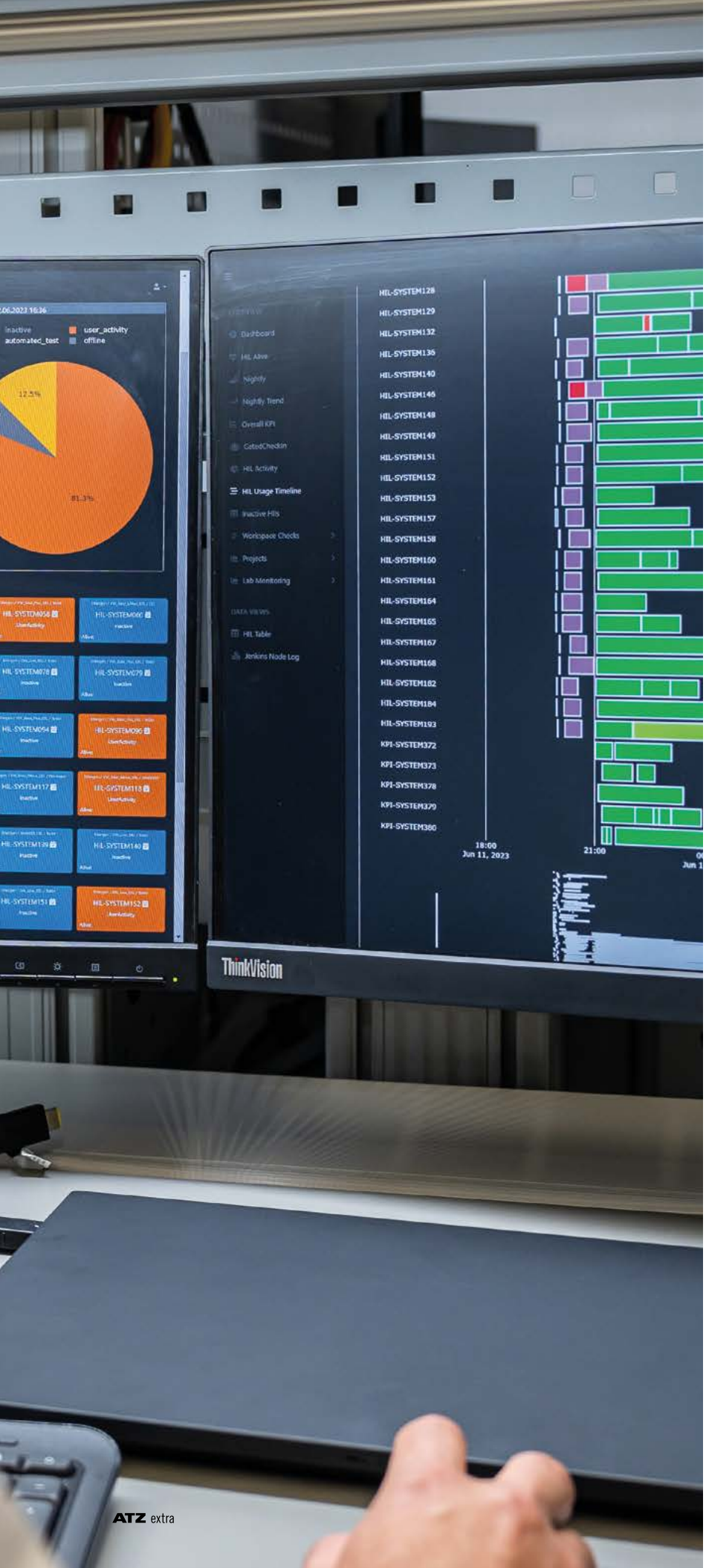
Continuous Integration and Testing of Software for Electric Powertrains

On the road to CO_2-neutral mobility, innovative solutions and products for electric powertrains are becoming increasingly important. The underlying software must meet strict functional and cyber security requirements, making continuous software testing during development essential. The software test center from Valeo makes this possible by automating the entire test process and thus achieving high software quality at reduced costs with a shorter time-to-market.



© Valeo

WRITTEN BY

Harish-Kumar Nibbagandla, B. Eng.
is Software Test Architect at Valeo eAutomotive Germany GmbH in Erlangen (Germany).

Dipl.-Ing. (FH) Rico Kleist
is System Engineer at tracetronic GmbH in Dresden (Germany).

Eike Heimbach, B. Sc.
is Head of Department at Valeo eAutomotive Germany GmbH in Erlangen (Germany).

Dipl.-Ing. (Univ.) Johannes Weickert
is Global Software Development Director – Software Development Environment at Valeo eAutomotiveGermany GmbH in Erlangen (Germany).

