

Improved Automated Testing for Protective Relays

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Introduction

The reliability of electricity generation, transmission and distribution is directly related to the reliability and quality of the protection system. Regardless of which generation of protection equipment is protecting the individual elements of the electricity system; it is always necessary to prove its proper functioning during commissioning and again periodically after a certain duration of service. Where electromechanical relays have problems with ageing mechanisms and coils; or the static relay generation with drifting analog circuits, the digital relays struggle with software bugs and firmware updates. Complex technical devices, and protection equipment can fail for any reason therefore 100% security is impossible. Due to the inactive nature of relays during proper network conditions a possible relay malfunction can only be detected at the instant of a power system fault. Thus, due to the vital role protection relays play to achieve high power system stability and also in preventing the power system owner from high financial losses due to damaged power system elements, the risk of malfunctioning relays should be minimized. Thorough commissioning and routine testing of relays should be undertaken to minimize this risk.

On the other hand, trends like liberalization of the electricity market and privatization of utilities put the relay commissioning, routine testing and protection engineering departments under pressure to save costs.

How can the quality of the protection system and as a direct result, the power system, be sustained or even improved when the staff for relay evaluation, commissioning and routine testing is generally reducing? One way to escape this dilemma is to increase the productivity of the remaining experts through automation. Automation can save the relay expert's time allowing them to concentrate on solving and analyzing actual failures during power system operation or relay commissioning and maintenance. Furthermore automation can even increase the depth of testing in a shorter time, raising not only the efficiency but also the quality.

Important aspects regarding automated relay testing

The following error sources should be considered:

- The firmware of modern digital relays is complex software and like all software it is not free of bugs.
- Although the influence of hardware component drift or error could be reduced in digital protection equipment (self monitoring) there is still hardware which is not monitored and which may fail.
- Dozens of parameters have to be set correctly. Only 1 wrong setting may lead to a maloperation when correct operation would be important.
- Frequent firmware updates of modern relays are on the one hand eliminating errors, but may also be a source for new errors.
- Changes in network topology become more frequent due to trends such as distributed generation and network liberalization. Changes in relay settings are an error source and correct operation after changed settings should be verified.
- Wiring errors.

Modern multifunctional digital relays present many hurdles for test automation:

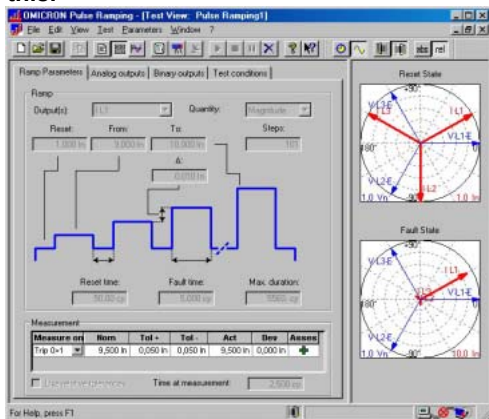
- Many, often overlapping functions, are active in parallel.
- Not every function has a dedicated contact routed for easy checking of its proper functioning.
- The parallel operation and interaction of those functions should especially be tested.
- Free programmable logic functions may differ from relay to relay and make it impossible to create standardized test plans.

General rules for successful test automation programs:

- Standardization of relays and their parameterization is the key to successful test automation.
- 100% Standardization is impossible therefore a test automation system has to provide the tools to quickly and easily adapt standard test plans to fit non standard applications.

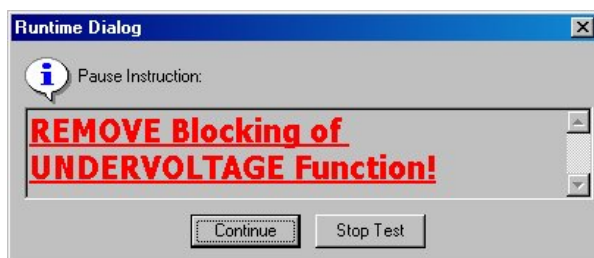
The listed aspects lead to the creation of rules which should be observed when testing:

