Flexible HiL Interface Implementation for Automotive XiL Testing

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***Abstract*—The growth of X-in-the-Loop (XiL) testing has been accompanied by a rapid growth in tools tailored for testing. While this increases the accessibility of tools for various specific applications, using multiple model and testing softwares can introduce compatibility issues when performing tests in the integration stage. This article provides a demonstration framework of a flexible Hardware-in-the-Loop (HiL) interface utilizing both Typhoon HIL and SIEMENS Amesim software and hardware for full vehicle emulation. First demonstrations of these HiL interfaces for a Plug-in Hybrid Electric Vehicle (PHEV) are shown. Flexible HiL interfaces such as these represent a much easier way to integrate full vehicle models within existing vehicle development frameworks.**

Keywords—HiL, XiL, modular testbed, model-based development, PHEV.

I. Introduction

Virtual testing methods, including Hardware in the Loop (HiL) and Model Based Development methodologies are becoming a requirement for Automotive vehicle design and deployment [1]. Many automotive companies use a V-curve development model, even in mechatronic and embedded systems development processes [2][3]. Maintaining a consistent model fidelity is a critical aspect of these systems, with simplifications in the modeling of systems often resulting in small deviations throughout the design process. HiL systems represent fast, flexible, and efficient means for validating these models throughout the design process as well as performing pre-validation of control systems prior to deployment [4]. It is for this reason that having a flexible HiL testing infrastructure that easily integrates hardware interfaces from multiple sources is an important piece towards practical adoption of Model Based Development techniques.

This article highlights the specific integration framework critical to the H2020 PANDA project and how this integration enables rapid model development. Demonstrations of this framework using a Plug-in Hybrid Electric Vehicle are shown. This framework allows for two real-time HiL simulators to work in parallel, maintaining active connections with Typhoon HIL's suite of testing tools, the Simcenter AMESIM Cloud, and the local resources under test.

II. Hardware Integration Framework

A. System Overview

There is a constant need to develop hardware interfaces for interfacing Typhoon HIL real time simulators (*Figure 1*) with specific equipment under test (EUT). Most equipment have one or more standard interface connections, although frequently there are specific interface needs that require a more custom approach. Typhoon HIL real time simulators have a standard interface which includes various communication ports (RS232, CAN, Ethernet, USB, etc.), and also the digital and analog inputs and outputs with standard 5 V digital logic and ±10 V analog ranges, available on standard DIN41612 connectors [5].

Figure 1. Typhoon HIL Real Time Simulator

For the H2020 PANDA project was to develop a hardware interface that can be used for most equipment needed for Hybrid Electric Vehicles (HEV), Plug-in Hybrid Electric Vehicles (PHEV) or Battery Energy Vehicle (BEV) system evaluation. Every HEV or BEV contains battery and its supporting system, as well as electrical drive. PHEVs additional have a built-in battery charger infrastructure. Due to the similarity in the core components necessary for PHEV, HEV and BEV applications, only the PHEV model is featured here for simplicity.

In order to boost processing performance, and to build an upgradable system for different vehicle use cases, a modular approach was adopted. Four testbeds (*Figure 2*) were built, using the same hardware design to emulate the different vehicle design topologies.

Figure 2. HiL testbeds with HIL real time simulators and hardware signal interfaces

Each testbed consists of two paralleled Typhoon real time emulators and two interfacing devices – HIL Connects, which converts standard Typhoon IO levels to the specific levels required for the application. Mechanical emulators, including electric drives, inverters, batteries, and battery chargers can be connected using this hardware setup.

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B. Testbed Architecture

The PHEV that was evaluated in PANDA project consists of two separated electrical drives and one combustion engine (*Figure 3*). The PHEV was assumed to have a total weight of 1400kg, an electrical traction power of 18 kW, and a battery capacity of 10kWh.

