ALBATROSS

Advanced Light-weight BATteRy systems Optimized for fast charging, Safety, and Second-life applications

SEPTEMBER

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This project received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No 963580- ALBATROSS

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This newsletter aims to provide an in-depth look into the developments of the activities carried out for the different tasks of Work Package (WP) 4. We hope that you enjoy to read and know about them, as much as we have enjoyed working on them!

Battery Management System

The Battery Management System (BMS) consists of 2 main components: Battery Master Unit (BMU) and Cell Monitor Unit (CMU). The Battery Management System is built up in a "Master-Slave" architecture. The CMU controllers shall be placed on the cell modules and only communicate to the BMU by communication lines.

The Battery Master Unit (BMU) is the central controller of the system, through an electronic board which houses necessary microcontroller unit, communication circuits, load drivers and many other electronic circuits for related functions. The BMU will interact with other boards and components of the battery, such as the Cell Monitor Modules and other corresponding controllers. The BMU controls high voltage path components such as main contactor, pre-charge contactor and also controls thermal management components such as heater, cooler, pumps, etc.

Cell Monitor Units are responsible for the related tasks and have required circuits and components for monitoring and balancing the circuits. CMU also has circuits for performing Electrochemical Impedance Spectroscopy (EIS) measurement and communicating within wireless link to the BMU.

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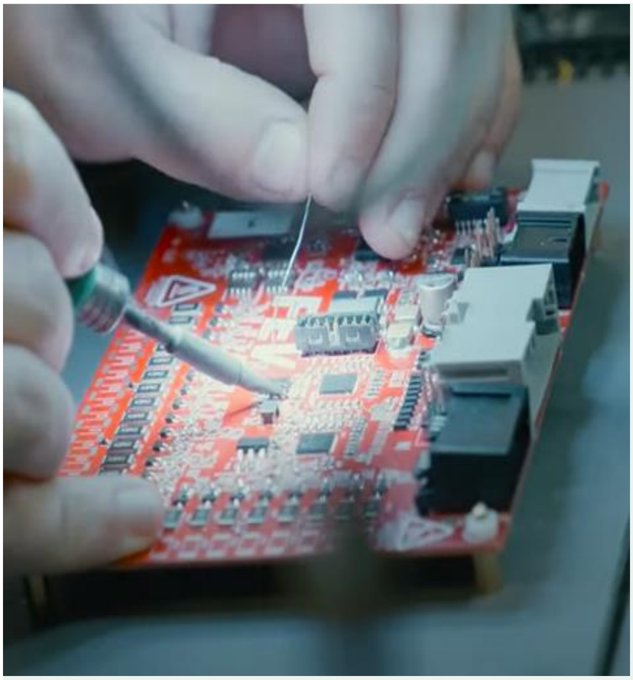

The BMU will be responsible for the functions:

- State of Charge (SOC)
- State of Health (SOH)
- State of Power (SOP)
- Contactor Control & Monitoring
- Cell & System Monitoring
- Vehicle Interface
- HVIL & Isolation Monitoring
- Diagnostics/OBD
- Thermal Management
- Cell Balancing
- Error Handling

The CMU will be responsible for:

- EIS test control and monitoring
- Cell voltage/temperature measurement
- BMU communication

Accurate knowledge of battery SOC is not only useful for EV range determination and trip planning but also essential for the BMS to ensure battery reliability and safety.

Many approaches have been investigated for SOC estimation such as Artificial Intelligence (AI) methods that have shown strong robustness against dynamic loading, nonlinear dynamic nature, aging, hysteresis, and parametric uncertainties.

AI methods present better battery SOC estimation in comparison with other methods and also a high estimation accuracy. A hybrid SOC estimator taking the advantages of the AI based approach and a model-based filtering approach is proposed to estimate the SOC.

The model-based filtering approach will be the Kalman filter, which has been successfully used for state estimation in a range of industrial applications. The Kalman filter was therefore employed to estimate the battery capacity in ALBATROSS.

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The accurate SOC estimation can greatly improve the power distribution efficiency and is the premise of the accurate estimates of the battery peak power capability.

Accurate peak power estimations are critical in practical applications, since it is necessary to determine the power available in the moment to meet the acceleration, regenerative braking and gradient climbing power requirements, without fear of over-charging or over-discharging the battery. Model-based approaches will be used to estimate the State of Power (SOP).

The performance, life and safety of the battery are very sensitive to temperature. The temperature change of the batteries is usually inevitable, because they can be affected by ambient temperature and release heat during charge and discharge.

Efficient thermal management should maintain the proper temperature range and prevent high temperature gradients during the charge and discharge.

The BMS will ensure a homogeneous temperature distribution across the cells. The temperature difference between cells shall be less than 5°C. In addition to that, the cells should be kept between 20°C and 35°C to avoid any adverse effect to the battery.

Temperature sensors collect the temperature of every single cell in the battery and provide these data to the CMU. The BMU evaluates the required cooling power according to the cell temperatures with its intelligent thermal algorithm and demands cooling from the Vehicle Control Unit.

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The BMS will monitor the difference between the coolant inlet and outlet temperature and monitor the difference between average coolant temperature and average cell temperature. If the coolant temperature is 5°C lower than the coldest BEV battery cell temperature, the BMS shall deactivate the battery e-pump. The BMS should manage the cooling loop by controlling the valves that are required for the battery heating/cooling.

From a thermal management point of view, the BMS shall:

- *Monitor the temperatures inside the pack*
- *Provide temperature information on CAN*
- *Calculate the actual battery temperature by taking the average of the temperature value for all slave modules*
- *Control cooling/heating power based on cell temperature*
- *Estimate cool down/warm up time duration that is based on the available charging power*
- *Calculate the cool down/warm up time prediction from current cell temperatures*
- *Indicate if the temperature of the system is very high or low*

High temperatures might negatively affect battery health while low temperatures might negatively affect the maximum power transfer. Since the maximum power transmitted is dependent on temperature, to predict the total charge time, the temperature should also be predicted. Therefore, a temperature prediction algorithm was developed.

The battery surface temperature data was analysed since it is easier to find and easier to measure, although the internal temperature can also be estimated using the surface temperature and a thermal model of the battery. This last estimation was not used since the difference between the internal and surface temperature in cylindrical cells can be ignored.

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If the cycle can be predicted, the temperature can also be predicted. Therefore, the most used cycles must be known, such as fast charging cycle, or other cycles such as WLTP, NEDC and home-work cycle, in-between others.

The user's personalized cycle are logged and transferred to a cloud-based system to make long term predictions and for each drive cycles, different algorithms shall be trained. AI based prediction algorithms are being used worldwide and will be used in ALBATROSS to forecast future temperatures. As for the Anode Controlled Fast Charging, a PID controller will be used for charging optimization. For the State of Health (SOH) estimation, the concept of the on-cloud AI-based SOH estimation is already defined, and a preliminary software architecture was prepared.

During operation, vehicle online measurements including battery voltage, current and temperature will first be saved in the vehicle data storage device. Then, when an internet connection is available, the collected data will be transferred onto the cloud service. It is then processed according to the demand of the SOH estimation algorithm and used as input in the main software structure.

The machine learning (ML) algorithm will be trained offline and it will calculate parameters of capacity and resistance, and determine the SOH by comparing the present value with the beginning of life (BOL) value.

Overall, the requirements for the AI-based SOH estimation software are already defined and in general, they include training of the algorithm, online cloud operation and recalibration of the algorithm.

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