Real-Time Modelica Simulation on a Suse Linux Enterprise Real Time PC

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Abstract

This paper presents a real-time simulation system for a Suse Linux Enterprise Real-Time (SLERT) operating system workstation. With this system can be executed Hardware-in-the-loop (HIL) simulation. HIL is the integration of real components and system models in a common simulation environment. The main focuses of this simulation system presented in this paper are the development and the validation of simulation models of electric components (e.g. battery systems, electric drives etc.) for Hybrid (HEV) and Electric Vehicles.

The system is based on a Linux real-time computer with numerous analoge/digital input and output channels and all simulation models are implemented in Modelica using the for example the SmartPowertrains and SmartElectricDrives libraries. The models are simulated with the Dymola simulation environment for Linux.

Keywords: Real-time simulation, hardware-in-the-loop simulation, hybrid electric vehicle

1 Intoduction

Hardware-in-the loop (HIL) is a useful method for the testing hybrid and electric vehicles components and is important for the validation and the verification of implemented simulation models. The integration of real components and virtual models in a common simulation environment highly supports the development processes of hybrid and electric vehicle components like electric drive systems or energy storage systems.

At Arsenal Research vehicle models are implemented in Modelica using the powerful SmartPowerTrains and SmartElectricDrives libraries. These vehicle models can be simulated with the Dymola simulation environment. The proposed hardware-in-the-loop simulation workstation is based on a Dual CPU Xeon system with a SUSE Linux Enterprise Real-Time (SLERT) operating system. This operating system allows CPUs to be shielded from other processes and guarantees a highly deterministic execution environment. This system guarantee short response times and fast cycle times which are essential to meet the requirements of HIL simulations of for example electric drive trains. On this computer system can be executed standard Linux application such as the Dymola simulation tool. With the Modelica Real-Time Interface software, which was developed by Arsenal Research an interconnection between the simulation tool and I/O processes was realized. On this system sampling times up to 400 microseconds can be achieved depending on the complexity of the simulation model and the number of input and output channels. The I/O functionality of the HIL workstation is realized by data acquisition cards on which can be connected the high-power energy storage test bench and the high dynamic dynamometer. The energy storage test bench has a maximum charge power of 48kW and a maximum discharge power of 44kW at a maximum voltage of 600V. With the drive train test bed (dynamometer) can be tested electric drives with a maximum power of 110kW and up to a speed of 8000rpm. To connect Electronic Control Units (ECU) to the HIL simulator there exists also a CAN interface to the simulation environment. In that way the simulation can for example generate reference values which will be transmitted by CAN to the testing system or for example the simulation receives signals from the ECU and can evaluate these signals.

Detailed information about the implemented hybrid and electric vehicle models and especially about their real-time capability will be given in the paper. Also the connection between the Dymola simulation tool and the I/O functionalities will be described. Finally as an application example for the test facility a HIL simulation of a real electric drive system (electric drive, power electronics and battery) for a two wheels vehicle will be shown.

