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LEAD ACID BATTERY MANAGEMENT SYSTEM FOR ELECTRICAL VEHICLES

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ABSTRACT

The high level of energy and power density of Lithium-ion and Zinc batteries amongst electrochemical batteries such Lead acid battery etc. makes them suitable as the energy storage in electric, hybrid electric vehicle, and plug-in vehicles (EV/HEV/PHEV). The battery management system is an electronic system that manages battery. One of the requirements in electrical system is rechargeable battery and its precise management. The Battery management system (BMS) monitors very important battery parameters i.e. state of charge, state of health, coolant flow for air or fluid, ampere hour counting, terminal voltage and flowing current (in and out).Open circuit voltage and integral of discharging current of the battery be used for estimation of SOC and are the function of SOC. The on line measurement and comparison of the predicted and measured terminal voltage and integral of current provides a tool for estimating the SOC and SOH. The BMS is also used for calculating secondary reports and reporting the generated data. The BMS also helps in controlling or balancing battery environment. In this research paper attempt is made to design the battery management system for electrical system or plug-in vehicles.

KEYWORDS: Battery management system (BMS), plug-in-vehicles-state of charge (SOC), state of health(SOH)

I. INTRODUCTION

Automobile industry is focused on fuel saving automobile vehicles and/or electric, hybrid electric vehicle, and plug-in vehicles (EV/HEV/PHEV). The rechargeable battery plays major role for deciding many electrical specifications of battery operated vehicle.

Rechargeable batteries like Lithium-ion and Zinc batteries have high levels of energy and power density amongst other electrochemical batteries such Lead acid battery [1], [2]. The high level of energy and power density of batteries makes them suitable as the energy storage in electric, hybrid electric vehicle, and plug-in vehicles. Multi-battery parameter reading or recording is an important way for studying the functions the rechargeable battery. Monitoring of the battery performance parameters gives more information about the battery status and health of the battery. Recently, many commercial data acquisition systems are available and are also powerful. The battery management system (BMS) is an electronic system that manages battery and battery parameters precisely. The BMS system monitors important battery parameters like state of charge, state of health, coolant flow for air or fluid, ampere hour counting, terminal voltage and flowing current (in and out).The BMS is also used for calculating secondary reports and reporting the generated data. The BMS helps in controlling or balancing battery environment. Therefore the battery management systems are generally used in electric, hybrid electric vehicle, and plug-in vehicles (EV/HEV/PHEV). As far as electrical vehicles concern the fuel gauge of the battery makes direct use for decision making for driving a car. The readings of fuel gauge monitored in terms of percentage with accuracy of 1% will be highly needed. Instead of displaying battery parameters like voltage, current and AH values, the mileage and SOC in terms of fuel gauge is displayed on the computer screen. After complete development of the system it would be directly displayed on car dashboard. Owing to the improvement of computing power, computer-aided multi-unit acquisition and separation rapidly proliferated during the last two decades. To utilize this technology is, however, not easy since task-specific designs are usually mandatory. To overcome this obstacle, a commercially available National Instrument (NI) USB 6009, data acquisition system is used to evaluate, this research paper describes a design and development of a real time monitoring system for the measurement of battery performance parameters. The battery performance parameters are computed continuously with designed hardware and software setup. The designed system monitors battery related parameters and provides information regarding health of the rechargeable battery. This experimental data could be used to know certain parameters of battery like rate of charging, rate of discharging and power drawn by electrical loads. Real time monitoring system provides key information to the user in an electrical car or battery operated systems or electrical power system in deciding mileage, range, specifications and other related parameters.

II.BATTERY MANAGEMENT SYSTEM (BMS)

The battery management system is an electronic system that manages battery .The BMS system monitors very important battery parameters like state of charge, state of health, coolant flow for air or fluid, ampere hour counting, terminal voltage and flowing current (in and out). The BMS is also used for calculating secondary reports and reporting the generated data. The BMS also helps in controlling or balancing battery environment. The BMS may include Monitoring, Electrical vehicle system: Energy recovery, Computation, Communication, Protection, Optimization and Topologies.

