

Efficient Type Testing of Digital Protection Relays

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1 Abstract

Shorter innovation time-periods and rapidly growing functionality characterize today's numerical protective relaying. This naturally results in an increasing use of advanced testing tools and an advanced use of innovative automation systems by numerical relay manufacturers. This paper describes the use of OMICRON's test system "TEST UNIVERSE" in the relay development process at Siemens.

2 Introduction

During the development and manufacturing process, protective relays are subjected to numerous tests. In the manufacturing process, each relay has to run through a routine test and it is only shipped to customers if it passes the test. Each protection device is supplied with a test report.

2.1 Scope of the routine test:

- Burn-in test
- Electrical insulation test
- Functional tests of all hardware components
 - Binary IO
 - LCD display, LED's and key pad
 - Calibration of the measurement channels
 - Communication interfaces
 - and more
- Selected functional tests of the software
 - Selected pick-up values
 - Selected trip times
 - Operating measured-values

The development process contains the following test phases:

- Module tests tests on module base (in parallel to implementation)
- Integration test tests on device base (completion of implementation)
- Acceptance test transition to subsequent type test
- Type test final release for serial production

3 Testing Environment for the Type Test

3.1 Requirements:

Conventional protective relays provide a single protection function only, which can be set with very few parameter settings. In contrast to that, today's numerical relays offer much more complex functionality as an integrated solution, such as:

- Entire protection systems (Distance Protection + Emergency-Definite-Time-Overcurrent-Time-Protection + Ground Fault Protection + more)
- Auxiliary functions like fault locator, transient recorder, autoreclosure, etc.
- Controlling technology

At the same time, a maximum possible amount of user specific requirements are considered. Today's generation of numerical protection devices can flexibly be set via approximately five hundred parameters. In many cases, these devices provide a set of more than one thousand different messages, which then can be released.

The increasing functionality of protection device technology leads to a higher complexity, which finally results in even higher requirements for the quality assurance. A protective relay has to release the correct messages under all possible parameter configurations and also, at various operating or faulty power system conditions within a defined time frame. The combination of the huge number of setting possibilities, the respective different operating or faulty power system conditions and the possible relay messages results in an astronomically high variance of different test cases. Even a meaningful selection of tests forces the automation of the test processes.

When analyzing the different sections of the test process, one notices that the most time consuming part is the documentation and the assessment of the test results rather than the performance of the test itself. Therefore, a crucial requirement of the test system is to support the entire test process.

