Challenges of Batteries for Electric Vehicles

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***Abstract* — Battery represents arguably the most important and most technically challenging component of the electric vehicle (EV). 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 (ESSs) with regard to their safety, size, cost, and overall management issues, hence the reason for the stated seminar topic on the challenges of batteries for EVs. In addition, the hybridization of ESSs with advanced power electronic technologies has a significant influence on optimal power utilization to lead advanced EV technologies. Batteries for electric vehicles have many real-life challenges. First, you need a sophisticated system to monitor the batteries to make sure that they are balanced charged and that they are protected from a lot of external conditions like overcharge, over-discharge, over current, short circuits. If any of these conditions occur at any time, it might trigger thermal runaway and cause disastrous consequences to humans and the environment. Finally, the paper also highlights a number of key factors and challenges and presents the possible recommendations for the development of next-generation of EVs and battery management systems for electric vehicles and battery energy storage systems.**

Keywords— Batteries, Energy storage systems, Electric Vehicles, Battery State of Charge.

I. INTRODUCTION

The world is moving toward development by ensuring proper utilization of advanced technologies. Many developing and underdeveloped countries are competing to achieve the technological advancement of developed countries. Addressing the transportation needs of citizens symbolizes the furtherance of technology and economic growth. Global mobility and development of many cities have significantly increased the number of vehicles on roads. The increase of vehicles on roads has caused two major problems, namely, traffic jams and carbon dioxide (CO_2) emissions. Generally, a conventional vehicle dissipates heat during consumption fuel be it petrol or diesel etc. [1].

Energy in terms of CO2, carbon monoxide, nitrogen oxide, hydrocarbon, water, and other greenhouse gases (GHGs); research shows that 83.7% of total gas emissions are carbon dioxide (CO2). Carbon dioxide (CO2) emission by transport has increased dramatically over the years [2].

II. BATTERIES FOR EVS

A. Performance fundamentals of batteries for EVs One of the key factors determining the energy contained in a battery is the choice of materials for the anode and cathode. Multiplying the voltage by the capacity gives the energy; thus, higher voltage and higher capacity materials will contain more energy. Energy may be measured in terms of weight or volume; these metrics are called specific energy and energy density, respectively. The energy density and specific energy represent the maximum energy that may be obtained from a material. Depending on how the battery is designed and operated, the energy actually obtained may be less.

Power is also extremely important for EV applications. In contrast to specific energy, which is a material property, specific power depends strongly on factors like electrode thickness and the size of electrode particles, which may be controlled in the manufacturing process. Manufacturers have developed sophisticated proprietary manufacturing techniques, such as coating electrode particles with other materials that are more conductive,4 in order to increase the power density of their batteries.

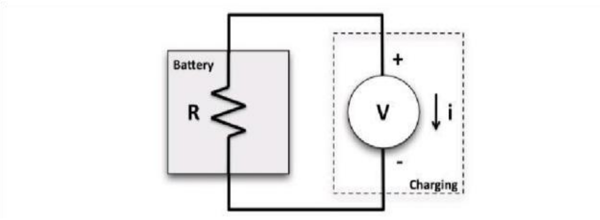

FIGURE 1. Equivalent circuit of a battery.

Therefore, according to Ohm's Law, if the voltage, V, supplied (from the charging station) is constant then the current is scaled by V/R. The energy is computed by taking the time integral of the power, which is the product of the current and the voltage, I and V. After imposing Ohm's Law, the energy equation is given by:

$$E\ (battery) = \int P(t)\,dt = \int i(t)\,v\,dt = \frac{V^2 t}{R}$$

The Equation above states that the energy of the battery is inversely proportional to the internal resistance; in other words, if the internal resistance increases, the energy of the battery decreases [3].

B. Challenges of batteries for EVs

Batteries are a major technological challenge in this new century as they are a key method to make more efficient use of energy. Although today's Li-ion technology has conquered the portable electronic markets and is still improving, it falls short of meeting the demands dictated by the powering of both hybrid electric vehicles and electric vehicles or by the storage of renewable energies (wind, solar). Some of these concepts, relying on new ways to prepare electrode materials via eco-efficient processes, on the use of organic rather than inorganic materials or new chemistries will be discussed. Achieving these concepts will require the inputs of multiple disciplines outside my field of study electrical and electronics engineering [4].

