Flexible Configuration

- **Joint project between Volkswagen AG and University of Paderborn**

- **Hardware-in-the-loop system**

- **Testing ESP and EPS systems**

A joint project between Volkswagen AG and the Professorship for Control Engineering and Mechatronics at the University of Paderborn, Germany, has developed an integrative hardware-in-the-loop system. This consists of two HIL subsystems, each complete in itself, which can be used either separately or together as an overall system for validating the functions of networked chassis control systems. Designed using the model-based approach, the HIL system can be configured flexibly and is ideally suited for use in the automotive industry.

Hardware-in-the-Loop in Automobile Development

The sheer number of ECUs is not the only reason why in-vehicle electronics are becoming more complex: Networking between ECUs is another cause.

The automobile industry is therefore working intensively on setting up new development processes and testing methods to master this rapidly growing complexity.

Hardware-in-the-loop (HIL) simulation is playing a major role in all this as a proven method of testing ECU software. Together with Volkswagen AG, the Professorship for Control Engineering and Mechatronics at the University of Paderborn has developed an HIL system for testing the control functions of either individual or networked ECUs, and also, to a great extent, verifying vehicle dynamics under real-time conditions.
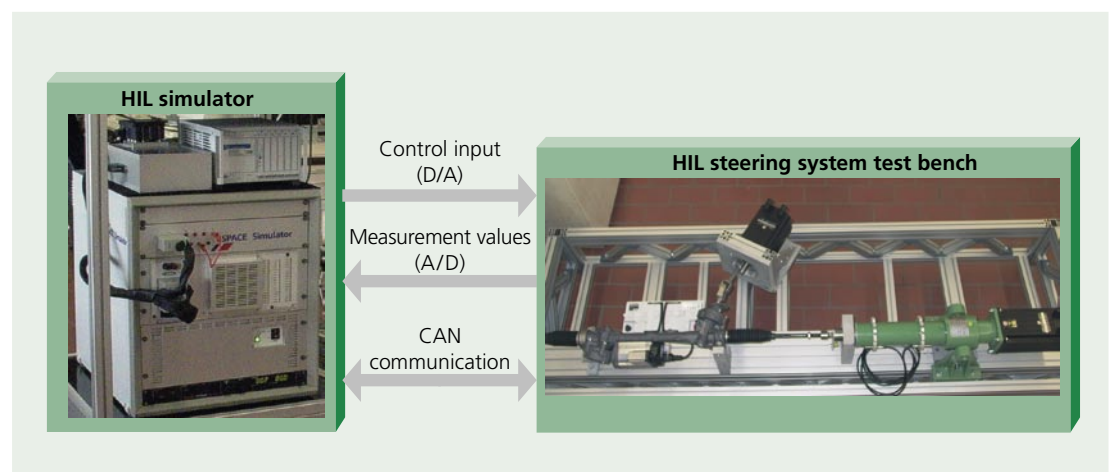
One HIL System – Different Configuration Options

The HIL system is hierarchical in structure and designed for validating the two chassis control systems ESP (Electronic Stability Program) and EPS (Electric Power Steering – the electromechanical power steering in VW vehicles). It consists of two subsystems:

- HIL simulator with an ESP ECU
- HIL component test bench with a real steering module and an EPS ECU

HIL Simulator in an ECU Network

The two subsystems can run separately and can also be combined to form one overall HIL system. The overall HIL system with the ECUs for ESP and EPS supports the development and testing of the entire ECU network. To create the overall HIL system, the two HIL simulators and the individual ECUs were coupled

HIL simulator

Control input (D/A)

Measurement values (A/D)

