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Battery Pack Design and Battery Monitoring System for a Reliable and Safe Electric Vehicle

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ABSTRACT: The design of battery pack and battery management system for transportation application is a major challenge for the development of Electric Vehicle. Battery monitoring is vital for most Battery Electric Vehicles (BEVs), because the safety, operation efficiency and even the life of the passenger depends on the battery system.This paper focuses on the major functions of the Battery Management System (BMS). The BMS checks and controls the status of battery within their specified safe operating conditions. The charge control system provides protection for the battery during charging and discharging conditions. During charging, charge controller provides protection against overcharging and also maintains the battery voltage at a particular level for the protection of the battery. The integration of battery energy storage system with battery management system (BMS) makes the system more efficient, reliable and safe. This integration is completely effective in development of an optimized system design.

KEYWORDS: Battery pack,Battery Management System (BMS), charge controller, Battery Electric Vehicle.

I.INTRODUCTION

India is one of the top ten automotive markets in the world. In the last couple of years, there have been a lot of discussions around the price of fuel apart from the deregulation of petrol prices. Moreover the threat of disruption of supplies from the Middle East has heighted the debate on energy security and brought the focus on to alternative drive train technologies. The potential for alternative technologies in automobiles such as Electric Vehicles (EV) in India as in the case of many other comparable markets depends on improved battery technologies, driving ranges, government incentives, regulations lower price and better charging infrastructure.

There seems to be a lot of interest on the part of I C engine based manufactures to adopt electric technology and also there are specialized EV manufacturers that have come up all over the world. Factors that influence the EV market are understood intellectually by carrying out a consumer survey to study perceptions and expectations of potential for an alternative technology in automobile such as electric vehicle (EV). India is not a country where electric cars are sold as much as Canada, Japan, China, Europe, United States and other countries. Hence this present situation creates a huge potential to introduce retrofitted electric cars in India. When we move to electric world, complete disposal of all the IC engine cars are not practical. Thus retrofitting of the existing vehicle is better and feasible solution for this problem, with a relative small amount of capital cost. New battery electric vehicle for individual consumers is sold at high retail price. So in the coming years a few electric vehicles that are powered by rechargeable battery will merge on the market.

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The success of battery electric vehicle (BEV) is very dependent on the battery technology. The development of batteries for EV will go on in the coming years, resulting in development of energy storages with higher specific power and energy.

II. PROPOSED SYSTEM

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

Battery monitoring is important for most electric vehicles (EVs), because the safe reliable operation and security of the passenger depends on the battery system. The Battery management System (BMS) 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 on the bases of data from sensors. The BMS helps in controlling and balancing battery environment. The BMS may include Monitoring, Energy recovery, Computation, Protection and Optimization Topologies. The charge controller is provided for protection against overcharging condition formaintaining the battery voltagelevel.

III. BLOCK DIAGRAM

The retrofit kit consist a 10 kW,72V BLDC motor as load. There are 6 units of 12V, 130 Ah lead acid batteries to power the BEV. The battery is connected to the 72V charge controller with a Battery management System (BMS) and a current controlling device. Motor controller converts the 72V DC to frequency controlled three phase supply. The supply is given to the 3 phase winding of the motor. The battery unit mainly consists of a BMS which provide real time monitoring of voltage, current and temperature. The BMS also consist of a protection unit that provides overcurrent protection, overvoltage protection and protection against temperature rise. The system also contains a cooling unit to avoid temperature rise in battery. Charger plus charge controller is installed in this unit for proper charging.