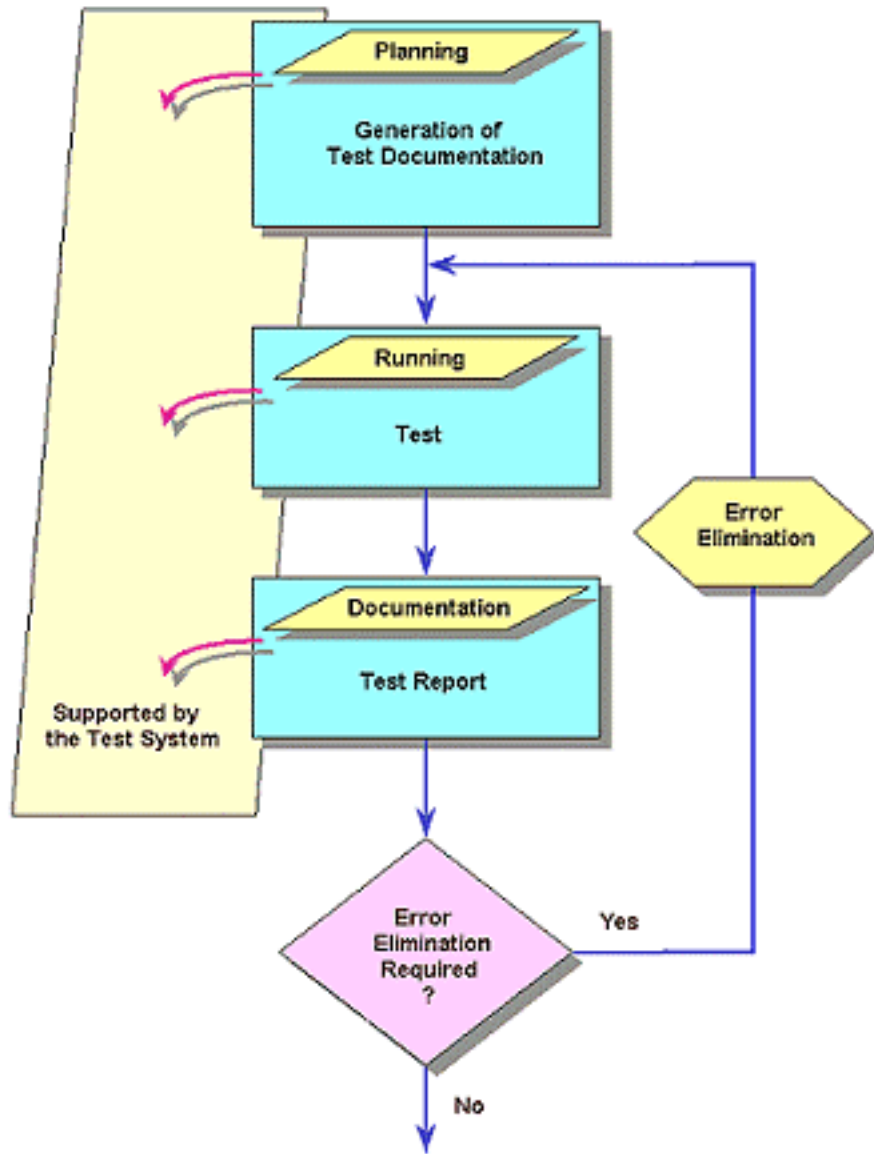


Figure 1 - The Phases of the Test Process

As a summary, the following requirements can be identified:

- Comprehensive automation of the tests.
- Parameterization of the protection will be part of the automation.
- Support of all phases of the test process especially
 - Planning of the tests
 - Running the tests
 - Assessment of the tests
 - Documentation (test reports)
- Flexible expandabilities.

4 The Test Hardware Environment

The test hardware is an OMICRON CMC product device, which is controlled via the parallel interface of a Microsoft Windows compatible PC. The test object is connected to the CMC test set. The CMC test set generates the output values (the currents and the voltages of the power system as well as the binary signals), applies them to the test object and analyzes the binary feedback of the protection device (e.g. trip command). In addition, there is a serial connection between the protection device and the PC in order to exchange data. The main purpose of this connection is to parameterize the protection by the test system.