The challenge in developing embedded automotive software for the electric powertrain is that it is dependent on the availability of the hardware. The software developed must be executable shortly after the hardware is made available, to allow realistic software testing and early identification of defects. Development teams are therefore faced with the major challenge to provide high-quality software within very tight schedules. In order to rise to this challenge, efficiency in the software testing process must be increased.

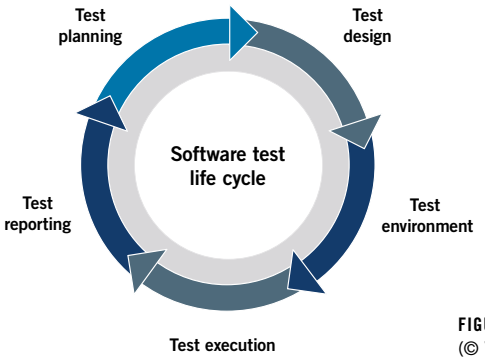


FIGURE 1 Software test life cycle (© Valeo)

To this end, Valeo has developed a state-of-the-art software test center that offers maximum flexibility and scalability within the software testing infrastructure. In combination with a fully automated software testing process, the company delivers innovative software solutions for electric powertrains quickly, efficiently, and with high quality.

CONTINUOUS TESTING AS A SUCCESS FACTOR

Continuous software testing is essential in order to ensure that Valeo products are of high quality and more reliable. Short release cycles are made possible by cost-effective, scalable, and flexible software test infrastructure, which also includes continuous integration and testing. This approach ensures that all stakeholders receive quick feedback on software functionality. Newly implemented or modified code can be immediately evaluated at various levels of validation, including the final hardware product.

The software testing process encompasses all activities in the software test lifecycle shown in **FIGURE 1** – from initial test planning and specification, through test case development and execution, to comprehensive reporting and integration into the Application Lifecycle Management (ALM) system. The advantages of these approaches range from early detection of critical issues in the development phase to complete validation of the software – thus resulting in cost savings by removing the need for subsequent troubleshooting.

SOFTWARE TEST INFRASTRUCTURE

The automated test process is based on a powerful, scalable, and flexible software test infrastructure, which is operated from the company's own data center in Erlangen, Germany. It operates a large number of Hardware-in-the-Loop (HiL) and Real-Time Processor-in-the-Loop (RT-PiL) systems (summarized as XiL). In these XiL systems, dedicated real-time processors execute mathematical models that emulate engine dynamics, among other things. In addition, vehicle sensors and actuators can be connected to the XiL systems, as these usually have a high degree of non-linearity. This means that the software for the final product can be tested without having to be modified for testing.

Standardized XiL systems, **FIGURE 2**, guarantee the flexibility and scalability required for rapid adjustments. This means that Valeo product hardware can be replaced without having to adapt the measurement and simulation hardware. To ensure permanent operation of the XiL systems, which are remotely accessible from various Valeo sites around the world, the entire infrastructure is continuously monitored. The data collected is used to identify potential problems at an early stage, help maintain system stability and increase the efficiency of system use. Together with the results of the Continuous Integration (CI) and Continuous Testing (CT) runs, this data is visualized on central dashboards. This creates transparency for all stakeholders and provides a clear overview at all times.

TEST AUTOMATION

CT requires a tool for implementing and executing automated test cases. For this purpose, Valeo has been using the test automation tool ecu.test from tracetronic since 2014. With this tool, structured, modular and reusable test cases can be created using a graphical editor.

To simplify the implementation of test sequences, an extensive library of reusable functions for the electric powertrain has been built up. All files required for test execution are provided in a self-contained workspace and versioned in a source code management system. As ecu.test offers interfaces to a large number of software tools widely used in the automotive industry, it can be used across all customer projects. In the software test center from Valeo, ecu.test has been extended with its own scripts to support

FIGURE 2 Standardized and modular setup of XiL systems (© Valeo)

