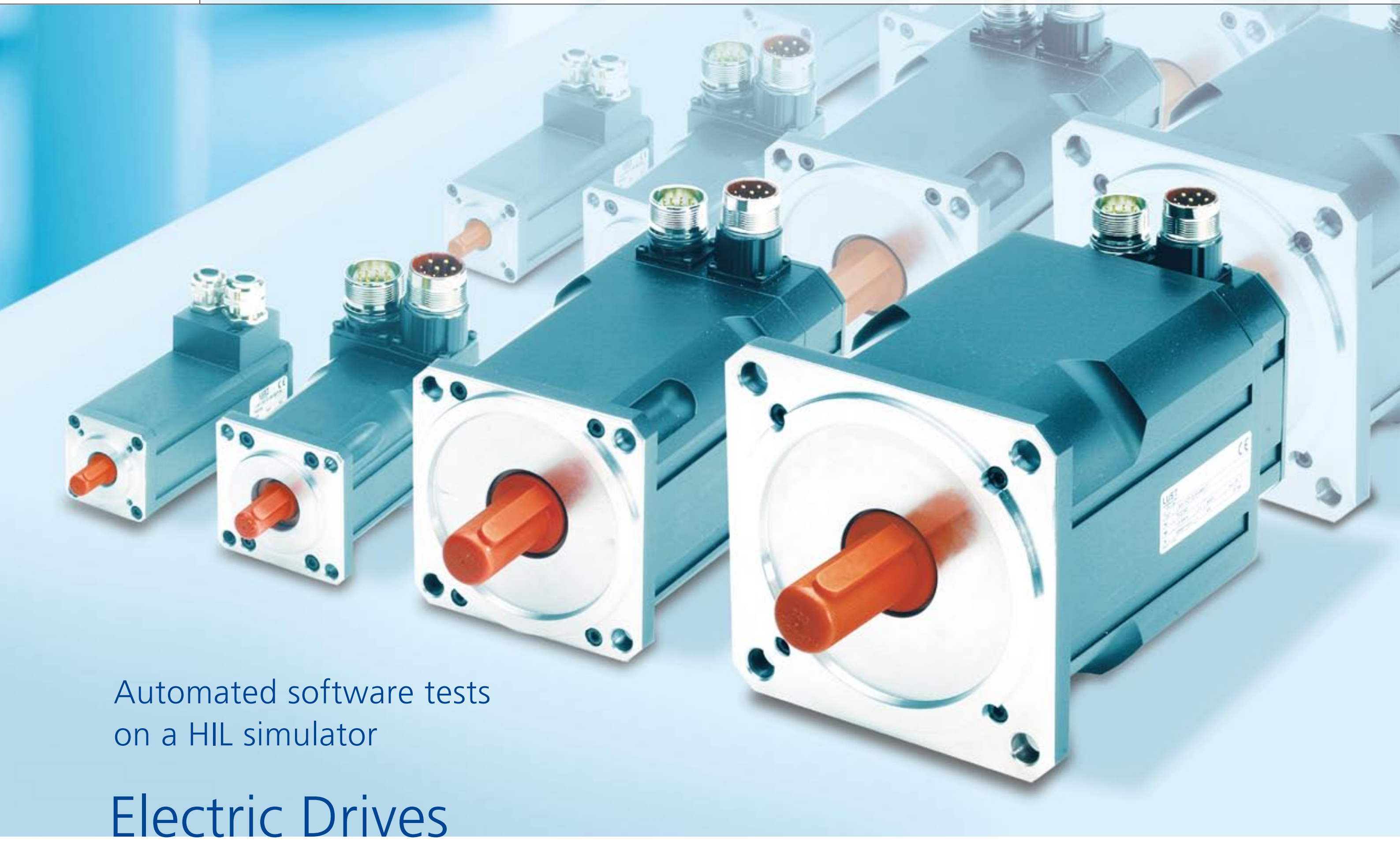


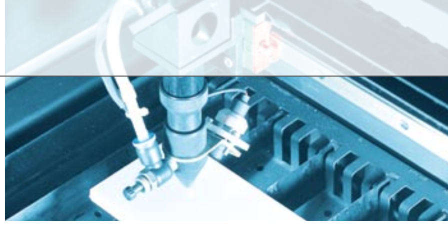
Automated software tests on a HIL simulator

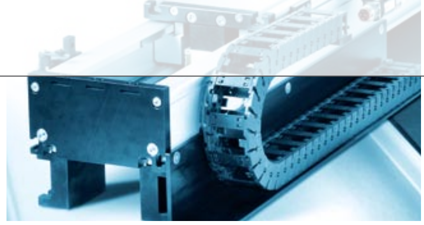
Electric Drives

Efficiently Virtualized

Controlled electric drives are a key technology in numerous engineering applications. Handling so many applications calls for a high degree of flexibility, especially for servocontrollers in industrial automation. And with all the possible configuration options for the servocontroller software, there is a high number of variants, involving an enormous testing workload. With automated testing on a HIL simulator, these tests can be simplified and accelerated significantly.