1. A relay has to be tested to its actual settings. Testing a relay to factory default settings or other changed settings does not guarantee a proper function with actual settings. -> **Automatic test plans have to be adapted to fit the actual relay settings. (and not the other way round)**
2. Blocking/disabling of overlapping functions for testing purposes should not be done. There is the danger that the unblocking/enabling is forgotten after the test. Secondly the influence the parallel functions may have on each other (e.g. limited processing power) is not tested. -> **Test algorithms have to be smart to allow stimulation of exactly the function under test although the other functions are active in parallel. The test software must support this.**



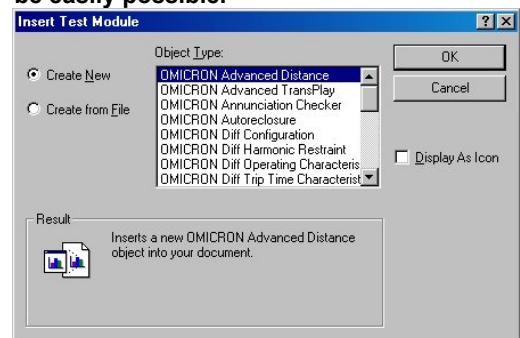
Picture 1: OMICRON Pulse Ramping, designed to test the pick up of overlapping protection elements.

3. If there is really no way around blocking/disabling of overlapping functions for testing purposes the blocking/disabling process should be automated or the flow of testing has to contain reminders to ensure that the functions are enabled again. -> **The automated test plan has to set message-breakpoints to remind the tester.**



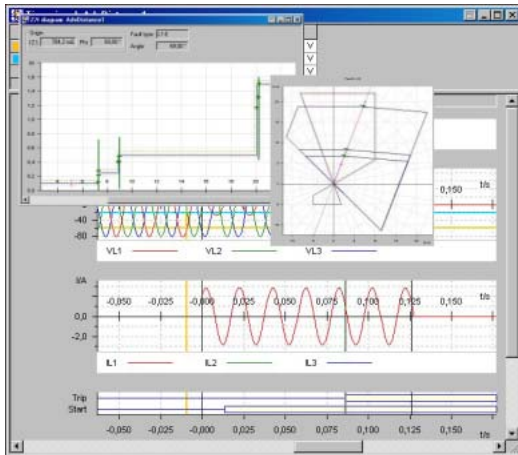
Picture 2: OMICRON Pause Module, designed to set breakpoints and instructions in an automated test.

4. Routing of additional relay outputs only for testing purposes is also dangerous and may be a source of error. Again: Do not touch the relay parameterization for testing purposes. -> **Test algorithms have to be smart to allow stimulation of exactly the function under test although the other functions are active in parallel. The test software must support this.**
5. Testing of relays should be done against the settings calculated in the relay setting sheet. Reading the settings file directly from the relay and testing against those settings introduces the danger of (human) errors when setting the relay or unwanted re-parameterizations, for whatever reasons, are not discovered. -> **Testing against the settings read directly from the relay is not covering an important error source.**
6. As it is possible to freely program the logic of modern digital relays it is required that the tester can easily add new tests to a standard test plan for those "non standard" functions. -> **Adaptation of standard test plans has to be easily possible.**



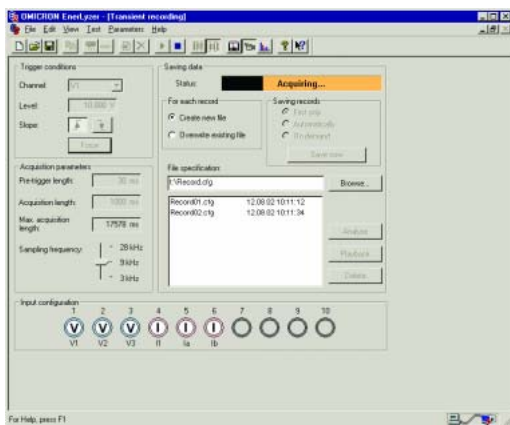
Picture 3: OMICRON Control Center allows flexible insertion of new Test Modules if necessary

7. Automatic assessment of test results, according to given relay tolerances, is a must. However, the automatic assessment can never fully replace the plausibility check of the results by the testing relay expert. -> **Visualization and straight forward graphical representation of the results is necessary to allow the expert a quick and easy plausibility check of the test results.**