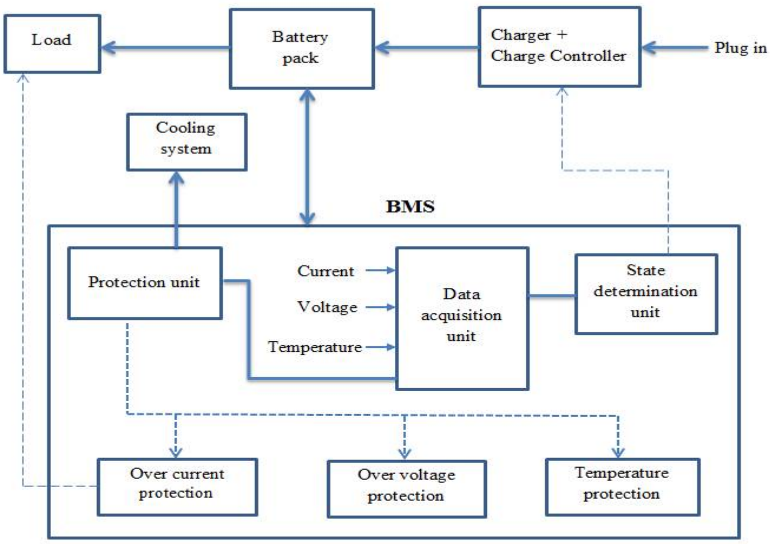

Figure 1:Block diagram of battery management system

IV.METHODOLOGY

The system consists of current, temperature and voltage sensing sections followed by its signal conditioning blocks as shown in Figure 1. The necessary settings are made according to the requirement of the system. The temperature

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measurement is very much important because temperature parameterdecides internal resistance of the battery, therate of charging and discharging and some other electrical parameters of the battery. The temperature of the battery is read through the DHT22 temperature and humidity sensor and corresponding output voltage is directly given to the Data Acquisition Server (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 codes like temperature of battery, lower/higher voltages, Total power of the battery and the remaining power of the battery, 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.

V. COMPONENTS OF BATTERY UNIT

Battery unit mainly consists of a Battery pack, Battery Management system (BMS) and Charge controller.

A. Battery pack

Battery Capacity	9500Wh battery pack
Type	lead acid
Voltage	72V
Ampere-hours	130Ah
Temperature range	10 to 50 degree Celsius

Table1: Specifications of battery pack

An Electric Vehicle (EV) uses a battery unit for its propulsion. Electric Vehicles uses secondary rechargeable battery. The most common rechargeable batteries used in EVs include lead-acid ("flooded", deep cycle and VRLA), Ni-Cd, Nickel metal hydride, Lithium ion and less commonly, zinc-air and molten salt batteries. Electric-vehicle batteries differ from starting, lighting and ignition (SLI) batteries because they are designed to give power over sustained periods of time. Traction batteries must be designed with high ampere-hour capacities. Batteries of EVs are characterized by specific energy and energy density. It should also have good power to weight ratio which helps to improve overall efficiency and performance of vehicle.

The major requirements of an EV battery are safety, long driving range, high power, small size, less weight, high capacity and long life. Considering these factors three types of battery choices available in present market are Li-ion battery, Lead acid battery, Lead acid dry cell. The parameters used to compare these three batteries are weight, discharge rate, efficiency cycle life, voltage, cost, safety. Lead acid battery is selected as its cost is low and safety is much more than a lithium ion and lead acid dry cell.

Lead acid batteries are the cheapest and most common used traction battery. For electric vehicles, more robust lead acid batteries that withstand deep cycling are used. In the lead acid cells the negative plates have a spongy lead as their active material, while the positive plates have lead dioxide. The plates are immersed in an electrolyte of dilute sulfuric acid. The sulphuric acid combines with the lead and the lead oxide to produce lead sulphate and water, electrical energy is also released during the process. The lead acid batteries are not so expensive but it performs with high reliability. It has a voltage range of about 2V per cell. Charging a lead acid battery is a complex procedure, if carried out incorrectly it will quickly ruin the battery and decrease its life. The charging must not be carried out at too high a voltage, as it results in water loss. The most commonly used technique for lead acid batteries is called multiple steps charging. In this

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method the battery is charged until the cell voltage is raised to a predetermined level. The current is then switched off and the cell voltage is allowed to decay to another predetermined level and the current is then switched on again.

