Electro Mobility with Li-Ion Battery for Future Vehicles

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Abstract

When the talk on the current scenario the number of electrical vehicles take place the I.C. Engine vehicles. The reason behind this is the zero pollution produced by the electrical vehicles. But there is a drawback of this is the current electric vehicles are not producing sufficient output power and speed. The charging drawback and some running criteria while full charge of battery. Now a day's most of the electrical or hybrid vehicles are using the lead acid battery pack for their power requirement. But in this research of future work to cover the some drawback of lead acid battery, using the Li-ion battery. While this is reducing the weight of the battery pack.

Keywords: Electro Mobile Vehicles, History, Components of Electro Mobile Vehicles, Li-Ion Battery, Acronyms & Terminology

I. INTRODUCTION

Now days the most of the vehicles are using the I.C. Engines for the public and goods conveyance. But while using it producing the high pollutant contents and increasing global warming effect. To reduce such dramatically issue regarding society benefits the automobile industries is focused on the electrical vehicles instead of the I.C. Engine. Where not only foreign govt. tries to positive on electrical vehicles but Indian govt. also very much focusing and interested in this. As the reports are that Britain to ban sale of all diesel and petrol cars and vans from 2030, Where the in India at Karnataka to have electric vehicle and energy storage policy soon, Tata Power launches electric vehicle charging facility, Minister of State for Power and Renewable Energy said the centre is preparing a road map to ensure that only electric vehicles will be produced and sold in the country by 2030, 25 charging stations installed in Bangalore for electric vehicles on a pilot basis, Ashok Leyland announces strategic partnership with Sun Mobility for electric mobility, Isro's battery technology may soon power India's e-vehicle dream, and many more. So by this all positive and by changes of power course of the vehicle (i.e. turn I.C.Engine in to Electric vehicle).

