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Energy Storage System for Electrical Vehicle

[1]Miss.Shubhangi Bawane, [2]Miss. Kavita Bhangale, [3]Mrs. Ashwini Rathod

[1,3]Ass. Professor, CSMSS College of Polytechnic,Aurngabad

[2]UG Scholar, CSMSS Chh. Shahu College of Engineering, Aurangabad

ABSTRACT

The world is moving toward development by ensuring proper utilization of advanced technologies. Many developing and under- developing countries are competing to achieve technological advancement. Since the last few decades, environmental impact of petroleum based transportation infrastructure, along with fear of global warming, has led to renewed interest in an electric transportation infrastructure. The electric vehicle (EV) technology addresses the issue of the reduction of carbon and greenhouse gas emissions. The concept of EVs focuses on the utilization of alternative energy resources. However, EV systems currently face challenges in energy storage systems. This paper compressively reviews the technologies in the energy storage system. In this paper we are focusing on Li-Ion batteries.

***Key word*-:** Energy storage systems, Electrical vehicle, Battery electric vehicle, Li-Ion batteries.

1. INTRODUCTION

The increasein the emission of greenhouse gases (GHG) is one of the most important problems in the world. Decreasing GHG emissions will be a big challenge in the future. The transportation sector uses a significant part of petroleum production in the world, and this leads to an increase in the emission of GHG. The increase of vehicles on roads has caused two major problems, namely, traffic jams and carbon dioxide (CO2) emissions. Generally, a conventional vehicle dissipates heat during consumption of approximately 85% of total fuel energy in terms of CO2, carbon monoxide, nitrogen oxide, hydrocarbon, water, and other greenhouse gases (GHGs); 83.7% of totalgas emissions are CO2. The result of this issue is that the increase in global warming and pollution and the population of the world befouls the environment by the transportation system automatically. Electric Vehicles (EV) have the potential to solve a big part of CO2 emission and energy efficiency issues such as the stability and reliability of energy. There is not a traditional fuel for transportation systems at hand that is both clear and efficient (mostly fossil fuels), while on the other hand, electric fleet systems can work with lower GHG emissions and energy losses. Therefore, changing fuels seems the best idea to get the best result here. Many action plans have been approved by governments individually and collectively to reduce GHG emission by replacing the conventional internal combustion engine-run vehicle with electric vehicle (EV). Hence, a significant reduction of GHG emissions is projected in the next few decades. Electric-driven vehicles are attracting attention because of their low emission and efficient reduction of CO2 emission. The EV is a system with higher engine efficiency and does not emit pollutants through tailpipe emission, fuel evaporation, or fuel refining. Thus, it is known as a zero-emissionvehicle.

1.1 WORKING OF ELECTRICALVEHICLE

The electrical vehicles are the vehicles which operate on electrical energy. Depending on the source of power, EVs are of several types, such as hybrid electric vehicles (HEVs), battery-powered electric vehicles (BEVs), plug- in hybrid electric vehicles, photovoltaic electric vehicles, and fuel cell electric vehicles. Unlike conventional vehicles, EV uses a more efficient power source and electrical motor. Regenerative braking and thermoelectric generators are used in EVs to reduce energy waste. The braking process of the vehicle absorbs its energy, converts it back to electrical energy, and returns the energy to the batteries, while the thermoelectric generator converts heat from the engine and machine systems to electricity automatically. The electric energy stored in the battery systems and other storage systems is used to operate the electrical motor and accessories, as well as basic systems of the vehicle to function. The driving range and performance of the electric vehicle supplied by the storage cells must be appropriate with sufficient energy and power density without exceeding the limits of theirspecifications.

Many requirements are considered for electric energy storage in EVs. The management system, power electronics interface, power conversion, safety, and protection are the significant requirements for efficient energy storage and distribution management of EV applications. Providing advanced facilities in an EV requires managing energy resources, choosing energy storage systems (ESSs), balancing the charge of the storage cell, and preventing anomalies. In this paper, available energy storage technologies of different types are explained along with their formations, electricity generation process, characteristics, and features concerning EV applications. The review focuses on hybridization technologies of the ESSs for their efficient deployments in EV applications. Thus, the contribution of this study is the improvement of future ESSs for sustainable development of theEVs.