The voltage range of entire battery unit is 72V, six lead acid batteries of 12V, 130 Ah is used. The battery will power a 10kW BLDC motor. Operating temperature should be below 40^0C. The battery has 50%-95% charging and discharging efficiency. The total time taken for full recharge is 8 hours (90% will be recharged in 1 hour).The self-discharge rate of lead acid is 3-20% per month. The battery has life cycle up to 800 to 80% capacity. The battery can power the vehicle for about 3 hours in normal conditions. If the motor runs at its full peak load, the battery is able to provide a backup of minimum 1 hour.

B. Battery Management System (BMS)

A Battery Management System (BMS) is a critical component of host single cells or banks of cells arranged in series, parallel or combination systems that utilize arrangements. In order to provide safe and reliable battery operation, a BMS performs state monitoring charge control and cell balancing (in multi-cell pack systems). Certain battery operations, such as over-discharge can cause reduced cell capacity due to irreversible side reactions. Therefore, a BMS also monitors and controls the battery packs. Whenever any abnormal conditions are detected, such as overvoltage or overheating, the BMS notifies the user and execute the pre-set correction procedure and thus monitors and control the battery, based on the safety circuitry incorporated within it. Functionality wise, BMS are similar, however there are three broad categories, including centralized, distributed and modular structures. Essentially, these categories consist of a layered structure of sensors for monitoring and data acquisition.

The data coming from the sensors is used for battery state determination, which in turn used for calculating the battery performance characteristics such as discharge profile, charging time, cell status and the thermal and mechanical aspects of the cells. The battery state evaluation forms a critical input into the BMS for the battery pack safety and reliability. The battery state determination helps to characterize the stresses that the environment may apply on the battery and provides information about the charge and discharge operations. Although some algorithms used in commercial products use a ratio of the current battery capacity to the maximum capacity as a battery health indicator for a complete state of health or SOH evaluation.

Over current protection:

Over current protection is an essential feature in any electric vehicle. Pre-calculated current limits are very important as computer needs to quickly make decisions based on the power available from the electric system. Failures on reliable limits allow the main control computer to draw too much current from the battery, causing the limits to suddenly dive. Then with respect to the new limit, the main drive computer would be forced to reduce current, leading to a jerky or possibly dangerous driving experience.

BMS unit simply provide an on/off switch to allow and prohibit discharge and charge currents, the BMS carefully calculates the actual maximum ampere limits and controls the current. At peak loads, the motor draws high current from the battery. This high current leads to temperature rise in the battery pack. Battery management system protects the battery from high temperature caused by the high current drawn by the motor. Also an additional fuse unit and circuit breaker is used for the protection of the battery.

Over voltage and under voltage protection:

If the voltage across the battery pack is allowed to fall below its minimum operating value, the cell will be damaged. The extent of damage depends on how much over depleted the battery is and how long it stays over depleted condition. In the best case, when the voltage falls only slightly below the minimum, there will be a minor loss in capacity and the self-discharge rate will increase. The lower the cell voltage gets, the more pronounced these effects become. If the cell

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voltage gets too low, then it becomes dangerous to attempt to recharge the batteries because it may develop a short and cause severe damage to its surroundings.

During charging condition the battery pack voltage must keep in a safe limit. If the voltage is increase beyond that limit, it will lead to a dangerous situation. If the battery voltage increased above the pre-set value, BMS automatically controls the voltage level in a safe limit. Also if the voltage drains below the safe limit, the BMS automatically senses and provide alert to the driver and cut off the circuit. Thus the BMS protects the battery from over and under voltage conditions.

Thermal protection:

Battery pack used in electric vehicle must need thermal protection to safeguard the battery from burning out, causing dangers to the life of the passengers and the vehicle. Normal charging and discharge cycle heats up the battery. The temperature of a battery depends upon the charge rate and the charging and discharging current rating. During peak loads the motor draws high current from the battery pack. This high current will lead to generation of high temperature in the battery pack. If the battery temperature increases beyond the safe limit, it will affect the proper working of the battery. Also the high temperature leads to creation of internal short circuit inside the battery. Sometimes it will lead to huge explosions and death. To prevent this situation thermal protection is an essential feature in a BMS. 25^0C to 33^0C is optimum working temperature for the lead acid battery pack used in electric vehicles. Temperature above 50^0C is dangerous for the batteries.

