter motor or an integrated starter generator (ISG), either belt-driven (B-ISG) or crankshaft mounted (C-ISG). The benefit of regenerative braking depends on the power level of the electromechanical component. For Micro-HEVs, with typical generator capacity in the range of 2–4 kW and corresponding conventional 12 V battery technology, the limited maximum torque minimizes the need for modifications of the brake system. Fuel consumption and CO₂ emissions can be reduced by 1.5–4%, depending on vehicle, drivetrain, and driving conditions. At higher voltage levels (≥ 42 V), limited electric propulsion assist becomes possible, and here larger B-ISG and C-ISG systems with hybrid electric propulsion functionality are known. Mild-HEVs offer propulsion assist at lower engine speeds only, whereas Medium-HEVs can support the engine at higher engine speeds, too. The higher electromechanical power level also enables higher fuel saving benefits from regenerative braking.

4.4.1 Multiple Energy Sources Hybridization:

As mentioned before, none of the available energy sources can easily fulfil alone all the demand of EVs to enable them to compete with gasoline powered vehicles. In essence, these energy sources have a common problem: they have either HSE or HSP, but not both. A HSE energy source is favourable for long driving range, whereas a HSP energy source is desirable for high acceleration rate and high hill climbing capability. The concept of using and coordinate multiple energy sources to

power the EV is typically denominated hybridization. Hence, the specific advantages of the various EV energy sources can be fully utilized, leading to optimized fuel economy while satisfying the expected driving range and maintaining other EV performances. A lot of work has been done to investigate methodologies to sizing and control strategies for fuel-cell-battery, fuel-cell-supercapacitor, fuel-cell-battery-supercapacitor, battery supercapacitor vehicles. These studies add a significant knowledge to the field but do not provide a detailed comparison of a battery supercapacitor-PV array, principally of the daily energy evolution, in function of the test cycle. As the fuel-cell vehicle is an expensive choice, it is necessary to analyze other solution for EV hybridization. The present study aims at developing a methodology to help the designers to optimise the sizing of the power components in a small urban EV. For that, it used different driving cycles, specified acceleration performance and maximum speed requests.

4.4.2 Energy Management

The expanding functions of the vehicle electric/electronic system call for significant improvements of the power supply system. A couple of years ago, broad introduction of a higher system voltage level, 42 V, initially in a dual-voltage was considered as a viable solution. However, the cost/benefit ratio associated with this type of configuration in systems operating at 42 V or less turned out to be too low for widespread implementation. Furthermore, the electric propulsion that can be generated at this voltage level is generally considered too low to make mild-hybrid electric vehicles attractive. At the same time, several hardware components for the conventional 14 V system experienced significant technological progress. For example, enhanced 14 V clawpole (Lundell) alternators were developed that can continuously generate an electric power output of 3 kW or more. AGM batteries demonstrated at least three-fold longer shallow-cycle life, compared to conventional SLI batteries. Finally, the introduction of high level energy management control strategies can ensure system robustness and optimal energy efficiency and thus help stretch the boundaries of the 14 V system. Energy management functions can be separated into two groups: Power Supply Management (PSM): Control of the on-board electric generation, i.e. control of the alternator setpoint in conventional electrical systems, aiming at optimizing all of the following: electrical function availability, battery life, vehicle performance (e.g. reduced alternator load when

maximum acceleration is demanded), or fuel consumption (e.g. reduce alternator output at idle to allow for lower idle speed). Whereas many of these functions can be considered state-of the-art in modern voltage regulation, particularly the latter has garnered growing attention recently. Electric generation contributes significantly to fuel consumption, at least in real-world conditions. An average alternator output of 1 kW involves as much as 1–1.4 l gasoline fuel consumption per 100 km, depending on vehicle parameters and driving conditions. Decoupling the electric generation from the loads' demands can significantly reduce this specific fuel consumption contribution by optimizing the system efficiency of engine and alternator at any point in time. This will introduce supply voltage fluctuations into the electrical system and systematically exploit the battery as a short-term energy buffer. Significantly more advanced strategies of PSM are of course needed for HEVs, where electric generation plays a more vital role. Power Distribution Management (PDM) is used to schedule the allocation of available power and energy to electric loads on a subsystem or component level. Effectively, it must ensure the controlled function delivery of individual electric features by prioritization. Whenever a power deficiency occurs, the PDM algorithm aims at ensuring rail voltage stability, charge balance and robustness, as well as minimizing battery charge throughput in the case of peak loads. Depending on the definition of electric feature priorities, a PDM strategy can dictate a temporary functional degradation under appropriate conditions. Here, a careful balancing of priorities is required, especially for functions that are directly perceivable by the customer. Advanced PDM algorithms will schedule electric feature functionalities dynamically rather than statically. Electric energy management actively uses the energy storage system (battery, supercapacitor, etc.) and hence relies on precise status information about this device. A battery monitoring system (BMS) has to deliver these essential inputs to the energy management control system.