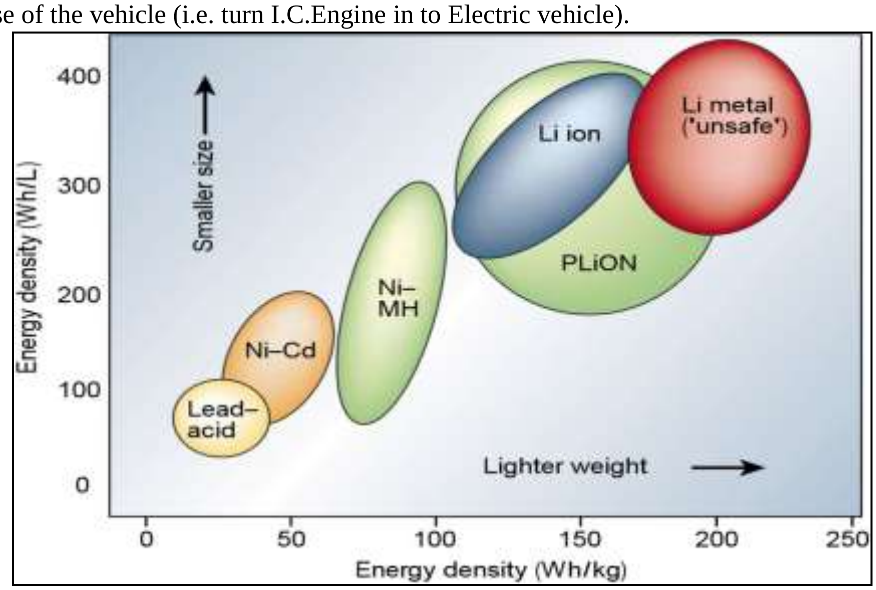

Fig. 1: Energy Diagram of Different Battery Weight & Size

II. HISTORY OF ELECTRO MOBILITY

Electro mobility has always been an issue that has helped drives the development of vehicles. It did become less important for a while because the oil fields did not appear to be drying up, but now electro mobility is becoming increasingly significant as people become aware of the depletion of oil reserves and need for of global environmental and climate protection. In year 1821 Thomas Davenport builds the first electric car with a non-rechargeable battery and a range of 9 to 19 miles (15 to 30 km). 1860 The rechargeable lead-acid battery is invented. 1881 The first officially recognized electric vehicle is a tricycle made by Gustave Trouve in Paris. Using a rechargeable lead-acid battery, the vehicle can reach speeds up to 7.5 mph (12 km/h). 1882 In this year, Ernst Werner Siemens builds an electrically driven carriage. This vehicle, which was also known as the “Elektro-Motte” or “Elektromote”, is considered to be the world’s first trolleybus. 1898 A company belonging to Charles Jeantaud from Paris is the leader in the field of electromobiles at the turn of the century (1893 to 1906). One of these vehicles sets a speed record by reaching 23.4 mph (37.7 km/h). 1900 Ferdinand Porsche presents a vehicle with in-wheel motors on both wheels of the front axle at the world exhibition in Paris. 1902 A. Tribelhorn, a pioneering Swiss electro mobility company, builds its first vehicles with an electric motor. Over a period of almost 20 years, the company produces mainly electrically powered commercial vehicles. They only manufacture passenger vehicles in small numbers and mainly as prototypes. 1913 The first gasoline station starts business in Pittsburgh (USA). Soon after, gasoline stations open in every town. A better infrastructure, cheap gasoline and the development of internal-combustion engines with greater ranges are all reasons for the success of vehicles with internal-combustion engines. 1960 Dr Charles Alexander Escoffery presents probably the world’s first solar car. It is a Baker Electric from 1912 registered in California with a photovoltaic panel made up of 10,640 single, 1969 The “Lunar Rover” is developed in the USA for the moon landings. It has an electric motor at each wheel. Two silver-zinc batteries are used as the power source giving the “Lunar Rover” a range of approximately 57 miles (92km). 1973The first oil crisis shows the industrial nations how dependent they are on oil-exporting countries. Fuel prices rise drastically. 1985 The world’s first race for solar powered cars, the “Tour de Sol”, is staged in Switzerland. 1987 The “World Solar Challenge”, a competition for solar vehicles, is staged. 1991 The THINK is one of the first cars to be conceived as a purely electric vehicle and not a conversion into an electric vehicle. 1992 German car manufacturer Volkswagen develops the VW Golf Citystromer, a converted Golf that is equipped with an electric motor. 1995 PSA Peugeot Citroen builds 10,000 electric vehicles from 1995 to 2005. 1996 General Motors offers the two seated electric coupe “EV 1” (Electric Vehicle 1) with 1,100 lb (500 kg) lead-acid batteries. Later nickel-metal hydride batteries improved the performance of the vehicle. 2008 The exclusively electric-powered “Tesla Roadster” built by Tesla Motors is launched on the US market with 6,187 laptop batteries connected in series. It accelerates from 0 to 62 mph (100 km/h) in 3.8 seconds. 2009 The German government introduces the national electromobility development plan (Nationalen Entwicklungs plan Elektromobilität, NEPE). The goal is to promote the research and development, the market preparation and the launch of battery-powered vehicles in Germany. It is hoped there will be one million electric cars on German roads by 2020 and Germany will develop into the lead market for electromobility.

III. COMPONENTS OF ELECTRO MOBILE VEHICLES

HEVs have these two designs connected in three different configurations – series, parallel and the split. A power electronic interface converts the battery’s DC power to AC power for the motor and the generator’s AC power to DC power which is used to recharge the battery pack. In any HEV, fuel is conserved by using an electric motor that assists ICE during acceleration and harnesses kinetic energy during braking to recharge the battery. This requires for an efficient power management scheme which uses a smaller IC engine and improves the acceleration.

