CURRENT PROTECTION CHECK
BY USING DIGITAL TESTING SYSTEM

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Abstract: Existing domestic technical facilities for setting up and checking current protection are mainly based on analogue devices, which do not provide the required check accuracy but are time-consuming. With the appearance of digital testing systems, a protection check can be automated. An appropriate algorithm and its digital implementation have been developed for the automatic check of current protection characteristics using a digital testing system. This resulted in creating a digital system module intended for testing devices of relay protection and automation, capable of automatic checking the basic current protection characteristics of any configuration.

Key words: relay protection, current protection, digital testing system, relay characteristics.

1. Introduction

At present, specialized technical facilities for setting up and checking devices of relay protection and automation (RPA) have been created both abroad and in Ukraine. They are mainly manufactured by using digital technology. These facilities allow the RPA device characteristics, including those of current protection to be checked quickly and accurately. The most common systems for checking RPA devices used in the Ukrainian power systems are "Omicron" (Austria), "Double" (USA), "Relay-Tomograph" (Russia), and "Relay-Tester" and "RPA-Tester" (Ukraine).

The last two systems are joint developments of Kharkiv-based (technical implementation of the checking devices) and Lviv-based (development of special software that ensures the process of checking the RPA devices) enterprises [1].

2. Statement of problem

When checking the characteristics of current relay protection, especially that made on a digital basis, there arise difficulties of meeting the requirements for its verification by the traditional facilities existing in the power systems of Ukraine. As a rule, such checking tools are manufactured on analogue equipment and cannot ensure the required accuracy and are time-consuming. Consequently, there is a necessity to develop an algorithm for checking the current protection, to carry out its digital implementation, and to create a module of the digital testing system for the optimal check of current protection.

3. Module of Digital Testing System

The digital testing system is intended for setting up and checking the RPA devices. This system is a hardware-software complex consisting of a special GRAN Test System software, which is installed on a PC, and a microprocessor device "RPA-Tester" (manufactured by PJSC "YUNITI") [2].

The special GRAN Test System software developed by us

– controls the digital testing system;

– sets the parameters for checking a certain RPA device, including current protection;

– digitizes signals of voltages and currents under certain laws for the check of RPA devices;

– sets the change in output binary signals;

– displays the results of RPA devices check;

– forms checking reports;

– forms a library of the objects under check.

The special GRAN Test System software works in the operating system Windows, has a convenient and simple interface to use. This software has a modular structure [1]. Some modules allow the user to form digital graphs depending on the object under check – distance protection, differential protection, etc. Besides, GRAN Test System provides the formation of digital graphs of voltages and currents that correspond to different modes of the power system – short circuits, synchronous fluctuations, asynchronous movement, open-phase modes, etc [3].

A module for checking the current protection has been created in the special GRAN Test System software.

The module is designed to set up and check respective devices of both foreign and domestic firms, made on electromechanical, semiconductor and digital technologies.

Using this module allows you to check practically all characteristics of current protection – operating zones of individual stages, taking into account the

permissible errors, operating time characteristics of individual stages, stability to higher harmonic components, reaction of RPA devices to various disturbances of the power system, as well as some other characteristics. It is possible to check multi-stage current protection and directional current protection with arbitrary operating time characteristics.