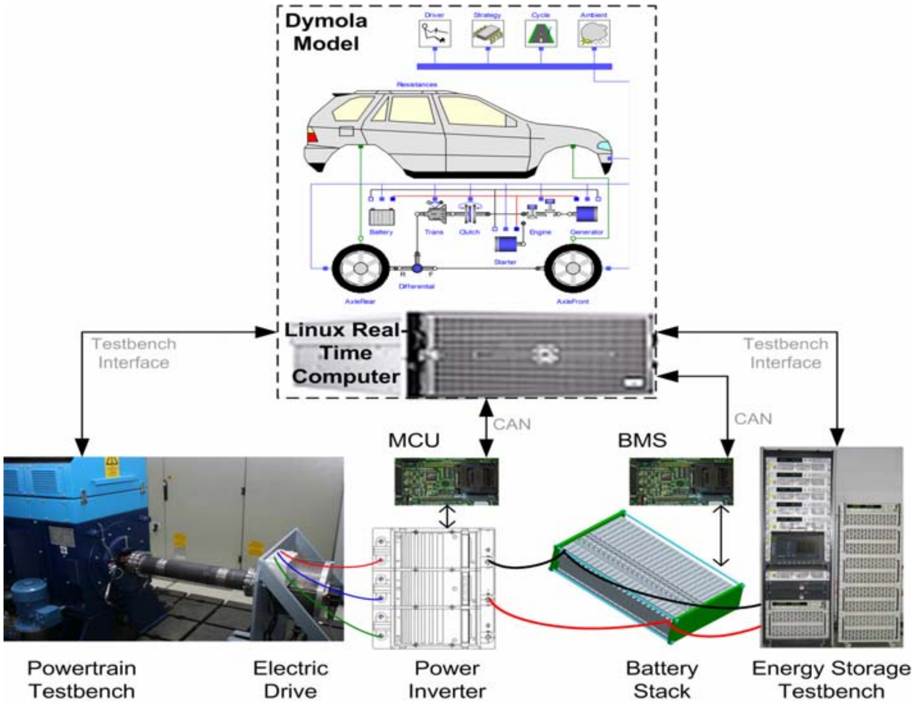

Figure 1: System overview of a HIL configuration for testing the electric components of a hybrid electric vehicle

2 System Overview

2.1 Real Time Computer

The main part of the proposed system is a 3.2 GHz Dual CPU Workstation with a SUSE Linux Enterprise Real-Time (SLERT) operating system. On this system operates a normal Dymola simulation environment for Linux on which can be implemented and simulated Modelica models. The effort of this system is that the simulation models can be executed in real-time directly from the simulation environment.

The proposed simulation computer with the SLERT operating system guarantees short response times and fast cycle times; such fast sampling time is for example required for HIL simulations of drive trains. A sampling frequency of over 2 kHz can be achieved depending on the complexity of the simulation model and the number of input and output channels. The input and output functionality to the test benches is provided by an analoge/digital data acquisition card connected and for the digital communication with Electronic Control Units (ECU) by an external CAN interface.

2.2 Testing Infrastructure

The simulation environment on the Linux computer generates reference values for the drive train test bench on which is connected the testing drive and for the energy storage test bench on which is for example connected a real battery. As feedback the simulation tool receives measured values from the real components. In figure 1 is given a possible schematic overview of the HIL system for testing the electric components for a hybrid or an electric vehicle. In this case the motor control unit (MCU), the power electronics (inverter), the electric drive, the battery management system (BMS) and the battery stack are the systems under test. The behavior of the vehicle for example the internal combusting engine, the driving dynamics, the ambient conditions, the drive cycle and the driver will be simulated on the real-time simulation workstation.

Table 1: Technical data of drive-train test-bench (dynamometer)

Peak Power	110 kW
Peak Torque	500 Nm
Peak Speed	8000 rpm
Control Modes	Torque or Speed
Ext. Data I/O Freq.	500 Hz

Table 2: Technical data of electric energy storage test-bench

Charge mode	
Peak Voltage	480 V
Peak Current	100 A @ 480 V or 500 A @ 60 V
Discharge mode	
Peak Voltage	600 V
Peak Current	540 A @ 600 V or 750 A @ 60 V
Control Modes	Voltage, Current, Power, Resistance

3 Modelica Real-Time Interface

The Modelica Real-Time Interface provides an interconnection between the Dymola simulation tool and the input and output functionalities of the system. The interface guarantees the synchronisation between the simulation time and the real time. Simulation time means the virtual time inside of the simulation time which will be matched with the time in the real world by the Real-Time Interface. The interface provides also the signal conditioning of the simulation variables to input and output values of the DAC channels, in that way the test benches can be connected directly to the simulation workstation.

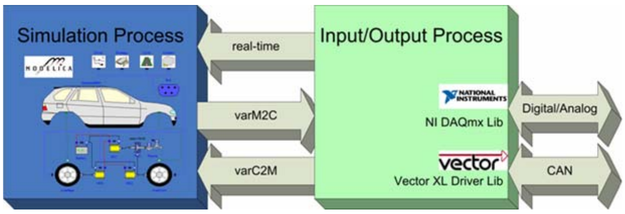

Figure 3: The two main processes for the real-time simulation

For a running real-time simulation two main processes the so-called Dymosim process and the RTmod process works together. The model and solver are executed in the Dymosim process, this is the left-handed process in figure 3 . The model can be build with the RTInterface blocks for example for Trigger functions and data I/O. Data I/O is implemented by a Shred Memory and synchronized by semaphores. All functionality in Modelica is implemented using external c-functions and Modelica standard blocks. The RTmod process (right-handed process in figure 3) is completely c-written it includes the Frequency Based Scheduler synchronization the Data I/O over shared memory and the DAQ functions for analoge and digital In- and Output.

