An Individuate Study On Hybrid Vehicle Battery And Their And Management, Charging Issues And Performance

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Abstract*— Different types of electric vehicles (EVs) have been recently designed with the aim of solving pollution problems caused by the emission of petrol and diesel powered engines and also economic problems caused by the rising prices of fossil fuels. There has been an increasing attraction towards plug-in hybrid electric vehicles (PHEVs) within the auto industry. PHEV is a hybrid vehicle which utilizes rechargeable batteries, or another energy storage device, that can be restored to full charge by connecting a plug to an external electric power source (usually a normal electric wall socket). A PHEV shares the characteristics of both a conventional hybrid electric vehicle, having an electric motor and an internal combustion engine (ICE); and of an all-electric vehicle, having a plug to connect to the electrical grid. As it is well known, one of the weakest points of electric vehicles is the battery system coupled with high battery prices and short life spans have led to growing interest in development of advanced charging techniques and algorithms. Vehicle autonomy and, therefore, accurate detection of battery state of charge (SoC) together with battery expected life, i.e., battery state of health, are among the major drawbacks that prevent the introduction of electric vehicles in the consumer market. In this paper an attempt has been made to review the batteries used in PHEVs and EVs which include different charging methods such as constant voltage, constant current, pulsed charging and burp charging are investigated. Termination methods such as time, voltage, voltage drop (dv/dt), current, and temperature are also discussed. Also discussed is a battery exchange system, where a discharged battery module(s) is replaced in seconds with a fully charged one. The battery powered car with an integrated battery will have a battery weighing nearly eight times that of the battery exchange car. The battery system choice is a crucial item with emphasis on vehicle range and performance. A solution is also proposed which features a high capability of energy storing in braking conditions, overvoltage and undervoltage protection and, obviously, SoC information

***Keywords*— Electric Vehicles. PHEV, Hybrid, SOC, ICE**

I. INTRODUCTION

The significance of Electric Vehicles (EVs) is clear to all specialists in the related fields. The benefits that can be obtained by replacing conventional Internal Combustion Engines (ICE) with EVs such as reducing oil consumption and pollutions in a large scale are really noticeable. One of the main reasons that EVs are not commercially produced in a large scale is batteries. According to today's technology, the batteries that can store enough amount of energy being able to run an EV in a reasonable range comparing with conventional cars are very expensive, resulting in the low attraction of consumers buying EVs. Another choice can be hybrid electric vehicles (HEV) however; because of their small capacity batteries they can increase the mileage only between 10% to 15%. The intermediate solution is Plug-in Hybrid Electric Vehicles (PHEVs). In all cases batteries have an outstanding role. One of the important issues regarding EVs, HEVs and PHEVs is prolonging the life cycle of batteries, resulting in lower expenses for the final customer because of later necessity for replacement of battery pack. This is highly dependent on charging algorithms and techniques and also charging management system. Moreover, more batteries are damaged by improper charging techniques compared to all other causes.

THE BATTERY CELL

IN BASIC chemistry, it was determined that when a chemical reaction occurs, there is a net change in potential energy. That change normally appears as heat being evolved or absorbed from the surroundings. However, the potential energy change in some chemical reactions appears as electric energy. One such type of chemical reaction involving electricity is that of electrolysis. **A** typical electrolysis circuit is composed of the following: dc source such as a battery, cathode attached to the negative terminal, anode attached to the positive terminal, and electrolytic solution such as sodium chloride. Electrons from the dc source enter the cathode and are collected by the positive ion, in this case, sodium. The sodium ion is neutralized by the electron. On the right plate, the anode, electrons are released from the negative ion, in this case, chlorine.

BATTERY BASICS

As was previously shown, a battery is an electrochemical cell which can be used to deliver current or power to a load. In this paper, the discussion will center around a battery system which is a group of electrochemical cells that supplies dc power at a nominal voltage to an electrical load. The number of cells which are connected in series determines the nominal voltage of the battery system, and the size of the cell is the basic factor in determining the discharge capacity rate. The lead acid battery which is commonly used in a battery system has a nominal cell voltage of 2 V. Table I provides a list of typical battery voltage ratings. Other battery systems may have a different voltage rating per cell and number of cells in series for a particular application. For example, the Nickel-Cadmium battery (Ni-Cad) has a nominal cell voltage of 1.2 V and requires more individual cells for a particular application when compared with the lead-acid battery system. **A** typical 24-V Nickel-Cadmium battery-system would require 20 cells.

