Impact of faster development cycles of IEDs onto protection testing

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Abstract

Life cycles of modern digital protection devices are becoming shorter and shorter. Additionally, the time periods between firmware updates for these devices are decreasing. Therefore, the need for testing in different life cycle phases is increasing: Manufacturers need to ensure the devices' product quality in their final inspection routine, utilities need to verify, for instance, the functional requirements, the quality of the new firmware, the correctness of commissioning, the parameter settings, and more.

This paper focuses on the life cycle of a protection device from a utility point of view. It classifies the different phases of this life cycle and shows the requirements for testing in different phases. The aspects of testing from first prequalification work to the periodical maintenance tests are discussed. The impact of specifications and of standardization is shown and the synergies are highlighted.

As an example for successful automated testing the solution for 380-kV-OHL maintenance testing at National Grid Saudi Arabia is presented.

Key words: firmware, specification, prequalification, type testing, factory acceptance test, commissioning test, maintenance test, standardization, protection device, life cycle

1 Introduction

Life cycles of modern IEDs are becoming shorter and shorter. Additionally, the time periods between firmware updates for these devices are decreasing. Therefore, the need for testing in different life cycle phases is increasing: Manufacturers need to ensure the devices' product quality in their final inspection routine, utilities need to verify, for instance, the functional requirements, the quality of the new firmware, the correctness of commissioning, the parameter settings, and more.

2 Life cycle of an asset

This section shows the different life cycle phases of an IED from a utility point of view. The phases which are mainly located at the IED manufacturer's site are neglected here. Here, the different phases are referred to as:

- Planning Phase
- Tendering Phase
- Factory Acceptance Test Phase
- Commissioning Phase
- Maintenance Phase

During each phase different actions are necessary. But during these actions also faults can occur. These faults have to be prevented or eliminated.

2.1 Planning Phase

During the planning phase of the protection system the whole system is defined. The planning engineer has to determine 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, such 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?

Nevertheless, the planning engineer can make mistakes: the protection system can be non-selective, or the protection system does not cover the other aspects required. Furthermore, IED settings can be faulty due to miscalculations. Even unknown or faulty data of primary assets can lead to wrong IED setting sheets.

2.2 Tendering Phase

The tendering phase is probably the most important phase. It consists of many different steps. First, 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 [1]. This procedure helps to eliminate the time pressure from the tendering process because it can be started any time before the tender is published. 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 [2].

The prequalification procedure can include a written description of the tests the IED has to pass or even digital files which can directly run on dedicated test equipment. .

But as always, also in this phase faults can occur which could strongly influence the usage of the IED at a later point of time. For example, on the one hand test cases during the prequalification process may not cover all aspects, on the other hand the IED may not work properly according to the predefined standards.

2.3 FAT (Factory Acceptance Test) Phase

The FAT phase takes place 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.

If there are still faults in the setup they will be most probably wiring faults in the cubicle which then have to be eliminated with a higher amount of work during the commissioning phase.

2.4 Commissioning Phase

The commissioning phase starts with the delivery of the protection cubicles onsite. All IEDs, processes, and 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.

The IEDs will get their final settings. A Site Acceptance Test (SAT) will finish this procedure. But also here faults could be overseen. The IED could have a wrong setting due to a mistake of the commissioning engineer or due to a miscalculation, if the IED settings have to be set during commissioning. Wiring faults, communication faults and interlocking faults can still occur in the substation.

2.5 Maintenance Phase

Some time after being put into operation, the IED will have its first maintenance check. The goal of this check is to assess the proper functioning of the whole IED in its surrounding processes. If the tester can be sure that in the meanwhile nobody changed any settings at the IED, the test can be quite short. Nevertheless, the test sequences have to be defined in such a way that any misbehavior of the IED and connected processes (incl. CT/VT, merging units and CB) are working properly.

If not the right test cases are applied to the IED, failures of damaged components or faults that are still existing from the commissioning phase won't be detected.

2.6 Consequences

During the different phases during the life cycle of an IED, it will undergo a lot of test cases. The quality of a specified test case in a certain life cycle phase has to have a very high quality. The goal should always be that a certain phase is finished with zero remaining faults. As this is only theoretically possible the goal should be that the number of faults at the end of a phase is minimized.