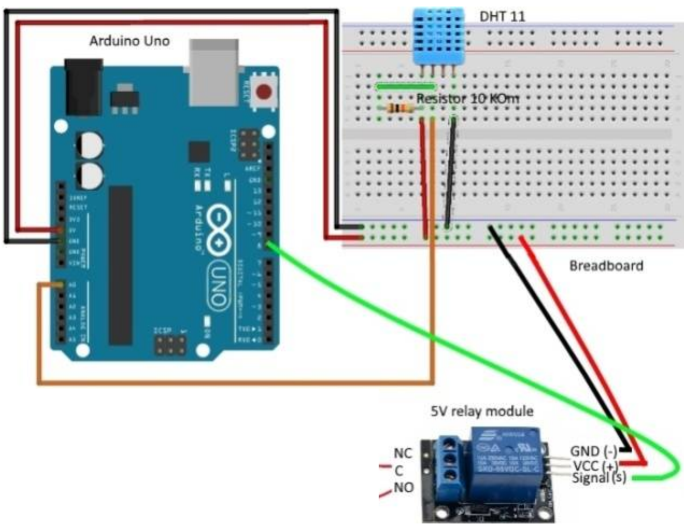

Figure 2: Temperature controller

The thermal interface also includes the ability to control an external cooling fan. The controller can be configured for ON/OFF operation or for a variable fan speed using a PWM output. For reliability reasons, the fan driver is external to the BMS and is optional. The fan controller interface includes a fan monitoring circuit which monitors malfunctioning of cooling fan and set error codes if a fault is detected. The fan can be configured both to cool the battery when it is hot and to warm the battery when warmer ambient air is needed. All thermal settings are programmable through the user interface. The temperature monitoring and controlling will increase the efficiency and life of the battery pack. The BMS ensure the complete regulation and safety of the battery.

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C. Charger plus Charge controller

The retrofitted electric vehicle is fully powered by a 72 V, 130 Ah rechargeable Lead-acid battery pack. This battery pack is recharged by a 72 V auxiliary charger. The current output of the charger is adjustable from 0A to 12 A. The output of the auxiliary charger is directly connected the battery pack through a charge controller. A 230 V ac supply is converted to 72 V dc supply for the battery pack. The charger includes features like short circuit protection, overvoltage protection by incorporating a charge controller.
Input of the charger =230V ac
Output voltage = 72 V dc
Output current= up to 10 A (adjustable)

Charging method:

The battery is charged in two modes. Initially the battery is charged in a constant current mode and then it is charged in constant voltage mode as shown in Figure 3.

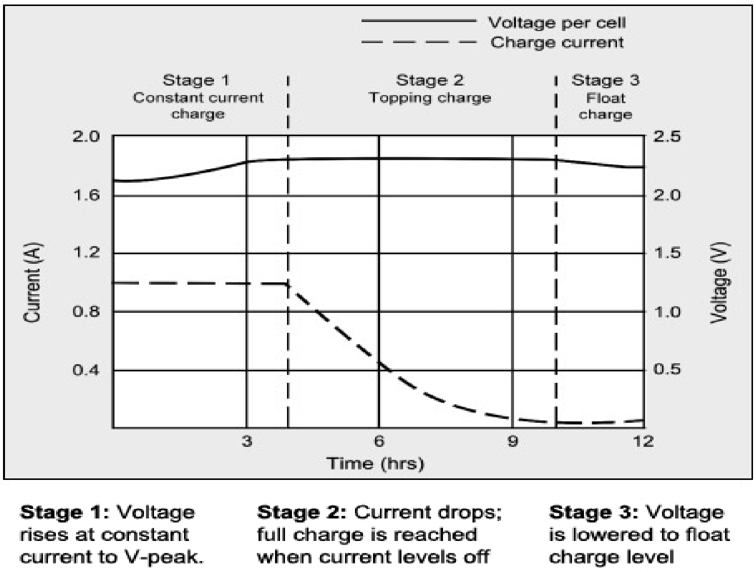

Figure 3: Charging characteristics.