Powertrain hybridization: In recent years, a number of new hybrid electric vehicle propulsion systems for passenger cars and light trucks have been developed and brought to the market by automotive manufacturers. By adding an electromechanical component to the driveline, improvements in propulsion efficiency and reduced exhaust gas emissions could be shown. Different levels of hybridization can be distinguished, implementing the following hybrid functions to different extents, engine stop/start operation, regenerative braking, modification of engine operating points and various levels of

hybrid electric propulsion assist. For example, a Micro-HEV technology demonstrator and a full hybrid in series production. The lowest level of hybridization, the Micro-HEV, combines automatic engine stop/start operation with regenerative braking. Several electrical drive systems can deliver the stop/start function, e.g. an enhanced starter motor or an integrated starter generator (ISG), either belt-driven (B-ISG) or crankshaft mounted (C-ISG). The benefit of regenerative braking depends on the power level of the electromechanical component. For Micro-HEVs, with typical generator capacity in the range of 2–4 kW and corresponding conventional 12 V battery technology, the limited maximum torque minimizes the need for modifications of the brake system. Fuel consumption and CO₂ emissions can be reduced by 1.5–4%, depending on vehicle, drivetrain, and driving conditions. At higher voltage levels (≥ 42 V), limited electric propulsion assist becomes possible, and here larger B-ISG and C-ISG systems with hybrid electric propulsion functionality are known. Mild-HEVs offer propulsion assist at lower engine speeds only, whereas Medium-HEVs can support the engine at higher engine speeds, too. The higher electromechanical power level also enables higher fuel saving benefits from regenerative braking.

Energy management system (EMS) : HESS To maximise the benefits of the HESS in the EVs/HEVs, it is very important to properly manage the energy derived from and into the system. The significance of the EMS and its design has been described in the literature. The design, most of the times, considers the following inputs: batteries SOC and outputs, vehicle's speed and acceleration, the current demand, the load voltage, state of health (SOH) of the battery, SOC of the SCs, the battery degradation under sub-zero temperatures. In some studies, the power and energy controlled flow into the HESS and the batteries Ch/Dch rates have also been investigated. Armenta et al, proposed a rule-based EMS that allows a high consumption of the RB energy and a high acceleration at any time. They proposed three flowcharts for controlling the power supply based on different modes . Based on the analysis, when the EMS implemented, it could increase the efficiency of the EV in the range of 8%–25% by using an RE. The proposed EMS controls the SC based discharge in a way that the minimal power is delivered to the load due to the possibilities to obtain an enough and necessary space to absorb the energy from RB. In this case, the acceleration for a new cycle is supported. A simulation test protocol was developed to demonstrate the benefits of the proposed EMS algorithm, considering an EV of 1550 kg. The energy delivered from the SC bank to the DC

bus is performed, utilising BD-DC/DC-C while the battery bank is directly connected to the same bus. The EMS with the novel multimode HESS presented in the previous section also employs the rule-based control strategy for the model selection while for the power distribution between the batteries and SCs utilises the power-balancing strategy. The proposed configuration of the novel multimode HESS and its energy management were validated. Jung et al. proposed a control design method and constructed an experimental system to validate their method. According to the proposed method, instead of choosing the battery current and the SC current for the HESS design, they chose the battery current and the load voltage. Here, they relied on the SC's ability to supply or absorb almost any current as needed. The authors addressed some control design problems for a power system driven by battery-SC HESS devices. The currents in the battery and the SC were actively controlled by two bi directional buck-boost converters. Two control objectives were addressed in their work: the control design problems were converted into numerically efficient optimisation problems with linear matrix inequality constraints. The value of the control design methods was first verified by simulation and then validated experimentally.

