Digital real-time simulator

Hardware-in-the-loop protection system tests for optimized device settings

At a glance

Despite the rising complexity of our power systems, the demands on power system availability are higher than ever. This increases the importance not only of protection devices, but also of the reliability of their setting values. A calculation and verification of protection device-specific settings in front of the green screen is hardly possible. Hardware-in-the-loop tests of the complete protection scheme in a power system environment simulated in real time can make a difference to complex power system protection studies.

Siemens Power Technologies International (Siemens PTI) has more than 30 years of experience in the testing of protection systems. In more than 100 customer projects and approvals, Siemens PTI has built strong expertise in hardware-in-the-loop testing of real protection devices and protection systems using a real-time digital simulator (RTDS). Siemens PTI services include:

- Modeling of the primary power system based on project demands

- Detailed modeling of the interface equipment like instrument transformers (i.e. current transformers or capacitive voltage transformers) tailored to the customer's demands and practice

- Adaptation of protection setting values to the actual power system demands

- Detailed documentation of the performance of the tested devices which can be used for further reference and analyses during actual power system operation

- Expert advice and knowledge transfer on protection device behavior, setting and analysis over the entire project

The challenge

When a new power system element is installed, the appropriate protection devices need to be selected and the settings determined. Depending on the protection object and the size of the power system this may be a complex task, because the functionality and operation of the different protection devices may vary substantially. Therefore, it is very helpful to gain knowledge on how to parameterize and operate a certain device in order to be able to decide whether it is suitable for application in a certain system.

In protection relays, the setting values determine if and when the circuit breaker disconnects the faulted grid element. Disconnections due to wrong setting values can lead to unnecessary - and often fairly high

expenses for the system operator. Such unnecessary costs can be avoided by optimizing the setting values of the installed protection relays. These values can be optimized and verified for different fault cases by means of real-time digital simulation. Such hardware-in-the-loop tests allow protection engineers to acquire knowledge not only of the operating principles of different protection devices, but above all to learn the power system operation and its interaction with secondary equipment.

Our solution

Technical details

Siemens PTI's RTDS performs calculations for networks with typically up to 100 single-phase nodes with a sampling rate of around 20 kHz. Different types of generators, sources, multi-circuit lines, series capacitors, shunt reactors, power transformers, loads, current transformers with saturation, capacitive voltage transformers, circuit breakers, etc. can be simulated. Protection devices (hardware) work with the simulator in a closed loop to carry out complex switching sequences like single-pole or multi-pole re-closings, multiple or inter-system faults or switching onto faults.
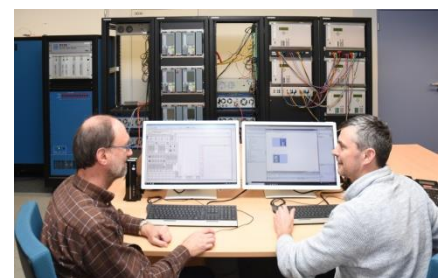

Figure 1: Technical equipment of the simulator (from left to right): RTDS, amplifiers, signal distributor, protection devices

Voltage amplifiers and current amplifiers that can provide currents up to 128 amperes per phase and a high-quality-customer-tailored documentation system complete the hardware-in-the-loop simulator.

Performing tests and evaluations

Performance of the tested devices is documented at every test with measured relay tripping times, further customized binary information gathered by RTDS, complete relays fault logs and fault records (in COMTRADE format).

After a certain system disturbance has been simulated using RTDS, the fault logs are analyzed, and the fault recordings are thoroughly evaluated (Figure 2).

Figure 2: Example of documentation for an in-depth analysis of a test case

This step is very crucial to understand the actual events and technical processes in the protection system as a whole. From the primary values, over auxiliary contacts of circuit breakers and isolators through the current transformer (CT) and voltage transformer (VT) performance to the protection relay action. For example, in the protection system of a transmission line, the behavior of the protection devices at both line ends is analyzed in detail. During this process, the operating principles and philosophy of Siemens SIPROTEC devices can be understood in detail. Of course, non-Siemens devices can be tested as well.

Unlike with sudden disturbances in real operation, during simulation the information of the fault type and its characteristic (like fault location and fault type) is clearly available before each test case. In this way the expected chain of events and the response of the protection system can be

checked against the actual response of the tested system at a glance. Customers have the opportunity to discuss the power system and relay behavior with Siemens PTI experts. A customer meeting room equipped with flip charts and projector allows detailed discussions (Figure 3).

Figure 3: Meeting room (RTDS testing) at Siemens AG premises in Erlangen, Germany

Siemens DIGSI software compiles information on several individual events into single protection alarms or messages to provide details on complex configurations or sequences. The analysis via Siemens SIGRA software, for example in the impedance plane, helps to understand the actual event scenarios and processes in the real system, with respect to distance measuring principles.

Specification of tests

Depending on the customer's demands, the test program can be tailored to share the test scenarios and the training aspects. Typically, hundreds of tests can be carried out for a period of one to two weeks in a row.

Application example

Test results are fully documented for every tested case. Current and voltage wave forms as well as binary signals including tripping times of relays are recorded and stored for every simulated network fault case time, synchronized in one folder. Figure 4 shows an excerpt of a results page.
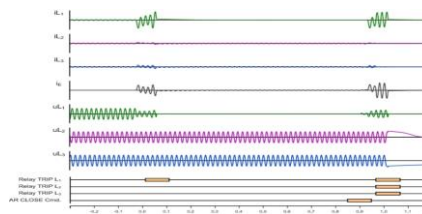

Figure 4: Example of a results page

How you can benefit

The benefits from hardware-in-the-loop testing at Siemens PTI include:

- transient processes in the power system (switching, energization and above all, during short circuits) can be analyzed in detail and thus better understood,

- setting values can be optimized, verified and discussed based on an in-depth analysis of the complete protection system performance for every tested fault case,

- the high-quality documentation for every tested case can be tailored to individual requirements, enabling a detailed evaluation of protection system performance according to customers' needs,

- hands-on training in programming, parameterization (DIGSI) and fault records evaluation (SIGRA) of protection devices is an inherent part of customer stay,

- customers gain expertise in the evaluation of fault printouts and records. This skill is manufacturer-independent and can be used in fault analysis for all modern protection devices.