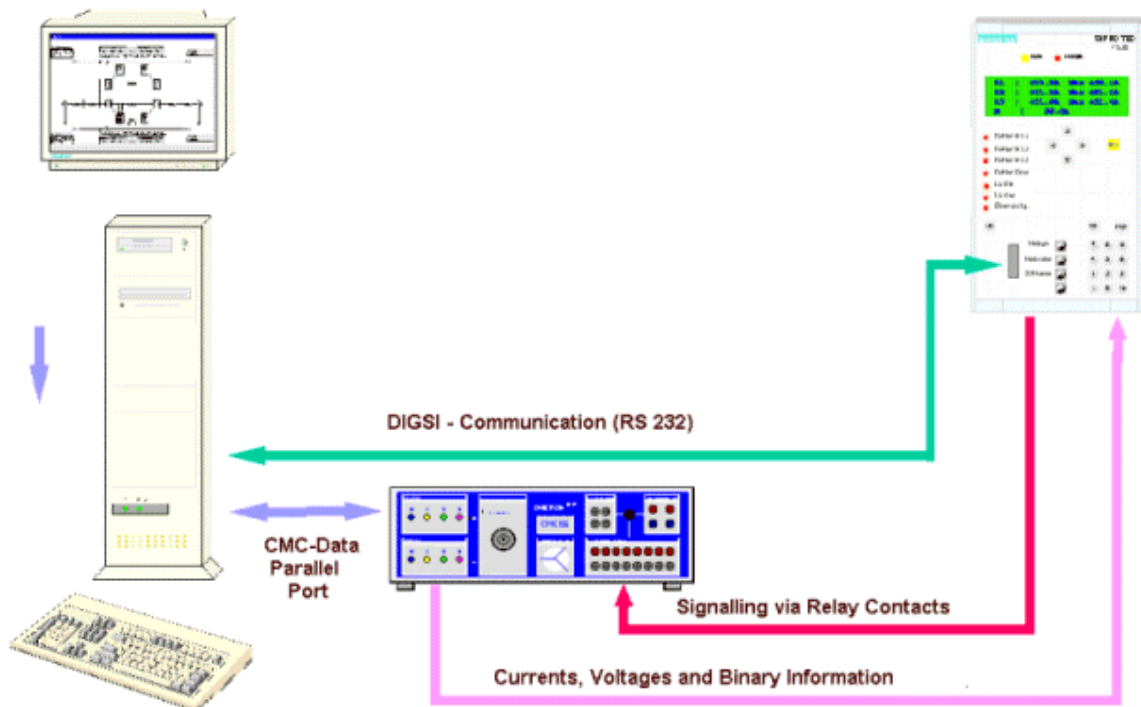


Figure 2 - Hardware Testing Environment

5 Test Environment Software

A central component forms the Omicron Control Center (OCC), which resembles at first glance a text-processing program. As a matter of fact, the OCC offers the most important text processing functions. The test developer drafts the inspection scheme in this master program – beginning with the first page, followed by the overall general instructions, the testing instructions, the headers and the footers, ending with a summary.

The OCC also has the characteristics of an OLE (Object Linking and Embedding) container. That means that the so-called OLE server applications can be embedded into the test document. This is a characteristic that most Windows applications offer. An example here would be embedding a designer drawing into a document of the WinWord text processing system. This technology is used here in a special manner.

The software provides a library of test modules. Each test module is a Windows application, which performs a certain test function. An example of such a test function is measuring a distance protection zone. A test module controls the CMC test hardware, receives the results of the measurement, evaluates the results of the

measurement in relation to the tolerance specifications and logs these results. These test modules are designed as OLE servers, which means that they can be embedded into the OCC document. After the test data were obtained, they are visualized in the OCC. Because many of these test modules can be embedded consecutively in a test document, a whole inspection scheme, respectively a test report, is created.