4.4.3 Energy Management System (Ems):

HESS To maximise the benefits of the HESS in the EVs/HEVs, it is very important to properly manage the energy derived from and into the system. The significance of the EMS and its design has been described in the literature [5,6,33,42,45–54]. The design, most of the times, considers the following inputs: batteries SOC and outputs, vehicle's speed and acceleration, the current demand, the load voltage, state of health (SOH) of the battery, SOC of the SCs [35,49], the battery degradation under sub-zero temperatures [50,55,56]. In some studies, the power and energy controlled flow into the HESS and the batteries Ch/Dch rates have also been investigated Armenta et al. proposed a rule-based EMS that allows a high consumption of the RB energy and a high acceleration at any time. They proposed three flowcharts for controlling the power supply based on different modes. Based on the analysis, when the EMS implemented, it could increase the efficiency of the EV in the range of 8%–25% by using an RE. The proposed EMS controls the SC based discharge in a way that the minimal power is delivered to the load due to the possibilities to obtain an enough and necessary space to absorb the energy from

RB. In this case, the acceleration for a new cycle is supported. A simulation test protocol was developed to demonstrate the benefits of the proposed EMS algorithm, considering an EV of 1550 kg. The energy delivered from the SC bank to the DC bus is performed, utilising BD-DC/DC-C while the battery bank is directly connected to the same bus. The EMS with the novel multimode HESS presented in the previous section also employs the rule-based control strategy for the model selection while for the power distribution between the batteries and SCs utilises the power-balancing strategy. The proposed configuration of the novel multimode HESS and its energy management were validated. Jung et al. proposed a control design method and constructed an experimental system to validate their method. According to the proposed method, instead of choosing the battery current and the SC current for the HESS design, they chose the battery current and the load voltage. Here, they relied on the SC's ability to supply or absorb almost any current as needed. The authors addressed some control design problems for a power system driven by battery-SC HESS devices. The currents in the battery and the SC were actively controlled by two bidirectional buck-boost converters. Two control objectives were addressed in their work: Based on the state-space averaged model, the control design problems were converted into numerically efficient optimisation problems with linear matrix inequality constraints. The value of the control design methods was first verified by simulation and then validated experimentally

4.5 Batteries For Electrified Vehicles:

Batteries used for EVs are the most known and commonly used application for power systems due to their ability to transform a chemical energy source into electrical energy and the other way around. The batteries are appraised for their energy and power capacities; therefore, the most important characteristics that should be considered when designing an HESS are battery capacity measured in ampere-hours (Ah) with values between 0.02–40 depending on the BEV type, the amount of energy packed in a battery measured in watt-hours with specific energy ranging between 30–180 Wh/kg, and the useable state-of-charge (SOC) of the battery which indicates the percentage of energy currently contained within the battery. On the market, there are numerous battery varieties depending on their chemical structure. Currently, lead-acid batteries, nickel-metal hydride (Ni-MH), and lithium-ion batteries are the three the most common rechargeable battery types

used in EVs lead-acid batteries: Lead-acid batteries are rechargeable electrochemical products which have been employed in both domestic and industrial settings. Lead-acid batteries provide several advantages, including low capital costs, high-energy efficiency (>80% [21,24]), quick response times, and minimal rates of self-discharge of only 2% of rated capacity per month (at 25 °C). However, lead-acid batteries have a poor specific energy density 30–50 Wh/kg and a short cycle life of maximum 1500. The use of lead-acid batteries has been rising, which is why the disposal of the parts are increasing. Lead is dangerous and has negative environmental impacts

nickel-based batteries: There are four different types of nickel-based batteries: nickel-iron, nickel-cadmium (NiCd), nickel-metal hydride (NiMH), and nickel-zinc (NiZn) . All three varieties utilize nickel hydroxide as the positive electrode and a potassium hydroxide aqueous solution mixed with the electrolyte being primarily lithium hydroxide. The NiCd type employs cadmium hydroxide as the negative electrode, the NiMH type uses a metal alloy, and the NiZn type uses zinc hydroxide. The maximum energy densities for alkaline batteries are often higher than those for lead-acid batteries, and their specific energy densities vary from 50 Wh/kg to 95 Wh/kg. With up to up to 10,000 cycles , NiCd batteries have more extended average operating and cycle lives than lead-acid batteries.

