



VIII STPC VIII Seminário Técnico de Proteção e Controle
28 de Junho a 1º de Julho de 2005
Rio de Janeiro – RJ

INTEGRATED TEST AND SIMULATION SYSTEM

Authors:

Nilson de Oliveira. ZIV do Brasil. n.oliveira@zivbrasil.com.br

Rafael Quintanilla. ZIV P+C, S.L. r.quintanilla@ziv.es

1. KEYWORDS

Test, protection, simulation, oscillography, communications.

2. ABSTRACT

This technical report describes an innovative test system for protective relays. The system combines the features of a new platform of protective relays with a software utility, providing fast and efficient testing of any of the relays included in the new platform without the need of a physical test set for injection of voltages and/or currents.

The software utility, installed in a personal computer, allows the definition of the analog parameters (currents and voltages) and the digital signals needed for the test. The program allows creating an oscillography file to be loaded locally or remotely in the memory of the relay under test. Once the file is loaded, a command switches the input source of the analog and digital parameters, from the physical inputs to the oscillography memory containing the defined waveforms and signals. From this moment the relay will respond to the memorized samples as if they were physical inputs, generating, metering values, signals, events, oscillography and all the required information to verify the relay functions.

This procedure can be applied to a single relay or to a group of coordinated relays, as could be the case of distance relays located at different ends of a line with a teleprotection scheme in place.

3. GENERAL CONSIDERATIONS

People familiar with protective relay maintenance or fault and disturbance analysis often experiences the need of immediate testing after collecting the data from the relays involved. This test should

prove the correct operation of the relay to determine if corrective actions are required.

The immediate capability for testing is subject to the availability of the required test equipment, such as injection systems, status simulators, or auxiliary contact monitoring devices, not always at hand. In cases where the data is collected remotely from the engineering office, testing requires a trip to the location of the “suspect relay” impeding immediate testing.

In the present environment, quality of service is more important than ever and user sensitivity to service interruption is continuously growing. Fast response to maintenance issues is key when devices in charge of system reliability are involved. We believe that the ideas presented in this report will be of great help to all those responsible to guarantee system service and service continuity.

4. A BRIEF STORY

Every day, James arrives to his office at the Electric Company headquarters, where he works as a protection and disturbance analysis engineer. His daily task is to analyze the operation of the protection system under his supervision: fault analysis, settings calculations, maintenance, etc.

The days where the only information available was a signal list from the control center indicating tripped breakers and maybe the relay involved, were before James times.

In the past, if an oscillography was required the engineers needed to wait until somebody or themselves physically went to the field to collect the paper printouts with the signals, and the voltage and current waveforms. A visual analysis of these printouts allowed identifying the cause of

the disturbance and the proper operation of the protective relays. If the analysis determined the need for further testing to the equipment a second field trip was required, this time hauling large test sets.

But James is a lucky fellow. The Protection Management system installed in his company has already done much of the required work before James arrives to his desk. With a few keystrokes a number of computer files are available containing event lists, oscillography, metering values, and fault reports. Display and analysis tools are readily available, and James can concentrate his efforts in the valuable part of his job: the disturbance analysis of a highly complex power system. In few minutes, all the required information is available in the monitors of the engineering desk. The wonders of digital technology and communications at work.

Having all the information in a matter of seconds and being able to perform the analysis in a matter of minutes is not the end of the story. In many cases it is the beginning of dedicated research and maintenance tasks.

Last night, it looks like there was a single disturbance worth of James attention. The information is available, but after the analysis there are few issues to clarify. One of them requires testing of an impedance relay with voltage and current injection. This relay is located in a substation several hours away. While James is preparing his field trip he realizes that the relay in question includes a new integrated test tool called, TESIS (TEST AND SIMULATION INTEGRATED SYSTEM).

The relay test requires the corresponding tagging of the bay by the control center. James will prepare the procedure before the circuit is available for testing.