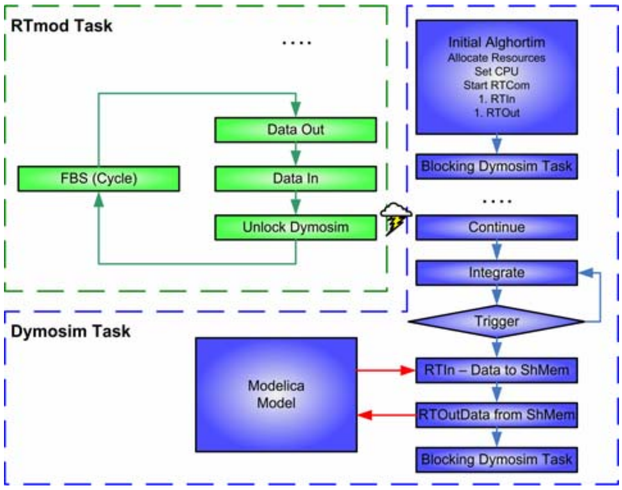

Figure 2: Functional overview of the Modelica real-time interface

4 Application Examples

4.1 Hybrid Electric Vehicle HIL Simulation

A hardware-in-the-loop simulation of a HEV system will be shown as an application example. The behavior of a Mild HEV is simulated on the Linux real-time computer on which is connected a real electric drive with a peak power of 12 kW and the motor control unit for this electric drive. The whole HEV is modeled in Modelica using the SmartPowertrains library and the SmartElectricDrives library. Based on suited power requirements pointed out by a drive cycle, the simulation model generates the reference values for the testing drive, (e.g. a reference torque) which are communicated to the Motor Control Unit (MCU) via the CAN bus and the power inverter generates the electric signals for the drive. The measured torque in the load cell of the test bench corresponds to the torque of the power train, this feedback value goes back the simulation model and new reference values can be calculated.

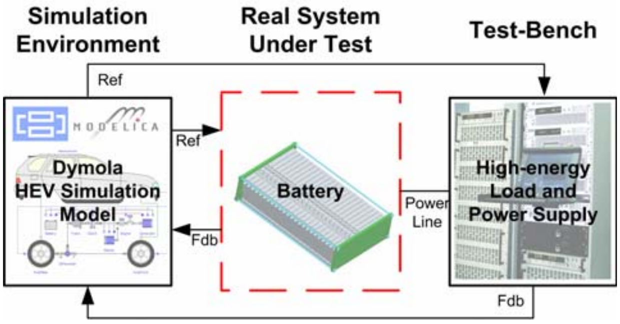

Figure 4: HEV hardware-in-the-loop simulation

4.2 Electric Two-Wheeler HIL Simulation

The capabilities of electric two-wheelers are intensively investigated due to their high potential for improved urban mobility as well as tourist or sport application. Nevertheless existing products are in many cases lacking of appropriate range or power to achieve a broad (satisfactory) customer acceptance. To evaluate the technological potential of electric two-wheelers different e-scooter concepts have been analyzed by simulation. Based on the simulation environment available at arsenal research an electric scooter model was set up and simulations using different electric drive configurations have been performed. The results allow for determination of high power scooter concepts. For validation and demonstration of a high power two-wheeler an e-scooter prototype has been realized and tested. The simulation and test results in e.g. performance and range will be given as well as the further improvement potential will be discussed.

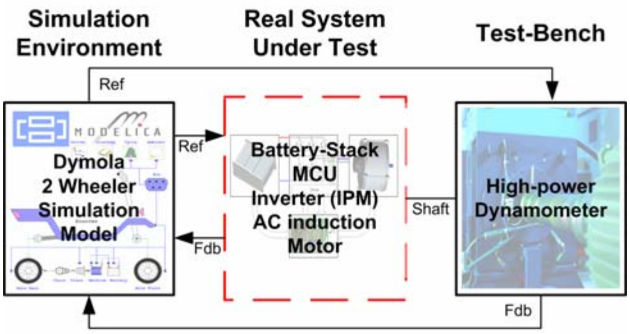

Figure 5: Electric two-wheeler hardware-in-the-loop simulation

5 Conclusion

In the provided paper is presented a HIL simulation solution for development and for testing of components for HEV`s. The powerful hardware of the simulation computer and the real-time operating system allows the simulation of complex models with a fast data exchange with the real components which are connected to test benches. With the described *Modelica Real-Time Interface* it is possible to execute the HIL simulation direct from the *Dymola* simulation tool with which was implemented the model.

The benefit of this system is that a simulation engineer can for example validate an implemented model directly, matching the simulation results with the measured values at the connected real component. Or in the advanced development an engineer can test a developed component also when the entire system is not available; the prototype of the system exists only as a virtual model in the simulation.

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