2. ENERGY STORAGE SYSTEMSINEV'S

At the present and in the foreseeable future, the viable EVs energy sources seem tobe batteries, fuel cells, super capacitors (SCs) and ultra high speed flywheels. Batteries are the most mature source for EV application. But they offer either high specific energy (HSE) or (relatively) high specific power (HSP). Fuel cells are comparatively less mature and expensive for EV application. They can offer exceptionally HSE, but with very low specific power. In spite of some quite expensive prototypes, such low specific power poses serious problems to their application to EVs that desire a high acceleration rate or high hill climbing capability. Also, they are incapable of accepting the high peaks of regenerative energy during EV braking or downhill driving and, worse, their overall energy efficiency is very low (about 25% from `wind to wheel"). SCs have low specific energy for standalone application. However, they can offer exceptionally HSP (with low specific energy). Flywheels are technologically immature for EV application. For the "full electric" EV the solutions pass by significant progress in battery technology and by using different energy sources with optimized management of energy flow.

In this paper, we will focus on batteries which are currently used in the electrical vehicles. EVs batteries must be solid and have these suitable parameters: rating of power, charge and discharge, the density of power and energy, response time, efficiency, self-discharge and lifetime. Today, four types of batteries are better used in electric vehicles, such as Li-ion, NiCd, NaS and ZnBr. However, the specifics are different for each material. The properties of EVs' batteries are given in Table 1. The cost of each type of battery is different, but the technical side of this issue clearly shows that Li- ion batteries are the best choice for EVs in every situation. Li-ion batteries with some alloy such as Fe and Mn give the best performance, so they boost the battery capacity and safety. In the latest measurements, EVs can travel between
250 and 350 miles with Li-ion batteries. Generally, LiFePO4, LiCoO2 andLiMn2O4types of batteries are used in EVs. All of them are produced as anode and cathode types. Table
2 illustrates the type of Li battery and its specifications.

Table 1. Type of batteries and their specifications.

Battery Parameters	NiCd	NaS	ZnBr	Li-ion
Power rating (MW)	0–40	0.05–8	0.05–2	0–0.1
Discharge time	S–h	S–h	S–10 h	Min–h
Power density (W/l)	75–700	120–160	1–25	1300–10,000
Energy density (Wh/l)	15–8	15–300	65	200–400
Response time	<S	<S	S	<S
Efficiency (%)	60–80	70–85	65–75	65–75
Lifetime in years	5–20	10–15	5–10	5–100
Lifetime in cycles	1500–3000	2500–4500	1000–3650	600–1200
Cost $ (kW)	500–1500	1000–3000	700–2500	1200–4000
Cost $ (kW/h)	800–1500	300–500	150–1000	600–2500

Table 2. Some type of Li batteries and theirspecifications

Type of Li-ion	Practical Energy Density (Wh/kg)	Cycle Life	Safety
$C/LiCoO_2$	110~190	500~1000	Poor
$C/LiMn_2O_2$	100~120	1000	Safer
$C/LiFePO_4$	90~115	>3000	Very safe
$LTO/LiCoO_2$	70~75	>4000	Extremely safe
$LTO/LiFePO_4$	~70	>4000	Extremely safe

The batteries' performance depends on the alloy used, so to know the grade of battery quality, manufactures of EVs or users of the Li battery check the result of tests performed on it. Current, voltage, mechanical strike and temperature are important parameters to be considered in all tests on the batteries, as these parameters fluctuate during the day. In this paper we will have a thorough review on Lithium ionbatteries.

2.1 BASICS OF LI-IONBATTERIES

In 1985, the first Lithium- Ion batteries were created. It took a further 6 years of research before they were commercialized. The current predominant battery energy storage technology for EVs is the Li-ion battery. A Li-ion battery is constructed by connected basic Li-ion cells in parallel (to increase current), in series (to increase voltage) or combined configurations. Multiple battery cells can be integrated into a module. Multiple modules can be integrated into a battery pack. For example, the 85 kWhbatterypack in a typical Tesla car contains 7104 cells. Typically, a basic Li-ion cell consists of a cathode (positive electrode) and an anode (negative electrode) which are contacted by an electrolyte containing lithium ions. The electrodes are isolated from each other by a separator, typically micro porous polymer membrane, which allows the exchange of lithium ions between the two electrodes but not electrons. In addition to liquid electrolyte, polymer, gel, and ceramic electrolyte have also been explored for applications in Li-ion batteries. Figure 1 illustrates the basic operating principle of a typical Li-ion battery cell. The basic design of Li-ion cells today is still the same as those cells Sony commercialized two decades ago, although various kinds of electrode materials, electrolyte, and separators have been explored. The commercial cells are typically assembled in discharged state. The discharged cathode materials (e.g., LiCoO2, LiFePO4) and anode materials (e.g., carbon) are stable in atmosphere and can be easily handled in industrialpractices.

