REGRESSION TEST APPROACH FOR MAINTENANCE TESTING – A SECURE METHOD TO DETECT DEFECTIVE COMPONENTS

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Abstract

Life cycles of modern protection IEDs are becoming shorter and shorter. Additionally, the time spans between firmware updates for these devices are decreasing. Therefore, the needs for qualified testing strategies are increasing. The utility needs to verify e.g. the functional requirements, the quality of the new firmware, the correctness of commissioning, the parameter settings and more.

This paper focuses on the method of regression-based testing that is well known from software development. A fixed testing procedure that is developed i.e. during the commissioning phase is set as a reference for further tests. The method requires written definitions which types of test the IED has to undergo during its life cycle. Due to the high quality of the documentation the utility has furthermore a good tool to keep the knowledge in the company. This fact is very important to support the internal knowledge management system.

Due to this new approach the testing quality could be increased while the testing time is decreased at the same time.

Key words: regression test, testing strategy, IED life cycle, knowledge management, maintenance test

1 Introduction

The requirements for testing modern IEDs are increasing faster and faster. The life cycles of the IEDs are becoming shorter, there are hundreds of parameters which have to be tested or verified. Besides of this, the reasons for testing are often quite different. From the manufacturers point of view the product quality is in focus, from the utility point of view the functional requirements, the new firmware update, the commissioning quality and more have to be checked.

In that context it is very important to first have a look to the whole life cycle of an IED from the planning and engineering phase until decommissioning. All testing during planning, engineering and assembling finally comes to the Site Acceptance Test (SAT) which is the final test to check if an IED is now ready to take over its application purpose.

2 Life cycle of an asset

In the following section the different phases during the life cycle of an IED from a utility point of view will be shown. The phases which are mainly located at the IED manufacturer’s site are neglected here. A detailed description of the different phases is shown in [1]. The different phases could be named as:

- Planning Phase
- Tender Phase
- Factory Acceptance Phase
- Commissioning Phase
- Maintenance Phase

During each phase different actions in relation to testing have to be done. But during these actions also faults can occur. These faults have to be prevented or eliminated.

During the planning phase of the protection system the whole system is defined. The planning engineer has to consider which primary assets he wants to protect and how. The protection system is characterized by its selectivity, speed, reliability and availability. All these attributes have to be chosen in such a way that the protection philosophy of the utility can be fulfilled. Several questions have to be answered as: Which protective functions are used? If a doubled protection system is required: which protective functions are covered by IED main 1 or main 2? How is the backup protection realized? Which communication system within the substation or between substations is used?

The tendering phase is probably the most important phase of all. It includes a lot of different steps. First of all, a prequalification procedure has to be defined that includes the description of all test cases that a new protection IED has to undergo to get qualified [2]. A prequalification procedure helps to eliminate the time pressure from the tendering process because it can be started any time before the tender is published. By this way a manufacturer and his product can become prequalified and the publisher of the tender knows that only products which fulfill his needs are offered, so he can concentrate on other issues i.e. the price [3]. The prequalification procedure can include a written description which tests the IED has to pass or even digital files which can directly run on dedicated test equipment. For a more detailed description see the following sections.

The phase of factory acceptance test (FAT) runs – as the name explains clearly – at the factory of the IED's manufacturer. The customer himself or somebody else who witnesses the tests are also part of the procedure. The functionality of the IED in his protection cabinet can be tested. Even the communication between IEDs within the same cubicle or between cubicles or other remote processes can be part of the test. As parameters very often, a standard setting of the customer is used to check the performance of the IED.

3 Commissioning Phase and SAT

The commissioning phase starts with the delivery of the protection cabinets onsite. All IEDs, all processes, all communication channels have to be tested. The whole system will be assembled to obtain a perfectly running system. This includes also CTs, VTs, merging units and CBs.

