Tests of microprocessor-based relay protection devices

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The operational condition of relay protection devices is usually checked with specific settings used for the relay operation in a certain network point. In the author's opinion there is no need to use the actual settings at which the relay is to be operated in a certain network point to carry out tests.

In order to verify the proper operation of complex multifunctional microprocessor-based protection devices (MPD) at their inspection, start-up after repairs, or during periodic tests, they should be tested for proper operation at several of the most critical preset characteristic points as well as with several preset characteristics constituting its most complicated (combined) operation modes, including the dynamic operation modes with preset transition processes specific for standard power networks (not necessarily for a specific point). The proposed set of actions for the unification of software platforms of the modern, microprocessor-based relay protection test systems will enable examination of modern MPD in a new way.

Relay protection constitutes a major part of any power system that provides for continuous control of operation modes of power system elements and generates tripping commands for the failed parts or elements of the system. Faulty operation of relay protection due to internal malfunctions can lead to the development of failures and even to the collapse of the power system with attendant financial losses. For this reason the performance of the relay protection must be periodically tested. There exists a vast variety of relay protection devices with different operating principles and construction [1]. Lately all but microprocessor relay protection devices (MPD) have disappeared from the market. MPDs based on a various principles of operation have their advantages and disadvantages [2, 3]. However, one of the problems is the complexity of the procedures for testing operation.

Usually the operational condition of a relay protection device is checked with the settings used at a specific network point. Any change of the settings during the normal relay operation requires repeating the working condition test with these new settings. When electromechanical relay protection devices were used, this procedure was quite reasonable, since any change of settings was effected by the mechanical adjustment of the internal relay elements or switching the taps of the built-in transformers, etc. Following a change of settings, a failure in the internal relay circuits connected to a new tap of the transformer

(rupture of a wire, contact failure, insulation damage etc.), relay imbalance caused by the change of the mechanical parts position, relay "grinding" and other problems might occur. Using an electromechanical relay at one setting did not necessarily ensure its correct operation with other settings.

For MPDs a change of settings is not accompanied by physical changes in their internal structure. The input and output circuits as well as logic elements, central processor unit (CPU) or power supply operate regardless of the selected settings or operation modes. Moreover, activation or deactivation of specific relay functions is not related to the physical condition of its circuits. Checking the appropriateness of the selected protection logic and the correctness of the setting calculation for specific circuit conditions is a totally different task, not at all connected to testing the working condition of the relay. Further, these tests are performed by engineering services responsible for the setting calculations and the selection of the internal logic of the relay operation rather than by the relay operation personnel who are responsible for its proper operation. In fact, when an operational test is performed, simulation of all the real situations and all the possible combinations of factors acting in a real circuit becomes for all practical purposes impossible. Detecting such situations is not a part of the protective relay operational test. Moreover, it can be demonstrated that the results of the relay tests with the nominal settings only, is a positive measure because of a so called "human factor" (which causes about 50% of relay malfunctions). The fact is that the settings selected for specific operational regime in multifunctional MPDs make the testing of a specific relay function possible only by the desensitization or complete disabling of another competing function. Often a failure to re-enable such desensitized or disabled functions to their initial condition causes wrong protective functions in emergency modes.

The similar approach to a problem of MPD tests is used in [1]. In this document (having the status of the standard), all tests of the protective relay are divided into two kinds: calibration tests (setting and configurations of

the relay) and functional tests. For functional tests typical test intervals of 4 years for all types of the relay (including electromechanical and microprocessor) are required, but for calibration tests an interval of 4 years only for electromechanical relays is established. Routine (periodic) calibration, i.e. checking of relay setting, for MPD is not required at all. Authors of [2] come to similar conclusions: at routine tests of the MPD there is no necessity testing of internal setting preservation.

Experts of one of the leading manufacturers of the relay test equipment - Omicron [3] distinguishe the three kinds of the MPD tests: type test, commissioning and routine tests. Type tests are understood as functional test and basic characteristics of MPD testing. At commissioning test such addition test procedure as calibration must be completed also, i. e. check of actual setting and the internal logic programmed for concrete application is made also. And, at last, at periodic (routine) tests only the serviceability of the MPD is checked. Thus, according to Omicron expert's opinion, testing of an MPD with an actual setting is required only once at commissioning of a new protection and should not be repeated at routine and type tests.

New view on the problem

On the basis of the above several principles applicable for testing the MPD may be formulated:

• In order to verify the proper operation of complex multifunctional MPD at their inspection, start-up after repairs or during periodic tests there is no need to use the actual settings at which the relay is to be operated in a certain network's point,

• In order to test the working condition of a MPD, it should be tested for proper operation at several of its most critical preset characteristic points as well as with several preset characteristics constituting its most complicated (combined) operation modes, including the dynamic operation modes with preset transition processes specific for standard power networks (not necessarily for a specific point). Such tests should cover all the physical outputs and inputs of the relay. At the end of tests and

verification of its proper operation all the test settings should be automatically replaced with a set (file) of actual settings prepared in advance,

- To the best of our knowledge such testing of MPD in the most complicated modes of operation will allow for more comprehensive testing of the MPD than employing a very limited test at strictly limited specific settings that will be further used during the relays operation,

- Integrated testing of MPD during the stage in which it is put into operation under the most severe operation conditions enables ruling out additional tests of the relay operation at every change of setting during routine operation.

