Department of
ENERGY TECHNOLOGY
E.T.

AALBORG UNIVERSITY
DENMARK

Li-Ion Battery Pack

A Li-Ion modular battery pack was designed, built and installed in the former engine compartment (Fig. 1). Design considerations included factors as integration in chassis structure, weight and volume limitations, cells selection screening and configuration, capacity vs. driving range, voltage and current levels, power capability, thermal design, housing, internal and external interconnections, switch box design, Battery Management System (BMS) configuration, overcurrent protection and communications.

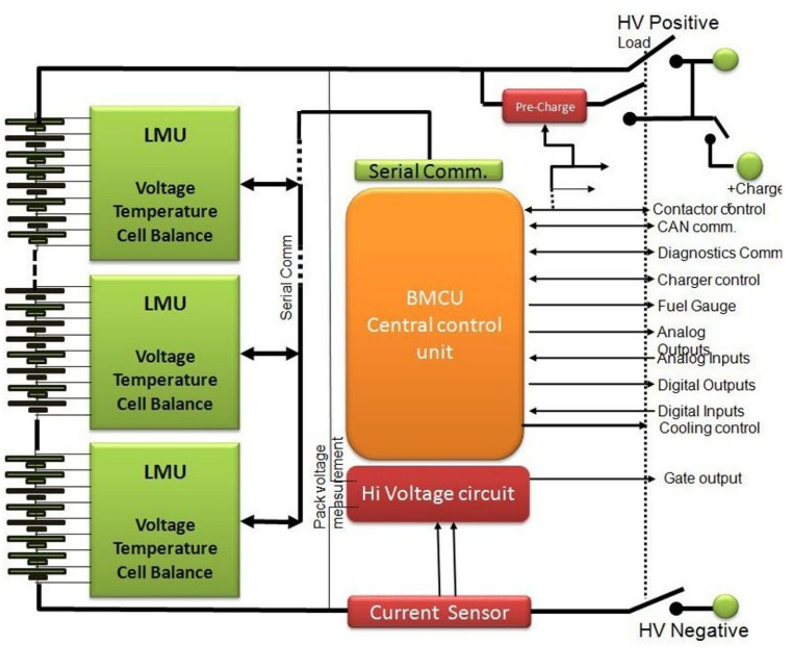


Fig. 1: Block diagrams of BMS and battery system.

System requirements

Specific system requirements were agreed at the beginning of the project: the drive set must be able to work as an integrated bidirectional charger, regenerative braking must be possible in conjunction with traditional friction-based braking, the driving range must be higher than 150 km, no major changes should be done in chassis frame, the BMS must ensure that the cells are operated within their Safe Operating Area, extreme temperatures should not be reached even under maximum vehicle performance and system must allow fast charging.

Sub-pack no. / Specification	1 to 4	5	Total
No. of cells in series	40	32	192
Nominal voltage [V]	148	118	710
Upper/lower voltage [V]	168/108	134/86	806/510
Rated capacity [Ah]	53		
Rated capacity [kWh]	7.8	6.3	37.7
Max. charge current [A]	106		
Max. discharge current [A]	265		
Weight [kg]	74	56	352

Table 1: Technical specifications.

Key figures

- 192 Kokam Li-Po 53Ah pouch cells connected in series.
- 5 sub-packs (4 x 40 cells + 1 x 32 cells) (Fig. 2&4).
- Higher voltage level than typ. commercial packs in order to avoid the DC/DC converter when the drive works as an integrated bidirectional charger (higher efficiency) (Fig. 3).
- State-of-the-art 1kV BMS by Lithium Balance.
- BMS architecture: modular, non-distributed.
- 24 Local Monitoring Units (LMUs), one for each group of 8 cells, connected in series to a Battery Management Central Unit (BMCU) (Fig. 1).
- Air cooling: fans installed beneath the sub-packs. There is a slight increase of cells surface temperature during full discharge at expected max. continuous discharge current.

Fig. 2: 3d CAD view of the sub-packs installed in the AAUDI.