During the commissioning phase all components of the protection system have to be wired, connected to each other. Furthermore all parameters of the IED have to be set to the desired values. So, a lot of test cases is required with different kind of testing purpose.

Testing Purpose	**Content (as an example)**
Overall protection scheme	Test if the protection system (all IEDs which are installed) on a parallel line is working properly: selectivity for all kinds of faults, backup protection is properly configured, CB failure protection is working properly.
IED parameter verification	Test if the IED is working properly with the actual parameter settings within its tolerances described by the manufacturer
Substation communication	Test if the communication within the substation or to remote processes is working as desired
Tripping logic schemes	Check if a self-developed logical scheme within an IED is working according the definition
End-to-end	Check if a teleprotection scheme is working properly or a line differential IED
Alarms	Check if all alarms are generated in the desired way. The tester should give his full attention to define a test case in such a way that only the checked alarm is triggered and not many others.
Wiring checks	Check if all wires are connected at the right terminals

A (witnessed) Site Acceptance Test (SAT) will finish this procedure. For the following procedures it is necessary that a test equipment is used that automatically records all used test cases and can replay these test cases to a later time with the same test values and the same accuracy.

4 Requirements for accurate commissioning testing

After a Site Acceptance Test there is one main question: is the protection system now in a proper condition that it behaves as it should behave? It's also a truth that you never can be 100 % sure that the protection system has no faults inside which will lead to maloperation under certain conditions but testing persons can set up well defined procedures to eliminate as many faults in the commissioning phase as possible.

For the following considerations we assume that a well-defined prequalification phase has taken place so that the used protection IEDs are capable to deliver the desired functionalities.

To receive the highest quality in commissioning testing the elements of such a test should be:

- A description which system functions have to be tested (Commissioning Functional Requirement Specification, CFRS)
- A description how the functions have to be tested (Commissioning Testing Requirement Specification, CTRS)
- Testing tools with an accuracy at least 10 times better than the tolerances of the used IEDs
- Testing tools which can define the testing procedure already long time before the SAT happens.
- Testing tools that can save all test results in a way that no manual actions have to take place or that the test report can be changed afterwards without notification
- A description how the testing tools have to be used for the certain application (user manual of the customized test plans)
- Testing persons that understand the protection system and know how to use the test system.

A sample of a CTRS and a user manual is shown in Figure 1.

