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

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Publishable Executive Summary

This deliverable is the third deliverable of WP 5. It is the endpoint in the development of the methodologies to be used in WP5 for reliability and safety assessment. Therefore, this deliverable together with the two previous deliverables 5.1 and 5.2 will in sum show the finalized methodological approach.
These three deliverables will be the basis for the upcoming analyses. In D5.4, the baseline of the considered OBELICS subsystems of the power train will be analysed with the methods presented so far. Based on that, D5.6 will contain the results of the analysis based on the OBELICS improvements in modelling and system integration approaches achieved especially in the WPs 2 and 3.
In order to achieve a thorough reliability and safety analysis of complex systems like electrified power trains, sophisticated methods are needed which address the reliability and safety issues which will be specific for the main subsystems of a power train, in particular the HV-battery, the inverter and the e-machine. Finally, holistic system approaches are necessary to combine all findings on subsystem level to a final reliability and safety analysis valid on powertrain level. A third prerequisite for a reliable and safe system is the implementation of advanced on-board real-time diagnosis features, especially for the HV-Battery. In OBELICS, it is planned to reach these goals by enhancement of existing tools like FMEA as well as the creation of novel methodologies like impedance spectroscopy for batteries. The following are the key results presented in this deliverable:

1. Probabilistic FMEA: As introduced in OBELICS deliverable D5.1, the novel approach of the 'probFMEA' (probabilistic FMEA) extends the classical FMEA and the advanced graphically supported FMEA, based on a qualitative representation in failure nets, by algebraic expressions that allow for its probabilistic evaluation. In short this means, that the main content of an FMEA, which is given by the systematic descriptions and models for failures of components, their resulting malfunctions and (possibly critical) consequences during the operation of a system can be evaluated in numbers of the form of probabilities of causes and their effects. In this deliverable the full explanation including the mathematical background is formulated.
2. Functional safety of embedded software: In the UC3.4 to enhance the functional safety of the FO demonstrator vehicle a holistic approach that considers minimizing the error in each phase of the software development cycle together with hybrid redundancy is proposed. In this context ISO26262 recommendations and standardised templates (e.g. IEEE) and tools are integrated to the development process. In terms of the assessment of the functional safety also a more formalised and standardised process that encompasses software-based fault injection with quantified requirements tracing is proposed. In the following stage of the project to demonstrate the safety enhancement ability of the targeted electric vehicle class different vehicle configurations will be considered.
3. Methodologies for assessing ageing, overloading/thermal effects of batteries: The aim of the present task is to follow ageing (degradation) of commercial LG 811 NMC-graphite batteries by using electrochemical impedance spectroscopy (EIS) combined with Post Mortem Analysis of battery components extracted from batteries that exhibited considerable degradation of electrochemical performance. In order to accomplish this goal we need to carry out several necessary research pre-steps. It is required to identify and map out the main impedance features of these types of battery systems.
4. Impedance estimation into safety concept: The method elaborated here is characterized by an electrochemical impedance estimation of a Li-ion cell using a cheap and compacted embedded electronic system. Tests were performed bringing the cell under test (and its coupled electronics) at various temperatures, by means of a climatic chamber, to determine what and how changes regarding its impedance response. The residuals obtained by comparison of the estimated impedance and the one retrieved by the model of the cell (RC-series model), available in the CEA's database, in order to prevent dangerous states of the cell, were characterized.

With the results presented, the methodological approach to characterize reliability and safety in OBELICS is completed to a large extent. The points 1 and 2 address the system-related overall approach aiming at combining

the subcomponent-level findings to a holistic summary of safety-related properties. The aspects described in 4 and 5 are dedicated to the HV-battery, the powertrain subsystem with the strongest impact on safety (in the view of OBELICS). Result 3 describes the methodology of assessing ageing, overloading and thermal properties of batteries, while 4 addresses the monitoring/diagnosis concept based on these findings. The latter is able to perform an online/on-board and real-time diagnosis of the SoH of the battery and therefore is believed to play a key role in the overall safety concept discussed in OBELICS.

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