LTi DRiVES GmbH in Germany develops, produces and distributes servocontrollers for electric drives with performance ranges from a few hundred watts to 250 kW. In addition to operating in classic automation technology, drive products from LTi serve such different application areas as medical technology, wind farms and high-speed drives. And more than ten years ago, LTi also started equipping diesel-electric industrial trucks with custom-developed inverters. No matter what the field is, the level of software in elec-





tric drives is getting higher, while innovation cycles are getting shorter. So it is extremely important to execute the software tests for servocontrollers efficiently.

One Servocontroller for All

The core functionality of any servo-controller is to control the current, rotary speed and position of various motor types such as direct-current, synchronous and asynchronous. The ServoOne server controller from LTi has numerous additional functions that users can configure for a wide variety of applications. Figure 1 shows software function modules that are typical for a servocontroller, all requiring extensive testing. Obviously, the large number of variants and the broad functionality involve an enormous testing effort. Against this background, automation regression tests in the software modification promise enormous savings.

The Challenge: Real Parts

The software must be tested intensively not only in isolation, but also in interaction with a large number of hardware configurations. Different power stages, different types of motors and encoders, and different field bus and technology option boards can all be combined in different ways. Test bench tests require extensive setup work, such as performing the electrical and mechanical installation of the inverter and motor when real hardware is used. This not only prolongs the software release process, but also ties up valuable test bench capacity.
Many of the test conditions for using real parts in software tests are safety-critical, so they pose another challenge. Such conditions apply when critical errors are tested, such as overcurrent, overvoltage, overspeed and overtemperature.

The Solution: HIL Simulation

The solution for testing extensive software functions and hardware configurations is hardware-in-the-loop (HIL) simulation. This replaces the necessary controlled systems and real parts with simulation models, so that most of the setup work otherwise performed during testing is unnecessary. A HIL simulation can run under automated control, so testing can be done around the clock. Test automation is especially helpful with routine tests for verifying compliance with standardized field bus profiles such as CANopen, SERCOS and CAN J1939. Technical safety approval procedures also require that test sequences with error simulations are reproduced repeatedly. This too is immensely simplified by test automation.

Simulation Hardware Setup

All the simulator's components are integrated in a mobile cabinet (figure 2). A dSPACE system is used as the platform for real-time simulation. It consists of a processor board (DS1005), two I/O boards for simulating electric drives (Electric Motor HIL Solution) and a CAN interface board (DS4302). The connection technology and signal conditioning

> "The HIL simulation technology provided by dSPACE is an important aid to quality assurance and development cost reduction at LTi."
>
> *Dr. Harald Wertz, LTi DRiVES GmbH*

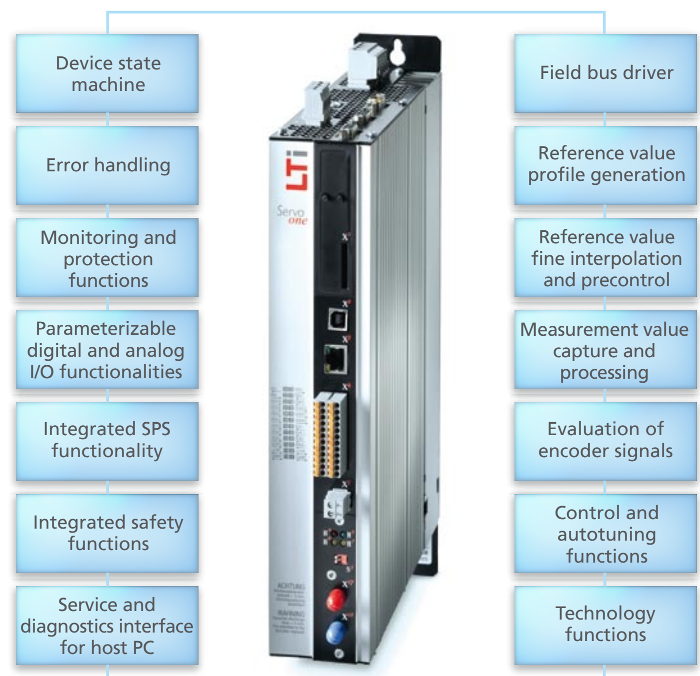


Figure 1: Typical software components of a servercontroller.

between the dSPACE system and the electronics in the object under test were planned and implemented by LTi. The cabinet also contains an industrial PC, which acts simultaneously as the field bus master and as the host for the test automation software. To give the simulator maximum versatility, boards for control parts taken from different drive products can be integrated in the cabinet as test objects. This is done by using a pull-out tray and a standardized adapter that has robust plug connectors with a high pin count.