Energy is the lifeblood of modern society. Global warming, finite fossil-fuel supplies and city pollution conspire to make the use of renewable energy, together with electric transportation, a worldwide imperative. There is a pressing need to design electrical energy storage systems to balance supply with demands, as renewable sources are intermittent, and to power the upcoming plug-in hybrid electric vehicles (PHEVs) or electric vehicles (EVs). Numerous energy storage solutions enlisting mechanical, magnetic, chemical storage, etc., are being presently investigated [4]. Therefore, as we want to store energy in order to restore it as electricity, the most attractive path is to convert chemical energy into electrical energy, as they both share a common carrier, namely the electron. Fuel cells and batteries are electrochemical storage devices that ensure such conversions to occur in a single or reversible way, respectively [5].

With such attractive performances, coupled with its long life cycle and rate capability, Li-ion technology has captured the portable electronic market, invaded the power tool equipment market, previously kept for Ni–MH technology, and is on the verge of penetrating the EV market on condition that improvements can be achieved in terms of cost and safety. Indeed, long-term stability, high-energy density, safety and low cost seem to be the overriding factors in high-volume applications. Therefore, it implies assessing present Li-ion technology so as to define the challenges that lie ahead to ensure its long lasting success. Attempts to answer such questions will constitute the core of this project seminar, which will mainly, but not exclusively, deal with Li-ion technology. Research directions to increase the Li-ion battery energy density, lower its cost, improve its safety and make it more sustainable and 'greener' will be discussed. New upcoming chemistries will also be brought to the scene and benchmarked with today's systems [5]- [6].

[1] *Advancement on li-ion battery which necessitated its wide use and application for electric vehicles*

a) Means to increase energy density

Despite the new lease of life recently brought by the arrival of nanomaterials, present Li-ion technology falls short of meeting all of the requirements dictated by the large volume of applications linked to renewable energy and electric transportation fields (I.e. EVs).

First, we should be aware that a colossal (big) task is awaiting us if we really want to compete with gasoline, as an increase by a factor of 15 is needed for the energy delivered by a battery to match the one of a litre of gasoline taking into account corrections from Carnot's principle (efficiency of a heat engine is temperature dependent I.e. dependent on temperature of hot and cold reservoir). Knowing that the energy density of batteries has only increased by a factor of five over the last two centuries, our chances to have a 10-fold increase over the next few years are very slim, with the exception of unexpected research breakthroughs. Fortunately, the automotive industry has set a more realistic target: doubling the present Li-ion energy density in the next 10 years so that the autonomy of EVs approaches 500km. The energy density of a battery is the product of its capacity and its potential, and is mainly governed by the capacity of the positive electrode. Simple calculations show that an increase in cell energy density of 57 per cent can be achieved by doubling the capacity of the positive electrode, while one needs to increase the capacity of the negative electrode by a factor of 10 to get an overall cell energy density increase of 47 per cent [6].

So, the chances of drastically improving today's Li-ion cells energy density are mainly rooted in spotting better positive electrode materials, i.e. materials that could either display greater redox potentials (e.g. highly oxidizing) or larger capacity (materials capable of reversibly inserting more than one electron). (b) Means of increasing safety

Manipulating energy inevitably leads to intrinsic safety risks that hold regardless of the devices or electrochemical systems used, with the rule of thumb being that the risks increase with the size of the energy-storing device; hence the requirement for extra safety conditions for large-sized batteries in the case of PHEV and EV applications. Numerous attractive solutions relying on either the use of chemical additives to the battery electrolyte (solid– electrolyte interface (SEI) modifiers, shut-down and redox shuttles additives, ionic liquids) or improved cell design and electronics have been pursued, therefore Li-ion technology is not exempt from incidents [7]. More conservative approaches) consist of coupling a highly oxidizing positive electrode material ($LiMn_2O_4$ or others) with a less reducing material ($Li_4Ti_5O_{12}$ instead of carbon) in order to eliminate the formation of a solid electrolyte interface at the negative electrode, which is a source of concern when dealing with safety. Therefore, this approach provides extra safety at the expense of the battery performance, as $LiMn_2O_4/Li_4Ti_5O_{12}$ Li-ion cells display a low energy density when compared with $LiMn_2O_4$/C cells. Overall, it turns out that whatever the followed approach might be, safety and cost follow each other. Along that line, it is unfortunate that, today, the Li-ion battery is the victim of fierce cost cutting and attempts to cram more and more energy in the same volume; therefore, there is a constant risk of safety issues. Besides accepting this cost–safety tie, future Li-ion technology will undoubtedly rely on a sound understanding of electrode–electrolyte components, especially as we move to the next generation of either positive electrode based on higher voltage (5V) insertion nanomaterials or negative non-insertion electrodes (e.g. Alloying or conversion reactions) made of highly divided materials. Novel strategies to harmoniously couple the next generation of cathodes or anodes with suitable electrolytes will have to be found. Future research necessitates to challenge past basic understanding of electric batteries [7][8].