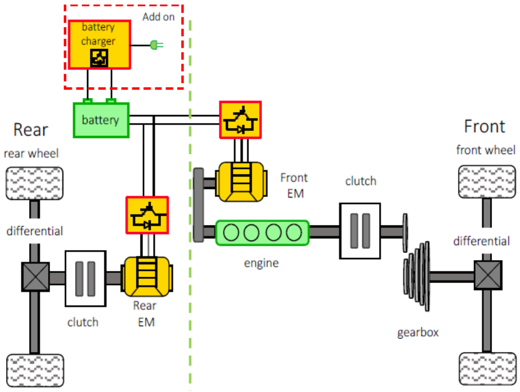

Figure 3. Simplified characteristics of the studied PHEV

Electrical drives are controlled with a dSPACE controller, while the mechanical part of the PHEV (wheels, gearbox, clutch, internal combustion engine, etc.), and the PHEV control unit (ECU) are emulated using the Typhoon HIL system. Two electric machines with their inverters are used as a mechanical emulator, coupled with drive machines (*Figure 4*).

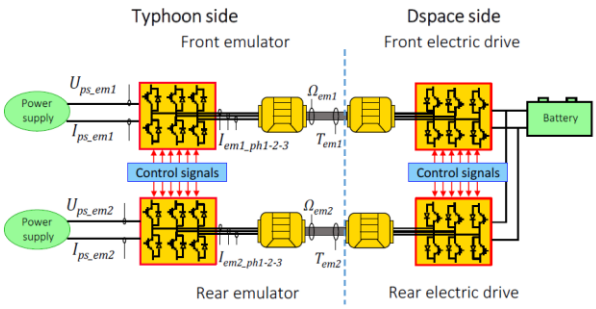

Figure 4. PHEV mechanical emulators and electric drives

The inverters and machines were provided by Valeo. These are three phase inverters with 6 switches. To control the machines, inverter PWM inputs, and machine feedback signals (voltages, currents, quadrature encoder signals, torque, etc.) are connected to the Typhoon HIL simulator. For this purpose, the HIL Connect Type 1 was developed as a part of the HiL testbed (*Figure 5*).

Figure 5. HIL Connect Type 1

The other key component of the PHEV system is the battery. For battery real time testing and evaluation, an AC-DC converter serves as a bidirectional power source, which is used as a battery charger or discharger.

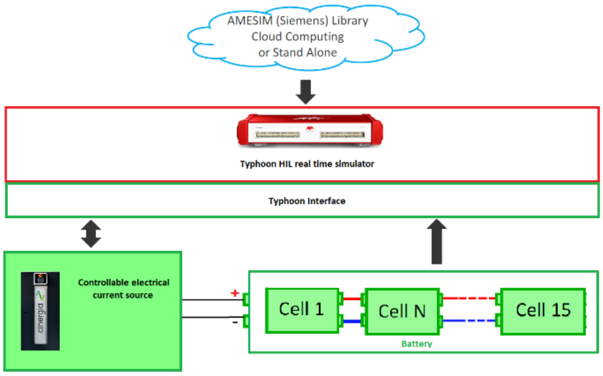

Figure 6. Battery real time test system

This AC-DC source is connected to the HIL Connect and controlled by Typhon HIL real time simulator (*Figure 6*). Voltage and current of the battery are monitored, as well as cell temperatures. For this purpose, the HIL Connect Type 2 was developed (*Figure 7*).

Figure 7. HIL Connect Type 2

The entire HiL test setup is mounted into a standard 19-inch rack cabinet. It consists of two Typhoon HIL real time simulators, and two HIL Connects (*Figure 8*).

Figure 8. PANDA HiL Testbed

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III. Plug-In Hybrid Vehicle (PHEV) Demonstration

A. Model Under Test

To demonstrate the performance, a Signal Hardware-In-the-Loop EMR model was developed and integrated into SIEMENS Amesim emulation software [6], generating a traction model for the PHEV under test (*Figure 9*).