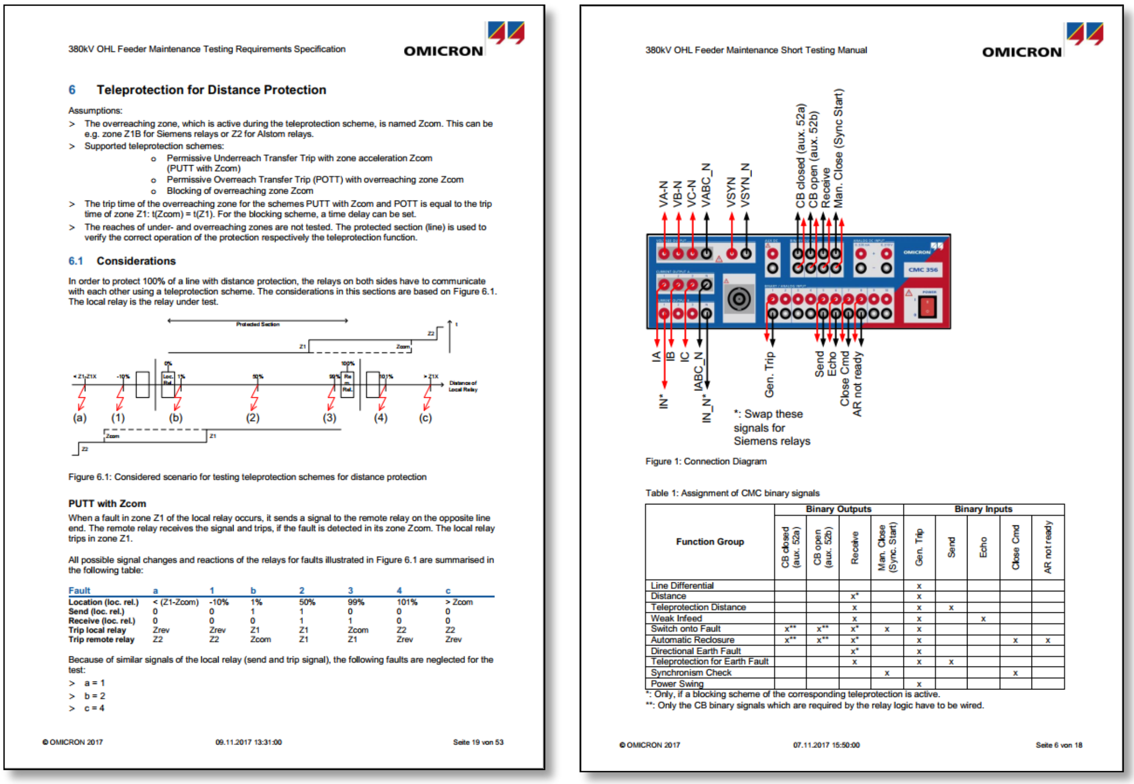

Figure 1: Sample of CTRS and Testing user manual

If all these requirements are fulfilled the test documents including all test files and results from the SAT can now be saved to be used as a benchmark for later tests in the maintenance phase.

5 What is a regression test?

To explain why such a benchmark is so important for further testing, we will make a short view to another type of testing procedures which are used in software development.

If new software components in OMICRON software have been developed it has also to be ensured that old software components are still working in the new software version as they did in the former software version. To do that, a regression test is done. Therefore, a test object is needed which can be used as a benchmark or reference, the so-called “relay test bench”.