lithium batteries (libs): are the most appropriate energy storage system for automotive use because of their low mass, high specific energy, high specific power up to 4000 W/kg, and high energy density up to 250 Wh/kg Additionally, LiBs have no memory effect and contain no toxic elements, such as lead, mercury, or cadmium. To achieve the desired capacity and voltage for automotive applications, LiBs are made up of numerous electrochemical lithium-ion cells that are incorporated into modules. To transcend the existing storage limits of the LIB packs, significant improvements in the chemistry/formulation of the electrolyte and electrodes are required. The difficulty for battery research in the coming years will be to develop greater electrochemical/thermal stability electrolytes. To assure a sustainable future for BEVs, a protracted change to battery chemistries, such as Li-S and metal-air, appears unavoidable, as evidenced by life-c.

CHAPTER 5

RESULT AND DISCUSSION

5.1.Result:

As an AI language model, I do not have access to the specific results of a particular study or project related to the design of a battery optimized energy storage system for an electric vehicle (EV). However, I can provide a general overview of what such a study might entail and some possible outcomes. The primary goal of designing a battery optimized energy storage system for an EV is to maximize the vehicle's range and performance while minimizing the size, weight, and cost of the battery. This requires a detailed analysis of the vehicle's power requirements, driving patterns, and charging infrastructure, as well as the characteristics and limitations of different types of batteries. Some possible results and discussions that may arise from such a study include:

- Battery type and chemistry:** One of the most critical factors in designing a battery optimized energy storage system is choosing the right type and chemistry of battery. Lithium-ion batteries are currently the most common type of battery used in EVs, but other types such as solid-state batteries, sodium-ion batteries, or zinc-air batteries could offer better performance and cost-effectiveness in the future. The study may discuss the advantages and disadvantages of different battery chemistries and recommend the best battery type for the particular EV application.
- Battery size and capacity:** Another crucial factor in battery optimization is determining the optimal size and capacity of the battery. The study may analyze the vehicle's power requirements and driving patterns to estimate the minimum range and maximum payload capacity required. It may also consider the charging infrastructure and recommend a battery size and capacity that balances the range, payload, and charging time.
- Battery management system (BMS):** To maximize the battery's lifespan and performance, an effective battery management system is crucial. The BMS monitors the battery's state of charge, temperature, and voltage and controls the charging and discharging process to ensure safe and efficient operation. The study may discuss different BMS designs and recommend the best BMS for the particular battery and EV application.
- Integration with other components:** The battery optimized energy storage system should be integrated with other components of the EV, such as the

electric motor, power electronics, and regenerative braking system, to achieve maximum efficiency and performance. The study may discuss the integration process and recommend the best approach for the particular EV application. In conclusion, designing a battery optimized energy storage system for an EV requires a comprehensive analysis of various factors and considerations. The results and discussion of such a study may include recommendations on battery type and chemistry, battery size and capacity, battery management system, and integration with other components to achieve maximum efficiency, performance, and cost-effectiveness

5.2 Discussion:

considered driving cycles, specified maximum speed, acceleration performance, regenerative energy and gradeability requests. Some simulation results of multiple energy sources hybridization were presented, considering different ESSs and different scenarios for the small presented EV. The emphasis of this work is the comparative study on the impact of different ESSs utilization, namely different combinations of the considered sources, versus the different scenarios for daily use. It should be clearly stated that the presented results depend strongly on the ESSs price, weight, energy and power, and may change as these characteristics modify. The complete methodology is fast, objective, and quite accurate, since the simulations obtained for the proposed designs are within the minimum request results. It was also studied the possibility of using a backup system based on solar energy, that may be considered in the design, or as an extra to cope with unforeseen routines and to minimize the recharge of ESSs through the power network. The methodology can be improved by inclusion of techniques for multi-objective optimization, minimizing the initial cost, the cost of the ESSs recharges, and weight, maximizing the autonomy and life cycle of ESSs. This type of study is important for the correct sizing of the ESSs, depending on the intended uses of an EV, in order to maximize the autonomy and the performance with a minimum initial cost and utilization costs. In this section, some further analysis is given to explain the performance difference between the proposed strategy and the DP approach especially under the UDDS. As illustrated in the Section, the life cycle cost is reduced at a relatively low rate when the SC usage increases beyond the transition area. It seems that the reduction in the HESS life cost is not worth the increase in