2.1 Monitoring

The main role of the BMS is to monitor the battery parameters. The state of the battery and it may be as represented by various electrical parameters of the battery i.e. total voltage, temperature, state of charge (SOC) or depth of discharge (DOD),state of health (SOH), coolant flow for air or fluid cooled batteries and current in or out of the battery. In this work the terminal voltage, temperature, state of charge (SOC) or depth of discharge (DOD) are displayed on the screen of computer as shown in fig.1. In this monitoring system range of vehicle in km and amount of state of charge in percentage is displayed and which is needed for driver of the electrical vehicle.

Figure 1.0: BMS for Electrical Car

2.2 Electrical Vehicle System: Energy Recovery

The battery monitoring system will also control the recharging of the battery by redirecting the recovered energy. It is nothing but energy recovered from regenerative braking back into the battery packs. The pack is typically composed of few batteries. The batteries are charged through this regenerative braking and mileage would be increased. The efficiency of regenerative braking system decides status of charge present in the battery.

2.3 Computation

In addition with this existing system battery monitoring system may calculate different values based on the above items i.e. Maximum charge current as a charge current limit (CCL), Maximum discharge current as a discharge current limit (DCL), Energy delivered since last charge or charge cycle, Total energy delivered since first use and Total operating time since first use. The LabVIEW is used to store all the parameters in the excel sheet for ready reference.

2.4 Communication

A Battery monitoring system is designed to report all data to an external device, using communication links i.e. Serial communications, CAN bus is one particular implementation of a serial link most commonly used in automotive environments, Direct wiring, DC-BUS - Serial communication over power-line and Wireless communications. This existing system does not speak with any of the communication.

2.5 Protection

A battery management system may protect battery by preventing it from operating outside its safe operating area i.e. Over-current, Over-voltage (during charging),Under-voltage (during discharging), especially important for lead–acid and Li-ion cells, Over-temperature, Under-temperature and Over-pressure for NiMH batteries. The BMS may prevent operation outside the battery's safe operating area by:

- Including an internal switch which is opened if the battery is operated outside its safe operating area
- Requesting the devices to which the battery is connected to reduce or even terminate using the battery.
- Actively controlling the environment, such as through heaters, fans, air conditioning or liquid cooling

2.6 Optimization

The optimization of the system may leads in improving efficiency of the developed system. The rechargeable battery with proper optimization gives improved life cycle and stable electrical parameters within experimental limitations.

2.7 Topologies

Topographic study of a rechargeable battery and where it is used place, especially the history of a region as indicated by its topography. This term could be used in the estimation of some of the parameters of the battery.

III. EXPERIMENTAL

Data acquisition is the process of sampling signals that measure real world's physical conditions and converting the resulting samples into digital numbers that can be manipulated by a computer. Data acquisition systems (acronym DAS or DAQ) typically convert analog waveforms into digital values for processing. In this research work DAS is used to read parameters of the rechargeable battery continuously with number of samples per second is decided in the LabVIEW software. The charging or discharging rate of the rechargeable battery or electrical car battery is low or not constant as compare to other physical systems. The 20,000 samples per second, maximum sampling rate is possible for reading data with this card. In case of battery parameter reading process needs lower sampling rate and can be adjusted through DAQ assistant setting of the card through the software. The type of reading data (differential or single ended) can be decided through software Data acquisition applications are controlled by software programs developed using specialized software LabVIEW .This software tools used for building large scale data acquisition systems for rechargeable battery and its graphical programming environments for visualization.