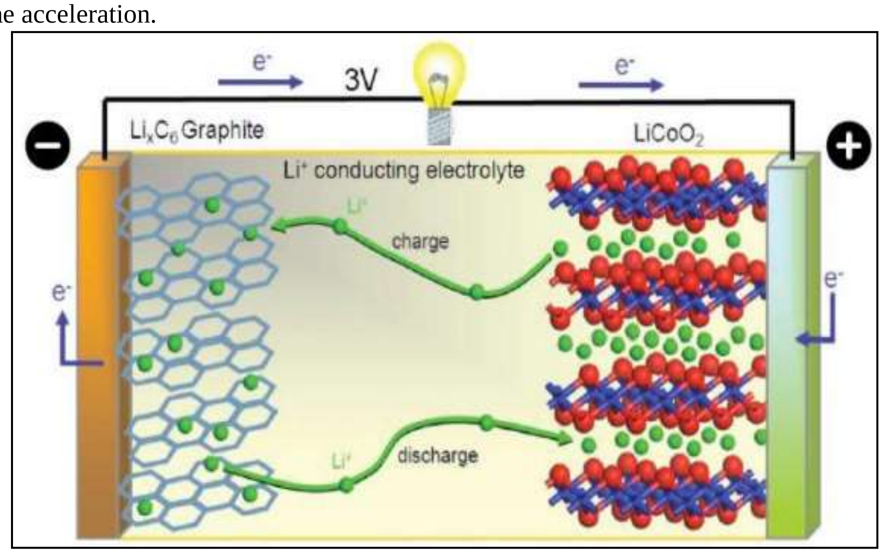

Fig. 2: Schematic of Ions (Charge & Discharge) & Electrons (Discharge) Movements in a Lithium Ion Cell

A battery is an electrochemical device which converts electrochemical energy to electrical energy. Many midterm and long-term battery options were investigated by the United States advanced battery consortium (USABC). A battery weighs about 25 – 75% of the vehicle by weight, volume and cost in HEVs. The desired features for a good EV battery are high specific energy, high specific power, high charge acceptance rate, long cycle life, long calendar life, low self-discharge rate, low cost, and recyclability. Where the li-ion battery cell have a 3-4V, (it is vary with the design and size). Initially, HEVs used lead acid batteries but with recent advancements in technology NiMH and Li-ion batteries are being used predominantly. Some of the important long term goals set by the USABC for advanced battery system are mentioned in Table 1.

Table – 1
Desired Characteristics any HEV Battery Pack

Desired characteristics	*Units*	*Value*
Power density	*W/L*	*460*
Specific power	*Discharge 80% DOD/30secW/Kg.*	*300*
Energy density	*Wh/L*	*230*
Specific energy	*Wh/Kg.*	*150*
Total pack size	*kWh*	*40*
Life	*Years*	*10*
Normal recharge time	*Hours*	*6*

Table – 2
Comparison of NiMH & Li-Ion Battery

Parameter	*NiMH battery*	*Li-ion battery*
Gravity energy density	*60-120*	*110-160*
Fast charge time	*2-4 hr*	*2-4 hr*
Resistance to overcharging	*Low*	*Very Low*
Cell voltage	*1.25 V*	*3.6 V*
Maintenance Cycle	*2 to 3 months*	*Not required*
Cost (for a 7.2 V,in US $)	*60*	*100*
Commercially available since	*1990*	*1991*

The most common active material for the anode is graphite. The cathode active material is currently either a lithium metal oxide or lithium iron phosphate. Current collectors - also called foils - are made of aluminum at the cathode and copper at the anode. The separator can be coated with a ceramic to improve thermal stability (developed by German company Evonic). The electrolyte is liquid (or a polymer/liquid or gel), most typically a lithium salt (e.g. $LiPF_6$) dissolved in organic solvents that conduct ions .Where some of using the solid material with the advantage of avoiding leaks.

The pack components ensure the cells are performing at their best, and they points described here:

- Battery Management System (BMS): Used for monitoring the cells and also for monitoring the state of health and state of charge.
- Power electronics distribute the high currents and include safety devices: For controlling the output of the pack.
- Wiring harnesses: Use to connect the main controller to the slave monitoring boards
- Internal cell support: It holds the cells together to the correct compression levels and allows a module assembly process.
- Temperature control: Maintaining the battery pack in the optimum temperature window is essential to maintaining and extending battery life.

