Chapter 37

Hardware-in-the-Loop Testing of On-Board Subsystems:
Some Case Studies and Applications

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ABSTRACT

Hardware in the Loop testing is a very powerful tool for the development, tuning, and synthesized homologation of safety-relevant on-board subsystems and components.

In this chapter some case-studies, based on typical topics of industrial research for railways, are introduced in order to emphasize some aspects of the mechatronic design with a particular attention to the integration of actuation systems into rig design.

## SYSTEM IN THE LOOP TESTING: INTRODUCTION

HIL (acronym of Hardware-In-the-Loop) testing is a technique commonly used for the development of advanced mechatronic systems in order to test them by simulating in a realistic way strong cross-coupling effects between the tested subsystem/component and the surrounding environment. The original term Hardware-In-the-Loop can be extended to a more general "System-In-the-Loop," where "System" might include electro-mechanical and electronic hardware, and/or software, and/or firmware, or all of them.

As visible in the simplified scheme of Figure 1, the interaction of the tested component with the surrounding environment is reproduced by a closed loop system composed of sensors, actuators and a real-time model able to calculate and reproduce a virtual testing environment which approximates real operating conditions: sensors are used to evaluate the response of the tested component; measurements from sensors are used by the real-time model to evaluate the corresponding evolu-

Figure 1. HIL testing, simplified scheme
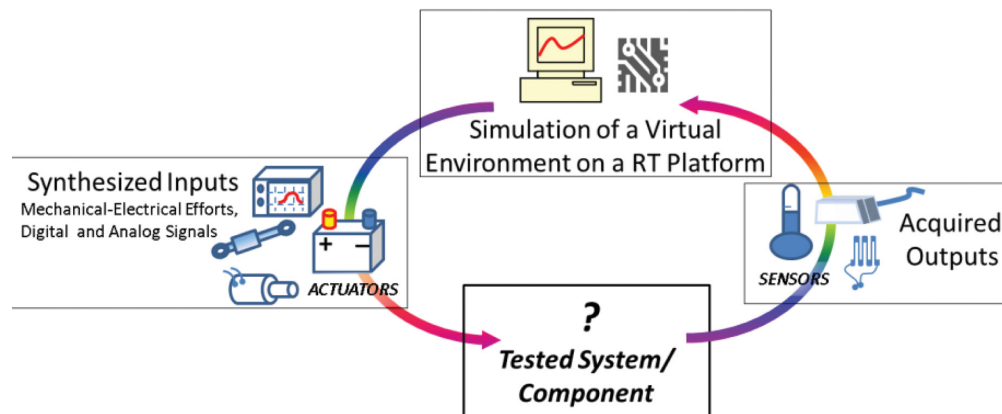
tion of the simulated environment. Actuators and signal generators are then used to provide inputs to the tested components in order to reproduce the calculated dynamical behavior of the simulated environment, thus closing the test-loop. Since the simulation loop is composed of real components, a finite delay between sensor measurements and synthesized inputs is involved; for HIL testing this delay has to be negligible respect to the typical time constants of the simulated environment. Also precision and bandwidth of sensors and signal generators are very important in order to obtain near to realistic testing conditions.

The application of HIL testing to safety-relevant railway on-board subsystems is highly recommendable for many reasons:

- **Different Operating Scenarios:** The testing conditions are reproduced by a numerical model so it is quite simple to change the testing conditions in order to reproduce different operating scenarios, even the least probable (but possible!) and potentially really dangerous in the real application.
- **Costs and Time Consumption:** Experimental tests of on-board subsystems involve the availability of testing trains, testing circuit/line and qualified human resources. As a consequence, this kind of experimental activities are quite expensive and time consuming. The availability of specialized test rigs for repeatable testing campaigns involves lower costs and lower time consumption.
- **Availability and Logistical Limitations:** Testing on railway lines involve the availability of resources which are often precluded to developers especially in the design and tuning phase of innovative systems. As an example, preliminary testing and tuning of an innovative traction control system may involve the availability of a vehicle or a complementary subsystem which is still in the construction phase.
- **Safe Testing Conditions:** With HIL testing, it is possible to simulate potentially dangerous conditions which can be quite difficult to be reproduced on line test for safety reasons: as an example, extreme testing conditions, which involve the risk of severe accidents.

On the other hand, validation of a proposed HIL testing procedure is a quite complex matter since it involves the qualification of a complete test rig composed of data acquisition systems, numerical models running in real-time and actuation/signal generation systems. HIL testing devices should

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