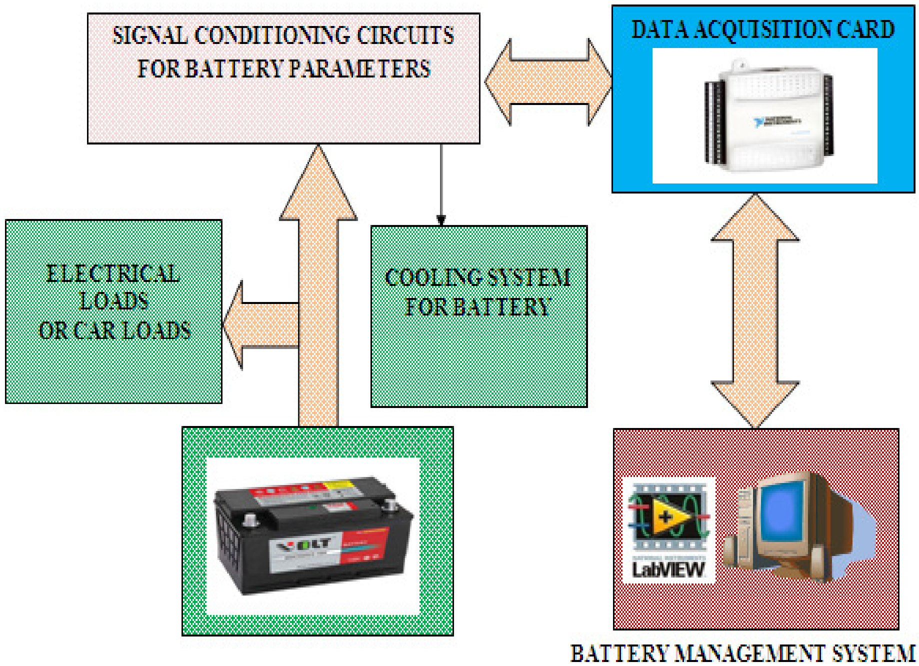

Figure 2.0: Battery management system for electrical vehicle

DAQ hardware is what usually interfaces between the signal and a PC. It could be in the form of modules that can be connected to the computer's ports (parallel, serial, USB, etc.) or cards connected to slots in the board. Not all DAQ hardware has to run permanently connected to a PC, for example intelligent stand-alone loggers and oscilloscopes, which can be operated from a Personal Computer (PC), yet they can operate completely independent of the PC.

The block diagram of the system consists of current, temperature and voltage sensing sections followed by its signal conditioning blocks as shown in Fig2.0. The necessary settings are made according to the requirement of the system temperature measurement parameters is very much important because temperature term decides internal resistance of the battery and rate of charging and discharging, and some required electrical quantities or parameters of the battery. The temperature of the battery is read through the sensor LM35 and corresponding output voltage is directly given to the DAS with signal conditioning output of the sensor.
Similarly the current and voltage part is also connected to the DAS system in order to make system ready for reading data continuously. Battery indications are also included in the software code like temperature of battery, lower/higher voltages, Total power of the battery, Remaining power of the battery and Charge holding time, Nominal Voltage and High temperature indications of the battery through emergency indicators. The different loads connected to the battery can be manipulated through software and corresponding load switching unit can be activated in order to use battery for optimum utilization.

The state of charge and depth of discharge are the most significant parameters of the battery. These parameters are used for the improvement of battery operation, performance, reliability and life span. Knowing the state of charge it is possible to avoid an overcharging that would lead to a decrease in working life or even to a battery malfunctions. The malfunctioning of the lead acid battery may cause large economical losses or in the case of more sensitive equipment, even the loss of human lives. The measurement of electrolyte density provides accurate value of battery SOC but for this measurement hydrometer is required and manual intervention is needed for its operation. For this reason online monitoring plays important role for avoiding many problems.

3.1. Battery State of Charge (SOC)

A key parameter of a battery use in an EV system is the battery state of charge (SOC). The SOC is defined as the fraction of the total energy or battery capacity that has been used over the total available from the battery. Battery state of charge (SOC) gives the ratio of the amount of energy presently stored in the battery to the nominal rated capacity.