(c) Means of reducing costs

As we know one of the key aim of engineering with respect to production is to reduce cost as lowest possible. There are numerous means of enlisting both engineering (cell manufacturing and assembly) and chemical (materials design and electrode composition) factors to combat the exceedingly high cost of the Li-ion technology, against the convectional lead acid technology [9].

DC Challenges of batteries for EVs

The first marketable battery was invented in 1836 by British chemist John Frederic Daniell. Since then, battery technology has advanced at snail pace. The first cellular phones—launched in 1979—used nickel-cadmium batteries. In the late ’90s nickel-cadmium batteries were replaced by nickel-metal-hydride batteries, which were replaced in the early 2000s by lithium-ion batteries, still in use today. Since the ’90s the computational power of cell phones has increased 10,000 times. During this period, the energy density of the batteries powering these cell phones has increased only 50 times, limiting the development of more powerful cell phones, tablets and laptops. The electrolyte is a crucial part of any battery, acting as a catalyst to increase conductivity by helping to transfer ions from the cathode to the anode when charging, and vice versa when discharging. Electrolytes can be either liquid-state, i.e. acids such as sulphuric acid (H_2SO_4) or soluble salts, or solid-state using polymers such as polycarbonate [10].

At the moment, all EV batteries are liquid-state, but solid state batteries offer many benefits such as being smaller and lighter, providing higher capacity and being cheaper to produce. Toyota announced that they plan to release an EV with a solid-state battery by 2020. Most EV battery electrolytes are Li-ion based, meaning they use lithium to carry the charge between electrodes. Although the principle is the same as a mobile phone battery, a typical EV battery uses 10,000 times the amount of lithium. As a result, the price of lithium has soared as demand increases. The slow pace of the lithium-ion technological progress is not its only shortcoming despite its general acceptance and recommendations for EVs. [11]

Problems/challenges generally experienced by EV batteries are as follows:

- *Overheating*

  They overheat and explode if charged too fast.

- *Short Life Time.*

  They die after less than 1,000 charge/discharge cycles.

- *Flammable*

  They use chemicals that are flammable. This causes electric cars to explode when hit in certain ways (among other problems).

- *Toxic*

  These chemicals are toxic, requiring special care when disposed.

- *Underperform in Extreme Temperature*

  The chemicals underperform when temperatures are lower than 0°C (32°F) or higher than 50°C (122°F), limiting the applications.

- Expensive *Casing*

  The chemicals are liquid, requiring rigid and expensive casing to prevent leakage.

- *Expensive to Transport*

  Extra precautions are needed to avoid explosions and additional approval is required to ship these batteries [11].

And this is not all, at the current rate of consumption lithium will start to become scarce at current prices by around 2020. To open up today’s non-economical lithium deposits, prices would need to double.

Hence to reduce cost of li-ion battery efforts must be put on the area of recycling already used li-ion battery so that we could get back the already used material and re use it again for making new cells thereby reducing the potentials of continuous mining of new lithium metal is not abundant here on earth [11]- [12].