The discharge rate of a battery is normally given in the term of ampere-hours **(Ah)** to a particular discharge voltage level.For the lead acid battery, the normal discharge voltage level is 1.75 V per cell, or approximately 87.5% of the nominal cell voltage rating. (For the Ni-Cad battery, the normal final discharge voltage is 1.05 V per cell, or approximately 87.5% of the nominal cell voltage). Depending on the particular application, the final discharge voltage for a particular amperehour rating may be higher or lower. However, 1.75 V per cell is typical. Batteries are normally provided with an ampere-hour rating based on a particular discharge rate. The most common rate is 8 h, however other discharge times are used. The ampere-hour rating for a particular discharge time is given as follows: ampere-hours = amperes x discharge time.

While the application of a battery would be quite simple if the load on the dc system were constant, in actuality, dc loads typically vary throughout the time period that the battery is being used. **As** such, a load profile or load duration curve needs to be developed to determine the proper battery capacity. Fig. 3 shows a load profile curve. Please note that the load current and time can vary considerably over the discharging cycle. There are numerous considerations required for battery sizing including life expectancy, load growth, temperature, safety margins as well as the load duration curve. Due to the normal critical nature of the battery system application, all factors need to be considered in the sizing of the battery.

CHARACTERISTICS OF COMMONLY USED BATTERIES

For more than one century, lead acid batteries have been used for various applications including traction. Their well improved structure has led to Valve Regulated Lead Acid (VRLA) batteries which can be considered as maintenance free batteries, which is a desirable characteristic for PHEVs.

Talking in terms of efficiency their efficiency is in the range of 95% to 99%. The main disadvantage of Lead-acid batteries is their weight, in other words, their energy density is low compared to their counterparts. Nickel Cadmium (Ni-Cd) batteries have a mature technology but considering traction applications their energy density is low as well. They are mainly used where long life, high discharge rate and price are of high importance. Considering environmental issues, they contain toxic metals. Nickel Metal Hydride (Ni-MH) batteries have higher energy density but lower cycle life. Lithium Ion (Li-ion) batteries have high energy density, power density and great potential for technological improvements providing EVs and PHEVs with perfect performance characteristics such as acceleration. Because of their nature, Li-ion batteries can be charged and discharged faster than Pb-acid and Ni-MH batteries, nominating them a good candidate for PHEV applications. Besides all, Li-ion batteries have an outstanding potential for long life.

Overcharge of Li-ion batteries should be carefully prevented, as they are highly potential for explosion due to overheating caused by overcharging.

Besides, Li-ion batteries have environmentally friendly materials comparing to Nickel based batteries. Lithium Polymer (Li-Polymer) batteries have the same energy density as the Li-ion batteries but with lower cost. This specific chemistry is one of the most potential choices for PHEVs. Because this type is a solid state battery, having solid electrolyte, the materials would not leak out even in the case of an accident. One of the other advantages of this type is that it can be produced in any size or shape which offers flexibility to vehicle manufacturers.

CHARACTERISITCS OF BATTERIES USED IN PHEVs:

The basic required characteristics of batteries used in PHEVs are as follows:

1) High energy density which results in higher mileage and less recharging cycles required.
2) High power density which allows high rates of currents to be drawn from the battery resulting in high acceleration characteristics of the PHEV.
3) Long cycle life with maintenance free and high safety mechanisms built into the battery.
4) Environmental friendly aspect of the battery, i.e., being recyclable and including low amounts of toxic materials.

CHARGING METHODS

There are various charging methods depending on the type, capacity, required time and other characteristics. Some well-known methods are mentioned here.

Constant Voltage Charge: A constant voltage is applied to the battery pack.

This can be constructed simply using a buck or boost converter being controlled using a simple controller to compensate for changes in load and/or source. This method is usually used for lead acid batteries, also for Li-ion batteries while using current limiter to avoid overheating the battery especially in the first stages of the charging process.

Constant Current Charge: A constant current is applied to the battery. This is achieved by varying the voltage applied to the battery to keep the current constant. Ni-Cd and Ni-MH batteries are charged using this method. Ni-MH batteries can be easily damaged due to overcharging, so, they should be accurately monitored during charging.

Taper current Charge: This can be used when the source is a not-regulated DC source. The current decreases when the cell gets charged. This is only applicable for Sealed Lead Acid (SLA) batteries.

Pulsed Charge: In this technique current is supplied using pulses. The average current can be controlled changing the width of pulses. The intervals between pulses called rest times provide enough time for chemical reactions inside the battery to take place and stabilize. It is claimed that this method can reduce unwanted chemical reactions at the electrodes such as gas formation and crystal growth which are the main reasons of life cycle reduction in batteries.

Burp Charge: Gas bubbles are produced on the electrodes specially during fast charging. This phenomenon is called "burping". Applying short discharge pulses, typically 2 to 3times the charging current for 5 milliseconds during the charging rest period resulting in depolarizing the cell will speed up the stabilization process and hence the overall charging process. Besides, there are other charging methods such as Current Interrupt or CI .