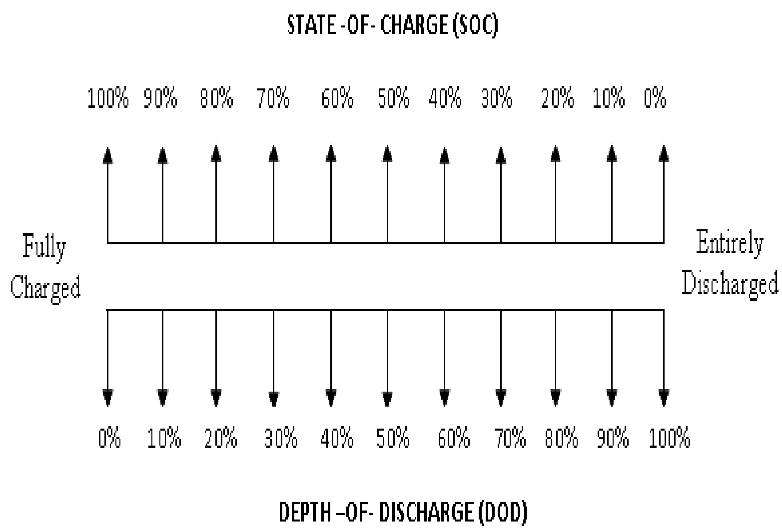

Figure 3: SOC and DOD relation strip

For example, for a battery at 80% SOC and with a 500 Ah capacity, the energy stored in the battery is 400 Ah. A common way to know SOC is to measure the terminal voltage of the battery and compare this voltage of a fully charged battery. However, as the battery voltage depends on temperature as well the state of charge of the battery; this measurement provides only a rough idea of battery state of charge.

3.2. Depth of discharge (DOD)

In any type of batteries, the full energy stored in the battery cannot be withdrawn or cannot be fully discharged without causing serious and often irreparable damage to the battery. Depth of Discharge is the amount of energy that has been removed from a battery (or battery pack). It is expressed in a percentage of the total capacity of the battery. For example, 50% depth of discharge means that half of the energy in the battery has been used. 80% DOD means that eighty percent of the energy has been discharged, so the battery now holds only 20% of its full charge.

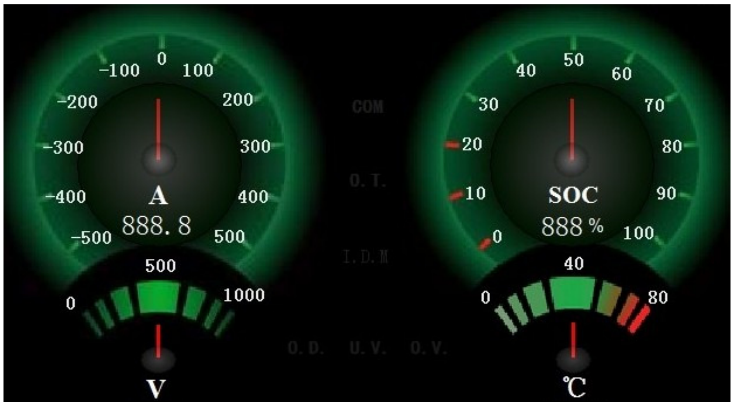

Figure 4: Monitoring SOC, drawn current using gauge diagram

3.3. State of Health (SOH)

It is a figure of merit of condition of the battery compared to the ideal conditions of the battery. The unit of SOH is percent points (100% Battery condition match the battery specification). Typically SOH is 100% at the time of manufacture and will decrease over time and battery use. SOH does not correspond to a particular physical quantity; there is no consensus in the industry on how SOH should be determined. The designer of battery management system may use any of the following parameter to derive an arbitrary value of SOH i.e. internal resistance or impedance or capacitance, capacity, voltage, discharge, ability to accept charge and number of charge discharge cycles.

3.4 Ampere-Hour measurement

The battery capacity determines the backup duration of the rechargeable battery. It is primarily defined in ampere hours (Ah) and selected on the basis of backup requirements of an individual. Higher the ampere hour capacity of the battery, larger will be the backup time for the system. The measurement of ampere hour is time consuming and not simple for variety of loads and for automation is also tedious. In this designed system ampere hour measurement is done effectively for variety of loads. A standard battery provides three hours backup time at full load and six hours at half load. One can increase backup duration by installing higher capacity batteries or adding extra batteries in parallel. The designed system measures current along with time so that ampere hour can be displayed on the monitor of the system. This helps to know how much load is connected to the system and corresponding time and how far battery will deliver charge to the load connected to it.