the HESS initial cost. However, an important benefit it brings is that the rule-based energy management strategy can be simplified. performance of the well-tuned rule-based strategy along the UDDS is compared with the DP approach when NSC changes from 2 to 7, and the result is shown in Fig. 16. The performance difference between the rule-based strategy and the DP approach decreases with an increase in MSC, which reveals that the rule based strategy can well imitate the power split operations of the DP approach when the SC configuration is large enough to absorb and supply the demanded power during the driving cycle. With regard to the limiting case, in which infinite SC modules are adopted, the optimal energy management strategy is to idle the battery and use the SC to supply all power demand during the entire cycle. In conclusion, the rule-based strategy performs better as the number of SC modules is increased, and the HESS life cycle cost can be therefore decreased. It is worth noticing that the rule-based strategy compared in Fig. 16 still has five control modes. It means that we do not simplify the rule-based strategy, although it has potential to be simplified when the SC amount increases. But the concern is that the initial cost of the HESS increases.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 Summary

Based on a dynamic battery degradation model, an integrated optimization problem for deriving the best solution of component sizing and energy split strategies of a semi-active HESS is addressed in this paper by utilizing the DP approach. For the system hybridization, the battery size is optimized according to the requested minimal mileage, which is an important index to evaluate the EV performance. The optimal size of the SC pack is obtained by globally searching the minimum HESS life cycle cost among all HESS candidates. Within the SC sizing process, the DP approach is adopted to split the demanded power P_{demand} into P_{bat} and P_{SC} along two testing scenarios: the typical CBDC and the UDDS. It turns out that the life cycle cost of the HESS can be rapidly reduced initially with the introduction of SC, though the reduction rate decreases as the SC cost increases. The HESS configurations that occur in the transition area can be selected as the best solutions ($MSC = 2$, $NSC = 25$ for the CBDC; $MSC = 4$, $NSC = 25$ for the UDDS in this paper). For the energy split strategy, a near optimal rule-based strategy, which can be easily implemented and has low computational cost, is proposed according to the DP results. To be specific, three control rules can be extracted from the DP result along the CBDC, and another rule can be extracted from the DP result along the UDDS. However, not all the characteristics within the DP results can be taken into consideration in practical applications as the information about the future driving situation is difficult to predict. Compared with the battery-only configuration, the HESS controlled by the proposed rule-based strategy can reduce up to 47% and 60% of the ESS life cycle cost along the CBDC and UDDS, respectively. Thus the effectiveness of adopting the SC in the ESS and the availability of the proposed rule-based strategy are validated. In addition, the performance of the proposed rule-based strategy can be improved by increasing the SC amount. This is reflected in a decreasing difference between the results of the proposed strategy and the DP approach, as the SC capacity increases. However, this also increases the initial cost of the HESS. So the conflicting targets:

- decreasing the system initial cost;

- improving the system performance, should be well balanced during the HESS design.

6.2 Conclusion:

However, the battery/SC system is not as simple as coupling two electrochemical power sources. In addition to the individual cell architectures, the entire electrical system should be subtly matched to build an integer power source. It is of important to decide when and how each electrochemical cell should be charged or discharged. This is accompanied by a complex usage procedure, which is different from regular testing of the electrochemical cells. Therefore, designing the future cells should be based on a close collaboration between the researchers working on the electrochemistry part of the power source and those who are designing the electrical system of the whole power source in the EV. There is still a huge gap between these two areas of research. Many of the hybrid systems tested for the EVs are based on commercial batteries and SCs, which have not been fabricated for this purpose. Instead, it is vital to design the batteries and SCs based on the requirements for the hybrid energy systems of the EVs. The critical important of this point lines in the availability of various electrode materials for both batteries and SCs, which might not be useful for the popular applications, but they provide new opportunities for the EV applications. A simple comparison between the size and performance of a laptop battery and the power source required for an EV reveals that entirely new types of electrochemical cells are required for the future EVs. However, most of the common candidates for the EV power sources are practically based on the scaled-up version of the same old battery systems. The present manuscript merely aimed to attract the attention of researchers working on different sides of this field to specifically focus on the opportunities for designing native battery/supercapacitor systems for the EVs. In this direction, the crucial differences between the performances of these electrochemical cells in a hybrid power source of EVs with the standard energy storage tests should be taken into account. Here, we attempted to provide an overview of the possible performance of the battery/supercapacitors systems in the EVs.

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