Using the software utility, James determines the parameters for the voltage and current levels to be injected to the relay (rms, angle), the pre-fault values (load), and the fault values along with their corresponding duration times. The next step is to determine the status and state changes of the digital inputs to the relay. Once the parameters are defined, the oscillography file is generated according to the sampling frequency of the relay to be tested. The final step is to upload the file and the oscillography in to the relay. Since the test procedure involves different test, James creates several test files.

Once the files are loaded into the relay, James waits for confirmation of availability from the control center. When the circuit is tagged the test

procedure begins by setting the relay to test mode. The test mode disconnects the connection between the relay logic and the physical inputs. Next, the first test file is loaded and executed. The relay signal acquisition is now done from the oscillography memory instead of the metering channels. The data is read at the same sampling rate as if it came from the analog channels. All the relaying functions operate as if they were responding to real inputs. The relay records the events, fault reports, and even the oscillography identical to the one under “real” conditions. For every test case, James has available the complete information to determine if the relay is behaving as expected. In this case all the tests indicate proper behavior of the distance relay. James decides to test the teleprotection scheme by testing the relays at both ends of the line.

The test procedure is defined as before, and one more piece of data is added: the time to run the loaded file in each relay. Both relays should be connected to a high accuracy timing systems (such as GPS) to begging the sampling synchronized. At the specified moment, both relays will start sampling data from the virtual inputs, activate their protection functions and send the corresponding signals via the teleprotection system. Everything is recorded by the different functions: oscillography, events, fault reports, and targets.

James has been able to run a series of test to the protective relays without leaving his office, independent of the distance to the physical locations. All the data collected in the tests is stored in the database of the Protection Management System. If required, the proper corrective or maintenance actions would be performed.

5. SYSTEM DESCRIPTION

The previous storyline includes some of the key features of the proposed Test and Simulation Integrated System. The following paragraphs describe in detail the different components of such systems.

TESIS is a system that allows testing of protective relays without the need of test sets in local or remote mode. The tests are performed under the same conditions of “real” tests that physically apply currents and voltages. Figure 1 shows a diagram of the test principles.

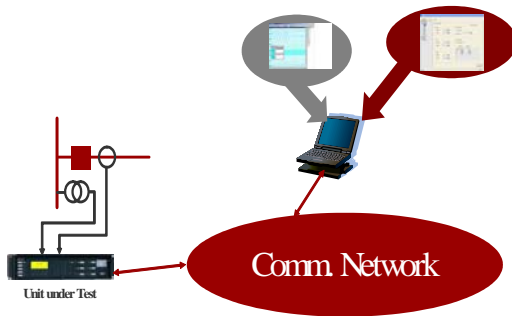


Figure 1

The system is based in two main components:

1. Software utility for definition and application of tests
2. Virtual sampling included in the protective relay

5.1 Software Test Utility

The software package, for use in a personal computer, allows the definition of the test parameters, both the analog values (rms values and angles) and the signals to the digital inputs of the relay. The program creates an oscillography file in COMTRADE format, and this file can be sent to the relay via any of the communication ports.

The test files can be created in three basic modes.

5.1.1 Manual Data Input

Figure 2 shows a sample screen, used to input the analog test parameters:

- Pre-fault parameters
- Fault parameters
- Trip parameters

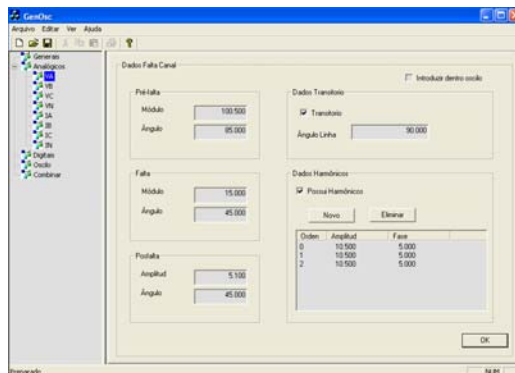


Figure 2

The specific parameters are defined in secondary values and are dependent on the relay model.