IV. IMPLEMENTATION

The real time battery monitoring system for measurement of different battery parameters are implemented with the help of software LabVIEW 2011 and DAS USB 6009 with some extra electronics for high side current sensing section and temperature sensor circuitry. The extra hardware is required for current sensing section of the setup because the high current of battery cannot be connected directly to the DAS card because of current measurement limitations. This card measures current up to 50mA and electrical car consumes current in terms of ampere. Hence the high side current circuit is designed with suitable gain of the differential amplifier with high CMRR operational amplifier.

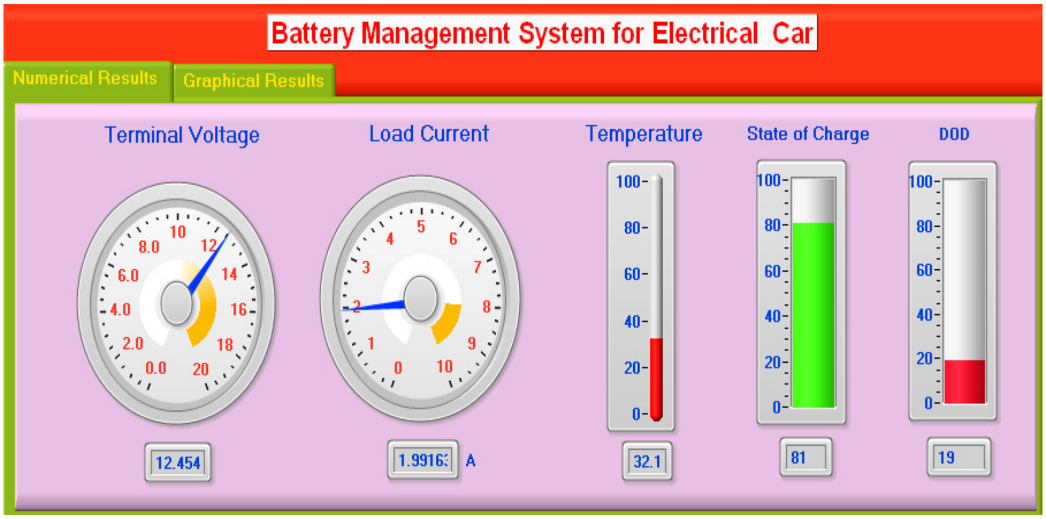

Figure 5: Front Panel of Battery Monitoring System using LabVIEW

The electrical load current is converted in to corresponding voltage and then given to the DAS card. The DAS driver software is needed to work DAS hardware on PC or Laptop. The device driver performs low-level register writes and reads on the hardware, while exposing a standard API for developing user applications. The experimental results are stored in particular file as a reference and comparison of previous and current data. The front panel of the designed Battery Monitoring System is shown in fig.5 and readings for different parameters are monitored as real time setup. This front panel also shows state of charge, depth of discharge, load current, terminal voltage, ampere-hour and backup time of the battery.

