Optimization of scalaBle rEaltime modeLs and functIonal testing for e-drive ConceptS

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2 Publishable Executive Summary

This document is the 4th of in all seven deliverables in WP 5. It fulfills several aspects within the story line of WP 5. This deliverable

- contains the final aspects of methodology development to ensure safety and reliability of the considered drivetrain components. In that course, together with the previous deliverables D5.4
- in that sense, this deliverable together with the previous ones defines the baseline methodology that will now be fixed for application to the power train components
- contains baseline reliability/safety data for the battery, which is considered to be the major player in the overall safety/reliability issue. These data will serve as a basis

The D5.4 will therefore serve as the prerequisite for the actual reliability and safety evaluation which will be presented in D5.6 and D5.7.
The set of methodologies will be regarded as the methodological baseline for the final stage of the project. The verb "to baseline", in general, refers to the act of placing an approved item under formal change control. In case of Obelics, and especially for this deliverable, this term was enhanced to the methodologies used and defined until this deliverable as well as the data gained on the undegraded state of the considered subsystems.
On this background, the main results presented in this deliverable revolve around the finalization of all methodologies and the presentation of baseline data for selected subsystems, especially the battery, which is considered the main subsystem affecting the safety/reliability question. In particular, the deliverable shows as follows:
System level approach: On system level modeling it is shown that various possible electric faults can occur in an electric drivetrain: e-motor winding short circuit, broken rotor bar for Induction machine, short circuit in the inverter, etc. In system level models, artificial failures can be introduced in the different electric subsystems to evaluate the impact on the other components, and to validate safety control strategy at subsystem level as well as at system level.

Hazop analysis: Due to the criticality of certain vehicle subsystems for the whole safety capability, braking system is used as reference for the definition and the application of criteria for safety assessment. In this document, an approach based on ISO26262 guidelines has been presented, showing the preliminary FTA according to the architecture of the system. Next steps include the definition of model modifications appropriate for the implementation of fault injection procedures; final aim is to provide a virtual Hazop study, whose results are expected to:

- Identify system criticalities, if any
- Estimate vehicle performance under degraded conditions
- Develop and validate fault management procedures.

The model updates needed for the Virtual HAZOP applications have been defined, in order to provide general indications for the adaptation to other vehicle or mechatronics systems.

Virtual reliability assessment of batteries – undegraded state: The system of implicit first order differential equations was solved numerically with the Newton-Raphson method. The results are presented for several different boundary and initial conditions. The results were generated for the fixed potential difference between solid and electrolyte, since the constant current regime model is much less physically relevant for the single active particle. The presented single particle model is designed for implementation in the Newman based electrochemical model, which was developed in WP2 and described in Deliverable 2.1. The introduction of such a model to the electrochemical model of a full cell will enable the determination of the initiation of thermal runaway of the cell in the temporal as well as the spatial domain.

Simulating and evaluating vibrational loads and their impact on reliability: Rough road vibration profiles from vehicle were transferred to battery level via a vehicle model. This way more realistic loads than pure standard reference profiles could be generated. Additionally, an eigenmode analysis was done on different implementation levels of the battery:

- Complete Battery
- Battery module only
- Empty battery tray

The main goal of this investigation was to have a deeper understanding of typical battery pack eigenmodes and stiffness contribution of different sub-assemblies. As a result, it was found that the module alone has a rather high damping coefficient and therefore eigenmodes are either difficult to notice or happening at high frequencies, which means potentially not excited through road excitations in a battery pack. The pack without modules had on the other hand eigenmodes with low damping factor (1% @80Hz) at low frequencies. Adding back the modules in the pack showed a drop of 30Hz for a specific mode but an increase in damping coefficient for all modes due to the soft materials used in the assembly.

Baseline data for battery safety: Safety with regards to traction batteries is a very wide field. There are imminent technology risk as electrical hazards but also thermal (fire, explosion) and chemical hazards. In order to get comprehensive overview about the state of the art of safety regarding traction batteries a standard catalogue for safety functions and safety focused design is set up.
As a basis for this work the failure modes of Fraunhofer LBF probFMEA was considered (refer to [LBF]).
Additionally, a further research for technology risks regarding safety was done in a workshop with AVL experts.
The evaluation was resulting in a set of state-of-the-art counter measures to mitigate technology risks.
In the last step the resulting set of failure mitigation and containment measures was reviewed on the example of two of the latest reference designs from AVLs Battery Benchmarking program. A rating system was developed to be able to categorize safety quality of the reference batteries. This way an external reference was established to compare OBELICs progress to and omit project internal bias.

Finally, this deliverable contains a thorough recommendations section showing the remaining steps within the project towards the final proof of fulfilment of the main demand of safety improvement by a factor of 10.

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Project partners:

Partner no.	Partner organisation name	Short Name
1	AVL List GmbH	AVL
2	Centro Richerche Fiat SCpA	CRF
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