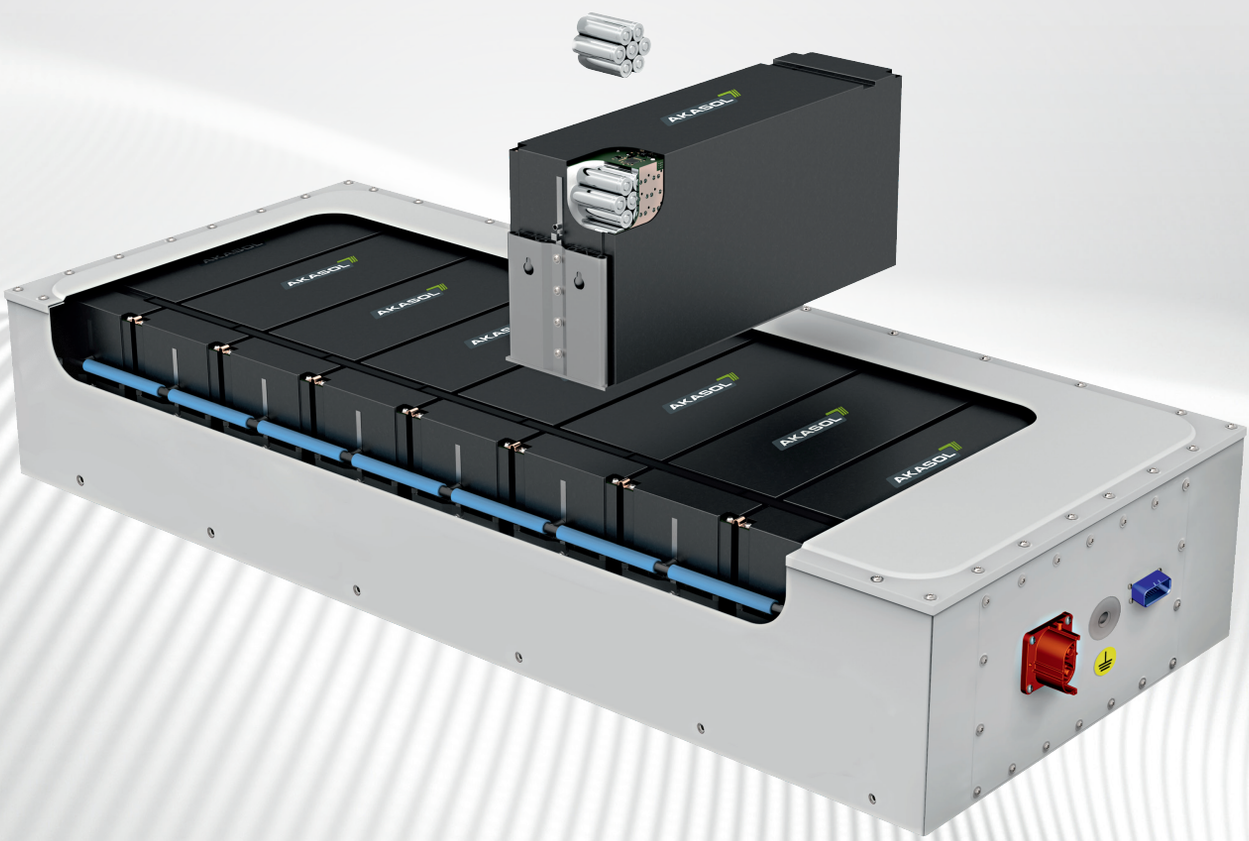
Ultra-High Energy Battery System for Electrified Commercial Vehicles

from BorgWarner



BorgWarner

Ultra-High Energy Battery System for Electrified Commercial Vehicles

BorgWarner's ultra-high energy battery system exploits the full potential of its Akasol battery technology to lower the total cost of ownership for electrified commercial vehicles.