V. RESULT AND CONCLUSION

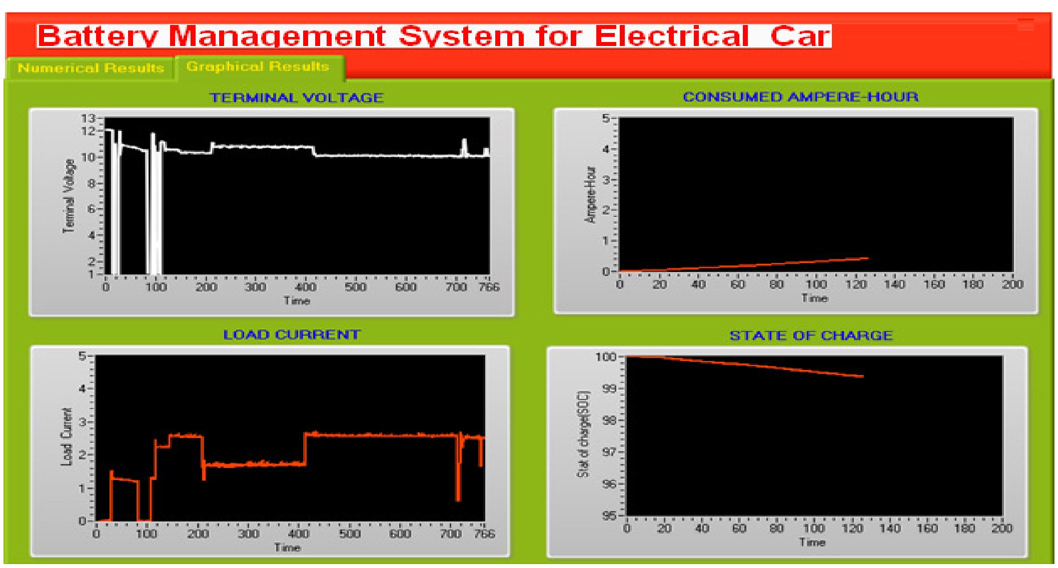

Figure 6: Graphical display of SOC, A-H, Load Current and Terminal Voltage

It is possible to keep continuous track on battery performance. The user of battery operated system will get exact value of charge holding time of the battery and required indications through indicators like displays and emergency alarms. The fig.6 gives graphical representation of important parameters of the battery. This graphical data can be used to know certain parameters of battery like rate of charging, rate of discharging and power drawn by electrical loads. Real time monitoring system provides key information to the user of an electrical car or battery operated systems or electrical power system in deciding mileage, range, specifications and other related parameters. In the graphical representation, the graphs are given for ampere hour, state of charge, load current and terminal voltage of the battery.

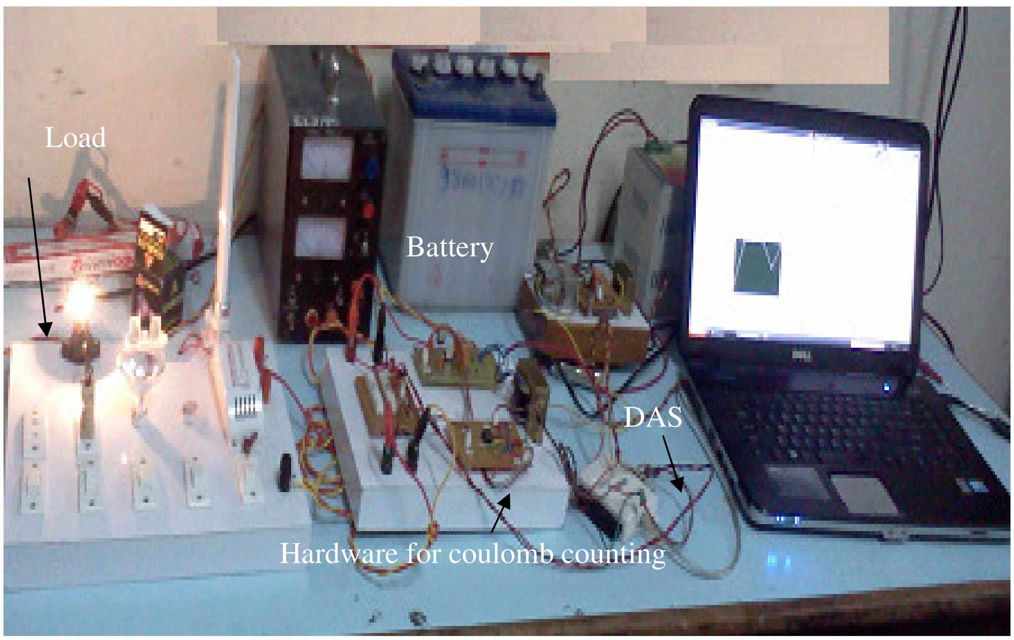

Figure 7: Experimental Setup for battery monitoring system

By knowing these parameters driver information system gives information related to mileage and fuel gauge related information to the driver. The designed system monitors battery related all parameters and provides useful information to the user about health of the battery.

Through this battery performance parameters and necessary preventive action are suggested through the developed prototype. The setup prototype is shown in the photograph of fig7.

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(http://scholar.google.co.in/citations?hl=en&authuser=1&user=g4yfOxEAAAAJ)

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