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

EUROPEAN COMMISSION
Horizon 2020
GV-07-2017
GA # 769506

Deliverable No.	OBELICS D 4.1	
Deliverable Title	Test specification for HF-inverters with e-motors	
Deliverable Date	2018-09-28	
Deliverable Type	REPORT	
Dissemination level	Confidential – member only (CO)	
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Status	Final	2018-09-28

Public/Publishable Summary

Facing a competitive amount of alternative energy, E-mobility will replace combustion drive-chains more and more in the next years and decades – with respect to environment protection. Presently, there is a „mega-boom" in China, doubling of sold E-cars in Germany compared to the year before and even a huge increase of E-mobility in the USA (Focus online, 19.01.2018, 12:00).
The demand of highly efficient E-cars and a narrow mesh of service stations is tremendous. This market is strictly competitive and Asian producers, as Toyota, do have a development-advance of about 10 years compared to those in Europe. Therefore, the need for efficient test methods and devices, which are supporting the research and development activities of European automotive manufacturers is obviously.

Within the Horizon 2020 program of the European Union, the OBELICS (Optimization of scalaBle rEaltime modeLs and functIonal testing for e-drive ConceptS) project refers exactly to this topic - that means to functional testing and test/system integration of battery, E-motor and Invertor. The present report focusses on the creation of requirements, test methodologies and validation / testing of all the functionalities developed all along the development process in order to shorten the time between design and test, simplify the handling of scalable real-time models for the purpose of testing and reduce the effort for transformation of testing methodologies in different stages of the development process.
The objective regarding to requirements is the efficiency increase of system engineering testing to increased improvement of test case generation and its management. These requirements are defined implicitly within the models (V-model) or are only loosely coupled. Aimed are: An improved degree of automation, a reduced set of test overhead, Project collaboration within Europe becomes more straightforward.

With view to a high quality of the undertaken R&D activities, several use-cases (UCs) were implemented, where similar ones were bound together to use-case clusters (UCCs). The whole project is developed along these UCs.
Moreover, a unique OBELICS-use-case contribution matrix was installed, which allows in steps of work-packages an interacting comparison of methods and results of all parallel developed UCs, resulting in discussions and conclusions. The implemented UCCs are following:

- UCCs 1 & 2 Complete Systems (incl. E-Motors): New e-drive concept & component sizing in earlier design phase (scalable models); E-vehicle system integration, optimization with real world verification (model-based testing)
- UCC 3 Batteries: Battery design and testing for improved safety & reliability
- UCC 4 HF-Inverters: E-motor, control and inverter design & testing

Work-package 4 (WP4), which is regarded here contains requirements, designs, test methodologies, and executes first well-defined tests. The test environment covers all tests, starting from MiL to SiL and furthermore the HiL, ViL, PiL via XiL test cases for HF-inverters in combination with e-motors and batteries and its infrastructure.

The investigated methods and results are manifold, as twelve high-sophisticated project partners are delivering contributions to this report. Representatively, the following three examples may illustrate the contributions of the tree named UCCs to the WP4-activities:

UCC 1&2: Real-time (RT) simulator will be used to virtual testing, meaning such model must comply with test equipment constraint as well as simulation constraint. RT capability has been defined in (Ponchant, Barella, Stettinger, & Benzaoui, 2017) by the fact the simulator is able to calculate and communicate with external connection within the real time step for each integration step.
Amesim RT simulator can correspond to some specific component like the inverter up to the full vehicle model and can be directly exported or through FMU with RT but in any case must run with fixed step solver. Integration step should be as high as possible in the limit of the test frequency sampling. For inverter purpose, this frequency can reach 20 kHz, meaning integration should not be higher than 10 µs for inverter model. Nevertheless for complete vehicle environment integrated not only component from WP2 but also component from WP3, test frequency sampling will be much lower allowing Amesim model to run with high integration step.