Here is also one argument because of which many utilities think that maintenance testing has to be made on a minimum level. But this opinion might be problematic. As shown before, at the end of the commissioning phase there are still some faults in the substation. At least the first maintenance test after the commissioning phase has to have a very high quality.

This is also very important especially in the case that the utility has sourced out the maintenance testing to subcontractors. In this case the best way for the utility is to define the test methods so that the subcontractor has clear advices of what to do.

3 The Testing Purpose

The test sequences which stimulate could have a totally different purpose. In the following table some kinds of testing purposes with their specific content are mentioned.

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 within its tolerances described by the manufacturer.
Substation communication	Test if the selected communication standard within the substation or to remote processes is working as desired.
Single protection function	Check if a specific function can protect a specific asset as desired. For example, if the polygon of a logical node with PDIS functionality can cover all faults with lightning arc on a selected transmission line.
Dynamic effects	Check if an IED is still working properly even if the belonging CT already saturated.
Tripping logic	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 pay full attention to the definition of 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.
Conformity for standards	Check if the IED is working according to a defined standard, i.e. according to IEC 61850 or IEC 60255-121.
Firmware update	Check if a firmware update is necessary, check if it fulfills all requirements (similar to prequalification process), check if the IED is working properly in the substation after firmware update.

For all kinds of testing purposes there is an important rule: not to change a setting of an IED just for the purpose of checking a specific functionality. This is also very important during the commissioning phase. Neglecting this rule leads to the fact that the tester will never check the final settings.

4 Faster development cycles in the industry

Due to the fact that new IEDs include a lot of features based only on software it is quite probable that firmware updates will be released by the manufacturer in shorter and shorter development cycles. As the implementation of a new firmware version into an IED is comparable with a prequalification and commissioning phase it makes sense to coordinate all test cases which are used to stimulate the IED. Therefore, it makes sense to think about a global testing strategy for the utility.

4.1 Uncoordinated testing

During every phase of the life cycle the IED has to undergo specific test cases. Before a test case can run the tester has to think about what the content of the case is and how the specific test result could be obtained. Defining the test case could be quite time consuming. Running the test case with modern digital test equipment which allows a high quality of automation is only a question of minutes. This means that the time for defining a test case and setting up the test set is very important if the goal of a utility is to become more efficient in terms of testing quality and testing speed.

In Figure 1 the time required for definition and execution of the same (or similar) test case during the different phases in life time are shown.