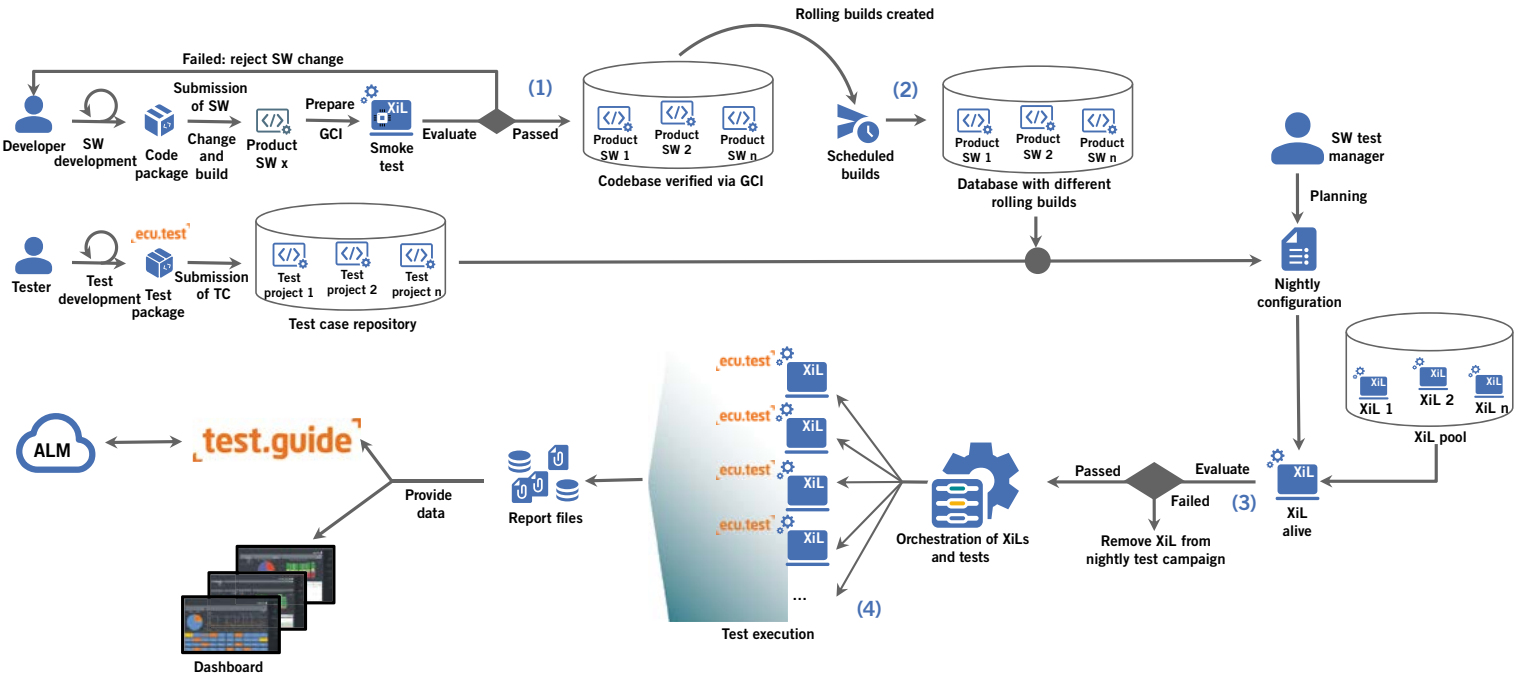


FIGURE 3 CI/CT process of the software test center from Valeo (© Valeo)

customer-specific tools and implement environment-specific automation. In addition to automating actual test execution, the entire test setup process has been automated. This includes preparing the testing environment, initializing measurement tools, configuring the target system, flashing the software under test, and managing the test data. This comprehensive automation minimizes manual intervention, reduces the risk of human error, and ensures consistent test execution. The use of trace analyses allows the in-depth investigation of system behavior during test execution, including validation of time-critical behavior.

All generated test results are automatically transferred to a standardized format and stored centrally for further processing, along with the associated measurement data. This approach ensures the repeatability and traceability of tests, which is essential for stringent validation and certification processes.

CONTINUOUS INTEGRATION AND CONTINUOUS TESTING

FIGURE 3 shows Valeo's automated software testing process, which is closely meshed with CI and forms the backbone of the CT strategy. Every code change triggers an automated build process, followed by a series of automated tests. This starts with static code analyses that checks individual software components in isolation. Subsequently, basic integration tests for resource consumption and smoke tests are executed for each change, using RT-PiL or HiL systems depending on the project status. The gated check-in is only accepted on the branch and merged with the codebase once the test sequence has been successfully completed, **FIGURE 3** (1). For each project, all changes made during the day are rebuilt at night, **FIGURE 3** (2), creating the so-called rolling build, which forms the basis for the nightly automated tests. To check the reliability of the test systems, each available XiL system is tested for correct functioning with a qualified software build in the so-called XiL Alive, **FIGURE 3** (3), and automatically scheduled for test execution. Based on the changes and other project priorities, test suites and regressions at all software test levels – from unit test to integration test to functional software test – are executed overnight, **FIGURE 3** (4). This step-by-step approach provides quick feedback to the developers. Defects are detected and fixed at an early stage, which significantly reduces the costs and effort associated with fixing them later in the development cycle.

The use of the software system Jenkins as a CI platform orchestrates this complex process and automates the build, test execution, and reporting. The business logic mapped in the Jenkins pipeline distributes the tests across the available XiL systems, optimizes the workload, and reduces the overall test time. The Jenkins setup is fully configurable, allowing individual teams to customize the CI/CT pipeline to their needs. Valeo uses this flexibility to ensure that the appropriate scope of testing is performed efficiently for each project in order to realize short release cycles. As visualized in **FIGURE 4**, the quality of the software is ensured by the quality gates integrated into the testing process. A software build is only released for subsequent process phases if specified quality criteria have been met. If this is not the case, the respective stakeholders automatically receive feedback.