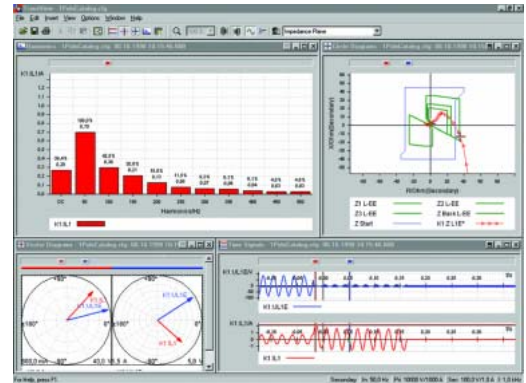


Picture 4: OMICRON's graphic result presentations, Time Signal View, Z/t Diagram and Impedance Plane

8. Once a failure is found in a relay, be it the relay itself, a wrong setting or even a wrong test plan, it is important to have the appropriate analysis tools and support to quickly locate and eliminate the error source. - > **Automated testing requires a very good documentation and visualization with event recordings and graphics of all the test steps. The test set should provide troubleshooting tools like transient recording, wiring checking tools or measurement functions**



Picture 5: Troubleshooting tool OMICRON EnerLyzer, transient recorder function in the CMC256

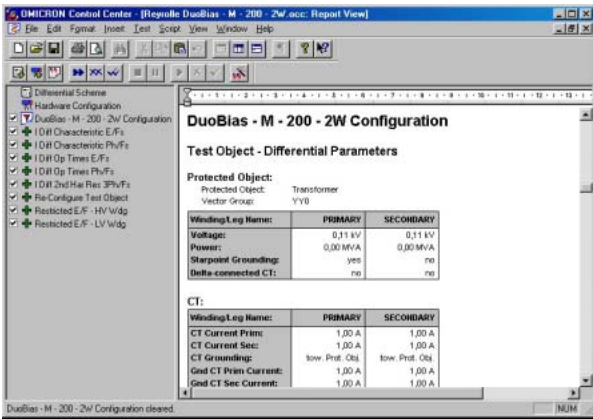


Picture 6: COMTRADE Analysis tool OMICRON TransView

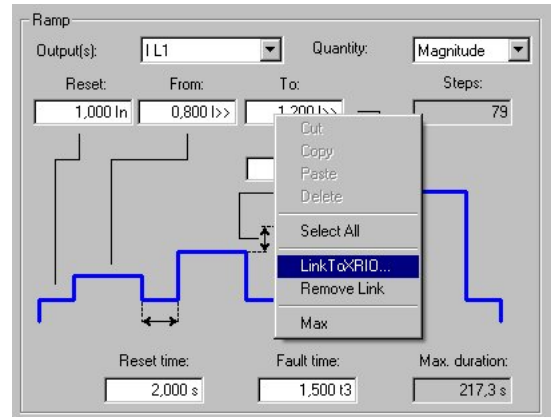
Status of Test Automation before Test Universe 2 was Released

The OMICRON Test Universe document-oriented automation concept is based on the OMICRON Control Center technology and OMICRON's RIO interface. Automatic test plans for relay types can be created based on Control Center files. The flexible Hardware Configuration concept allows the user to use different kinds of OMICRON test sets to carry out the automated tests. This automation concept allows the user to easily create automatic test plans for single function relays as well as for complex, multifunctional digital relays. Once an automatic test plan is created for a relay this test plan can be re-used and copied for testing the next relay of the same type. Depending on the complexity of the relay this adaptation of the test plan to fit the revised relays settings may cost some time and may require a good knowledge of the Test Universe test modules. In particular those functions which require testing with the "general" modules OMICRON State Sequencer and OMICRON Ramping or Pulse Ramping have to be manually adapted to the new relay parameterization. Some users and utilities use the "Test Module Automation" and scripting possibilities that OMICRON provides to set the "general" modules automatically, dependant on the actual relay settings.

As a summary one could say automated testing works very well with OMICRON's Control Center automation concept. All general rules for automated relay testing can be fulfilled. Further improvement is possible especially when adapting a relay type test plan to the actual relay settings.



