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Power Management Optimization in Hybrid Electric Vehicle Using Battery Management Systems

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Abstract- **One of the most critical components of a plug-in hybrid vehicles and any other type of electric vehicles is a Battery management system (BMS). On the contrary part the power management with that of its dual power source in plug-in hybrid electric vehicles (PHEVs) achieving higher fuel economy and less pollutant emissions. One of the most important purposes of the BMS is to ensure the reliable battery operation and guarantee safety. To ensure the safe and reliable operation in battery state monitoring, evaluation, charge control and cell balancing functionalities have been impeded in this Battery management system. In this paper, power management and optimal control strategies in PHEV have been investigated with subject to different operational and environmental conditions. Also, the results of simulations show that the proposed strategy gradually improves fuel economy, implying the present optimization approach very considerate in viewing the potential of power train hybridization. This review also addresses the current management systems. The evaluation results include battery, state of charging, state of health, state of life results of a BMS. Complete reviewing of the latest methodologies also the future challenges in BMS is presented and also the solutions are formulated.**

Keywords: battery management system, dual power sources, internal combustion engine, power management, plug-in hybrid electric vehicles.

I. INTRODUCTION

Automotive industry had made great effort in identifying energy and environmental credentials by developing electric vehicles (EVs), hybrid electric vehicle (HEV) and plug-in hybrid electric vehicle (PHEV). PHEV is an upgraded version of HEV which consists of an internal combustion engine (ICE), electric motor/generator and an energy storage system; not only have the access to operate on all electric mode over a significant distance like EVs, but also have an ability for extending range capability due to a small onboard ICE which is similar to the conventionnel hybrid electric vehicle. Due to that fact this PHEV attracts increasingly high interest and attention, global optimal strategy is required to effectively manage the power in order to achieve the full potential of PHEVs. Also, from disposable and portable electronics to high end electric vehicles, batteries are considered as primary sources of power in many applications. The intriguing interest in the EV can be backed to the start of the 19th century, that is when the first electric vehicle was introduced.

II. LITERATURE SURVEY

The electric vehicles today reduce the gasoline consumption to a level of 75% and also Electric vehicle's batteries have gained an advantage in consumer market for its renewable nature. A leading consulting group have reported that by 2022 the global market for futuristic batteries will the hit the market for $100 billion which is way more than the size of Lithium-ion battery’s market. In sight to increase the market share of EV and Hybrid electric vehicles safety and reliability are the top interests for the consumers. Therefore, both of the systems are subjected to not only the battery technology but also to the management system for the battery. Thus, the battery management systems (BMS) act as a bridge between the battery and vehicle which plays a very important role for improving the battery performance and also for optimizing the vehicle operation in a most reliable way. Also, optimization-based strategies for control may not require the knowledge of future power demand to determine a set of optimal control actions. Similarly, for the battery management for a gasoline car a gauge meter should also be given to the battery management system in HE and HEV. The BMS in EVs indicate the usage, state of the safety, performance, and longevity of the battery.

III. STATUS AND ANALYSIS

A lithium-ion battery could easily be overcharged due to the entropy changes and that could lead to an explosion which leads to serious problems. Specifically, in EV and HEV applications the explosion is a fatal accident and overcharge could lead to reduced cell capacity and to reverse the chemical reactions in the battery. Therefore, a battery management system should employ controlling of the battery and monitor the safety using the safety circuitry built in with the battery. So, the unwanted conditions such as over voltage or overheating are to be detected by the BMS should inform the user to encourage the user to make the correction procedures. In regards with the safety procedures the BMS also controls the temperature to make better power consumption of the battery.

A. Functions of BMS

An elaborative BMS should include functions such as, Data acquisition of the battery data, Battery safety Protection, Ability to find and predict the state of the battery, Battery discharging and charging controlling ability, Balancing of load cell, Management of thermal conductivity, delivery of status of the battery and authentication to a user interface.

