Design of Battery Pack for Electric Vehicles

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Abstract - *The Automotive industry is going through a change in phase. The conventional power transmission system is getting replaced by the electric power transmission system. This system has an Electric Motor as its prime mover instead of a Internal Combustion Engine and an Electrochemical Battery instead of gasoline as the source of energy. This paper deals with the design of a battery pack for an Electric Vehicle of mass 1250 kilograms and a range of 483 kilometers per charge.*

Key Words: Voltage, Electrochemical Cell, C-Rate, Electrodes, Electrolytes, Specific Energy

1. INTRODUCTION

An Energy storage system is a device which stores energy, discharges and also gets charged. The common types of Energy storage systems used Electric Vehicle applications are Chemical Batteries, Ultracapacitors, Supercapacitors and Fuel Cells. There are a few basic parameters which must be taken into consideration while selecting and Electric Vehicle. They are Specific Energy, Specific Power, Efficiency, maintenance requirement, cost, environmental adaptation, friendliness and safety. Of all these, Specific Energy is the most important parameter as the total range of the vehicle can be obtained from it.

2. ELECTROCHEMICAL BATTERIES

The Electrochemical Batteries are energy storage systems which convert the chemical energy into Electrical Energy. A Battery is a collection of individual cells stacked together. Each individual cell possesses all the properties that a battery on a whole possesses. The major components of a cell are the positive electrode, the negative electrode and the electrolyte.

2.1 WORKING OF A BATTERY

There are two major activities which take place in every cell. During discharge, the negative electrode or the anode reacts with the electrolyte and gains excess of electrons. These electrons are then passed to the positive electrodes and the positive electrode reacts with the electrolyte and also gains the two excessive electrons transferred from the negative electrode. This is how electricity is generated in each cell.

The charging of the cell is more or less the opposite process of discharging.

2.2 TYPES OF BATTTERY TECHNOLOGIES

There are mainly 3 types of Battery Technologies used in Electric Vehicles:-

i) Lead based batteries

The Lead Acid batteries are of low cost, have relatively high power capability and also have a good cycle. It is the oldest type of electrochemical batteries. These have a very low energy density and below 10° C the specific power and energy are greatly reduced.

ii) Nickel based batteries

Nickel is lighter than Lead and also has excellent electrochemical properties. There are three major types of Nickel based batteries:-

a) Nickel/Iron batteries

This type of batteries use Nickel(III) hydroxy oxide (NiOOH) as the positive electrode and Metallic Iron as the negative electrode while the electrolyte is concentrated solution of Potassium Hydroxide containing Lithium Hydroxide. The nominal voltage of a single cell is 1.37V.

b) Nickel/Cadmium batteries

These batteries have the same positive electrode and electrolyte as that of a Nickel/Iron battery. The negative electrode is Metallic Cadmium and each cell has a nominal voltage of 1.3V.

c) Nickel/Metal Hydride batteries

The Nickel Metal Hydride battery has hydrogen absorbed in a Metal Hydride as its negative electrode. It has a nominal voltage of 1.2V.

iii) Lithium based batteries

Lithium is the lightest of all metals and has excellent electrochemical properties. It's high nominal voltage leads to its high specific energy and power. There are mainly two types of lithium based batteries.

a) Lithium Polymer batteries

It has Lithium and Metal intercalation oxide (MyOz) as the negative and positive electrodes respectively. It has solidified polymer as the electrolyte and has a nominal voltage of 3V.

b) **Lithium ion batteries**

This is considered the battery of the future. Its negative electrode is lithiated carbon intercalation material (LixC) instead of metallic lithium and its positive electrode is lithiated transition metal intercalation oxide (Li1-xMyz). The electrolyte is either liquid organic solution or solid polymer and each cell has a nominal voltage between 3.5-4V.

3. BATTERY CELL SELECTION

After making a detailed study of each and every possible battery technologies available, the Cobalt based Lithium battery with graphite anode (LiNiMnCoO2) has been selected due to the following reasons:-

i) Very high specific energy and power.

ii) High thermodynamic voltage (3.7V) and excellent electrochemical properties.

iii) Good performance over a wide range of temperatures.

iv) Eco- friendly as they do not have any toxicity.

v) High operating cycles.

The cells used are 18650 cells.

Table -1: Cell Specifications

Nominal Voltage	3.7V
Operating Voltage	3.0-4.2V
Specific Energy	150-220 Wh/kg
C-Rate (During Charge)	0.7-1C for 4.2V
C-Rate (During Discharge)	1C
Cycle Life	1000-2000

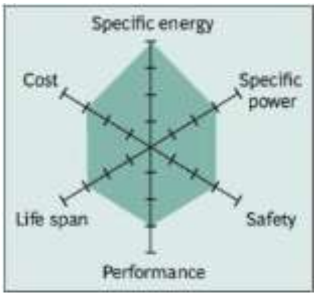

Fig -1: Characteristics of LiNiMnCoO2 Cells

4. BATTERY PACK DESIGN

The calculations have been done on a Electric Vehicle of mass 1250kgs (2756lbs) and a range of 483 kilometers (300 miles). The capacitance of the vehicle can be obtained by dividing the total mass of the vehicle (in lbs) divided by 10.