Picture 7: OMICRON Control Center with an automatic test plan for a differential relay



Picture 9: OMICRON Pulse Ramping with LinkToXRIO functionality

Test Automation Improvements with the new Test Universe Software Version 2.0

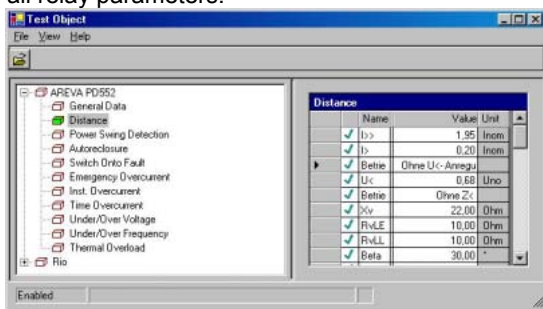
The fundamentals for the improvements are the new OMICRON technologies **XRIO** and **LinkToXRIO**.

Focus for the improvements was put on the following aspects:

1. The whole test plan automatically adapts to changed relay settings:

This goal is achieved by 2 major steps:

- A new OMICRON standard was created: **XRIO** which is the abbreviation for **Extended Relay Interface by OMICRON**. Where the old RIO standard was only modelling the most important functions like Overcurrent, Distance and Differential, the new OMICRON **XRIO** standard allows the modelling of all functions of a modern multifunctional relay. It can carry all relay parameters.



Picture 8: OMICRON XRIO Dialog. XRIO can e.g. cover all functions of a modern digital distance relay

- All "general" test modules have access to the **XRIO** parameters and allow the definition of relative test settings. This new technology is called **LinkToXRIO**.

2. Known automation hurdles are removed:

- New Circuit Breaker (CB) Simulation for all modules
- Control Binary Outputs from all important modules
- Simulation of the power system voltage in differential testing modules to remove the necessity to block them (e.g. undervoltage elements)
- 6 currents are provided in the Distance and Overcurrent module to remove the necessity to block the (e.g. generator-) differential function when testing the overcurrent or distance function.
- Set test points relative to the zone reaches and line angle, not only in Advanced Distance, but also in the general test modules like Autoreclosure and State Sequencer.
- Prefault load current in the Distance modules to remove the necessity to block e.g., the switch-on-to-fault logic
- Automatic Switching Box **CM ASB2** controlled by the test software for single phase mode applications (e.g.: high burden electromechanical relays) [4]

3. Improvements for the "Test Plan Designer": Test Plan Creation, Management, and Distribution are complete.

Note:

The "Test Plan Designer" should be seen as a distinct engineering role. Bigger utilities have engineers who are responsible for the creation of standardized test methods and test instructions. This person would be the classical "Test Plan Designer". In smaller utilities the "Test Plan Designer" and the "Tester" is often one and the same person.

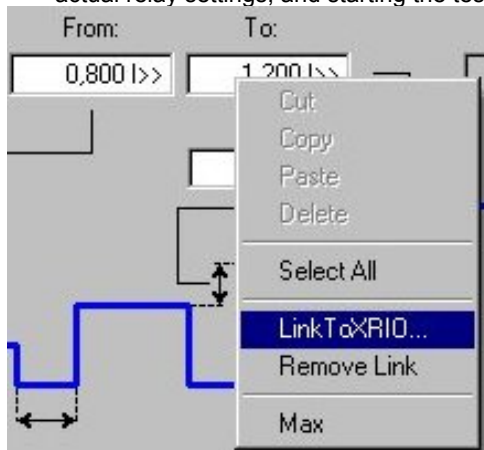


Picture 10: "Test Plan Designer" and "Tester" are two roles one can often find in the industry using automated testing.

OMICRON Control Center documents are the ideal tool to easily and quickly create, maintain, and distribute automated test plans for relay types. Functions once created for one relay type can easily be shared or re-used for a new relay type (copy/paste). The fact that Test Plans for different relay types share test functions leads to the idea of creating a library of standardized test steps. It is recommended that a test plan designer creates a library of standardized test steps to benefit from re-usage and synergies when creating test plans for relay types.

