Better Test Quality by Automation
Automated HIL Test System Ensures ISOBUS Functionality of Agricultural Machines

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The J1939-based ISO standard 11783 describes CAN-based communication in open networks for use in mobile machines in the agricultural industry. ISO 11783 is a multi-master network based on CAN, whose protocol is harmonized with J1939. The ISOBUS concept describes a minimum degree of functionality for software and hardware that ECU's or networks must provide. The ISOBUS protocol ensures that a suitable add-on implement such as a field chopper or manure spreader can be operated with any ISOBUS-conformant tractor and that its full functionality will always be available on the tractor's operating console. The individual parts of the standard, address such topics as Network Management, Tractor ECU, Universal Terminal (previously: Virtual Terminal), Task Controller, Diagnostic Services and File Server.

Goal of ISOBUS Functionality Only Attainable with Extensive Tests

Until everything functions as smoothly as in the example, numerous test runs and correction cycles must be performed by the testing and development departments. On the one hand, the ISOBUS standard leaves some room for interpretation in certain aspects, but projects of this com-
plexity need time in the prototype phase before they attain the required maturity level. There is no way to avoid conducting intensive and extensive conformity tests [1]. That is also why the various manufacturers meet regularly at so-called “Plug-Fests” where they test individual devices for their compatibility with one another.

Test Setup of the Entire Tractor Network with an HIL System

The AGCO Corporation is one of the world’s largest manufacturers and distributors of tractors and agricultural machines. In 1997, the US-based agricultural machinery corporation acquired the tractor manufacturer Xaver Fendt GmbH & Co. with headquarters in Markt-oberdorf, Germany, where it conducted its development production and sales of tractors. Along with tractors, the company’s lineup includes field choppers, combine harvesters and baling presses products which are handled by the company’s business sites in Bavaria, Sachsen-Anhalt and Italy.

To overcome the challenge of increasing testing effort, AGCO/Fendt conducts extensive tests on real tractor prototypes. For some time now, the company has also been working with the development and consulting company Gigatronik. AGCO/Fendt develops nearly all of its ECU software in-house, but it outsources some testing-related jobs to specialists in electronics and information technology. Its central tasks are to test Universal Terminals, Tractor Controllers and to validate ISOBUS conformity.

The key components of the test setup used at AGCO/Fendt are a breadboard fixture of the tractor network, a hardware-in-the-loop system (HIL system), a real-time server (RT target) with extensive I/O interfaces and a PC with the CANoe .ISO11783 development, testing and simulation tool from the company Vector, which is precisely tailored to ISOBUS requirements. CANoe .ISO11783 provides ISOBUS functionality for developments from the design phase to the testing phase and then maintenance. The complex ISOBUS communication structures can be analyzed, visualized and conditioned in many different ways. The room for interpretation of the standard mentioned above can be handled in a greatly simplified way, because the tool essentially embodies the standard as interpreted knowledge.

The tractor breadboard fixture incorporates all electrical and electronic tractor components such as ECUs, bus systems, wiring, lamps, switches and controls. They are mounted in a space-saving way on a frame with industrial-format racks, which is suitable for the laboratory. The fixture matches a production tractor fully; all it lacks are the diesel engine, transmission, body and add-on parts (Figure 1).

The breadboard fixture is connected to the RT server’s I/O routing block via a multicore cable (Figure 2). The server simulates various ECUs and the missing environment of the engine and sensor signals in real time via MATLAB/Simulink; it supplies such signals as speeds, rotational speeds and temperatures. User-initiated events such as button presses or movements of a joystick must be performed manually. A look at the I/O level illustrates the magnitude and complexity of the overall HIL system. It consists of several hundred voltage and current interfaces, countless digital inputs and outputs, and outputs for driving relays. In addition, there are frequency outputs, all sorts of CAN buses, a UDP interface and multiple voltage outputs with supply voltages for the ECUs of the breadboard fixture.
Manual Testing as Time-Consuming Emergency Solution
Another tool available for tests is a PC with CANoe .ISO11783 simulation and testing software. The system is primarily used for remaining bus simulation [2] and is capable of simulating individual network nodes up to entire sub-networks. In CANoe .ISO11783, entire implements can be simulated, and the simulated implements are used to put the tractor’s ISOBUS capabilities to the test. Even sub-areas, such as a UT, can be simulated and displayed with all of their functions on a PC screen using CANoe. Testing of ISOBUS applications takes a lot of time and effort, because conformity must be verified for all parts of the ISOBUS standard used in the tractor implement. This also involves internal tractor communication. Moreover, the ISOBUS standard itself is available in various implementation levels. Therefore, it is not sufficient to simply test to the current level, rather the test must also assure backward compatibility to a number of previous implementation levels of implements. Finally, numerous individual tests (test cases) must be run for many different variants.

Despite the availability of the described HIL system, employees at Fendt and Gigatronic still needed to perform some necessary tests by conventional manual methods. Specifically, this sometimes meant – depending on the test case – that an employee sat in the tractor and executed specific tractor and implement operating functions repeatedly, for hours at a time and over several days. During such testing, the test system logged all user actions, system reactions and the bus traffic. The logging record was then used to precisely analyze the contents of messages, terminal reactions, timing values, cycle times, etc.

Test Automation is at Top of the Wish List
However, the test method practiced in this way was still unsatisfactory for Gigatronic and Fendt. Highly qualified employees were overworked by simple yet time-intensive user actions. And despite the large amount of time required, the tests still exhibited a somewhat rudimentary character considering the many parameters. Therefore, managers began to seek out and evaluate options for systematic and in-depth test automation to replace the undesirable manual interaction. A solution with robots that could simulate the human movements with mechanically actuated control arms would not only be extremely difficult to implement; it would also be inflexible. So this solution was rejected early on.