E. *Possible Solution to The Faced Challenges On Electric Vehicle Batteries*

Remember that from chapter 1 where I heighted the major challenges of EV batteries once was the issue of the widely accepted EV battery precisely the li ion battery major production material being a scarce material which happens to be one of the reasons for its geometrical rise in price over the years, hence to solve this issue of the major solution is explained below [12]

- *Recycling*

There is need to recycle the worm out batteries by way of recycling. Electrification will rapidly increase the need for batteries. A new solution by Nordic clean energy company Fortum makes over 80% of the electric vehicle (EV) battery recyclable returns the scarce metals back into circulation and resolves the sustainability gap by reducing the need to mine cobalt, nickel, and other scarce metal. There are very few working, economically viable technologies for recycling the majority of materials in lithium-ion batteries. Fortum achieves the recycling rate of over 80% with a lowCO2 hydrometallurgical recycling process.
The current recycling rate for batteries is approximately 50%. The batteries are first made safe for mechanical treatment, with plastics, aluminium and copper separated and directed to their own recycling processes [13].

According to a forecast by the International Energy Agency, the number of electric vehicles on the world's roads will increase from 3 million to 125 million by 2030. In 2015 the global lithium-ion battery recycling market was worth about EUR 1.7 million, but it is expected to boom in the coming years to more than EUR 20 billion [14].

- *Maintenance of an Accepted Temperature for EV*

  Batteries.

It is a known fact that the performance of batteries is strongly depends on its operating temperature, it shows significantly poorer performance at high temperature (>45 degree Celsius) and also at low temperature (<-10 degree Celsius).

Hence in temperature away from the threshold operating temperature result to the stated challenges as if a sophisticated system is set up to monitor the batteries to make sure that they are balanced charged and that they are protected from a lot of external conditions like overcharge, over discharge, over current, short circuits which may impact on the battery giving rise or drop stated in chapter two of this seminar project report, if the sophisticated system capable of monitoring and possible monitoring y way of regulating the temperatures of batteries during charging and discharging are implemented in manufacturing of new era of li-ion batteries for EVs ,then a positive step has been taken toward solving one the challenges of batteries for EVs[16].

III. CONCLUSION

The greatest challenges for widespread adoption of electric vehicles are twofold. First, the cost and energy density of battery technology prevents electric vehicles from being comparable to internal combustion engine vehicles. In summary, advancements in battery development, in particular over the past few decades, has enabled the implementation of modern EV, HEV, and PHEV technology to augment the existing auto market. While these technologies still have a way to go before they are on par with ICE vehicles, they are beginning to impact the market and consumer's perceptions. As EVs, HEVs, and PHEVs become more widely accepted, consumers will be able to save money, be energy independent, have a lower impact on the environment, pollution, and greenhouse gases and have an enjoyable driving experience. Future research and development is needed to continue improving the specific energy and energy density of batteries being used by vehicles, while at the same time reducing the cost of the technology. Infrastructure to support widespread adoption of electric vehicles will also need further development and implementation. Efforts, such as those noted above, can add to alleviating range anxiety for consumers and potentially change overall perceptions of electric vehicles, and as a result, HEVs, PHEVs and EVs will have better market penetration leading to a dramatic change in the automobile and petroleum industries.

Hence below are the key concluding points for batteries precisely li-ion batteries for electric vehicles

- li-ion battery is currently the dominating technology for EVs.
- Li-ion based chemistry provides higher energy densities compared to existing commercially available batteries.
- There is strong need to Increase specific capacity by optimizing cell chemistry.
- Improve battery lifetime by enhanced stability of electrode material. Reduce the costs.
- Customers driving styles influences battery performance (life time, driving range).

IV. RECOMMENDATION

To solve the issues of batteries for EVs below are recommendations I suggest based on the carried out research

- Recycling On the Enormous Used Li-Ion Battery

recyclable returns the scarce metals back into circulation and resolves the sustainability gap by reducing the need to mine cobalt, nickel, and other scarce metal. There are very few working, economically viable technologies for recycling the majority of materials in lithium-ion batteries, as this will greatly reduce potential high cost of li-ion batteries in the future.

- Sophisticated System Set Up to Monitor Battery Temperature

If a sophisticated system is set up to monitor the batteries to make sure that they are balanced charged and that they are protected from a lot of external conditions like overcharge, over discharge, over current, short circuits which may impact on the battery temperature, sophisticated system capable of monitoring and possible monitoring by way of regulating the temperatures of batteries during charging and discharging are implemented in manufacturing of new era of li-ion batteries for EVs to enhance operational temperature threshold, will totally eradicated thermal instability with EV batteries.[15]-[16].

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