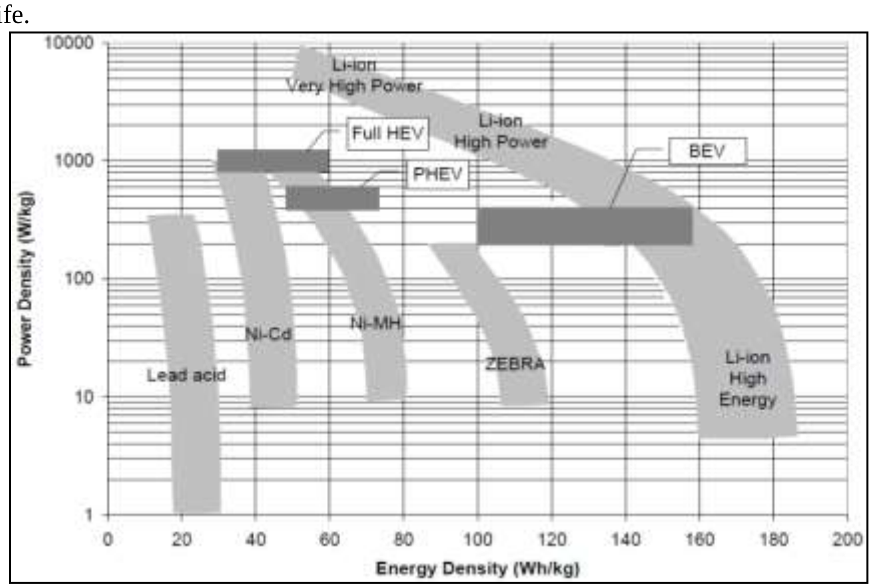

Fig. 3: Power & Energy Densities of Battery Technologies

After all this importance factors the automobile industry uses this as per below Table: 3

Table – 3
Development Time of Chemistries from Proof of Concept to Commercial Cell

Chemistry	*First paper/patent*	*First commercial rechargeable cell*	*First use in series car (small series)*
Lithium LCO	*1979*	*1991*	*2008(Tesla)*
Lithium LMO	*1983*	*1996*	*2009 (iMieV)*
Lithium LFP	*1994*	*2006*	*2007 (MODEC van)*
Ni-MH	*1967*	*1990*	*1997 (Prius)*

While in focusing on the electrical vehicles components the main source is the electric motor, battery pack, motor charger, and converter.

IV. ENERGY OF LI-ION BATTERY

Where as per the Britain the medium segment cars (lower medium and upper medium) fitted with 23kWh (useable energy) pack to deliver a 150 km range. To meet the power requirements some of the following terms must be required:

- To Meet Power Requirements
  Battery has lower discharge power at low SOC (state of charge) & lower charge power at high SOC.
- To Reduce Risk
  Limiting the Max. SOC avoids overcharging situations.
- To Maximize The Battery Life
  Lowering depth of discharge (DOD) window extends the battery cycle life.

Where the typical DOD window is 80% for BEV and 70% for PHEV.

V. POWER OF LI-ION BATTERY

Power is how the battery can quickly release its energy. It is defines as thermal management demand.
Different chemistries have different degrees of variation of power capacity with state of charge, due to variation in voltage profile and this must be taken into account when deriving SOC window.

VI. VOLTAGE OF LI-ION BATTERY

The minimum nominal voltage (V) required from a pack today is typically 300 or 350V for cars, and can be up to 700V for vans. A higher voltage reduces losses in wiring and in the electric motor. Using packs of lower voltage would be cheaper at battery level but would effectively move the cost to other parts of the vehicle, e.g. the motor and electronic control equipment. In the cost model, a 300V pack requirement is assumed in all years.

VII. LIFE OF LI-ION BATTERY

A battery cell deteriorates even if it is not used; it has a “calendar life”. The ageing is due to chemical reaction occurring between electrodes and electrolyte and any dissolved impurities. Ageing has two outcomes: Impedance growth and capacity loss.

Also have a cyclic life: It is deteriorates when used, some lithium deposits and reacts. (i.e. it will not interact with electrode and cannot charge.)The battery capacity it thus reduced. The end of vehicular application is defined as the point when the battery capacity less or equal to 80%.

Table – 4
Battery Life Dependencies & Typical Requirements

	Calendar life	*Cycle life*
Temperature Impact	*High Temperatures Decreases Life*	
SOC/DOD Impact	*Voltage/SOC* *A lower voltage is batter for life. Battery cells are not stored at full SOC before being assembled into a pack.*	*DOD* *Cycle life has a strong relationship with depth of discharge: the lower the DOD, the longer the cycle life.*
USABC/DoE goals	*15 years PHEV* *10 years BEV*	*1000 to 80% DOD, 1600 to 50% DOD, 2670 to 30% DOD.*

Battery life is critical for the economics of EVS both in total cost of ownership but in term of environment impact.