With FMU, there is no more need to use Simulink coder to generate binary file for real-time target. The real-time platform are already available (Concurrent SimWB 32 bits & 64 bits, dSPACE SCALEXIO, ETAS LABCAR 32 bits).
Configuration parametrization for compilation utility is available within Amesim. There is a long list of real-time target already available. We can also notice additional real-time platform could be integrated.

UCC 3: The main purpose of the method that CEA will develop is the estimation of the electrochemical impedance of a battery-cell, exploiting an active excitation technique (Galvano static excitation) performed by the electronics itself. The addressed frequencies of impedance identification process are in the bandwidth between 5 Hz and 5 kHz.
The impedance estimation will be the result of a broadband frequency-based signal processing technique taking as input the acquired voltage variation of the cell and the identification current (which is measured too). The identification current usually goes from 100 to 400 mA and has a particular shape and duration meant to address some specific frequencies. These two signals, current and voltage, are acquired by the ADCs of the embedded microcontroller. One microcontroller per monitored cell is necessary. Please keep clear the difference between the current cited above, switched from the cell and measured with specific electronics, and the motor current, which we can neither control nor measure.
A precise and robust cell impedance estimation is obtained through this method, and one of the goal in OBELICS project is to exploit at best this accurate impedance estimation, for example for safety purpose.
The knowledge of a precise and robust cell impedance value, in real time, might also be used to elaborate a SOH indicator and/or a maximum available power indicator.

UCC 4: For E-motor control and inverter design and testing the AVL PowerHiL apparatus is applied. Specific to the AVL PowerHiL E-machine emulator is an uncompromising 4-quadrant operation with an exact engine modeling in real time. Thus, the emulators are suitable not only for easy performance testing of inverters, but also make inverter tests a substantial substitute for traditional load systems. The profound modeling method of AVL PowerHiL enables the electric motor in your physical expression faithfully to be a "Power hardware-in-the-loop" map, which is available as a "virtual e-machine". Compared to the previously used typical arrangements with load machines, we’ve got here much more possibilities for error-stimulation and manipulation of the virtual machine - even at runtime with a realistic load. In addition, there is no mechanical danger from rotating parts.
Compared to conventional testing equipment, the motor provides emulation for product development, integration and validation of significant advantages:

- Time saving due to rapid change in the test variables / tests without pattern designs.
- Increased safety without rotating / vibrating components.
- Security of tests by electronic limitations.
- Energy consumption advantage by recuperation.
- Improvement through precise emulation and broad test coverage.
- Increasing of the test coverage in an earlier development phase.

Additionally, requirements resulting out of high frequency technology behavior of the inverter will be reflected to the used virtual motor model. An elaborate load cycle definition for testing of present real and coming high dynamic behavior for an inverter and the according test specifications will be worked out.
The final target is to have maximum validation coverage of the new technology combined with minimized cost and time efforts.

8 Acknowledgement

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Table 29 Project partners

Partner no.	Partner organization name	Short Name
1	AVL List GmbH	AVL
2	Centro Richerche Fiat SCpA	CRF
3	FORD Otomotiv Sanayi Anonim sirketi	FO
4	Renault Trucks SAS	RT-SAS
5	AVL Software and Functions GmbH	AVL-SFR
6	Robert Bosch GmbH	Bosch
7	SIEMENS INDUSTRY SOFTWARE NV	SIE-NV
8	SIEMENS Industry Software SAS	SIE-SAS
9	Uniresearch BV	UNR
10	Valeo Equipements Electroniques Moteurs	Valeo
11	Commissariat à l'Energie Atomique et aux Energies Alternatives	CEA
12	LBF Fraunhofer	FhG-LBF
13	FH Joanneum Gesellschaft M.B.H.	FHJ
14	National Institute of Chemistry	NIC
15	University Ljubljana	UL
16	University Florence	UNIFI
17	University of Surrey	US
18	Das Virtuelle Fahrzeug Forschungsgesellschaft mbH	VIF
19	Vrije Universiteit Brussel	VUB

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769506.