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History and Background

Various battery formats and chemistries have been experimented with for vehicle propulsion since the early 1900s. However, the diversity of today's mobility solutions prohibits the development of a universal battery type to suit all applications. Instead, battery designs must become more specialized to meet the specific requirements of each sector. For example, the electrified commercial vehicle (eCV) market is experiencing rapid growth, since buses and trucks can improve sustainability by providing higher transportation efficiency compared to smaller vehicles. To properly realize these advantages, the power source needs to be tailored to the operational demands of each type of eCV.

Ideas for the development of a next-generation ultra-high energy battery pack date back to 2018, when BorgWarner visited major electric bus and truck suppliers to gain a thorough understanding of their future needs. In 2019, this resulted in the battery module design that now forms the major building block of the battery pack discussed in this paper.

Battery Optimization for eCVs

Compared to a passenger battery electric vehicle (BEV), an electrified commercial vehicle (eCV) demands significantly different priorities from its batteries. For cars, initial purchase cost, energy and power density are primary considerations, but for the eCV market, the total cost of ownership (TCO) is critical, and this largely depends on how many times the battery must be replaced throughout the vehicle's life. Mechanical robustness, longevity, compact dimensions, and light weight of the battery assume much higher importance for the commercial vehicle market, where continuous, long-term usage must be assured while keeping vehicle payload capacity as high as possible.

To address this need, BorgWarner has developed an ultra-high energy (UHE) battery system for energy intensive electric drivetrain applications operating at up to 750V. As BorgWarner's award-winning cylindrical cell (CYC) battery module already sets the benchmark for energy density in the eCV market, this is employed as the power source in the UHE battery pack. The new system provides battery life of up to 4,000 cycles. It is also sufficiently versatile to be matched to a customer's usage profile; cells can be optimized towards maximum power density to take advantage of quick charging stops (opportunity charging) for an urban bus, or they can be optimized towards maximum energy density for

long distance traffic such as buses using overnight charging facilities, intercity coaches, and trucks.

CYC Module: The Battery Pack Building Block

The design of the CYC battery module is based on the 21700-format cylindrical lithium-ion (Li-ion) cell. To achieve the high energy density required and the necessary charging and discharging power, the type of cell chosen is specially designed for professional and commercial applications with an additional focus on cycle life. Each CYC module contains 600 cells; in standard form, these are configured as 20 serial connections of 30 parallel-linked Li-ion cells, providing a maximum module voltage that is below the electrical shock threshold for safe handling during production and maintenance. However, alternative cell configurations are possible by altering the current path routing within the side PCBs of the battery module. The module achieves an energy density of about 221 Wh/kg.

Ultra-High Energy Battery Pack Specification

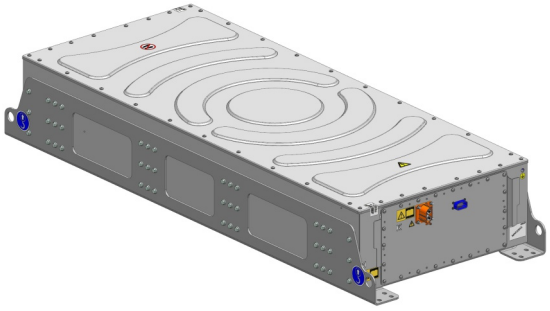
Nine CYC modules are connected in series to create a 9 AKM battery pack providing 98 kWh of energy. The nominal voltage output is 665 V, with a minimum and maximum of 520 V and 756 V respectively. The pack weighs 560 kg and measures 1,720 mm long, 700 mm wide and 300 mm high. This compact, energy-dense solution means that, for example, city buses and intercity coaches can be equipped with battery system capacities of 400 kWH to 1000 kWh depending on vehicle size - twice as high as the present generation of batteries.

Production of 6 AKM battery packs is also planned; these derivatives require low R&D effort, in essence simply scaling the length of the pack. The smaller packs could be used in conjunction with 9 AKM for vehicle applications where a mix of different pack sizes would make the most efficient use of available installation space. Mixed pack sizes can be handled with ease by the Akasol multi-string battery management technology.

