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High performance electric motorsport battery pack improvement based on distributed thermal management with thermoelectric modules

Bartek Kras
Impact Clean Power Technology S.A. Mokotowska 1, 00-664 Warsaw, Poland
bartek.kras@imotive.pl

Abstract

Electric motorsport high performance batteries are delivering power to a new class of sport electric cars. Cells are usually working with high discharge rates and battery have to utilize also a high regenerative braking current peaks. Without good and light thermal management system, battery performance can be limited during the race due to high cells temperatures. The solution is to manage the temperature of cell allowing high discharge rates for a whole race. An unique concept of active thermal management utilizing thermoelectric elements based on Peltier modules applied into motorsport battery pack design is presented in this paper.

Keywords: battery management, thermal management, BMS (Battery Management System),

1 Introduction

Electric motorsport is a new area of sport activities related to electric vehicles, where there is a chance for development of certain unique technologies which could be later use in normal road electric vehicles improving certain battery parameters.
Capacities of today's li-ion batteries are still insufficient to develop battery packs able to compete in races with classical sports cars in terms of range . However first vehicles has been built in different race classes with performance at least the same or better than corresponding combustion engine sport cars.

1.1 Electric motorsport BP issues

Development of battery pack for race vehicle is related to complete other types of load profiles and road conditions than "normal" EV batteries. There are several key issues related to cell performance, energy management, thermal limitations and mechanical design of the battery pack itself.

1.2 Performance demands

Impact Clean Power Technology has developed several battery pack technologies for a specialised racing cars maker and racing team – GreenGT. Vehicles has been build in several racing classes including classic GT body, sport concept vehicles and classic rally series EVs. Each of those cars had a slightly different demands related mostly to mechanical assembly and was equipped usually with same drivetrain.

Those vehicles were equipped with electric motors with powers between 150kW to 300kW.
Due to very limited space and weight in a sport car, the battery pack capacities were not exceeding 30-34kWh.
The current demands from the pack were on a maximum level of 750A.

1.3 Vehicles description

First type of electric motorsport vehicle was GreenGT 300, a GT bolid with a power of 300kW (two electric motors) and ultimate performance for regular racing together in other GT cars.

It has been equipped with 34kWh battery pack divided in two section.

Other type of vehicle was a sport concept vehicle having 200kW double electric motors and 31kWh battery

Third one was a classic rally EV with 150kW electric motor and 31kWh battery pack

2 Cells selection

One of a first goal was to select a proper cells technology to be able to match performance demands. In last couple of years a certain cells manufacturers developed cells dedicated to high performance application (i.e.F1 KERS systems with cells of abilities to deliver even 30C) but also with a lot of limitation like small capacities of single cell and low lifetime.

According to calculations for the battery, cells of a performance of 10C peak and at least 6C constant discharge were required. Another problem was a charge rate due to relative high regenerative braking current – it has been estimated for at least 3C capability.

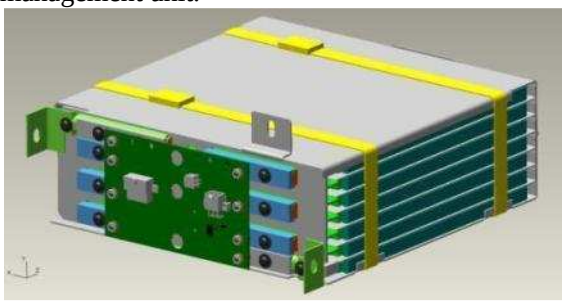
In ICPT labs many cells has been tested to select proper one for such a demanding application with large capacity flat prismatic li-ion as a winner.

Once the performance problem was solved, the new one arrived – very demanding thermal management and mechanical packing issues

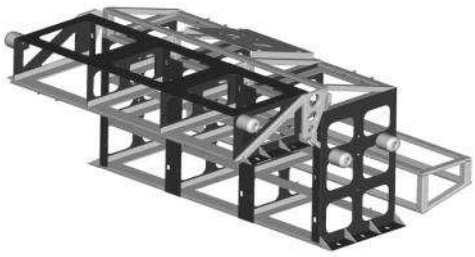
3 Mechanical constrains

The demands of racing cars in terms of mechanical limitation forced to develop a special mechanical solutions of battery pack design related to very limited space and strengthens of whole cells support.

Cells are grouped in block, which are individually managed electrically and thermally (usually 7 to 9 flat cells in one block). Front of a module is equipped with part of distributed battery management unit.



The blocks was placed in specially designed “cage” designed to meet space and durability requirements. Example of mechanical structure for modules is shown below:



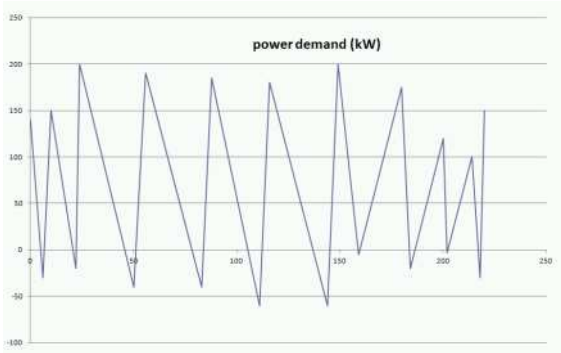
4 Energy management

Modules with cells has been equipped with specially developed distributed dBGS system able to manage cells in terms of electrical parameters measurement, safety, SOC calculation and calculating of dynamic power and current parameters for drivetrain. Electronics has been designed to meet also a special sport environment requirements as well as high EMC noise from the drivetrain.
Special task for dBGS system was also a energy management between multiple energy strings and providing sufficient safety level for the cells operation itself.