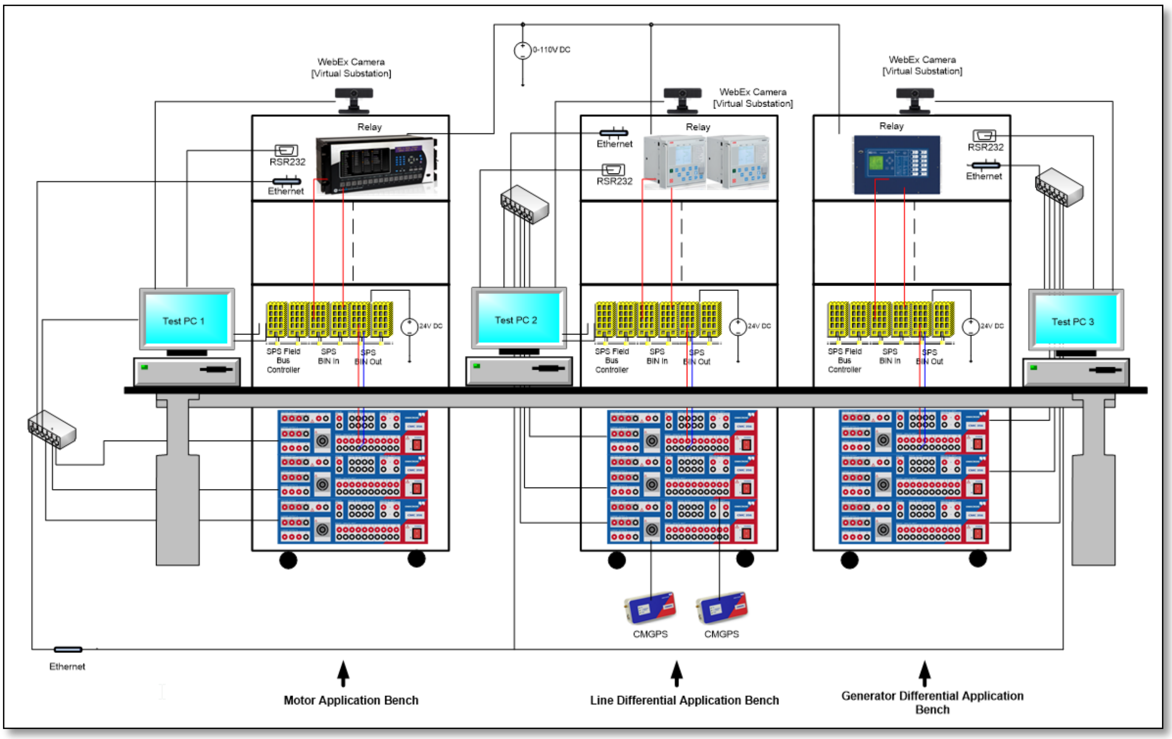

Figure 2: Concept for a relay test bench

The relay test bench is mainly a test system which contains different racks where different protection IEDs are mounted. These IEDs have specific parameters to deliver many different protective functions. The important thing is that from the particular time when the IEDs in the relay test bench got their settings it is strictly forbidden to touch the IEDs in a way that the functional behavior of the IEDs could be (accidentally) changed.

The following example will show how this works: During the development of a software version (e.g. V1.0) the software testers will report all software faults that have been identified during their testing procedures to the software developers who can now eliminate the faults from the software so that this software version is ready to be released to the customers. If now a new software version is under development (e.g. V2.0) it is quite simple to test the un-changed software functionalities using this test bench. If the software under test fails, the testers can be very sure that – because nothing in the test bench has changed – the cause for the undesired misbehavior is a fault in the new software version.

A testing method which is based on this approach is called a regression test. This principle now can be used for maintenance testing of IEDs where the testing files from the SAT will now be used as a benchmark. Therefore, it is strictly forbidden to make any changes during the maintenance phase to the SAT test files.

6 Testing in the Maintenance Phase

After some time after setting into operation the IED will have his first maintenance check, in many utilities this is after 4 years. The goal of this check is to assess if the whole IED in its surrounding processes is still working properly. The main reason for maintenance testing is therefore to search for defective components. In the following we assume that nobody changed any parameter settings in the IED since the SAT took place. Nevertheless, it can make sense to make a parameter check before testing if the settings from SAT are still the actual ones in the IED.

Even if no planned changes in the IED cabinet have been made since SAT, some unplanned things could happen in the meanwhile such as:

- Aging of components
- Drifting of components (nominal values out of tolerance)
- Loose contacts due to mechanical issues
- Weakness of insulations
- Disconnected signals due to animal attack