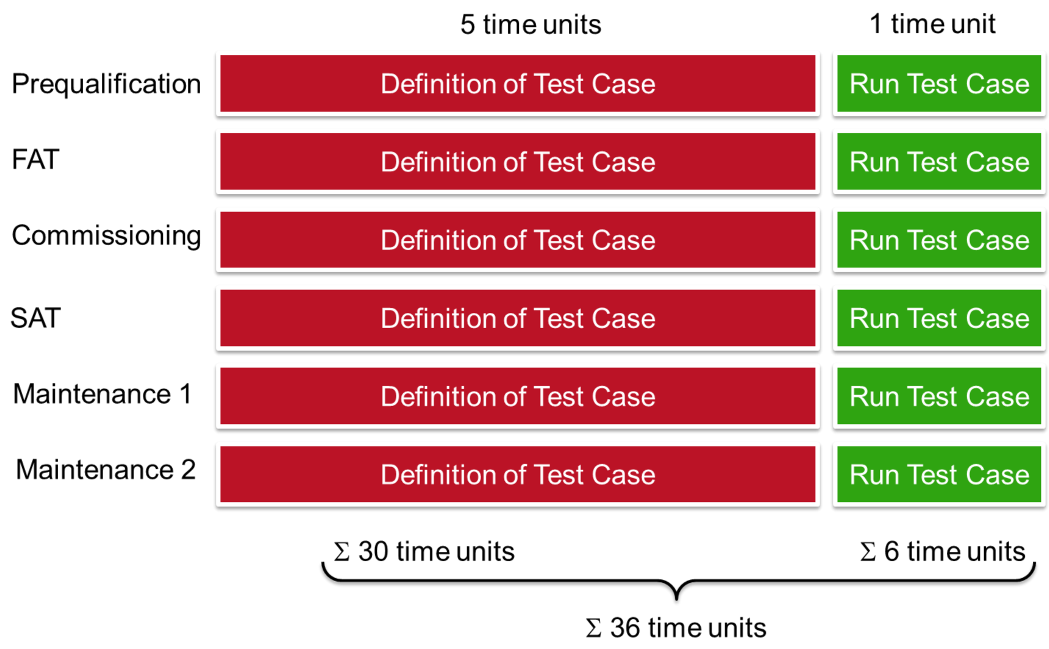

Figure 1: Total testing time for definition and execution of test case with uncoordinated testing

In every phase of the life cycle a dedicated person (probably from a different department) thinks about how to test a specific feature of an IED and how to set up the test equipment. If this consumes i.e. 5 time units and this test is defined by another person in another phase with the same amount of time, 6 x 5 time units are spent which results in 30 time units. Supposed that different testers run the defined test case with the same purpose they need 6 x 1 time units which results in 6 time units. For the whole definition an amount of 36 time units is needed if no coordination of testing procedures takes place.

4.2 Coordinated testing

If the definition of test cases is coordinated across the complete company a lot of time can be saved. Therefore it is necessary to adapt the common working processes in the company that people are working together even if they do not belong to the same department. The goal should be that a specific test case is not defined in every phase of the life cycle for new. This is similar to reinventing the wheel again and again.

If the test cases are only defined for the first life cycle phase and re-used for the following phases, a tremendous amount of time can be saved which can increase the efficiency dramatically.

As shown in Figure 2 an amount of 5 x 5 time units can be saved. This results in an amount of 70 % time reduction which is similar to the same amount of money. In case high-performance test equipment is used, it is possible to save these definitions in digital format in such a way that the test equipment can directly load the definition and can run the test. So every tester is able to perform the test with the same quality.

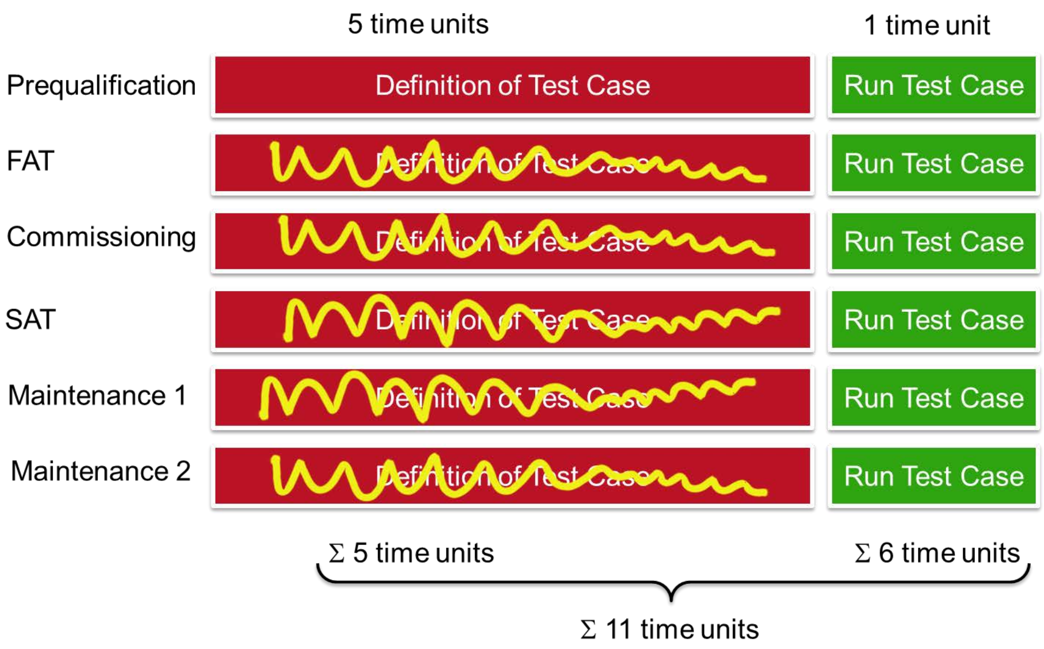

Figure 2: Total testing time for definition and execution of test case with coordinated testing