Figure 3: ControlDesk's user interface.

Figure 2: The assembled HIL simulator.

Simulation Models

The simulation model for the controlled systems was created in Simulink®. It was based on models from dSPACE's ASM Electric Components Library, such as synchronous and asynchronous machines and power converters. With their open structure, the models were easily adapted to LTi's requirements. Components from the SimPowerSystems Toolbox from The MathWorks® were also used, for example, to simulate three-phase networks in real time.

Drive Peripherals

Because of the high dynamics of the real plant, the real-time simulation of power electronics and electric drives makes very tough demands on the simulation system. The EMH board that dSPACE developed specially for the HIL simulation of electric drives has a series of intelligent I/O channels. The integrated FPGA (field-programmable gate array) executes I/O processes with a high time resolution. These include analyzing the PWM control signals generated for the power stage by the control electronics and generating the digital and analog signals that arise during position encoder simulation. The EMH board can simulate not only the usual analog resolver and encoder systems, but also TTL incremental encoders such as encoders with the serial transmission protocols SSI, EnDat2.1® and Hiperface®. The protocol of the serial encoder systems can also be parameterized flexibly to represent all common encoder types.

Test Automation

dSPACE ControlDesk is used for interactive work with the HIL simulator (figure 3). The automatic tests are implemented in the Python script language. Easy access to the simulator and the object under test from the host computer is implemented by using appropriate Python libraries created by dSPACE and LTi.

Comparing Simulation and Reality

To assess the quality of the real-time model, first the parameters of an 11-kW synchronous motor were determined on a real test setup, with the aid of the drive's integrated autotuning function. Following this automatic controller design, the step responses of the current and motor speed control were measured. Then the HIL motor model

was parameterized with the motor data identified on the real hardware, and the step responses were recorded with identical controller parameterization for the object under test on the HIL simulator. This resulted in good consistency between the respective processes (figure 4).

Outlook

The HIL simulation of electric drives in real time can be performed at a high quality level with the powerful dSPACE hardware and simulation algorithms that are specially designed for it. The precision of the real-time model is so good that even the most demanding control investigations can be carried out. LTi also found other interesting possible uses for the HIL simulator in addition to automatic execution of software tests for server controllers:

- Optimization of control parameters for customer applications to prepare and speed up on-site commissioning
- Early testing of software prototypes to run hardware-related tests on control functions
- Early evaluation of the design data of special motors for hybrid and electric vehicles in terms of control technology.

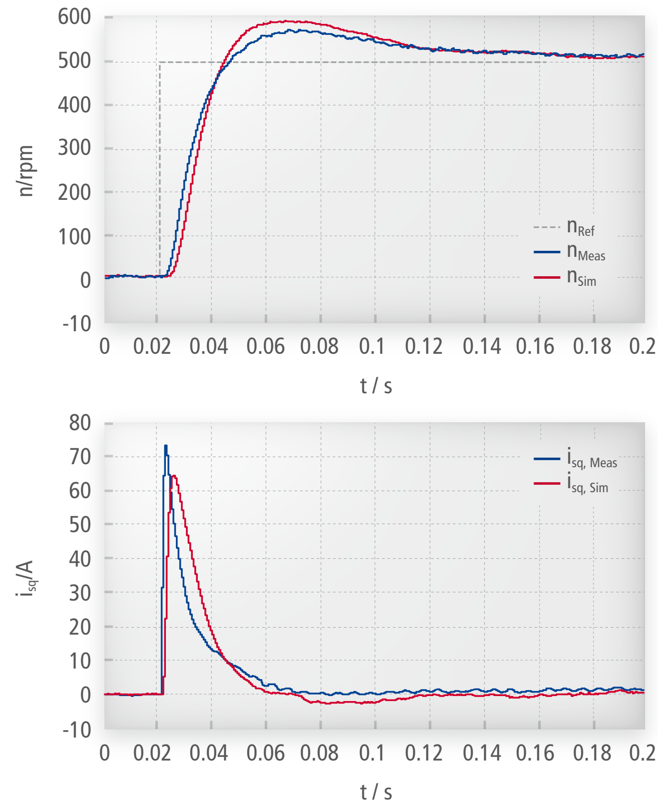


Figure 4: Comparison between motor speed control in HIL simulation (red) and in a real test setup (blue), each with a sampling rate of 125 µs.

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Pictured left to right are:

Dipl.-Ing. (FH) Thomas Küsterarent develops the software framework for test automation.

Dipl.-Ing. Jens Schirmer develops the real-time models.

Dr.-Ing. Harald Wertz is the head of software development.

Dipl.-Ing. Ulrich Schumacher is Project Manager for the HIL software test project.