- And even more

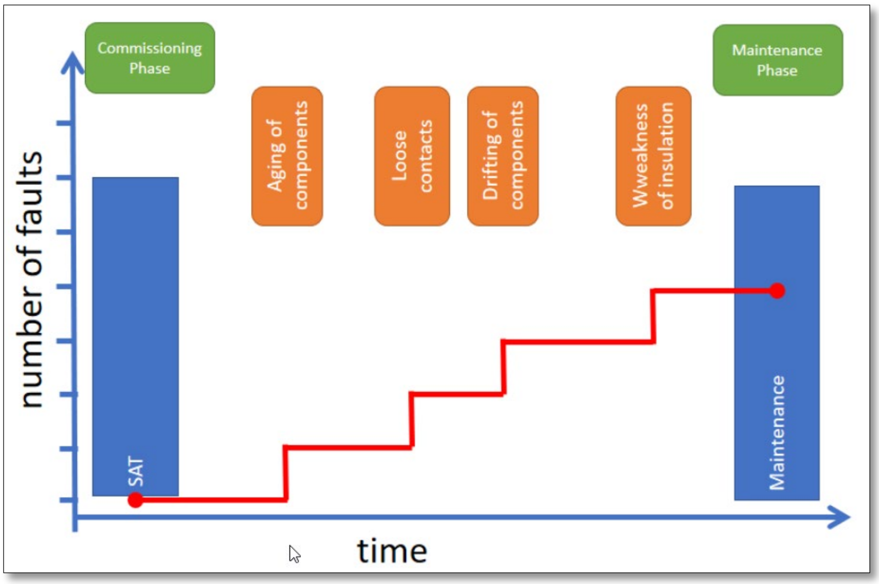

Figure 3: Faults in the protection system since SAT

This means that in the time from last SAT a number of faults could be in the protection system that have not been observed up to now due to protection maloperation (Figure 3). Now it is necessary to take the test definitions and the test files of the SAT and use them for the maintenance test. Normally the SAT includes many test cases and it makes sense to discuss if all these test cases are also necessary for maintenance testing. This is a question of testing philosophy of the utility and the answers can be very divers from "we use the same test cases as in SAT" to "we just make a visual inspection".

Using the high-qualified test sequences from SAT guarantees that all faults which have arose since SAT could be detected during the maintenance test.

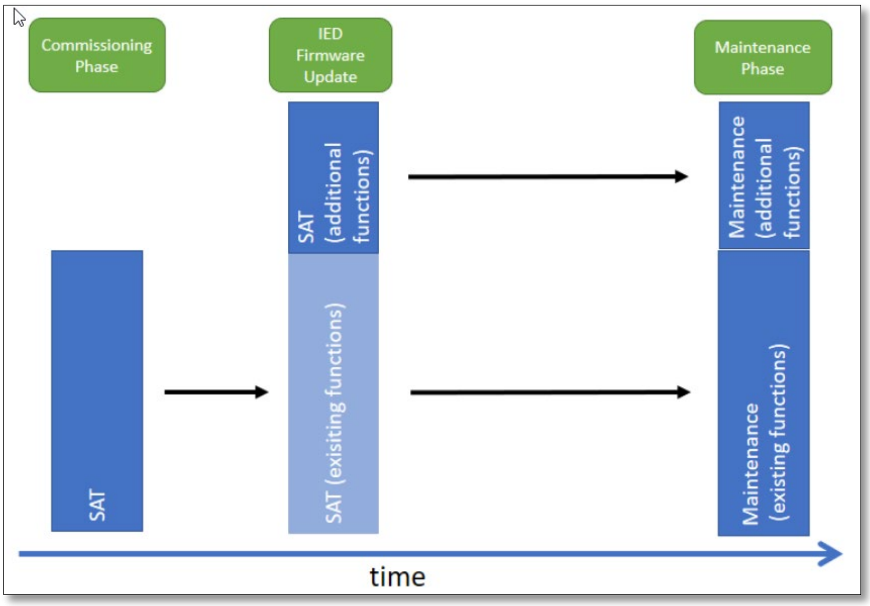

Figure 4: Procedures for firmware update testing

7 Firmware updates and other changes

Today there is quite often the case that before the maintenance test is due, a changed firmware has to be implemented in the IED. Here it is necessary to introduce also a kind of prequalification process before the new firmware is released.

Now three different scenarios have to be considered:

A. The IED manufacturer only eliminated functional faults from the IED which do not give any new functionality: in this case the tester can use the test cases from SAT. This gives the highest quality and speed of testing.
B. The IED manufacturer added additional functionalities (e.g. a protection parameter that has not been visible up to now is now visible to the user so that the value can be changed). The Tester can use the test sequences from SAT. Additionally the new functionalities have to be tested in a kind of SAT. The test sequences from SAT could be used to deliver the desired testing quality (Figure 4).
C. Very often the utility uses the case of firmware update (or even maintenance testing) also to update some relay parameters because the primary data of the electrical power system have changed in the meanwhile. In this case it is very useful to have a test system that is capable to produce all test cases not as absolute values but as relative values in relation to the relay parameters. Anyhow here it is recommended to make a kind of SAT (maybe without witnessing) which is based on test files that have high quality.