Battery Management and Cooling

The Akasol battery management system consists of an in-house developed battery management unit (Master) & cell supervising circuits and their corresponding software. It provides primary safety functions including over-temperature, over-/under-voltage and over-current protection but also performs detailed diagnosis of all actuators and sensors as well as innovative high level battery management functions, e.g. battery state estimation.

The UHE battery pack is equipped with extremely effective liquid cooling at module level.



Battery System 9 AKM 150 CYC

Module with cylindrical lithium-ion cells

This is indispensable for safety, providing even temperature distribution and operation within the preferred temperature range, and also for performance, ensuring high availability of power and energy, and contributing to slow aging and long life of the battery cells.

Safety in Operation

The main safety consideration during battery pack development was the prevention of any fire or explosion hazard. A combination of active and passive safety devices at both CYC module and battery pack level provides maximum protection against fire propagation resulting from a thermal event.

Within the CYC module, each cylindrical cell is physically separated from the next by a defined gap, that results from deep evaluations by simulation and validation, and covered by an optimized potting compound. In the unlikely instance of a thermal event occurring at cell level, this prevents thermal propagation between neighboring cells and allows controlled and safe dissipation of hot gases. Adjacent cells inside the module or in the neighboring module are not triggered and do not even change their state of charge; in fact, the battery system is equipped with a special thermal runaway detector (TRD) that monitors the internal pressure, cell temperatures and voltage behavior to identify a single cell thermal runaway within a pack. Furthermore, the wire bonded cell connections to the side PCBs act as a cell individual fusing concept in the case of an internal or external short circuit. Adjacent CYC modules are separated by fire retardant materials to additionally prevent fire propagation from module to module.

Further software and hardware safety elements are incorporated at battery pack level. The CYC module combines a rigid steel construction with further bracing elements between the modules. A durable stainless-steel housing protects the complete battery pack against damage in a crash situation. The system is also shielded from external thermal loads such as a fuel fire by surrounding the battery cells with sufficient thermal insulation material to protect against environmental hazards. An efficient cooling system and predictive algorithms within the battery management system software add a further layer of safety.

The intrinsic safety of the UHE battery packs is proven in use, as the first buses and trucks to be equipped with them have been running in major cities since 2020 without incident.

Charging and Maintenance

The UHE battery pack can be charged, dependent on cell type, at a rate of up to 1C with quick charging and is also suitable for use in fast charging infrastructure up to 500 kW power on vehicle level. All significant electronic parts aside from the CYC modules are placed in a removable contactor box. In the unlikely event of a field failure due to a fault in the battery electrics or electronics, the unique service concept of the UHE system allows this electronics compartment to be exchanged easily without the need for high-voltage trained technicians or the necessity to demount the battery pack from the vehicle.

Environmental Sustainability

BorgWarner’s UHE battery system is rated as a highly sustainable battery solution according to a TÜV (Technischer Überwachungsverein) audited calculation method in Germany. Several factors can be cited to demonstrate its sustainability:

- Lightweight solution: Increased energy density reduces the total weight required for the battery system, which has a positive effect on the vehicle's energy consumption.

- Longevity of battery cells: The very high cycle life of carefully chosen battery cells is extended by intelligent mechanical and thermal integration and sophisticated sensors. In the TCO-driven commercial vehicle business, maximizing the first life application of the batteries reduces the number of battery changes required throughout a vehicle's lifetime. Moreover, the environmental sustainability (e.g. CO_2 footprint) is maximized by energy density.

- Extended circular value stream of the batteries: This includes maximum recyclability of the raw materials, and/or finding second life applications for used batteries. For example, earlier generation battery systems can be taken back from OEMs and repackaged into stationary storage applications to serve the economy for another decade.

- Higher availability of energy from the vehicle's batteries: The consequent increase in operational range facilitates further intercity bus and light-, medium- and heavy-duty truck applications to be electrified, replacing internal combustion engines and reducing dependency on fossil fuels.

Summary

Mechanically robust, intrinsically safe, easily scalable and offering relatively low invest costs per kWh, BorgWarner's ultra-high energy solution for long distance transport sets new energy density standards for bus and truck applications and firmly positions BorgWarner as an innovation driver in the field of high energy batteries.

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