Besides the magnitudes, these are other parameters to be defined:

- Pre-fault duration
- Fault duration
- Trip duration
- Test initiate time

The Trip State includes the signals assuming that the breaker has operated correctly, opening the corresponding phases.

There are two test modes:

Simple, in which the defined parameters are applied in their final state value for the complete duration of the test. This mode takes into account the phase changes.

Dynamic, in which sudden changes in instantaneous values are not allowed (infinite first derivative). This mode requires a time constant to define the transient state of the currents. The constant is calculated based on the line impedance angle where the relay is connected.

The total test time is limited by the maximum oscillography memory available in the relay.

The test initiate can be set to respond a command from the software or from the relay HMI, or to initiate at a given time.

Figure 3 shows the software screen used to define the status and state changes of the digital signals.

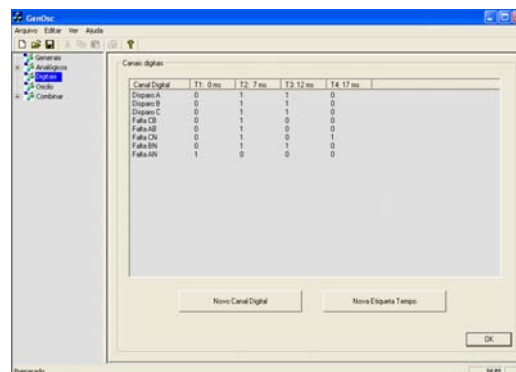


Figure 3

The signal definition is done setting the change of state times.

5.1.2 Data Input via Oscillography File

The software utility can import existing files in COMTRADE format, generated by relays like the one under test or by other recording devices.

In cases where the file is generated by a different device, is required to have the same sampling rate as in the relay. If the file has a different rate, the software includes a re-sampling tool and adapting tool. This tool can also adjust the length of the file, shortening the file to a length that can fit into the relay's memory

5.1.3 Data Input via Math Functions

A second mode of signal generation is via simple mathematical functions:

- Trigonometric functions
- Exponential functions
- Ramping functions (slope)

These functions can be operated as follows:

- Summation
- Subtraction
- Scaling
- Multiplication
- Derivative
- Linear combinations
- Harmonic generation

Figure 4 shows a screen for the generation of waveforms using math functions.

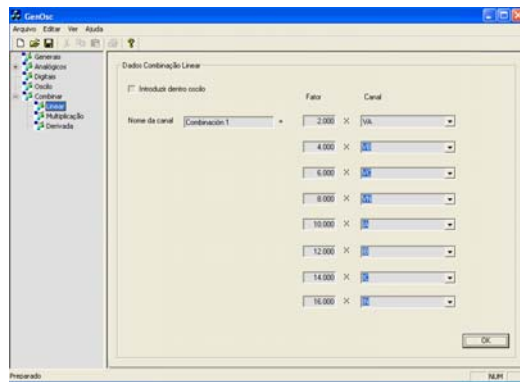


Figure 4

5.1.4 Creating and Loading the Test File

The software creates a COMTRADE file in base to the data entered or from the edited version of the original oscillography file.

Once the file is created is possible to save it for later usage or upload it to the relay under test. The software program is capable of local and remote communication with the relays. Once communications are established the file is loaded in the oscillography memory leaving the relay ready for the test.

5.2 Virtual Capture

Once the file is loaded in the oscillography memory, the relay is ready to receive the test initiate command. This order can be generated automatically when the internal clock reach the setpoint or manually via the local HMI or the remote communication ports.

Figure 5 shows the functional block diagram of the relay including the database storage for the waveform samples and digital signals.