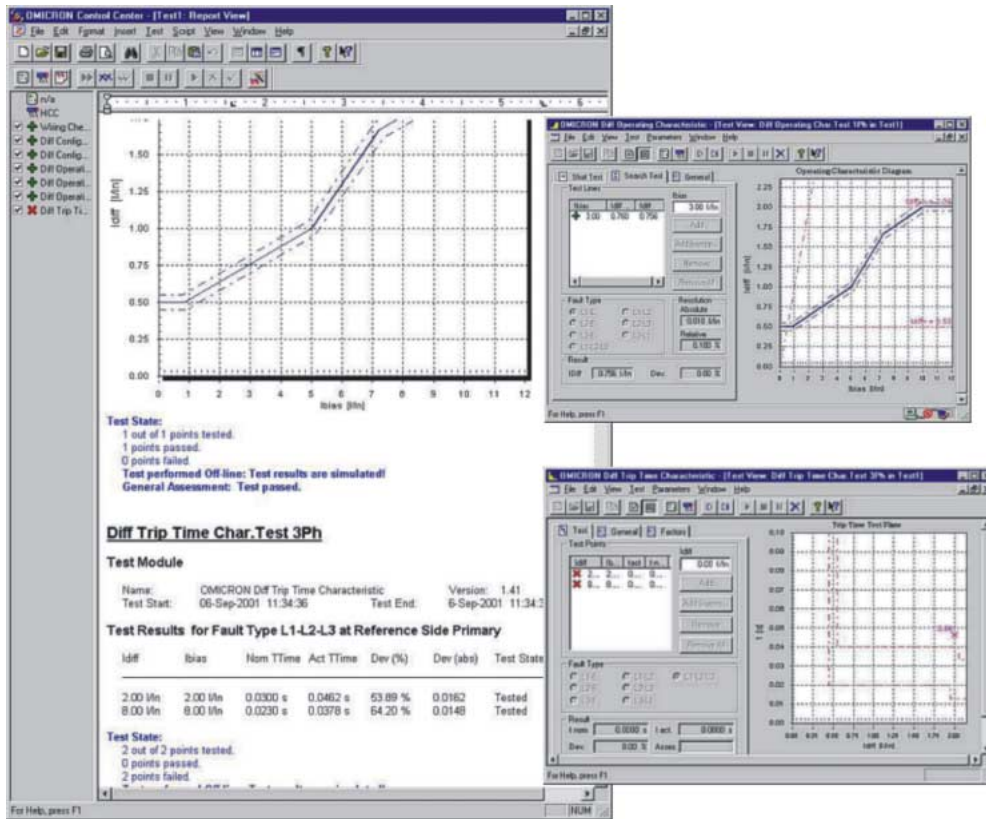


Figure 3 - OCC with Embedded Test Modules

For the controlling of the test modules from the OCC, a standardized software interface is used. As for the technology, OLE automation is used here. For example, the OCC can activate a total test this way. The OCC consecutively starts all test modules embedded in the document. Each test module executes the specified test, evaluates this test and then returns the inspection results in the OCC test document. Thus, a test plan turns into a complete test report filled with data including assessment by pressing the button "Test All". On the other hand, the button "Delete All" resets the test plan to the initial state making it receptive to new data.

The test system supplier offers a number of test modules, for example:

- Sequencer – Measures response times.
- Ramping – Measures accuracy of threshold values
- Overcurrent Protection
- Differential Protection
- Distance Protection
- And more...

This test module library is in constant expansion.

Beyond that, Siemens completed the system by self-developments of the test modules. These modules, which communicate with the protection over the serial interface, are primarily for the parameterization of the protection device. Here the test device manufacturer would be overtaxed to offer a generally accepted solution since the protocols for parameterization of protection devices were manufacturer specific but were not subjected to international standards as of this writing.

The parameterization module, developed by Siemens, enables the test engineer to download any parameter set to the relay via the test document. In the test sequence, this module is started as an OLE server, parameterizes the protection and logs the settings that were made. Naturally, multiple changes of parameter sets can be done between individual tests. The type tester determines this by embedding a number of subsequent and individually set parameterization test modules in the OCC document.