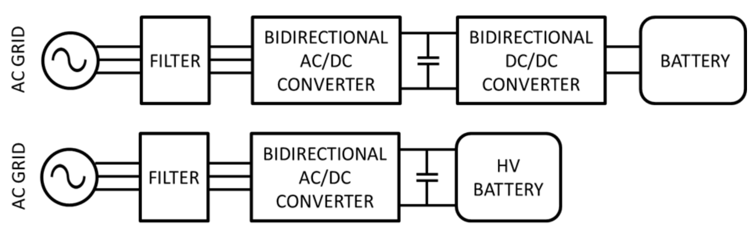


Fig. 3: Block diagrams of integrated bidirectional chargers.

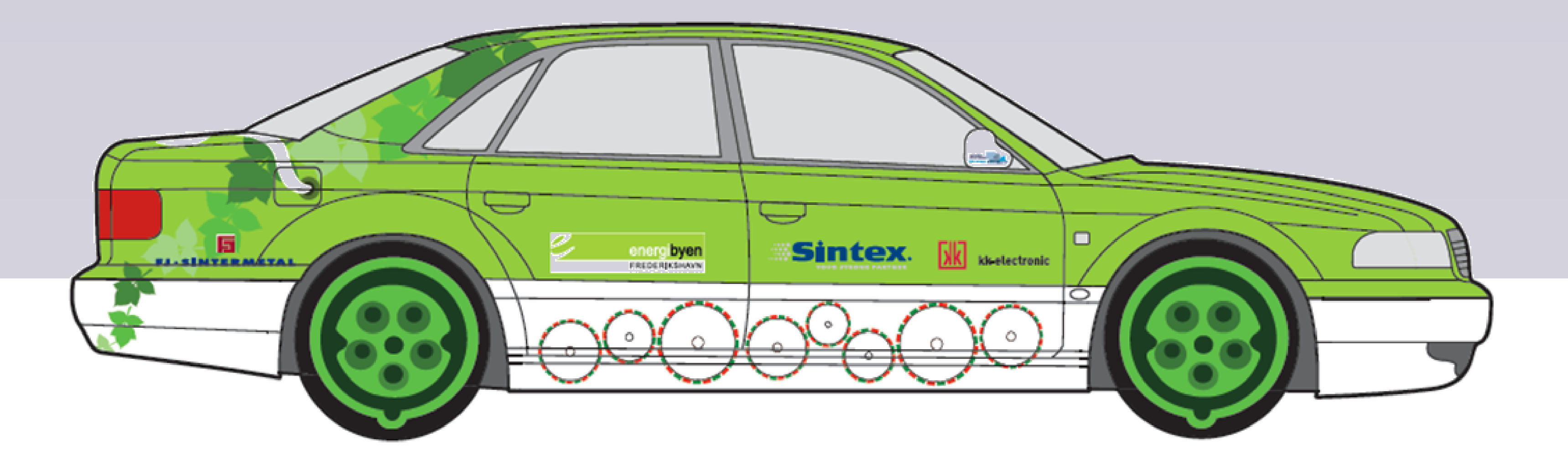
Results

A custom-made Li-Ion modular battery pack was installed in the front part (Fig. 4) satisfying the aforementioned design considerations and system requirements. A specific energy of 107 Wh/kg was achieved, similar to a Tesla Roadster and better than a Mitsubishi MiEV or a Chevrolet Volt.

Fig. 4: Views of the engine compartment: original Audi A8 4.2 Quattro (left), empty (center) and after conversion into AAUDI (right)

Outlook

Battery manufacturers are still facing many challenges. First of all batteries are expensive and therefore EVs are expensive too. Ways to decrease costs are advances in research and technology, economy of scale, novel ownership models, recycling and second use applications. However, due to expected further fuel price increases, the cost of the battery may be compensated step by step by overall energy costs. Calendar life, cycle life, abuse tolerance and performance issues (temperature window, energy and power capability) are also critical challenges, with the crucial problem in EV applications of the energy density and the specific energy.



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