During the charging process, the two electrodes are connected externally to an external electrical supply. The electrons are forced to be released at the cathode and move externally to the anode. Simultaneously the lithium ions move in the same direction, but internally, from cathode to anode via the electrolyte. In this way the external

Energy is electrochemically stored in the battery In the form of chemical energy in the anode and cathode materials with different chemical potentials. The opposite occurs during the discharging process: electrons move from anode to the cathode through the external load to do the work and Li ions move from anode to the cathode in the electrolyte. This is also known as the “shuttle chair “mechanism, where the Li ions shuttle between the anode and cathodes during charge and discharge cycles. Electrochemical reactions at the two electrodes released the stored chemical energy.

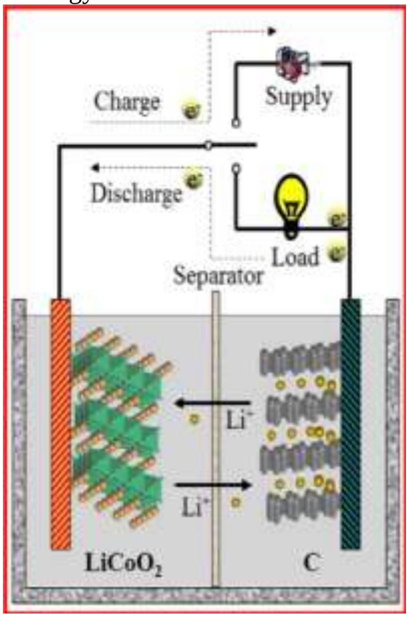

Fig 1. Basic components and operation of Li-Ion cell

2.1 PERFORMANCE EVALUATION OF LI-IONBATTERIES

The performance of Li-ion batteries can be evaluated by a number of parameters, such as specific energy, volumetric energy, specific capacity, cyclability, safety, abuse tolerance, and the dis/charging rate. Specific energy (Wh/kg) measures the amount of energy that can be stored and released per unit mass of the battery. It can be obtained by multiplying thespecific capacity (Ah/kg) with operating battery voltage (V). Specific capacity measures the amount of charge that can be reversibly stored per unit mass. It is closely related to the number of electrons released from electrochemical reactions and the atomic weight of thehost.

Cyclability measures the reversibility of the Li-ion insertion and extraction processes, interms of the number of charge and discharge cycles before the battery loses energy significantly or can no longer sustain function of the device it powers. Practically, the cycle life of Li-ion batteries are affected by depth of discharge (DOD) and state of charge (SOC), as well as operating temperature, in addition to the battery chemistry. Cycle life is enhanced with shallow DOD cycles and less SOC swing, and avoiding elevated temperature. Li dendrite formation on graphite anode can occur at low- temperature charge which should beavoided.

Safety requirements are very high for Li- ion batteries with multiple cells. Battery management systems (BMS) are typically employed in battery cells/packs/modules to prevent any possible thermal runaway. For example, in the case of battery cell failure inside a battery pack, the BMS could detect and isolate the particular cell. Abuse tolerance is a critical requirement for practical application of Li-ion batteries, especially in electric vehicles. Typically, mechanical, thermal, and electrical abuse evaluations are carried out on prototypes to evaluate abuse tolerance of the batteries. The mechanical abuse evaluation includes mechanical shock and drop, roll-over, nail penetration, and immersion in water tests. The thermal abuse evaluation includes radiant heat, thermal stability, overheat, and extreme cold tests. The electrical abuse evaluation includes short circuit, overcharge, over-discharge, and alternative current exposure tests. Those abuse tolerance tests are extremely important for their applications in electric vehicles, as electric vehicles are expected to compete with existing internal combustion engineer-powered vehicles that run well in rough conditions. The rate of charge or discharge measures how fast the battery can be charged and discharged, typically called C-rate. These are the parameters on which the performance of Li-Ion batteries is evaluated.

3. FUTURESCOPE

There are many other promising battery technologies under development. The new battery technologies may not be necessary to directly compete with Li-ion batteries in market share due to their unique characteristics in terms of performance, cost and size. In line with the aim to develop batteries with even higher energy, Li-air (Li-O2) and Li-sulfur (Li-S), achieving impressively high-energy density theoretically, have again attracted much attention recently. But these batteries are not commercialized as there are still some technical barriers. Hydrogen fuel cell cars are also a great option for a sustainable future. Plug in hybrid electrical vehicles are similar to battery electrical vehicles but also have a conventional dieselengine.

4. CONCLUSION

The paper has provided an overview on different energy storage systems in electrical vehicle. A short review on the different methods of energy storages are presented and compared. The Lithium Ion batteries are described. The Li-Ion battery has clear fundamental advantages and decades of research which have developed it into the high energy density, high cycle life, high efficiency battery that it is today.

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