In constant current mode the battery is charged using constant high current supply. Thus the battery can be charged like fast charging mode. It allows the full current of the charger to flow into the battery until the power supply reaches its pre-set voltage. The current will then taper down to a minimum value once that voltage level is reached.When the battery reaches 80% of fully charged condition the charging mode is automatically turns from constant current mode to constant voltage mode. In constant voltage mode the current will taper down to a minimum value once the required voltage level is reached. The charger output voltage will be constant and it is rated battery voltage. Then the charger compensates the battery voltage to its full charge condition. The constant current and constant voltage modes of charging are much efficient for lead acid battery charging.

Charge controller:

The charge controller controls the battery voltage in a safe limit during charging. While charging, sometimes the battery charges above the rated voltage. This will reduce the battery efficiency and reduces the life span of the battery

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pack. Thus while charging the charge controller in the charger monitors the live voltage level of the battery. If the battery voltage increases above the rated voltage, the charge controller automatically senses and cut of the supply from the charger output. Also the charge controller controls the current flow to the loads.

VI.FUTURE SCOPE

The future for electric vehicles is bright. Plummeting battery prices, longer-range models, and more charging stations are driving forward Battery electric vehicles. The energy storage capabilities and performance of the retrofitted car can be improved by the following means:

- Flexible solar panel in cooperated with body parts helps to increase the driving range of EV and it is an efficient method to use renewable source of energy.
- Super capacitor can be used for power surges, helps to reduce the energy demand on battery at time of peak load and also improves the efficiency of the battery. Again helps in increasing the battery backup and save the battery from over discharge that helps in increasing life of the battery
- Automatic emergency braking and collision avoidance, safeguards battery from sudden collisions and damages. Also provide protection for batteries from fire hazards due to sparking by collision and sudden brakes.
- Li-ion batteries can be used to reduce size of battery pack for EV. Since Li-ion has high energy efficiency and more lifecycles, it improves drive range and performance of vehicle.

VII.RESULT

The retrofitted vehicle is powered by a 72V, 130Ah lead acid battery pack. The Battery Management System monitors and controls the battery pack. The BMS contains protection for overvoltage, overcurrent and the cooling system is activated when the temperature goes above40^{0}C. A charge controller of 72V, 10A is also incorporated with the battery monitoring system for proper charging and discharging of battery pack and ensuring the safety of the passengers and the vehicle.

VIII. CONCLUSION

The conversion of IC engine vehicles in to electric vehicles accelerates e-mobility transitions. Linking this technique to the present situation improves air quality, decarbonizes our economy, reduce oil dependency, and grow new businesses. The final output will be a zero-emissive car below 1300cc.This paper titled “Battery pack design and battery monitoring system for a reliable and safe electric vehicle” deals with the design of a lead acid battery pack, a Battery Management System (BMS) and a charge controller for a retrofitted vehicle.The resultant electric vehicle is fully powered by a 72V, 130Ah Lead-acid battery pack providing a total capacity to drive a 10 kW BLDC motor of voltage rating of 72 V and current rating up to 130 A. So 130 Ah battery pack is sufficient to meet the requirement of the electric car. The Battery Management System protects and safeguards batteries and also used for real time voltage, current and temperature monitoring. Protection features include protection against overcharge, overcurrent, overvoltage, over discharge and temperature rise. The BMS improve efficiency, reliability and safety of the vehicle. The charge controller or battery regulator limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may protect against overvoltage and under voltage conditions and improves battery performance, lifespan, safety. The weight saved by removal of engine can be used to add more batteries to improve the driving range.The driving range can be improved in future by introducing solar roof for cars, providing charging stations at adequate distances, wireless charging road, high capacity Li-ion batteries and super capacitors etc.

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