Avoiding Thermal Hotspots in Automotive Battery Systems using a Multiscale Full Vehicle Model

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Local overheating zones, so called hotspots, can occur at various points in electrified vehicles e.g. on contactors, fuses, bus bars, in battery cells or in proximity of exhaust systems for PHEVs. They may be caused by an inadequate thermal system design, a cooling system failure, an electric overload or a component defect. Hotspots can lead to losses in system performance, to premature aging of battery cells, to a system failure, or even a thermal run-away of individual cells. Thus, designers aim for a holistic and consistent thermal design avoiding hotspots.

In this work high dimensional component models of battery cells forming an automotive battery system are integrated in a full vehicle simulation to get all the feedbacks of a real vehicle. The high dimensional models (HDM) can be used for several battery types and arbitrary geometries. The HDM´s implementation is done within the open source framework OpenFOAM using a finite volume discretisation. The physical domain is described by an electro-physical coupling. Using experimental data and the general approach of [1] for describing the heat source as a function of current, temperature and SOC the HDM has been validated. Still, estimating the potential of different thermal concepts, battery connections, types and sizes in the context of a full vehicle that performs highly dynamical driving cycles in different climate conditions, requires a model reduction of the HDM. Based on the Proper Orthogonal Decomposition a reduced order model (ROM) is derived. It provides a huge advantage in computational time while leading to almost negligible deviations of the results compared to the HDM. Nevertheless, the ratio between accuracy and computational time is adjustable due to the upcoming requirement. Transforming either the HDM or the ROM into the international FMI standard [2] a simulator independent model is generated allowing interdisciplinary exchanges as well as multiple connection possibilities. Connecting the battery models electrically and thermally a modular battery system can be derived. By integrating the battery system into a full vehicle model a holistic examination of the temperature distribution in the battery cells within realistic driving scenarios including all feedbacks from the full vehicle e.g. controller influence is possible.

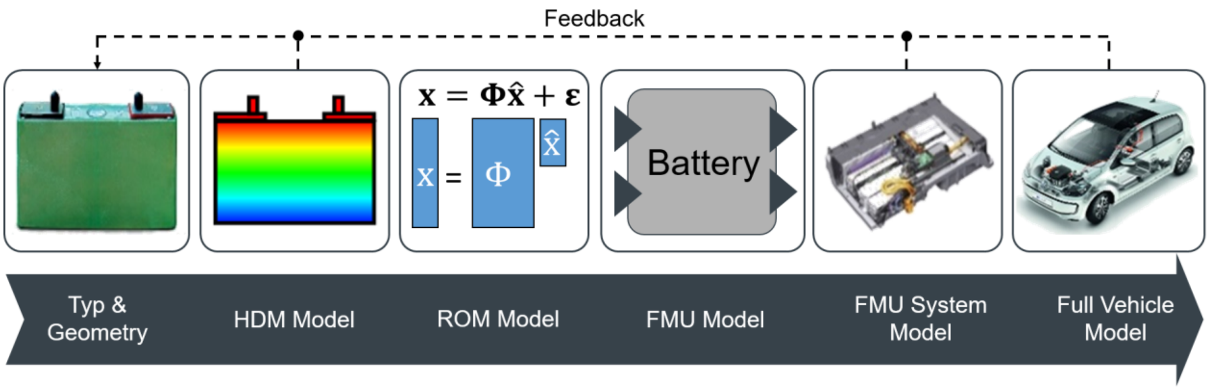

Figure 1: Process chain for the development of a holistic thermal design of electrified vehicles

References:
1. G. Karimi, X. Li, *Int. J. Energy Research* (2013), 37: 13-24
2. https://fmi-standard.org, called on 13 December 2018