TEST MANAGEMENT

The server application test.guide is another important component of the developed CI/CT solution. All test results generated by ecu.test, including all measurement data and metadata, are automatically uploaded to test.guide and stored in the accompanying database. With the help of the test report manage-

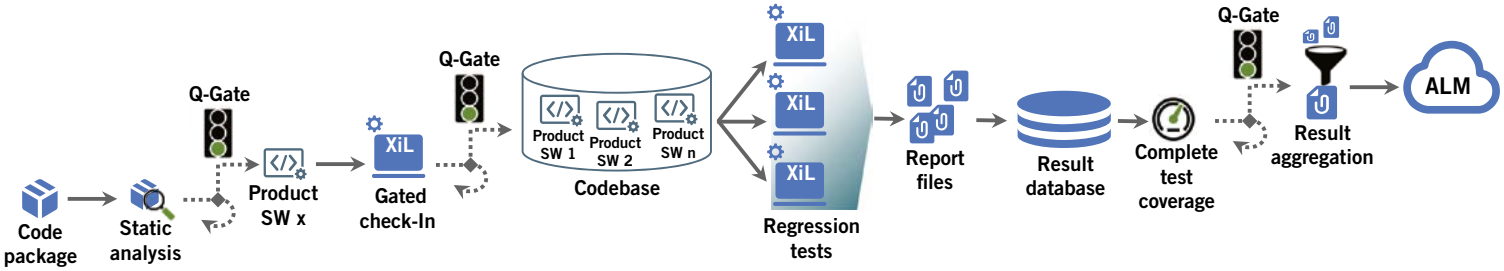


FIGURE 4 Quality gates of the software test process (© Valeo)

ment module and the associated filter options, a comprehensive overview of the current test progress in the respective project can be obtained. Test planning is supported by automatically generated releases the requirements of which are imported directly via the existing interface from the ALM system in use. This enables ongoing target comparison with the defined test coverage. When full test coverage is achieved for a tested software build, a final release result is aggregated and exported to the ALM system for archiving.

ADVANTAGES OF THE AUTOMATED TESTING PROCESS

Valeo's recipe for success is based on a combination of high-quality, customer-specific software, a comprehensive and automated test process, and flexible and scalable test infrastructure.
An overview of the advantages:

- Focus on quality: Continuous testing throughout the entire development process ensures the high quality of the software and minimizes bug fixes later on.
- Speed and efficiency: The automation of test processes, in combination with CI and CT, enables fast release cycles and efficient development.
- Flexibility and scalability: The standardized and flexible test infrastructure (HiL, RT-PiL) facilitates fast adaptations to different hardware and project requirements.
- Transparency and control: Central dashboards and integration with ALM systems ensure full transparency and traceability of tests and test results.
- Tool support: The use of specialized tools such as ecu.test and test.guide supports the automation, analysis, and management of the testing process.

SUMMARY AND OUTLOOK

The developed testing process is able to cover all test activities from initial planning to final reporting. Valeo relies on a combination of flexible and scalable software test infrastructure, test automation with ecu.test, continuous integration, and continuous testing. Not only does this ensure high quality software, but the resulting short release cycles also provide a decisive advantage for the dynamic electric mobility market. In addition, thanks to the standardized HiL and RT-PiL systems, faults can be detected and remedied at an early stage, which also reduces costs and development time. Centralized report management and system monitoring by test.guide ensure transparency and control across the entire testing process.

By implementing the process described before, combined with the scalable software test infrastructure, it was possible to shorten time-to-market, reduce required resources, and simultaneously increase test throughput. This demonstrates the success of the continuous testing approach as well as an increase in the performance and quality of software development. Efficiency is to be further increased in the future through optimization using artificial intelligence solutions. Therefore, an important part of meeting the industry's current and future challenges is the move towards holistic optimization of software development processes. Investing in a comprehensive test infrastructure and implementing an automated testing process will pay off in the long run and ensure competitiveness in the age of electric mobility.

IMPRINT
Special Edition 2025 in cooperation with tracetronic GmbH, Stuttgarter Str. 3, 01189 Dresden; Springer Fachmedien Wiesbaden GmbH, Postfach 1546, 65173 Wiesbaden,
Amtsgericht Wiesbaden, HRB 9754, USt-IdNr. DE81148419

MANAGING DIRECTORS:
Stefanie Burgmaier | Andreas Funk | Joachim Krieger
PROJECT MANAGEMENT: Anja Trabusch

COVER PHOTO: © phonlamaiphoto | stock.adobe.com