B. Power Management Tehniques in HEVs

Most of the power management techniques for PHEV have been extended from conventional (non-plug-in) hybrids, and can be commonly classified on the basis of mathematical approaches used, that is separated into two types: rule-based and optimization-based. Optimization-based control technique may or may not require the knowledge of future power demand to determine a set of optimal control actions to specify the future output of each power supplier in order to achieve the global optimization. To more accurately model these uncertainties in the driving cycles and load profiles, stochastic driving cycle models have been developed. Stochastic dynamic programming (SDP) has been used to optimize power management over a probabilistic distribution of drive cycles for that vehicle Dynamics of the Electric vehicle is analysed.

C. Current State of Battery Management System(BMS)

Most of the currently found applications of BMS are in portable appliances such as laptops and cellular phones but these devices do not have a fully developed system such as those found in EV and HEV. Also, the electric vehicle batteries are designed to be long lasting and to employ high power usage. Moreover, these batteries of EV provide high power and voltage which makes these more complicated than the others. The hardware structure of the BMS have three topologies such as centralized, distributed and modular structures. The function of BMS in each case is similar in their operation. The battery layer structure for battery monitoring, battery management and battery state are proposed by Meissner and Richter [2]. All the concepts mentioned are being combined to make a generic BMS system which is shown in the Fig. 1. Many different types of sensors are included in the battery module for the monitoring layer of the data acquisition. Data is being collected in Real time for the maintenance of the system, safety and identifying the battery state. Discharge strategy, charge time, thermal management and cell equalization are the factors that determine the battery state. The Common disadvantages of the BMUs are the Limited data logging function. The DLF plays a major role in the establishment of database, which stores the driving pattern.

The most common BMS Products include Maxim DS2726 [20], TI BQ78PL114 [21] and OZ890 [22].

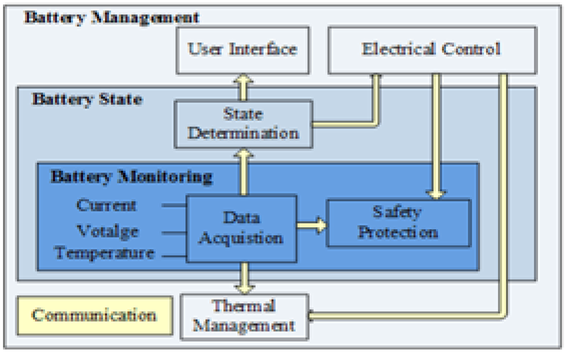

Fig. 1. Complete Module of BMS

IV. PROPOSED METHOD

The high prices of gasoline and continuous research in the field of Battery technologies are the reason why both electronic vehicles and HEVs are introduced in the end of 1990s and became popular in the 20th century. So, the lithium-ion battery technologies have been developed due to its marvelous properties such as extended life cycle, high energy density and minimal self-discharge and it is been used and extensively from then.

A. Factors Involved

BMS is made faster in EVs due to the changes brought in following factors proposed in this paper (1) battery state evaluation; (2) battery modelling; and (3) cell balancing.

1) Battery State Evaluation

The state of the battery not only aids in determining if the operational environment is safe and trustworthy, but it also offers information on the charge-discharge cycle, which is particularly crucial for cell balancing. SoC is analogous to the fuel usage indicator in gasoline cars, but the battery is difficult to measure due to ageing, changing ambient conditions, and charge-discharge cycles, making it difficult for a BMS to offer an accurate SoC estimate. SoH refers to the percentage of battery life left [1]. The definition of SoH, on the other hand, is debatable. Because, SoH does not correlate to the measurement of a specific physical characteristic, there is no agreement on its definition. Even though, the ratio between present capacity and maximum capacity is commonly identified as health indicator, other factors relating to field performance must be examined during SoH evaluation.

2) Battery Modeling

The complex electrochemical processes of batteries is a hurdle in developing a battery model. Scrosati reported voltage-to-capacity profiles of different Li/Li+ materials from the standpoint of chemical properties. When charging, $LiFePO_4$ exhibits a lengthy flat trend, but $LiMn_3O_4$'s voltage profiles progressively climb without a flat area. They demonstrated that a generic battery family model does not perform well in general situations. Currently, battery modelling for SOC determination is based on a variety of equivalent circuit (RC network) models, each with its own set of material properties and precision requirements [4].