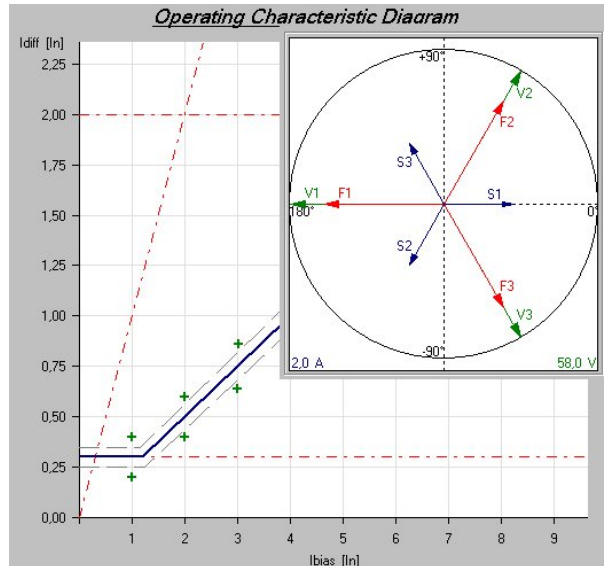
4. Testing with automated test plans becomes easier

- The fact that the whole test plan now adapts to changed relay settings without scripting increases the ease of use and reduces the actual work on site to wiring, entering the actual relay settings, and starting the test.



Picture 11: **NEW LinkToXRIO** technology is the key to relative test points which automatically adapt to changed relay settings

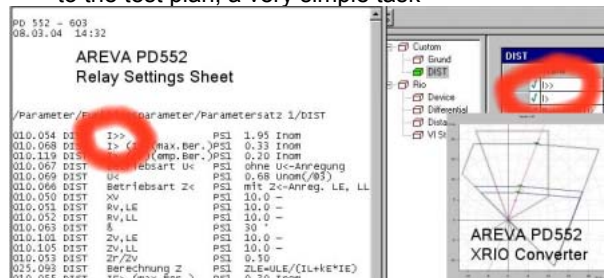
- Extensive use of visualization and graphics help to easily understand the test procedure and results. Furthermore it allows the expert a fast plausibility check of the results.



Picture 12: Visualization in Graphics helps the user to understand the test procedure and results

5. Relay Parameter Transfer becomes easier

- The **NEW** technology of **XRIO Converters** makes the transfer of actual relay settings, respectively data from the relay settings sheet to the test plan, a very simple task



Picture 13: **NEW XRIO Converter** technology allows the modelling of the relay exactly, parameter by parameter, automatically generating the test characteristics

Summary

The goal of OMICRON's test automation concept is to use the relay expert's time as efficiently as possible. It shall be the tool to increase the depth of testing while decreasing the testing time, allowing the expert to use his valuable time to eliminate possible errors in the protection system. It is the ideal method to visualize, document and handle the complexity of powerful modern protection relays. It is the tool to limit today's protection engineering complexity through test standardization. It is an important source of

convenience in operating the protection system. The resulting thorough and repeatable test documentation is the proof of state of the art protection engineering.

OMICRON's philosophy always was to provide powerful but simple tools enabling the user to create quickly and easily automatic test plans which fit his organization's requirements. **OMICRON's Test Universe 2.0** with its new technologies **XRIO** and **LinkToXRIO** building on the successful Control Center Automation concept, is the basis for a new era of automated testing.

Literature

- [1] International Standard, IEC 61850-7-4, Basic Communication Structure for Substation and Feeder Equipment – Compatible Logical Node Classes and Data Classes
- [2] Dr. Richard Marenbach, OMICRON, Effizienz und Qualität von Schutzprüfungen mit automatisierten Prüfvorlagen steigern. EW Jg.102 (2003), Heft 4
- [3] Jens Hauschild, Andrea Ludwig, Vattenfall Europe, Veränderte Rahmenbedingungen als Auswirkung der Liberalisierung für Betrieb und Prüfung von Schaltanlagen, OMICRON User Meeting, Friedrichshafen 2003.
- [4] Boris Bastigkeit, Time saving and simplification of protection testing through the use of the Test Universe Software 2.0 and CM ASB2 switching box at Valorec / Switzerland, OMICRON User Meeting, Friedrichshafen 2005