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Thermal Management of Lithium-polymer based Battery Pack for urban BEV

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Abstract

The results of implementation of advanced active thermal management system to product line of Li-Po based battery packs destined for small urban electric car is presented in this paper. Small urban vehicles requires a minimum distance of 70-100km per one charge and using battery packs between 5 and 15kWh. Usually there is not a lot of space available for cells and also low costs system is demanded. Using Li-po cells technology a lot of parameters has to be met to create a industry solution like meeting wide ambient temperatures and providing long lifetime. Impact Automotive has developed different approach for thermally managing the temperature of a pack using advanced thermal control algorithm and special design of a cooling/heating system. Applying advanced thermal management are resulting in the ability of using the pack (for both charging and discharging) in very wide ambient temperature conditions keeping high performance and massive extension of its lifetime.

Keywords: battery, battery management, BMS, cooling

1 Introduction

Present industrial high capacity lithium-polymer cells have very strict demands concerning operating conditions. Manufacturer's data of certain number of cycles is given almost always in laboratory conditions with constant load and room temperature. Battery pack based on such a cells and destined for standard automotive conditions has to withstand very wide range of ambient temperatures – usually from -20C to +50C, vibrations, high peak loads and charging. Users are demanding keeping long lifetime and big number of cycles.

The new approach to maintain the thermal management of cells inside industrial battery pack is described in this paper. The battery pack is destined for small urban electric vehicle. New SAM EV II is taken as an example.

2 Thermal tests of available Li-po and Li-ion cells

Three types (two manufacturers (A and B), two capacities (50 and 40 Ah)) were tested under nominal discharging current and 3C current.
Cells were stacked between two others of the same type (but not working) sandwiched with cooling plates (active or not).

Figures 1 and 2 show comparison of cells behaviour under 1C and 3C discharge. One can easily see the increase of the temperature with the time of all investigated cell.

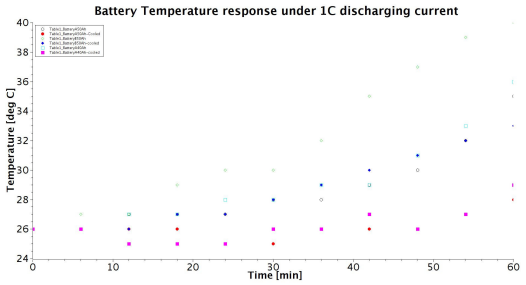


Fig .1 Comparison of cells temperatures in under 1C load

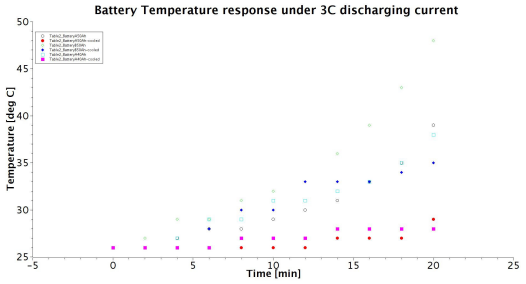


Fig. 2 Comparison of cells temperatures in under 3C load

After turning the cooling system to active the situation changes - there is either small cool down effect or significant temperature growth slowly down.

As the initial temperature was always kept at the same level (26 deg C) the cooling system is able to compensate almost all the amount of heat generated during discharging ensuring user to have Battery Pack operational with ambient temperature below overheat level.

3 Application Description

Typical approach to overcome the thermal and performance problems utilized by several BP manufacturers is to put inside pack larger capacity cells and use just a fraction of their capacity and smaller C-ratio. This solution has disadvantages – its costly and consumes lot of space and weight.

Small urban electric vehicle has to provide mobility for max 2 people for relatively short distances. Car has to be small also. So there is no much space left for batteries.

Impact Automotive Technologies has developed an advanced battery pack for a new SAM EV II.

It is small urban battery three-wheeler, able to carry two people and drive with max 90km/h. Under ECE15 cycle can run up to 100km per one charge.

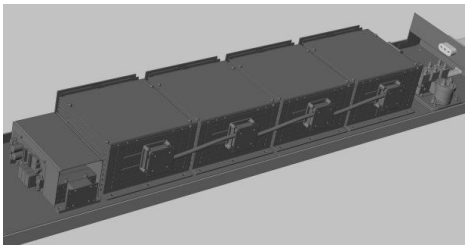
Pic. 1. SAM EV II prototype

vehicle. Battery Pack has 7kWh and 133V nominal. It weights only 67kg and takes space of 76 litres.