5 Testing Matrix

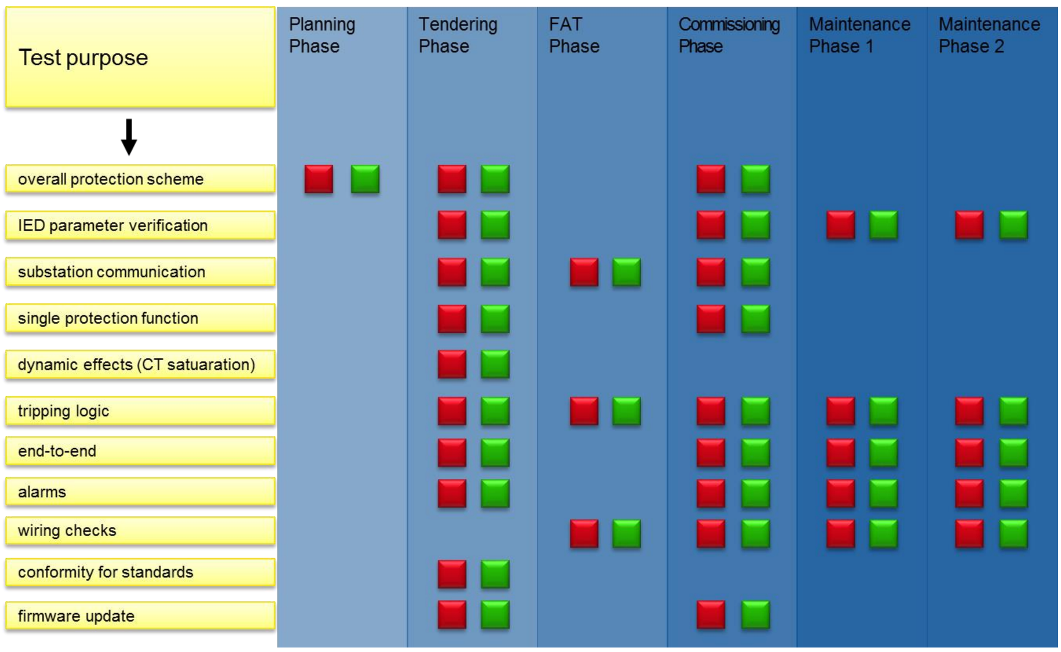

Figure 3: Total testing time for definition and execution of test case with uncoordinated testing

If all kinds of testing purposes and different phases of an IED within its life cycle are put together the complete overview of testing definitions and test cases can be summarized.

As shown in Figure 3 it is quite obvious that there are many situations where a test case definition (red square) is made if the workflow in the company is not coordinated. If it was possible to transfer test definitions from one department to another testing efficiency could be increased. For every testing purpose the test cases would need to be defined only once (cf. Figure 4). Following this approach a test case (green square) can be applied to the

IED as often as the company's testing philosophy defines the necessity. The result of this approach is shown in Figure 4.