5 Thermal management

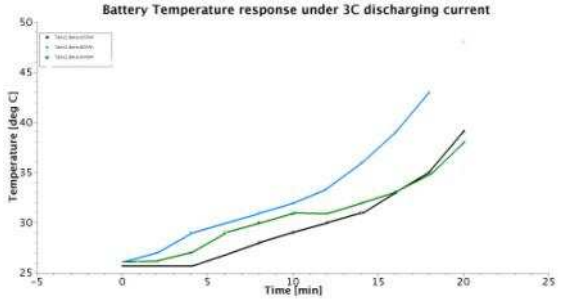
5.1 Load profiles

Typical load profile of racing car is completely different from the profile used to assess energy demands in road electric vehicles. The goal of the driver is to win a race getting from the car the maximum performance.
Simplified power demand profile of racing car is shown below



Most of the time the very high current is drawn from the cells resulting in its excessive heating.

As most of the time current is at a level of 3C, the cells are being heated in very accelerated way:

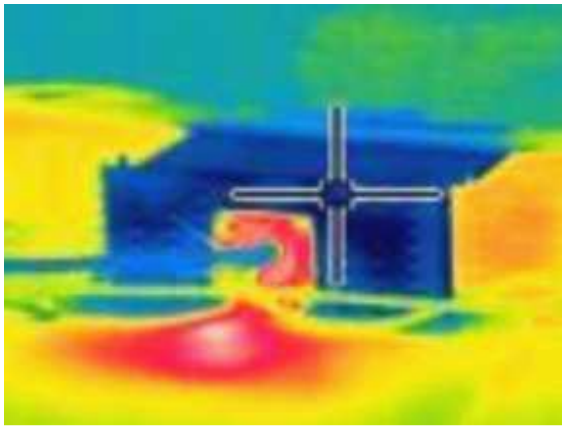


This effect results with limiting performance of the sport car and is also dangerous due to possible thermal runaway of whole battery pack.

5.2 A novel approach for motorsport

There are many ways of cool the cells in battery pack. In electric motorsport vehicles there is many constrains which are limiting use of already known methods like air or water cooling. A different factors has to be taken into consideration like air drag coefficient factor, very limited weight and space as well as thermal system performance.
A dedicated novel approach has been developed for electric motorsport vehicles based on thermoelectric modules working as a heat pump
Modules in battery packs are equipped with small heat exchangers with Peltier modules.

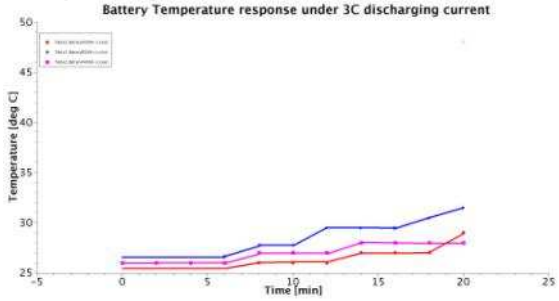
Peltier modules are controlled by dedicated power drivers which are connected to dBGS for gathering information about thermal management strategy.
By controlling the current of the Peltiers modules system can very precisely manage the temperature of cells.



Control algorithm receives the information of temperatures from set of distributed sensors and manages the cells in constant chosen temperature. Additional cooling liquid circuit is designed to

maintain proper temperature gradient between hot and cold side of the Peltier module on each stack of cells.
Such a design of local heat pump connected with relatively small and light water cooling circuit is able to cool the cells during whole race in very efficient way. It consumes a little energy from the battery but helps not overheat the whole system during ultimate performance.

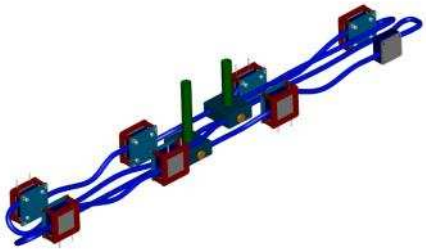
Cell thermal behaviour with thermal management present:



5.3 Battery pack design with thermoelectric modules

Incorporating thermal management system into battery pack in a sport car has been done by a special design of heat exchangers and improved thermal system around the cells in modules. Examples of motorsport battery is shown below:

It requires also a sophisticated water cooling circuits used for cooling hot sided of thermoelectric modules:



6 Conclusions

Distributed thermal management based on local heat pumps consisting of thermoelectric modules is greatly improving performance of motorsport battery packs. Thermal performance problems of li-ion cells especially in so demanding application like battery pack for motorsport are usually limiting the performance of the race car. After implementation of this method of thermal management, cells are kept during its operation in a safe temperature condition delivering ultimate discharge rates to the motorsport car drivetrian.

References

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Author

Dr. Bartek Kras
e-mail: bartek.kras@imotive.pl
Tel. +48 022 758 60 60

Bartek Kras, electrical engineer, works in Impact Clean Power Technology as VP and CTO. Received Ph.D. on Warsaw University of Technology. Worked on fuel cell based systems for stationary applications and vehicles.