

Virtual Application

Hardware-in-the-loop simulation (HIL simulation) makes it possible to test control units in a virtual driving test. At Volkswagen, HIL tests are carried out for the application of a new ESP system for the Golf V platform. A CarMaker/HIL test bench from IPG Automotive is being used as the simulation environment.

The Simulation Environment

At VW, the sign of the times was recognized very early. Long before HIL simulation had made a name for itself, ECUs were being tested at VW in the simulation environment CarMaker/HIL. The CarMaker software accurately simulates driving dynamics. Central to this is a vehicle model capable of real-time performance. It is valid up to the limits of driving dynamics. This is a Multi-Body System (MBS) in which the kinematic and elastokinematic coupling of the wheel carriers is described in parameter data sets. The MBS model forms the core model and integration platform for all other sub-components of the vehicle, such as the steering system, tyres, brake system, drivetrain and aerodynamics. Overall, the model environment of the virtual vehicle has a uniform, modular structure: the models of the

vehicle environment are arranged manageably in terms of the individual sub-assemblies. The way that parameters are set for the vehicle models is also linked to individual sub-assemblies and therefore to functional units and structures to which test drivers and application engineers are accustomed. When constructing the overall vehicle model, there are various variants to choose from for the individual vehicle components. A special ESP brake system is provided as a hydraulics model for testing the ESP control. Parameter setting for the hydraulics model had to be adapted for similarly controllable valves in order to meet the criteria of the analogue valve controls of the new brake system. Parameters were set for the hydraulics model in accordance with the ESP system to be tested on the basis of data on the

behaviour of the hydraulic valves in various operating conditions.

The virtual vehicle environment includes a robust driver model with full parameters as well as the virtual vehicle. All operating conditions necessary for the application of ESP control can be illustrated, for example various braking manoeuvres or lane changes at different speeds. The environment is completed by three-dimensional road models together with the virtual driver and vehicle. The road models can either be constructed from individual sections of the route or they represent real test routes that were defined from measurement data. In order to be able to make as good a comparison as possible between test and simulation, in-house test routes were digitised at VW and incorporated into the virtual vehicle environment. The hardware components of the HIL simulator include a power supply unit, a real-time computer, I/O modules and slots for the Electronic Control Units (ECU). The slots contain the signal conditioning for the ECUs and the recording unit for the magnet coils of the ESP hydraulics.

ESP ECU in the Simulation Loop

The new ESP ECU is connected into one of these slots of the HIL simulator. As a special feature of this control unit, the sensors for



The new ESP system of the Golf V platform is to be applied by means of HIL simulation.

the yaw rate and lateral acceleration are integrated into the control unit. To transmit the yaw rate and lateral acceleration calculated by the simulation models to the ECU the sensors must therefore be circumvented. Using a software switch the internal sensors are switched off and the yaw rate and acceleration are fed into the control unit via CAN. The ECU picks up the signals and executes logical and mathematical links. Depending on the simulated driving condition, the control intervention takes place by the control of the solenoid valve coils. At the same time, the HIL simulator records the magnetic fields in the coils and transfers the data to the simulation environment via an A/D converter. The brake hydraulics model calculates the brake pressures and transfers these to the vehicle model. By means of feedback to the control unit, the simulation loop between the ESP control and the HIL simulator is closed. The cycle of signal pick-up by the control unit, through calculation of all the models and signal feedback to the control unit, takes place in real time with a cycle time of 1 msec. However, since the brake hydraulics model has a high degree of rigidity, it was necessary to record the brake system signals at a frequency higher than 1 kHz. For this reason, signal pick-up and calculation of the hydraulics model takes place with four-fold over-sampling.

Before the HIL tests on the ESP control unit, the simulation environment of the HIL test bench is subjected to a thorough test. Simulation of the virtual Golf is validated using a selection of rep-

resentative standardised driving cycles. For this, the results of the simulation are compared to those of the real driving test. Model parameters are adjusted until a good match can be guaranteed between measurement and simulation. The same method is used to check the analogous valve data records of the hydraulics model. In the HIL simulation, the new ESP system is tested in numerous, virtually produced driving situations in order to make it compatible for use in the series production vehicle. During the test runs, the vehicle parameters, such as loading or road characteristics, are systematically altered, which allows possible weak points in the control units to be revealed. The driving situations in which weak points can be revealed can be reproduced in the simulation. This makes it easy to create optimum parameter settings for the control unit.

Integration of Brake and Steering

A feature of the new ESP system is that the braking intervention by the control unit can be combined with a controlled steering moment intervention. The ESP control unit sets steering moments that are converted by the electromechanical steering system and superimposed on the normal steering moments. To test this by software-in-the-loop (SIL) simulation the steering system model of CarMaker is modified to take into account the steering moment required by the ESP system, as well as the steering moment intervention by the driver. At a later development

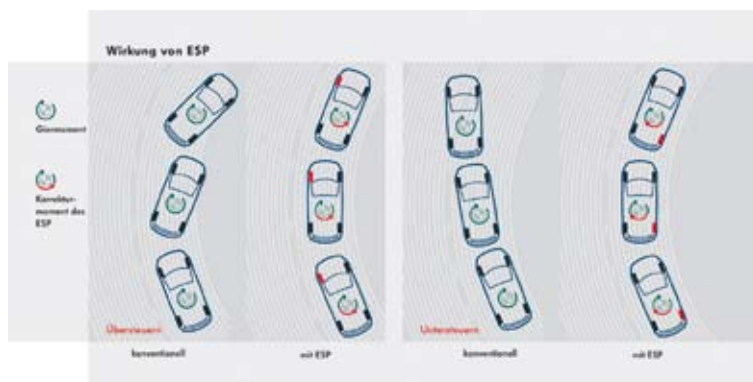


Virtual stabilisation tests of the vehicle-trailer combination with CarMaker/HIL – example of the new ESP system's performance tests.

stage, the steering system supplier will provide a model that more precisely maps the electromechanical steering together with the controls. To ensure that the virtual driver reacts in exactly the same way to steering with interventions from the ESP system as a real driver, the driver model must also be extended. For this purpose, the behaviour of human drivers is analysed in real driving tests. Once extensions to the test bench have been completed by adding the SIL simulation steering function, braking and steering interventions can be tested together. It is important to ensure that the interplay of both systems works perfectly.

Correcting Weaknesses Systematically

HIL simulation is an important component of development work at VW. If, during test drives, test drivers discover weak points in the setting of the control systems, these can be recreated in the simulation. The reproducibility of CarMaker's simulation results in virtual test drives makes it easy to investigate and correct these weaknesses systematically. This results in significantly reduced development times and creates an important competitive edge. (red)



The mode of operation of ESP.