An algorithm for automatic checking of current protection characteristics has been developed. The flowchart of the algorithm is shown in Fig. 1.
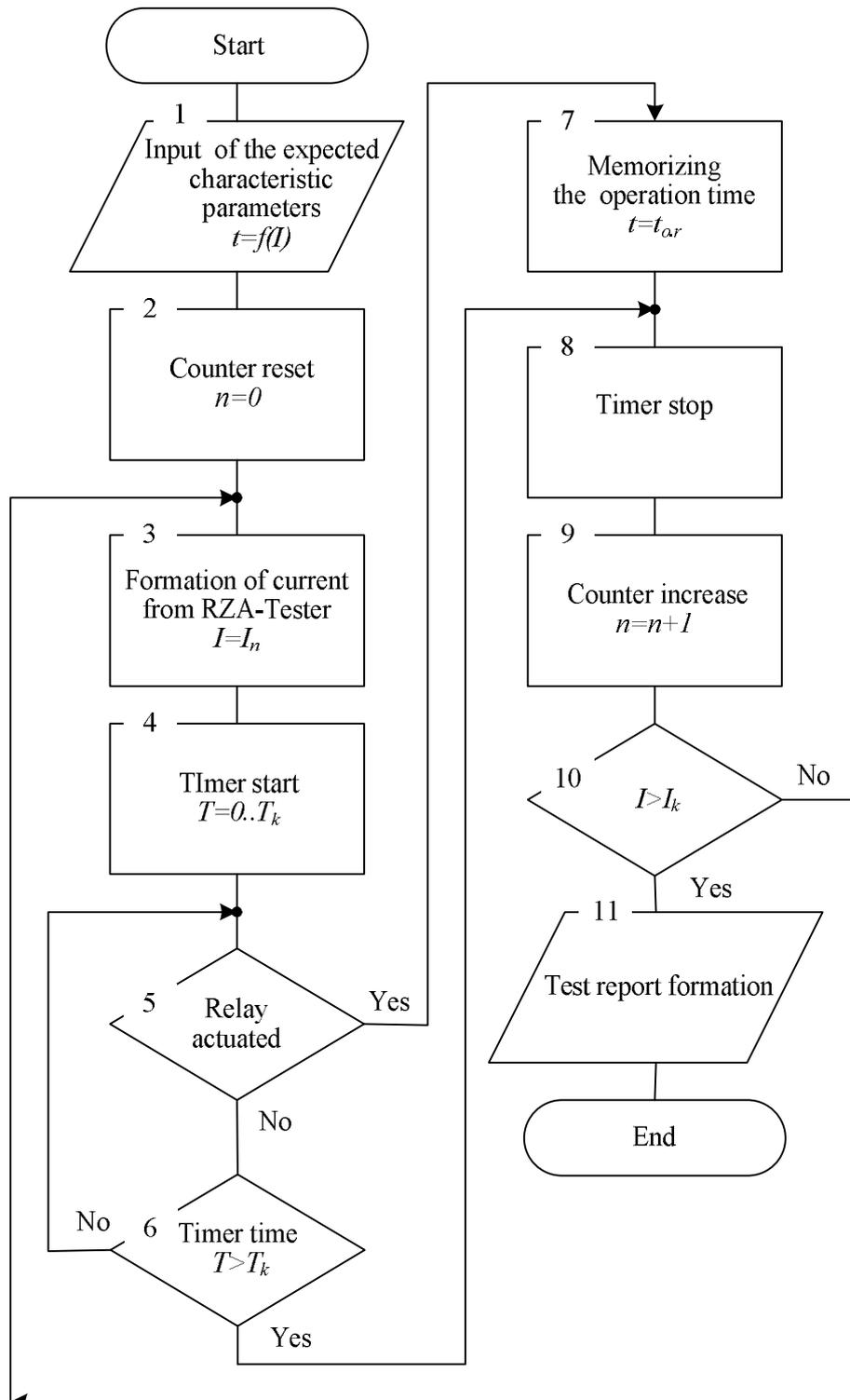