3) Cell Balancing

To meet the demand for large capacity in EVs and HEVs, cells are wired in parallel to create a block, while multiple cells are linked in series to give a high voltage [5]. Due to the manufacturing and chemical imbalance, each cell is unique. As a result, the current in a sequence of cells is the same, but the voltage is different. Capacity fading in batteries during charging might put a cell in risk if it quickly reaches full charge. In other words, it will be overcharged while the rest of the cells charge to full capacity. Over-discharge can also occur on the weakest cell, which will fail first during the discharging process due to the series network, a battery made up of many cells in series will have a greater failure rate than a single cell. An efficient cell balancing system which maintains the SOC values of individual cells in a battery pack as close to each other as possible should be developed to decrease this impact and extend battery life.

B. BMS Battery Evaluation Methodologies

The above research indicates clearly that the battery status evaluation is one of the weakest links in the BMS, despite the fact that it has a significant influence on BMS performance. The safety and dependability of a vehicle's power supply is the top worry for EV consumers. The main concern is whether or not they would run out of battery power while on the road. These concerns concern the estimation and forecast of the EV battery's SOC, SOH, and SOL. As a result, precise battery status quantification has become one of the most important responsibilities for BMSs. The most recent techniques for battery state estimate and prediction are discussed in this section.

1) State of Charge(SoC)

SoC is important, but it's impossible to measure with today's onboard sensor technology. SoC [5] is the ratio of presently available capacity to maximal capacity, which can be computed using Equation (1).

$$SOC = 1 - \frac{\int idt}{C_n}$$

where 'i' denotes current and C_n denotes the battery's maximum capacity. The SoC indicates how much charge is left in the battery. In EVs, it's used to calculate the remaining driving distance, whereas in HEVs, it's utilized to decide when the internal combustion engine should be turned on or off [6]. The maximum capacity of the battery progressively diminishes over time due to the battery's inherent chemical reactions and various external loads. Uncertainty about these variables will result in non-linear, non-stationary battery deterioration. In HEV BMSs, the Extended Kalman Filter (EKF) has been effectively used to estimate SoC [7]. EKF linearizes the prediction by using partial derivatives and Taylor series expansion, but the standard Kalman filter (KF) is preferred for linear situations. Based on an electrical model with two series RC networks, EKF could be used to predict SoC [8].

2) State of Health (SoH)

SoH denotes the physical condition of a battery, ranging from internal behaviours, like loss of rated capacity, to external behaviours, such as severe conditions [9]. Unlike SoC, there is no clear-cut definition of SoH. A general definition of SoH states that it reflects the health condition of a battery and its ability to deliver specified performance compared to a fresh battery [10][11]. The SoH in EV applications is used for characterizing the ability to drive a specific distance or range. SOH in HEV applications is a characteristic of the specified power, such as the cranking power from regenerative braking. The nominal capacity percentage is used by academics and manufacturers as the battery's health threshold [12]. Battery failure occurs when the capacity of the battery drops to 80% of its initial capacity during charge-discharge cycles. In terms of battery properties, test equipment, and diverse applications, research have specified several criteria or indications to measure the SoH.

3) State of Life (SoL)

The remaining useful life (RUL) of a battery is also known as SoL. Accurate SoL forecasts will make failure prevention and maintenance easier, allowing batteries to last longer. However, only a little amount of research has been done on SoL prediction in the past. The development of state-of-the-art algorithms has been aided by the rising need for battery dependability, particularly in military goods.

V. PROPOSAL OF A NEW BMS SYSTEM

A detailed assessment of existing methods is used to identify the shortcomings of current BMSs. To address these flaws, we propose that a complete and mature BMS include the components depicted in Fig. 2 as fundamental functionalities.