An electronic approach seemed more appropriate and appealing, especially since a high-performance test tool already existed in the form of CANoe. The ‘Test Feature Set’ integrated in the software produced a comprehensive tool chain covering all phases: from defining test requirements to executing tests and finally generating evaluation reports. CANoe can act as a test master, or it can be inserted in test environments. Interfaces such as COM or .NET are available for drive control and communication with other tools. Nodes referred to as test nodes can be created for the tests; they participate very normally in real bus events, similar to simulated network nodes. Test engineers define their behavior and functionality in test modules, using either the C-like script language CAPL or the XML standard.

Figure 2: The original HIL system is composed of the real-time target, tractor breadboard fixture and UDP interface for communication with a remaining bus system. The armrest with integrated user controls is implemented as a real component, for example, and must therefore be operated manually.

Figure 3: Integration of the CANoe interface in the existing overall system: The test module controls the existing test environment. The armrest, with its integrated controls, is implemented as a virtual component in the test system and can therefore be operated either manually or automated by the test program.
CANoe Bridges Gap to Real-Time Target
Before test automation could be successfully implemented, it was necessary to answer the question of how the CANoe tests and simulations would be linked to the real-time target in the HIL system. That is because a fast communication channel is indispensable between the two systems. The RT target has a UDP interface with a data link protocol created by Fendt for sending information to the RT target or obtaining information from it. Therefore, Gigatronik developed a compatible counterpart to the CANoe side with its resources – in the framework of a student's senior thesis. The test system can now control the RT server via UDP and optionally transfer to it the same signal vector that was previously made by manual interaction with a real component, e.g. an armrest with integrated controls (Figure 3). In principle, any real, manually operated component can be automated in this way. In the example, it was an intelligent armrest; in another case it might be a steering wheel. Now that these preparatory tasks have been completed, Gigatronik and AGCO/Fendt have the capability of comprehensively automating ISOBUS and ECU tests and quickly modifying them. In particular, the capabilities of CANoe .ISO11783 now contribute towards much more efficient test execution. For example, the UT provided by CANoe makes it possible to control an ISOBUS implement just as well as with the real UT on the tractor. While an employee would have to execute user control functions for hours on end at the real tractor armrest previously, now a simulated armrest with the same integrated controls automatically executes the same actions (Figure 4). The behavior of the simulated component in the individual test cases is defined precisely in CAPL test modules. The test user interface also makes it possible to start the (virtual) engine, and sequences can be programmed for forward driving and backward compatibility. Especially important is that, in contrast to manual operation, CANoe.ISO11783 can execute tests with absolute reproducibility. In addition, errors may be interspersed in a controlled way. During the test runs, the test system logs all relevant messages and signals, and afterwards it automatically generates a test report.

Decidedly Greater Test Quality by Automation
The automated test runs open up entirely new aspects of quality in ECU testing. It is easy to run tests overnight or over several days, without employees having to be constantly present. Naturally, this makes it possible to go into much greater depth, test much more, and systematically run through many more test cases. They include tests that would not have even been possible without the test tool, such as multiple repeated checks of bus loads, when the tractor drives off, when it stops, when multiple implements simultaneously lift an object, etc. The developer analyzes how other messages react in these situations and how timing values and cycle times behave. Statistical evaluations can also be performed, e.g. by starting the test run thousands of times and logging while varying such parameters as the latency times of certain messages or examining which effects might result when starting up the network.

Figure 4: Instead of using a real armrest with integrated user controls, the signals coming from this component are fully implemented by a GUI that can be switched between manual operation and control by the test program.
Finally, one significant part of EDCU tests is to subject the system under test to errors. Here too, the RT target generates all conceivable error situations upon instruction by CANoe.

Bernhard Stöckl, manager for the responsible testing department at AGCO/Fendt, is pleased: “Before, we had no test automation in the ISOBUS area. Previously, we conducted all of our work directly on prototypes which are not always available. We actually sat by the machine and operated the switches. Now, test automation offers tremendous relief in terms of workload. We require much less time on the real prototypes and no longer need to build so many extremely expensive test vehicles. At the same time, we saved a lot of time, which the developers are now investing in further automation efforts.”

**Outlook**

“Test automation” is the magic word for mastering the constant growth in testing effort, simultaneously improving quality and saving on time and costs. AGCO/Fendt and Gigatronik have shown the capabilities offered by test automation with the CANoe simulation and test system and how to achieve efficient test practice quickly and in an uncomplicated way. The flexibility of the test platform makes it possible to overcome even greater challenges related to communication and interfaces in the process of integrating a large HIL system.

Only by taking new approaches to integration tests can product quality be assured into the future. This issue is assuming increasing urgency in view of the further increasing diversity of ISOBUS-capable agricultural machines. Additional requirements will soon appear in the context of precision farming. More and more GPS applications that support work with field machinery will be implemented in both tractors and implements. In Tractor Implement Management (TIM), the implement controls the tractor, e.g. by specifying tractor speed or rpm. These extensions can be accomplished much more efficiently with test automation.

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Lead Figure: Fendt
Figure 1 – 4: Gigatronik

**Literature:**
[2] Albrecht, S., Decker, P.: Quick paths to a comprehensive remaining bus simulation – Create virtual networks with-