Thus,

Capacitance per mile = (Mass of the vehicle (in lbs))/10

= (2756)/10

= 275.6 wH/mile ....(i)

Hence, we can find the Total Energy of the Pack.

Total Energy of the Pack = (Range)(Capacitance per mile)*

= (300 miles)(275.6/1 mile)*

= (483km)(275.6/1.609km)*

= 82,731wH

= 82.731kwH

But, a battery pack is only around 80% efficient. So, the total pack size should be higher than 82,731wH. If it is assumed that the Battery pack is 80% efficient.

Thus the total energy of the pack is 103.413kWh ....(ii)

The voltage of the battery is obtained by the division of the capacity of each individual cell and the pack size. Let the capacity of each individual cell be 200 amp-hours.

Thus,

Voltage = (Total Energy of the Pack)/(Capacity)

= (103,413)/(200)

= 517.065 volts ....(iii)

Thus, the total voltage of the battery pack should be either equal to or greater than 517.065 volts.

The complete Battery pack has been divided into a different modules for the following reasons:-

i) Ease of manufacture

ii) Safety in manufacturing

iii) Safety during failure/crash

iv) Serviceability

Each modules has 540 cells. These are arranged in the 10s54p configuration which means there are 10 cells are arranged in series connection in 54 parallel rows.

The voltage of the module is the product of the number of cells arranged in series and nominal voltage of each individual cell.

Thus,

Voltage of each module = (Number of cells in series) (Cell Voltage)*

= (10)(3.7)*

= 37V ....(iv)

The total energy per module is obtained from the product of the cell capacity, the total voltage of the module and the number of cells arranged in parallel.

Thus,

Total Energy per module = (3.7)(37)*(54)*

= 7.393kWh ....(v)

Now, the total number of modules required can be found. The product of the number of modules multiplied by the voltage of each module gives the total voltage required for the battery pack. From (iii), the total voltage is 517.065V.

Thus,

The total number of modules needed

= (Total Voltage)/(Voltage per module)

= (517.065)/(37)

= 13.97 ≈ 14 ....(vi)

Thus, the total number of modules required are 14.

The total energy of the battery pack = (14)(7.393)*

= 103.502kWh ....(vii)

The total energy value obtained here is equal to the total energy value obtained in (ii).

Total Number of cells in the pack

= (Number of Modules)(Number of cells in each module)*

= (14)(540)*

= 7650 cells ....(viii)

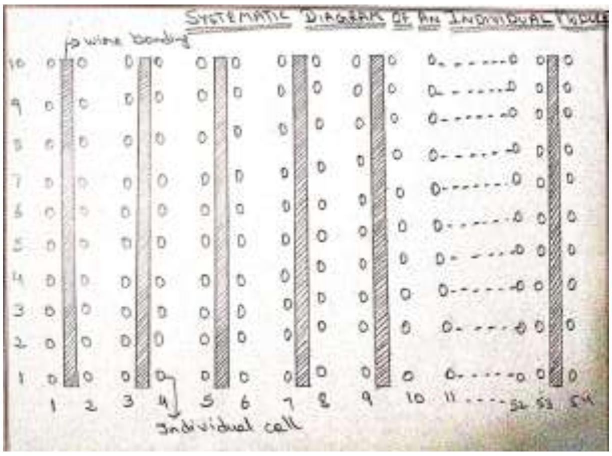

Fig -2: Systematic diagram of an individual module

5. SAFETY OF THE BATTERY PACK

Once the battery pack design is over, the safety of the pack must be ensured. The batteries operate at high energies. Thus, they are prone to catching fire easily if proper safety measures are not taken.

One of the most common safety device used is a fuse. It breaks open when excess current passes through it. Some fuses reset once the temperature goes down the maximum limit while others make the batteries completely useless once they open. Positive Thermal Coefficient (PTC) is one such device which resets once the temperature is below the threshold limit.

Another such safety device used is a Circuit Interrupt Device (CID). When the pressure inside the battery pack crosses 1000kPa the circuit breaks.

Fig -3: Lithium ion battery destroyed due to fire

CONCLUSION

This paper has dealt with the custom design of the Battery Pack of an Electric Vehicle. It fulfills all the requirements of the vehicle. The safety parameters of the Battery pack have also been discussed.

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