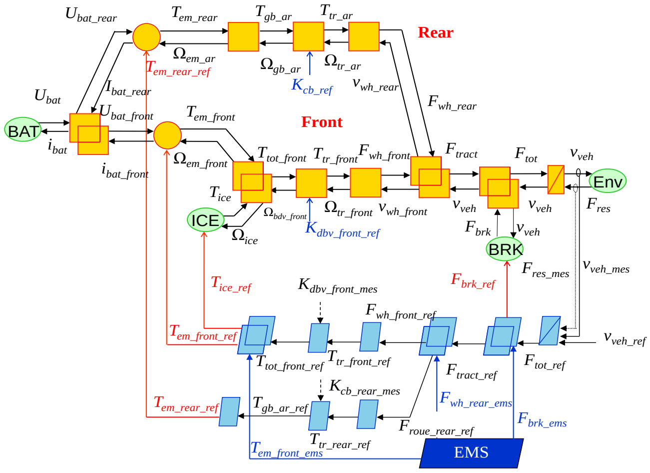

Figure 9. EMR of the studied PHEV

This EMR model was then exported automatically to the Typhoon HIL's software environment via a newly developed conversion tool and imported in Typhoon HIL Schematic Editor. This model is then compiled in Typhoon HIL SCADA software and a reference velocity profile is provided as an input. When run, the EMR model outputs the instantaneous Voltage and Ampere flow to and from the battery, as well as the battery system's State of Charge.

B. Module Under Test

In order to perform the HiL tests. The EMR model was deployed on the Typhoon HIL emulator and software is run via connected computer. The controller module under test was provided by Bluways and connected with isolation protections. These were then connected to a Cinergia DC power interface, providing the appropriate control signals from the simulation (*Figure 10*). For comparison, a real PHEV was also tested in Université de Lille using the same reference velocity profile.

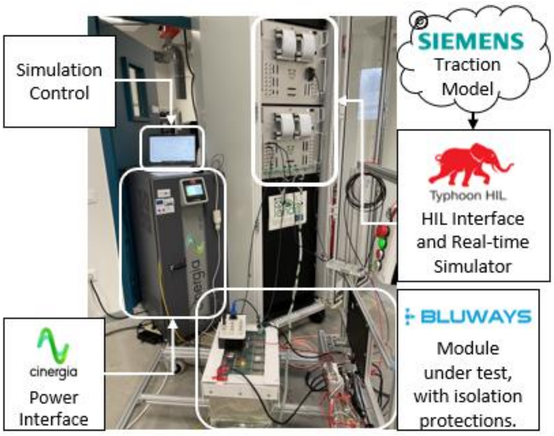

Figure 10. PANDA HiL Testbed with components under test

Based on the initial testing and validation, the real battery performance was found to have no significant deviation from performance testing compared to a real PHEV in voltage, current, or SoC (*Figure 11*).

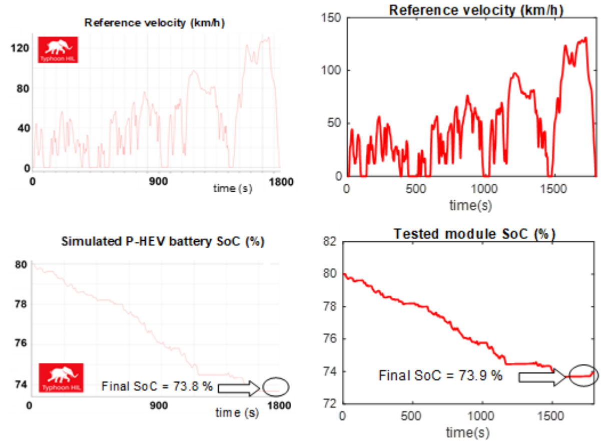

Figure 11. Performance analysis of the HiL Emulated PHEV (left) versus a real PHEV at 80% initial SoC

Additionally, the simulated vehicle model allows for continuous real-time testing with immediate, automatic reporting. As a result, the total testing time required to perform both simulated and real vehicle validation tests was reduced to just two days.

IV. Conclusions

This paper demonstrates a proof-of-concept for a flexible hardware interface for modeling vehicle performance of full HEV, PHEV, and BEV models. Implementing modular hardware in the loop interfaces such as those shown here allow end-users to better utilize their existing XiL testing infrastructure and design process for different production applications. This has the potential to greatly reduce the demand for engineering time and effort typically associated with applying model-based design processes to multiple workflows, while still maintaining high-fidelity in performance results.

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