The principles formulated above provide us with a different insight into the problem of testing MPD. One can assume that the first device for testing protection relays appeared almost simultaneously with the protection relays themselves. Of course, they were as primitive as the protection relays. At first they were simple calibrated inductance coils, shown in Fig. 1, and rheostats.

As relays have been improved, test units for them also have become more complex. Test benches have appeared (Fig. 2) containing inductances and active resistance sets, by means of which one could set angles between current and voltage within a wide band and examine rather complex electromechanical relays.

In different power systems one could establish different times for periodic testing of relay protection, for example, once every 2 - 3 years, but usually they were observed more stringently.

Fig. 1: Set of inductances from General Electric for testing of electromechanical protective relays

As microprocessor-based protective relays appeared on the market, the situation changed radically. Producers of these devices claimed that the microprocessor-based relays did not need periodic examinations, because they had powerful embedded self-

Fig. 2: Advanced test set TURH-20 type (ASEA) for testing of electronmechanical protective relays containing sets of inductances and resistances

test systems. This claim for MPDs appeared in advertising literature as their main advantage over electromechanical and analog electronic relays. Large advertising campaigns launched by MPD producers played a role. Many specialists in the field of relay protection believed unreservedly in this advertising, as they did not have the opportunity to verify if this statement was true. Even though it was patently obvious that it was impossible to create a test system on the basis of the MPD inner microprocessor which could examine the physical repair of many thousands of electronic components. Functionally it is also impossible to test the repair, for example, of an input unit or an output unit without turning it on and examining the relay's reaction to an input signal. In practice it has turned out that most MPDs simply do not sense the substitution of the whole printed board of one kind for the board of other kind which is not compatible with relay current settings. The author has already discussed other advertising connected with

MPD, that of "self-diagnosis", in numerous other publications.

Unlike MPD manufacturers, relay protection test systems (RPTS) manufacturers have always affirmed that all protection relays should be periodically tested, including MPDs, as so-called "self-diagnosis" covers not more than 15% of the software and hardware. Though MPD manufacturers have asserted that periodic examinations of protection devices were unreasonable, RPTS manufacturers have been intensively developing and putting on the market ever newer test systems.

Modern test systems for protection relays

As today's MPD construction principles are general for most manufacturing companies, it is natural that test systems that are offered nowadays by different companies are rather alike, and not only in their appearance, see Fig. 3, but also in their specifications. Modern RPTS are completely computerized devices without any physical controls on the cover (control is via a computer connected to the device's RS232 connector). All that shows are the sockets for external wires and the RS232 connector for the computer. RPTS such as these costs tens of thousands of Rands.

These systems are designed for running three types of tests: steady state, dynamic and transient. Steady state tests are used for examining the basic settings of relay actuation and as such are referred to as a "preliminary" examination of relay. The second type of tests is used, in general, to inspect complex protection behaviour, such as distance or differential protection, in different areas of characteristics and protection zones based on input parameter
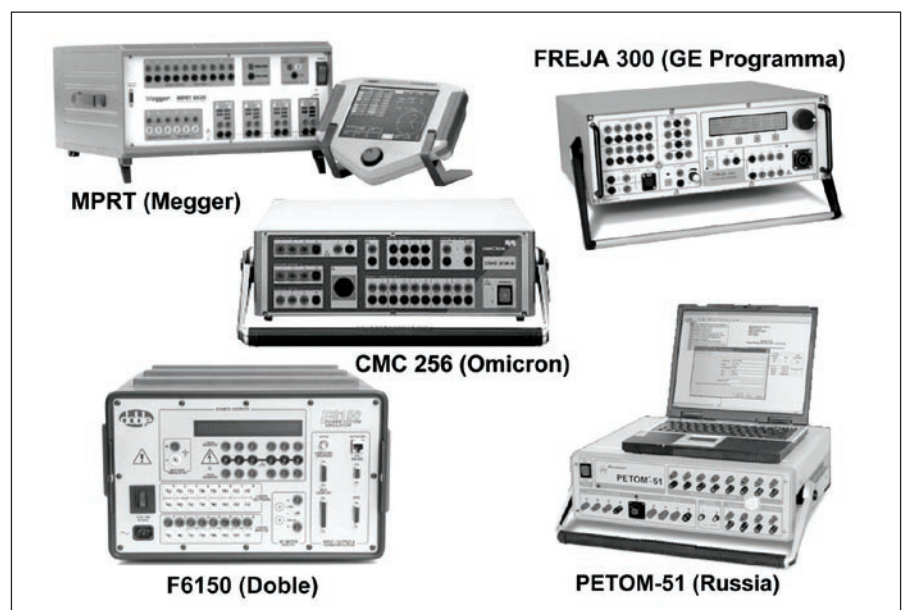

Fig. 3: The modern computerized test systems of last generation for testing of multipurpose microprocessor based protective relays.