Fig. 1. Flowchart of the algorithm for checking the current protection characteristics.
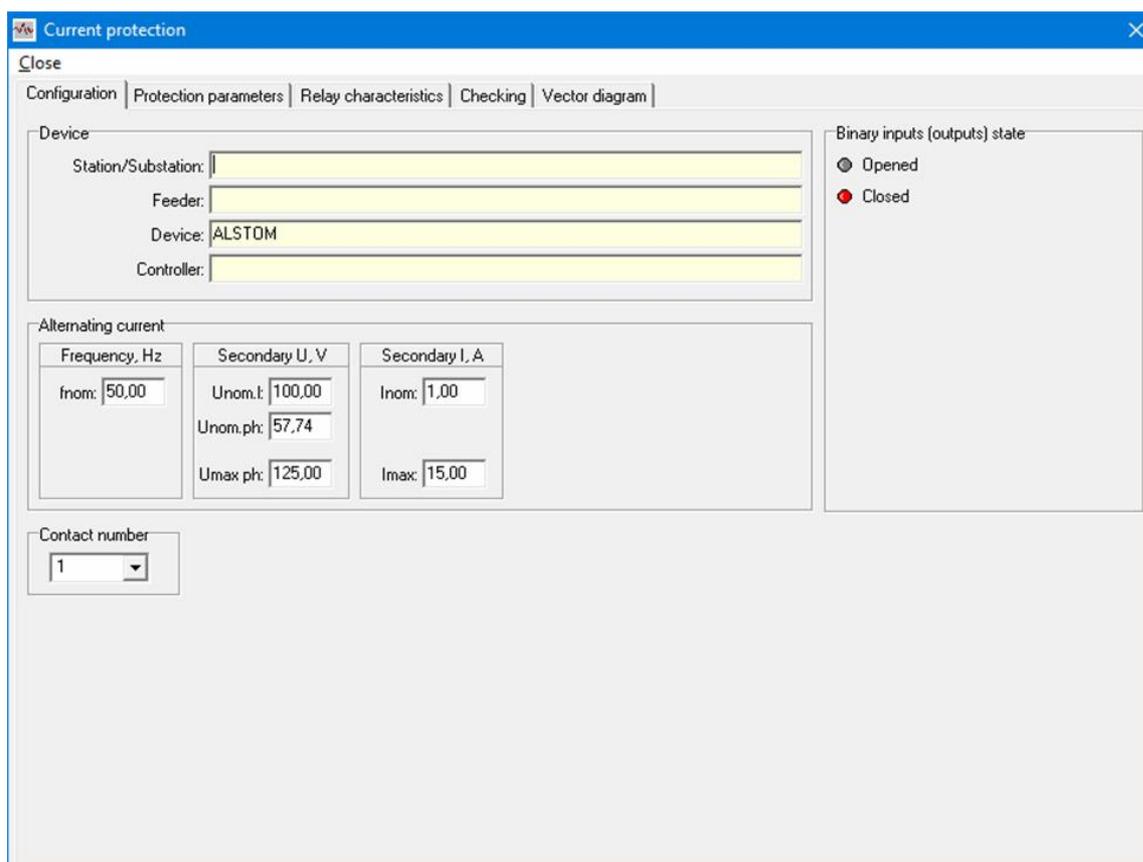
Fig. 2. Window of the module for current protection checking.

The current protection check begins with inputting the parameters of its expected characteristic $t=f(I)$ (block 1). The expected characteristic is formed as an array of currents and time of operation. Then, the counter n of the this array index is reset to zero (block 2). The value of the current I, which corresponds to the n-th element of the array, is determined. This current from the device "RPA-Tester" is fed to the current protection, whose characteristic is checked (block 3). The timer is started for a certain time T_k, during which the determined current is generated (block 4). The protection reaction to this current is expected. In case the output protection relay is actuated (block 5), its operating time is memorized (block 7), and the timer generating this current stops (block 8). The timer also stops if the protection does not actuate during time T_k (block 6). Next, we go to block 9, where the counter n increases by 1. If the final value of the current I_k is reached (block 10), the experiment is completed. A report on the test of current protection is formed (block 11). Otherwise, we go to block 3 and continue the test for another value of the current I.

Fig. 2 shows the window of the special GRAN Test System software module designed for current protection checking.

The module consists of separate functional pages: "Configuration", "Protection parameters", "Relay characteristics", "Checking" and "Vector diagram".

The functional page "Configuration" is used to enter general information on current protection and its object of application: an electric power station (substation), with the protection installed, a feeder where it is involved, controller's name, as well as information on current protection (its name, designation on the diagram, location of installation, nominal parameters). This information is entered in the test report and is not used directly in the relay cheking. On the same page, we provide information on the connection of the relay to the "RPA-Tester" – the voltage and current channels, to which the current protection windings are connected respectively, and the number of the binary input of the device, to which the output protection contact is attached.

The functional page "Protection parameters" is used to enter the parameters of current protection: nominal voltage and current, direction of protection (into line, to the buses), permissible errors in the reproduction of time characteristics of current protection, as well as the parameters of the pre-emergency mode.