CAN communication

HIL steering system test bench

▲ *The integrated HIL system with steering system test bench: real steering module, EPS ECU, actuator, sensor, and mechanical steering system.*

via the DS830 MultiLink Panel. The coupled HIL system is mainly for investigating the interaction between several ECUs. One example is tests on a vehicle's electrical system aimed at ensuring safe behavior if voltage drops occur when several energy consumers in the vehicle are all running simultaneously. The effects of the ECU, the power electronics, and the electric motors on other electrical devices are analyzed. The plausibility of the CAN signals between different ECUs can also be verified in this HIL system.
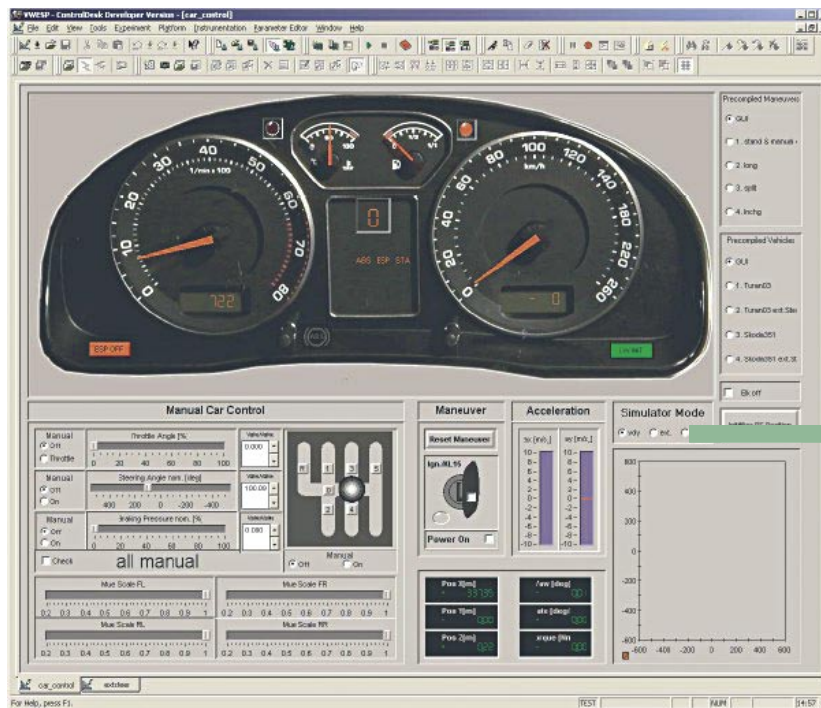
Set mode
○ *ESP simulator*
⊙ *EPS steering system test bench*
○ *ESP+EPS*

▲ *Configuration options on the test bench: This user interface was created with the ControlDesk experiment software. Developers can monitor measurement signals and operating states as well as run tests.*

Combined HIL Simulator with Test Bench

Increasingly, ECUs are not only networked with one another for testing, but also connected with a real system component. Thus, when new control functions are tested and validated, not only the ECU itself can be present in hardware form; the constellation can also include essential vehicle components. In many cases, these components come straight from the supplier, and they are often highly complex: for example, the entire mechatronic steering module including the mechanical steering system, actuator, controller, and sensor. It is not really possible to create a model for such a component, as many suppliers are not prepared to disclose their know-how. Thus it cannot be studied as a component model in the HIL simulator software. The solution is to include the real component module in an HIL test bench, and let the module communicate with other subsystems and ECUs via defined interfaces.

Easy Handling of Real-Time Hardware

To put the HIL system into operation and communicate with it, the Simulink®/Stateflow® models were quickly and automatically implemented on the dSPACE real-time hardware (DS1006 Processor Board) via the Real-Time Interface (RTI). This screenshot shows a part of the user interface that was created with the ControlDesk experiment software. There is a Set Mode function for easy switching between the three configuration options. In addition, important system and controller parameters can be programmed and synchronized with the operating states, making it easy to access system and controller parameters online. The simulation can be addressed interactively to feed in suitable driving maneuvers (µ-split, lane changing, etc.).

Summary

This article describes the development of an integrative hardware-in-the-loop system for validating the control functions of single or networked ECUs and also, to a large extent, for verifying vehicle dynamics under real-time conditions. The only way for the automobile industry to master the rapidly growing complexity caused by networking and the large number of ECUs is to use the new development processes and testing methods.