(current, voltage, and angle) changes with time. The third type of tests is based on the injection into input circuits current and voltage corresponding with the Comtrade transient files retrieved from recording devices, recorded real short-circuit transient processes, or simulated short-circuit transient processes based on files with the same format created artificially by means of special software. The test results are entered into a database realized, as a rule, on the basis of Sybase SQL Anywhere and automatically structured as a standard protocol that can be sent to a printer. RPTS manufacturers usually offer sets of test procedures (libraries) in the form of macros for different types of tests and even for some widespread relay types.

Modern RPTS problems

Modern RPTS are truly flexible and have many functional possibilities. These RPTS allow simulating almost any working condition of protection relays which can occur in practice, including the creation of artificial Comtrade files. Through these files one can create: artificial distortion of current waveforms, harmonic simulations, shift of current sinusoid relative to the axis (simulation of DC component), simulation of circuit breaker response, automatic modeling of the most complex polygonal characteristics of distance protections and synchronization of differential protections by means of satellites, etc. One of the drawbacks of these modern complex RPTS is the necessity to enter hundreds of parameters in many tables for every single relay test. However, embedded libraries of test procedures give little help in practice as they do not free one from the having to fill in countless tables. To this one should add the considerable flexibility and universality of the tested object (MPD), which also requires entering of a large number of parameters from many dropdown menus and tables. The smallest discrepancy of MPD and RPTS settings leads to wrong results. And given this, it is often impossible to know that the results one has received are wrong. Even in cases when the mistake is obvious (for example, an obtained relay characteristic does not correspond with the theoretic one), it is very difficult to identify where exactly the mistake was made, in MBR or RPTS settings. The author can confirm from his own experience that searching for a mistake is extremely difficult and requires much effort and time. Working with the Power System Model applied in RPTS for distance protection tests is not less difficult. In order to adjust the RPTS parameters in this mode, one has to know numerous parameters of the real electrical network that have to be entered with special indices in many tables. The technician and even the engineer of relay protection services often do not know many of these real mains parameters and applied indices, and this is why engineers from other power system services have to take part in the relay test procedure.

Offered solutions

Psychologists established long ago that the more buttons and levers (real and virtual, i.e., software) an operator has to manipulate, the lower the efficiency of a person's cooperation with such technique. Human perception simply does not grasp many functions and possibilities of such sophisticated techniques. How can one combine universality and the broadest functional possibilities of an RPTS with abilities of an average technician or engineer of a relay protection service who needs quick and accurate examination of limited relay types? Does one overcome the great difficulties by developing and adjusting one's own procedures and create one's own library of macros as their basis as was foreseen by the RPTS manufacturers?. We are ready to offer more radical solution of this problem:

It is unreasonable from a technical and economical point of view to use modern microprocessor-based RPTS for testing even the simplest electromechanical relays, such as a current and voltage relay (for example, type PT-40 or PH-54, as was attempted by the producers of Russian RPTS of Petom-51 type). One can use simpler test devices with much more effectiveness. There is no point in developing test procedures

for automatically testing these relays, if it doesn't involve testing hundreds of identical relays in their production process,

One can consider the reasonable usage of modern embedded libraries of test procedures requiring the entering of a huge number of parameters and exact knowledge of numerous indices only for complex electromechanical protection devices of the old type (for example, distance protection LZ-31),

In order to test a modern, complex multifunctional MPD, one has to develop one for all types of RPTS software platforms, the requirements of which should be fixed by international standards. An example of such a general software platform is the well-known Sybase SQL Anywhere, which is widely used for the creation of databases in different data collection and processing devices, simulators, and test units of different producers. Another example is universal format: Comtrade, used in all types of microprocessor-based fault recorders and, for that matter, in all types of RPTS for the simulation of transient modes,

Application programs for working with RPTS of different types can have absolutely different interfaces, but all of them should be implemented on the basis of general standard program platform,

MPD's producers should provide their protection devices with two CDs. One of them should contain full settings for specific modes of MPD protection functioning or for characteristic points of the characteristics for typical examples. The other CD should contain full sets of settings for the RPTS (each one under the number corresponding with number of protection settings) and the circuit diagram of MPD external connections to RPTS inputs and outputs,

In our opinion, effective usage of modern RPTS for testing modern, multifunctional MPDs is ensured only in the case when the whole test procedure comes to downloading of settings XX.1 in the MPD, and downloading of settings YY.1 in RPTS, connecting the MPD to RPTS and ...making a cup of coffee.

Conclusions

The proposed set of actions for the unification of software platforms used in modern, microprocessor-based RPTS will enable examination of modern multifunctional MPD in a new way. In our opinion, this will break many technical and psychological barriers and will encourage much wider usage both of MPD and RPTS.

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