VIII. SAFETY OF LI-ION BATTERY

Li-ion batteries have several failure can lead to thermal runaway and thus cause a safety hazards. It can start from a sufficiently large internal short circuit, following shocks, from deposited lithium that becomes very reactive. As cells contain combustible materials, in particular the electrolyte, a fire can develop. If small battery pack have no serious injuries but with a large vehicle pack the consequences could be made dramatic. The separator prevents short cut play a key role work to remain for preventing their softening at high temp. The quality of electrode is the key to minimize the growth of dendrites (lithium deposits). This can push through the separators and thus creates an internal short circuit. Quality manufacturing must be employed to ensure the quality of electrodes and thus improve cell safety. Electrode manufacturing is defined by minimal variation of electrode. Characteristics such as thickness, porosity, etc. Automobile cells safety demands dictate the need for reduced contaminants in finished electrodes. (i.e. cleaner working environment.) Automotive cell safety demands dictate the need for reduced contaminants in finished electrodes, i.e. cleaner working environments. Current best clean standards installed in cell manufacturing are ISO6, while ISO4 or ISO5, levels are needed for safety demands of automotive cells.

IX. OTHER PARAMETERS

Battery packs have other attributes, briefly summarized here:
Operating temperature range, e.g. ca. -5°C to +40°C for today's packs. For reference, the USABC minimum goals for long term commercialization are -40°C to +50°C (20% performance loss permitted) and long term goal -40°C to +85°C. The cost of technologies (pack thermal control) allowing for such a wide temperature range are not explicitly estimated in the cost model.

A. Charging Rate

Continuous charge rate (commanding pack recharge time) and pulse rate (regenerative breaking). Current generation batteries are specified at lower charge rates, but higher discharge rates. This is due to concerns about safety and the very close control that is required during high charge currents while ensuring safe operation. Future batteries might be required to handle charging rates higher than the typical current charging post (3 to 7kW). For reference, the USABC long term goal is 40-80% SOC in 15 minutes. Charging rate capabilities are not explicitly modeled.

X. SUMMARY

- Battery pack cost will be modeled for a selection of vehicles representative of the GLOBAL market: small cars, medium sized cars, high power cars and panel vans. Current vehicles attributes such as energy consumption are defined based on existing models while future vehicles attributes account for the expected light weighting and increased range. Drive trains considered are pure electric and plug-in hybrid electric.
- The general architecture of a battery has been presented: cells, module, thermal control and electronics controls.
- Among the past and existing automotive battery technologies, lithium-ion has the highest energy density and has replaced other battery chemistries in production vehicles. On this basis, it will be the only technology modeled for the short term.
- Current lithium ion cells work on the principle of intercalation: reversible insertion of a guest atom (lithium) into a solid host structure without inducing a major disruption of the host material (electrode materials).
- Attributes of batteries have been presented. Some, such as safety and life, affects the lithium-ion battery pack design and cost as they require over sizing the pack and integrating an advanced thermal control.

XI. ACRONYMS & TERMINOLOGY

- BEV Battery Electric Vehicle. A pure battery electric vehicle contains a battery and an electric motor only. The vehicle is charged by mains electricity. Examples include the Nissan Leaf and Mitsubishi i-MIEV.
- BMS Battery Management System.
- Cathode The electrode of a cell at which reduction occurs, by convention this is the positive electrode and is the electrode that electric current flows out of (and electrons flow into) at discharge.
- CCC Committee on Climate Change.
- DOD Depth of discharge.
- ICE Internal Combustion Engine.
- KW Kilowatt (unit of power).
- KWh Kilowatt hour (unit of energy, 3.6MJ).
- PHEV Plug in hybrid electric vehicle. A PHEV can be charged from mains electricity and runs in electric mode until the battery is depleted (or high power is demanded), at which point the ICE takes over. An example of this vehicle is the Toyota Plug-in Prius.
- SOC State of charge.