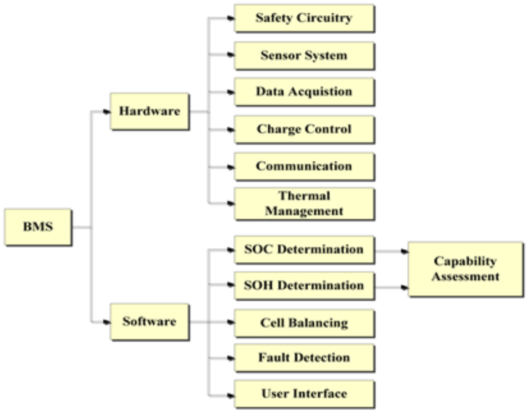

Fig. 2. New BMS Model Components

VI. POWER MANAGEMENT SYSTEM OPTIMIZATION

As previously stated, the power requirement from a driving cycle may be satisfied with an unlimited number of power split combinations between the engine and the battery. The goal therefore is to determine an ideal power split for each instant of the driving cycle so that fuel efficiency is increased and pollutant emissions are decreased as much as possible over the course of the journey, a process known as globally optimized power management. The optimum action set refers to all of these optimal power divisions.

A. *Optimization Objective*

The objective of PHEV power management is to increase fuel efficiency and minimize pollutant emissions to the greatest extent feasible. As a result, the objective function is defined as follows: J = fuel + · electricity + · NOx + · PM This covers total fuel and electricity expenses, as well as NOx and PM emissions, where, and are the equivalent weighting factors for electricity, NOx, and PM emissions, evaluated relative to the fuel, respectively. Because the affected region where the cars run is far away from the locations of power facilities providing electricity in general, the emissions created by electricity are excluded. Over the stochastic driving cycle, the optimization goal is to minimize the aforementioned objective function Fig. 3.

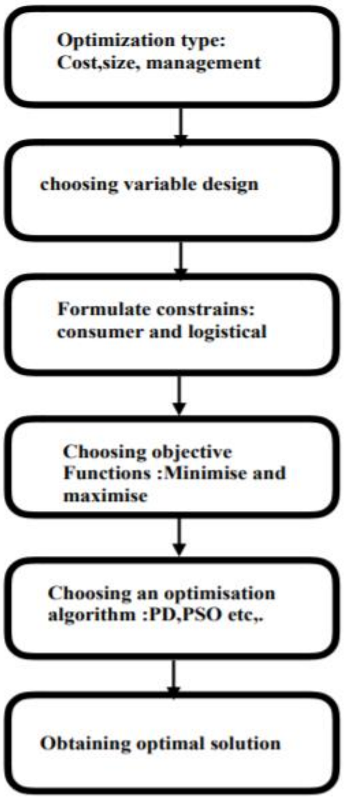

Fig. 3. Generic Optimization Diagram

B. *Optimization Strategy*

The power management will be implemented once the optimal control set has been achieved, as shown in the Fig. 4.

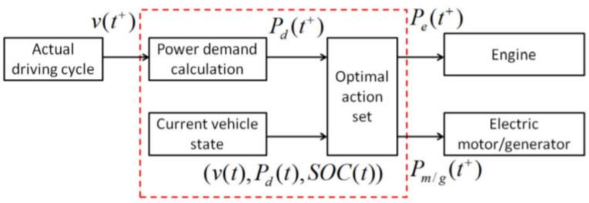

Fig. 4. Optimal Power management Implimentation

VII. CONCLUSION

Batteries are the primary source of energy in EVs and HEVs, so their performance has a significant influence on their marketability. As a result, manufacturers are looking for improvements in both battery and BMS technologies. Chemical processes in the battery are affected by operation circumstances, therefore battery deterioration might change depending on the environment. For firms who want to grow their market share, developing a complete and mature BMS is essential. In this study, the key problems of BMS were explored. Also an adaptive method may be devised to update the power demand transition probability and the commuting time distribution on a regular basis to further investigate the possibilities of dual power-source optimization. The suggested method might also be used to other dual power-source hybrid cars, such as fuel cell-battery and fuel cell-ultracapacitor hybrids, as well as multiple-power-source hybrid vehicles.

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