TERMINATION METHODS

It is very important to decide when to terminate charging to avoid overcharging which is more of important especially in high capacity batteries used in PHEVs and also to make sure that the battery is fully charged. Choosing the type of termination of charging process depends on different factors such as application and the environment that the battery is used. There are various termination methods but just the most important ones are mentioned here:

1) Time: One of the simplest methods used as a backup for fast charging or normally used for regular charging.

2) Voltage: Charging is terminated when the voltage reaches a value set before. This technique is usually used with constant current technique to avoid overheating damage to the battery.

3) Voltage Drop (dV/dT): This method utilizes the negative derivative of voltage over time. When it reaches a specific value set before the charging process is terminated. This is to avoid overcharging of the battery.

4) Current: In this method the charging process is terminated if the charging current drops below a preset value e.g. C/10 rate. Commonly used with constant voltage technique.

5) Temperature: The charging process must be terminated if the temperature of the battery pack raises above a specific value mentioned by the manufacturer, otherwise there is the risk of damage because of internal short circuit. This technique is usually used as a backup.

STATE OF CHARGE ESTIMATION

One of the important data for accurate charging is SOC. There are different techniques for SOC estimation. The more precise the SOC estimation is, the more accurate the charging algorithm can be managed. Specially, overcharging should be avoided for lithium-ion batteries in order to avoid permanent damage and this can be controlled by the exact knowledge of SOC because of the precariously vicinity of overvoltage threshold to the fully charged terminal voltage. Before measuring the SOC we need to know what it really is. One of the factors used in calculating SOC is the rated capacity of the battery. The problem is that this capacity changes over time according to different parameters such as degradation of electrolyte, corrosion of plated and etc. This is related to SOH determination which is a separate topic of research and not considered here. There are different SOC determination techniques and each one is suitable for specific types of batteries or applications. One method is to discharge the battery completely in a controlled manner to avoid any damage. This method is too time consuming and obviously cannot be applied to PHEV applications. Another method is ampere hour counting, which is one of the most utilized methods applied to SOC measurement systems. Although this method is easy to implement, there are some drawbacks. Because this method is based on current integration over time, if the current measurement is not accurate enough, it causes high error over time. Besides, even if it is accurate, because of the numerical integration methods used by microcontrollers there are always calculation errors which can sum up to a high value gradually. Furthermore, there are always loss reactions during charging process which should be taken into account. There are some techniques for considering these losses. The simplest one is considering a multiplication factor. For charging from PV panels develops an approach for calculating current losses. Another way to maintain the calculation errors in a reasonable range is to recalibrate the measurement system each time a specific point is reached, e.g. when a full charged is detected.

Another method to estimate the SOC is to measure the physical characteristics of the electrolyte. There is a linear relationship between the density change of acid and the SOC.This fact can be utilized to estimate SOC. The density can be measured directly or indirectly using parameters such as viscosity, conductivity, ion-concentration, refractive index, ultrasonic, etc. This method also has its own unreliability issues which are stratification of acid, loss of water and long term performance of sensor. Another fact which can be used as a tool for estimating SOC is the approximate linear relation of SOC and open circuit voltage in a specific region of SOC. The length of this region depends mainly on the type of battery. There are different factors affecting open circuit voltage like internal resistance. In the effects of internal impedance variation on the cell voltage are described.

The problem of this method is that batteries under use need some rest time to stabilize before the open circuit voltage becomes applicable. This rest period can be up to hours for some chemistry types which raise questions regarding the applicability of this approach for PHEV accurate charging applications. Soft computation methods such as fuzzy neural network or adaptive neuro-fuzzy modeling can also be utilized for SOC estimation. There are other methods under the category of heuristic interpretation of measurement curves.

Battery Exchange System

It is that idea in which a battery module(s) is replaced in seconds with a fully charged one.

The battery powered car with an integrated battery will have a battery weighing nearly eight times that of the battery exchange car.

The battery exchange standard module's external configuration would allow for future battery types thereby avoiding obsolescence. Module standardization would allow for competition between battery types and/or manufacturers yet still provide substantial advantages for the consumer. As battery technology develops, better vehicle batteries will be simply exchanged for old versions and provide increased range and or performance. We have tried to explore the relationships between operating costs, battery size and weight and the socio-economic advantages of battery exchange.

References

[1] T. R. Crompton, “Battery reference book,” Newnes, 3rd Edition, May 2000.
[2] S. Dhameja, “Electric vehicle battery systems,” Newnes, Oct.2001.
[3] John **P.** Nelson and William D. Bolin “Basics and Advances in Battery Systems” IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. **31,** NO. **2,** MARCWAPRIL 1995.
[4] Arash Shafiei and Sheldon S. Williamson”Plug-in Hybrid Electric Vehicle Charging: Current Issues and Future Challenges”.