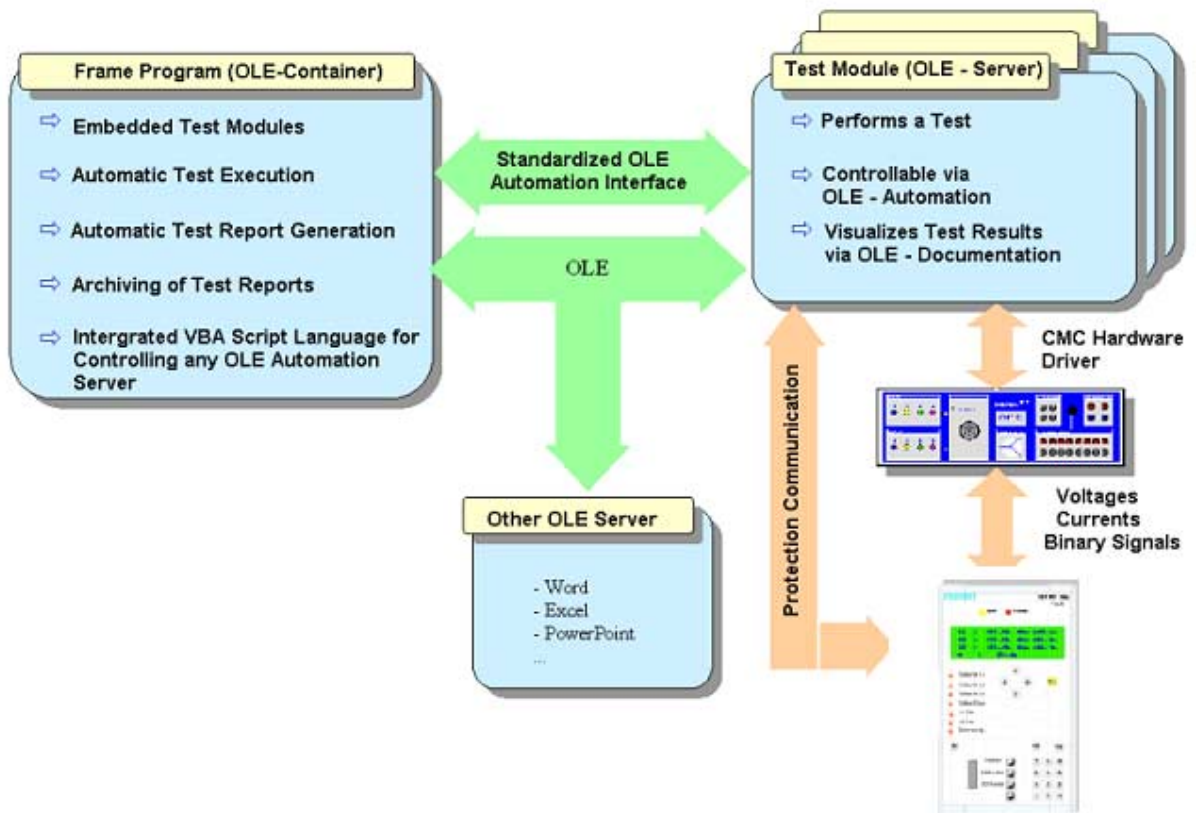


Figure 4 – Test System Software

6 Experiences with the Application of the Test System in the Type Testing

SIEMENS introduced the Test Universe test system in 1997, side-by-side with the development of the SIPROTEC protective device series. With the test modules available today, approximately 60 % of all functional tests of the protective functions are performed automatically by a comprehensive type testing. In this situation, comprehensive type testing means that the test system is used for the test planning, the execution of the test, the test object parameterization and the documentation.

In the test-planning phase, the test documents are created with the OCC in conjunction with the test module library, instead of using WinWord. Complete test documentation is developed this way usually without the presence of the tester. The manual work that remains is essentially identification and further handling of the found errors and the testing functions that are difficult to automate.

The test quality and thus the product quality were substantially increased by the application of the test system. The test depth was increased on the average by approximately 550 %. The type testers indicated that approximately 1/3 of all software errors were found due to the increased test depth. The test quality benefits likewise from the 100% reproducibility of the tests and the complete system-specific documentation.

In total, the expenditure of time could be lowered by about 60 % in relation to the manual tests. This figure was determined for the automated tests and was based on an equal test depth level. Generally speaking, there are higher expenditures for test planning, which are on the other hand more than compensated by the following phases in the test process: test execution, test assessment and documentation. The total test time expenditure proportionally reduces the volume of test runs being repeated. Repetition of the test execution might be necessary due to the elimination of errors found. Similar test plans used for existing projects can easily be adapted for new tests, which also leads to considerable time-savings. With the automated tests, the test engineer's workload is lightened considerably by eliminating the pointless operational sequences, which in turn positively affects the morale of the testers.

The test scope of a typical type test leads to a large amount of documentation, which comprises approximately two meters of printed DIN A4 paper.

7 Summary

The constantly rising functionality of the digital protection technique makes automation during the testing process of such devices inevitable. With the application of the Test Universe test system at Siemens AG, a considerable increase of the test quality and at the same time, a considerable lowering of the test expenditure in the type testing were achieved. The substantial advantages of the test system are the comprehensive support of the test processes, the automation possibilities and the modular structure of the test software. By supplementing the test system with Siemens-specific modules, especially for the relay parameterization, the efficiency of the type testing could be further increased.