4 Battery Pack construction

Battery pack for SAM EV II consists from the following functional blocks:

- Cells (prismatic 53Ah) grouped in four blocks connected in series.
- BMS (Battery Management System)
- PTC (Thermal Management Board)
- Contactors compartment (safety feature)

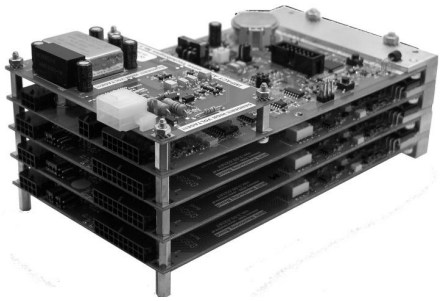


Pic.2 Overview of BP components location

Each block of cells (9 in this pack) has a separate heat exchanger, which is in the same way the construction component for the cells itself. Temperature of a heat exchanger is monitored by BMS (each block has distributed sensors) and kept within range by sophisticated circuit of Peltier cell and water flow. PTC board controls the heat flow to the cells in both directions – system can cool down or preheat the block of cells depending on BMS algorithm demands.

5 BMS

BMS is a heart of Battery Pack. The unit designed by Impact Automotive Technologies monitors Battery Pack cells' temperatures in order to protect them from overheating during discharge and proper charging current management during charging under 0 deg C conditions.
The analogue output line allows BMS to supply PTC board in case of battery temperature exceeding defined values.



Pic 3. BMS unit

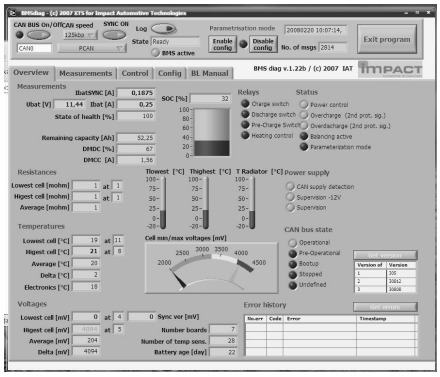
Over that BMS also introduce correction to the battery State of Charge dependent on the actual battery temperature (which is especially noticeable with zub-zero temperatures)

6 PTC controller

PTC board is a device designed to manage series of Peltier's modules used to control batteries stacks' temperature.
PTC read from BMS temperatures status and accordingly to temperature sensor location turns on thermal managing circuit proper for chosen stack.
In case of finding ambient temperature below zero deg C, BMS will not allow batteries to be charged at full power thus PTC will try to heat up all of them to let BMS disable the charging limitations.
In case of any cell getting too close to overheating level PTC will switch cooling circuit that will cool whole system down.

7 BMS Diag

To monitor and preset Battery Pack parameters a special software tool has been developed – a BMS Diag PC software.
The software allows to see and record live BP status and preview all calculations and measurements of voltages, currents, temperatures and other parameters.



Pic. 4 Screen from BMS Diag on PC

8 Achievements

Thermal management for lithium-polymer battery packs developed in Impact Automotive Technologies is based on specially designed Heat exchanger. System requires liquid heat evacuation (via fluid with external radiator and pump or forced air flow) but its performance is greatly increased in a comparison of passive usage of the cooling mediums. The source of cooling medium (pump of fan) can be also controlled from BMS providing adequate flow for current heat exchange demands.
The company conducted a series of test to properly set the parameters of thermal management control system according to specific cell's manufacturer demands. On the following diagrams the example of operation of system is showed (data from one block).

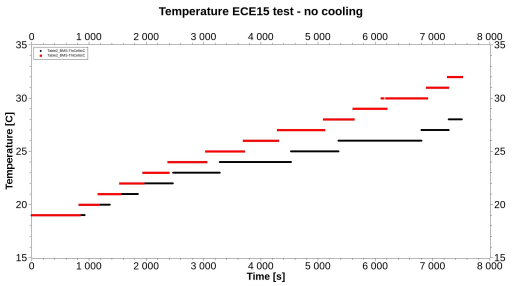


Fig. 3 Temperatures of lowest and highest cell during discharging with ECE cycle – thermal management is off

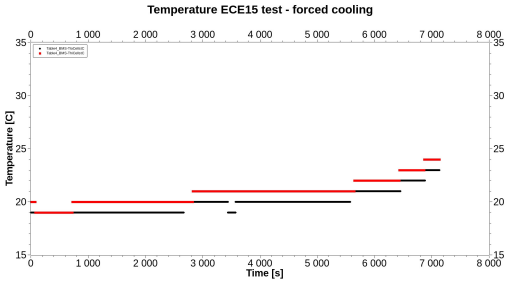


Fig. 4 Same block with cooling active

Results shows the ability of controlling the thermal behavior of a pack within desired temperature range.

9 Summary

Results of tests and BP prototypes shows the ability of controlling the thermal behavior of a pack within desired temperature range. On a base of SAM EV II experience, Impact Automotive Technologies can develop Battery Pack for SAM EV II has been industrialized and is manufactured as commercial product. Road test showed that battery pack is not affected by ambient conditions both in winter and summer and can deliver similar performance and distance to the car.

References

[1] Impact Automotive Technologies internal papers and patents

Authors

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