8 Test Coverage of SAT and Maintenance Test

There are very often discussions about what a maintenance test should include as already described before. Therefore, the aspect of the net and gross needed testing time (which is equivalent to the rate of the overall testing time to the IED testing time) should be taken into account.

As it has been proven in many substations: a standardized testing philosophy which is implemented in a fully automated test system can apply a lot of test cases in a very short time. Examples show, that a SAT for a Line-Differential-IED on 400-kV-level needs a testing time of 1,5 hours (without testing the alarms). This is the net testing time without driving to the substation, making the feeder ready for testing, connecting the test equipment, etc. This means that even if the number of test cases for maintenance testing is only 50 % of the number of test cases of SAT only 45 Minutes could be saved in testing time which is in this case only 10 % of the gross testing time (Figure 5).

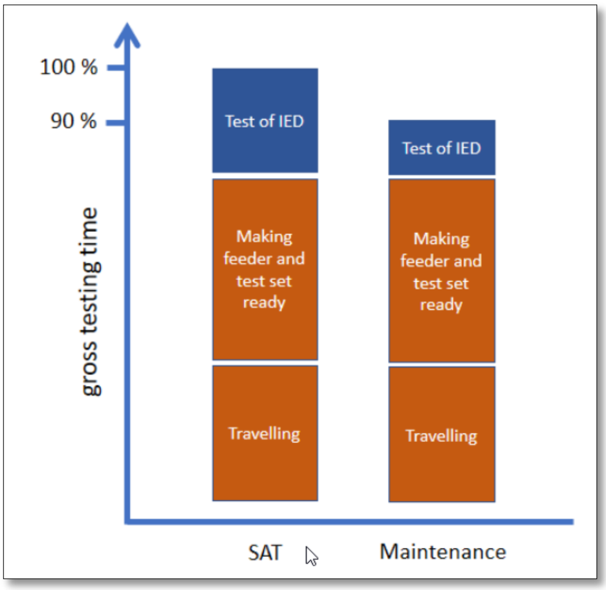

Figure 5: Comparison of gross testing time for SAT and maintenance testing

Because of this reason there are many utilities which use fully automated testing solutions that do not differentiate between SAT and maintenance test coverage. They always use all test sequences from SAT.

9 Knowledge management and testing quality

Using a standardized testing method which is based on a commissioning functional requirement specification (CFRS) and a commissioning testing requirement specification (CTRS) can have many benefits for the utility as shown in several realized cases [4].

The tester himself saves time for developing the test procedure: The test procedure is already defined, only the changed parameters have to be configured before the test of a new protection device starts. All test plans include the same tests, which means that the testing quality can be better controlled and, in the end, improved. Working together as a team is easier, as everyone is working with the same standards. The team members can exchange their experiences and share knowledge.

And as very important argument such a standardization helps to keep the know-how of the people in the company. It documents the experiences of the company. It becomes very easy to setup training classes for new employees to synchronize them with the testing philosophy of the utility.

New protection functions or new (improved) algorithms in protection functions can be recognized and the updated testing solution can be released to every tester at the same time. The development of such a test is only done once.

10 Conclusions

As the development cycles by IED manufacturers will be shorter in the soon future, testing processes within a company have to be adapted too. Overthinking the working principles can result in better efficiency in testing time and quality.

- Quality aspects: The tests are better reproducible and repeatable than manual tests.
- Cost saving aspects by saving time in preparation, execution and documentation of the test itself.
- Aspects of storing the knowledge of experienced employees in the company by writing the standard documents.
- Aspects of solving technical issues by a central team of specialists and spread out a standardized solution to the testers in the field.
- Aspects of improving the test depth by using test cases which are high sophisticated. These tests can normally not be done by every tester.
- Use of advanced features of the testing tools that may not be known to the testers in the field.

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