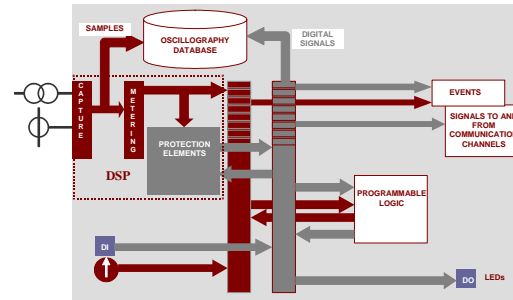


Figure 5

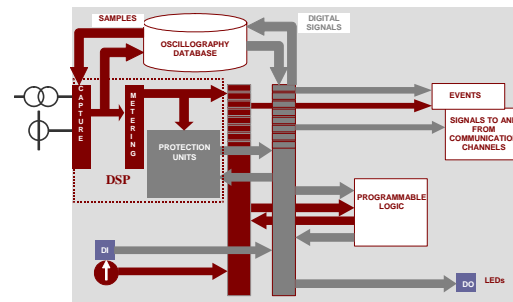


Figure 6

Figure 6 shows the logic diagram of the relay in playback mode. Once the initiate command is received, the DSP in charge of metering stops capturing the analog and digital channels and begins the sequential reading of the samples included in the database. The sampling rate remains the same, according to the rated frequency of the stored signals.

The digital signals included in the playback correspond only to the physical inputs to the relay. During the test is possible to program the relay to record every digital signal generated in the relay.

The operation of the relay is identical when sampling from the physical inputs or from the memory. In test mode every recording function is operative (signal activation, metering, events, fault reports, etc.). All the information is available as if the analog and digital inputs where used.

An important feature in the relay is that the oscillography recording is available while in test mode. Is possible to record the file on playback but in this case the memory available for test will be half the maximum.

6. LABORATORY TESTS

The story related before, described tests performed in remote mode, using the communication capabilities on the digital relays. The advantages of the TESIS system also apply for tests in local mode. Figure 7 depicts some of the advantages of testing in local mode:

- Test sets are not required. Test sets are usually expensive units and on high demand within companies.
- Complex wiring required is substituted by a single serial connection

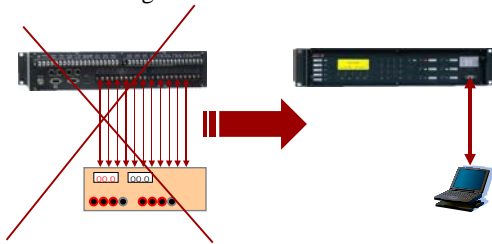


Figure 7

7. TELEPROTECTION SCHEMES TESTS

Complete teleprotection schemes can be tested in laboratory settings or in the devices installed in the field. The key benefit of testing over field devices is the verification of the complete teleprotection and communications systems involved in the scheme as depicted in Figure 8.

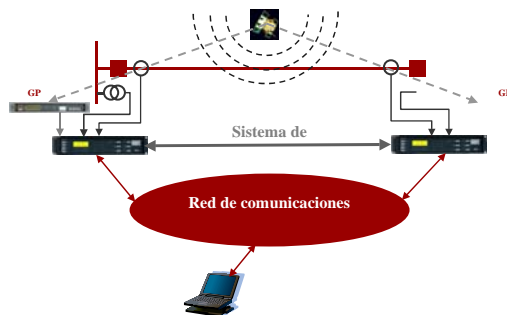


Figure 8

It is very important that the two relays involved in the test (or three in case of three terminal lines) are connected to a time synchronization system to guarantee a common time base. The synchronized times are required to initiate the test at the same time in all the relays, in order to get a meaningful and conclusive test.

8. SIMULATION TESTS

The source for the test file can be any COMTRADE format file. The file can be recorded by the following devices:

- Digital Network Simulator
- Substation Digital Fault Recorder
- Protective relay from the same or different manufacturer

The sampling frequency of the source file doesn't need to match the sampling frequency of the relay under test. The software utility can adapt the file to the required frequency.

9. CONCLUSIONS

The TEST AND SIMULATION INTEGRATED SYSTEM is a useful tool for testing protective relays and meters without the need of injection test sets. One of the key advantages is the ability of remote testing without traveling to the field locations.

An additional advantage is the system ability to generate customized test signals besides the use of existing files.