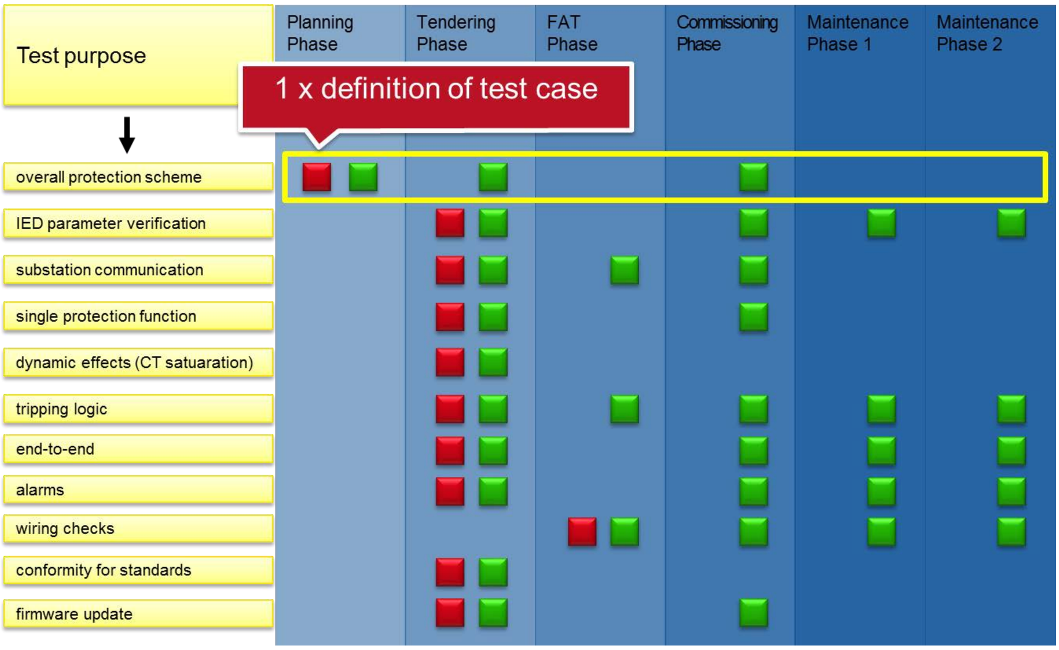

Figure 4: Total testing time for definition and execution of test case with coordinated testing

6 Solution at National Grid

National Grid runs the transmission grid in Saudi Arabia. The company decided to realize a testing solution for all protection relays within their grid. The approach is that every test engineer can do the test with the same testing quality. To do so a sophisticated testing definition is required [3].

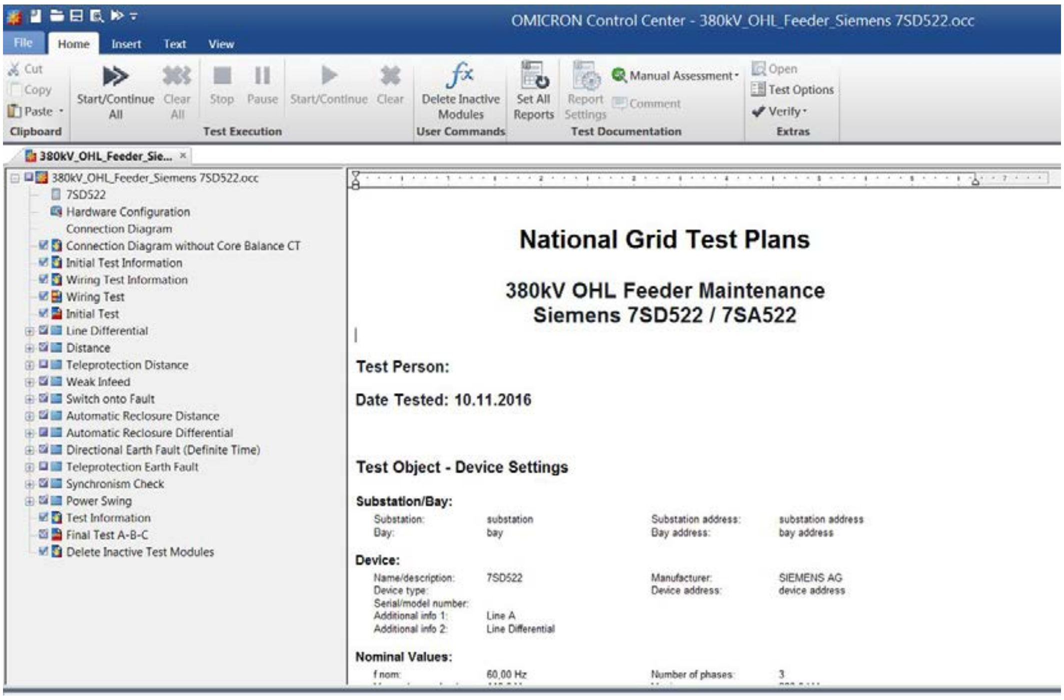

Figure 5: Automated test plan for 380-kV-OHL-feeder at NG

A simple solution for a test definition is to just write down all necessary test steps in such a way that a test engineer is able to perform the test with some test equipment. National Grid decided to go a step further to automate the test cases as much as possible. For this, the capabilities of OMICRON's Test Universe software were used, especially the unique XRIO feature. The software is able to save all relay parameters, the complete testing sequences for a complete relay resulting in all test cases that are necessary to test to following IED functions on a 380-kV-OHL-feeder in one single file:

- Line differential protection
- Distance protection
- Backup Overcurrent/Emergency Overcurrent
- Teleprotection schemes (Distance&67N)
- Autoreclosure
- Directional Earthfault
- Switch onto fault
- Power swing blocking
- Breaker failure

A screenshot of the test plan can be seen in Figure 5.

This highly automated solution consists of an OCC-file which includes all necessary tests for the specific feeder. If a tester wants to test a specific feeder with specific settings, he has to feed the information from the setting sheet of the IED into the software (see Figure 6). The unique aspect is the user only needs to put one relay parameter once into the test system. Using the XRIO technology by OMICRON all software modules have access to the relay data. Therefore, with the XRIO technology OMICRON actually offers test plans for more than 370 different IEDs of more than 20 different manufacturers, including all relay data that a test person could use [4].

Furthermore, the tests are fully reproducible at any time which can be extremely helpful during fault investigations.

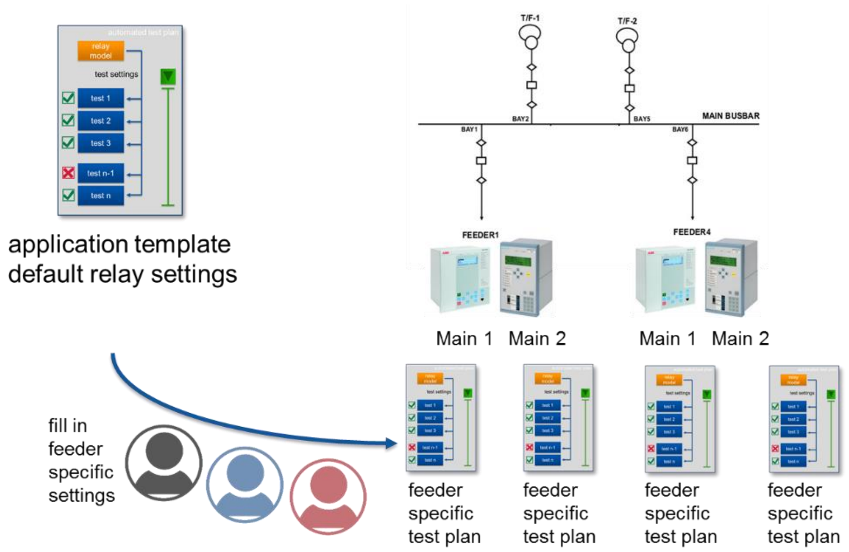

Figure 6: Working principle for maintenance testing at NG

7 Conclusions

As the development cycles by IED manufacturers will be shorter in the near future, testing processes within a company have to be adapted too. Revisiting the working principles can result in higher 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.
- Aspect of solving technical issues by a central team of specialists and spreading out a standardized solution to the testers in the field.
- Aspect of improving the test depth by using test cases which are highly 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.

References

[1] Prequalification of new Assets using the Example of Distance Protection Devices, Christoph Trabold, Michael Albert, Richard Marenbach (OMICRON electronics Deutschland), PAC World Conference 2016, Ljubljana, 2016

[2] Rules applicable to procurement by entities operating in the water, energy, transport and postal services sectors until 2016, Directive 2014/25/EU

[3] 380-kV-OHL protection testing at National Grid using customized test plans, Nashmi H. Al-Harbi, Ahmed Abdulhamied M. Yanbawi (National Grid, Saudi Arabia), OMICRON Saudi User Meeting, Al-Khobar, Saudi Arabia, 7th – 9th of May 2017

[4] Automated testing of motor protection IEDs, Michael Albert (OMICRON electronics Deutschland), PAC World Magazine, March 2017

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