The functional page, "Relay Characteristics" makes it is possible to create a library of characteristic, from

which you can then choose the one you need for setting up and checking the specified current protection. The library of characteristics is created depending on the type of fault. The library comprises the following groups of characteristics:

– characteristics of single-phase-short circuit protection;

– characteristics of interphase-short circuit protection;

– characteristics of negative-sequence current protection;

– characteristics of zero-sequence current protection.

The time characteristics of current protection are formed in relative units.

Characteristics of any complexity can be created and stored in the library where you can choose the required one. But if such a available characteristic is not available in the library, it is formed. The library provides the opportunity to add new characteristics, edit the existing ones, delete and copy them.

Typical and specific time characteristics can be set to check current protection. Such characteristics have modern current protection made on a digital basis, and traditional protection ones made on electromechanical relays, for example, an RT-80 series relay. The typical characteristics include:

– inverse:

$$t(I) = \frac{A \cdot T_{set} + K_1}{\left(\dfrac{I}{I_{set} \cdot I_{nom}}\right)^p} + B \cdot T_{set} + K_2; \qquad (1)$$

– I2t:

$$t(I) = A \cdot T_{set} \cdot ln\, \frac{\left(\dfrac{I}{I_{set} \cdot I_{nom}}\right)^p}{\left(\dfrac{I}{I_{set} \cdot I_{nom}}\right)^p - Q}; \qquad (2)$$

– characteristics of digital current protection of MRZS series:

$$n \cdot t(I) = \frac{A \cdot T_{set}}{\dfrac{I}{I_{set} \cdot I_{nom}} - 1}; \qquad (3)$$

$$t(I) = T_{set} - a \cdot \left(\frac{I}{I_{set} \cdot I_{nom}} - 1\right); \qquad (4)$$

– characteristics of an electromechanical current relay of RT-80 series:

$$t(I) = 3 \cdot \frac{T_{set} + 0,5}{\left(\dfrac{I}{I_{set} \cdot I_{nom}}\right)^2 - 0,5} + T_{set}; \qquad (5)$$

– independent:

$$t(I) = const, \qquad (6)$$

where I_{set} and T_{set} are the current and time settings; I_{nom} represents the nominal value of current; A, B, K_1, K_2, Q, P, α stands for the coefficients of characteristics.

When the characteristic is selected, it is necessary to spesify the values of the corresponding coefficients according to their equations (1)–(6).

In addition to these characteristics, it is possible to set the typical characteristics according to the standard MEK, ANSI/IEEE, AREVA. They are formed on the basis of the inverse characteristic formula (1). These characteristics are *"IEC Normal Inverse"* ($A = 0.14$; $B = 0$; $P = 0.02$; $Q = 1$; $K_1 = 0$; $K_2 = 0$), *"IEC Very Inverse"* ($A = 13.5$; $B = 0$; $P = 1$; $Q = 1$; $K_1 = 0$; $K_2 = 0$), *"IEC Extremely Inverse"* ($A = 80$; $B = 0$; $P = 2$; $Q = 1$; $K_1 = 0$; $K_2 = 0$). The formation of these characteristics does not require additional information, i.e the input of coefficients.

If the user needs to specify the characteristic that can not be described by equations (1)–(6), the type of characteristic "Table" is provided. For this case, the characteristic is given as a set of points – its coordinates. This set of points is given in tabular form.

It is possible to form complex time characteristics, which consist of separate sections, each of which is specified from the library of characteristics.

There is also an option to edit individual sections of the characteristic, delete the sections, copy them, and also import the characteristic sections recorded in DCC format.

For the time characteristic to be optimally displayed, the following display scales are possible:

– current – linear, time – linear;

– current – logarithmic, time – logarithmic;

– current – linear, time – logarithmic;

– current – logarithmic, time – linear.

It is also possible to display the characteristic in relative or absolute units.

Checking the time characteristics of current protection itself is performed from the functional page "Checking". The general view of the module window page is shown in Fig. 3.

The field "Time characteristic" displays the time characteristic of current protection formed on the page "Relay characteristics". In this field, the user can perform certain operations related to image scaling and the choice of a check point.
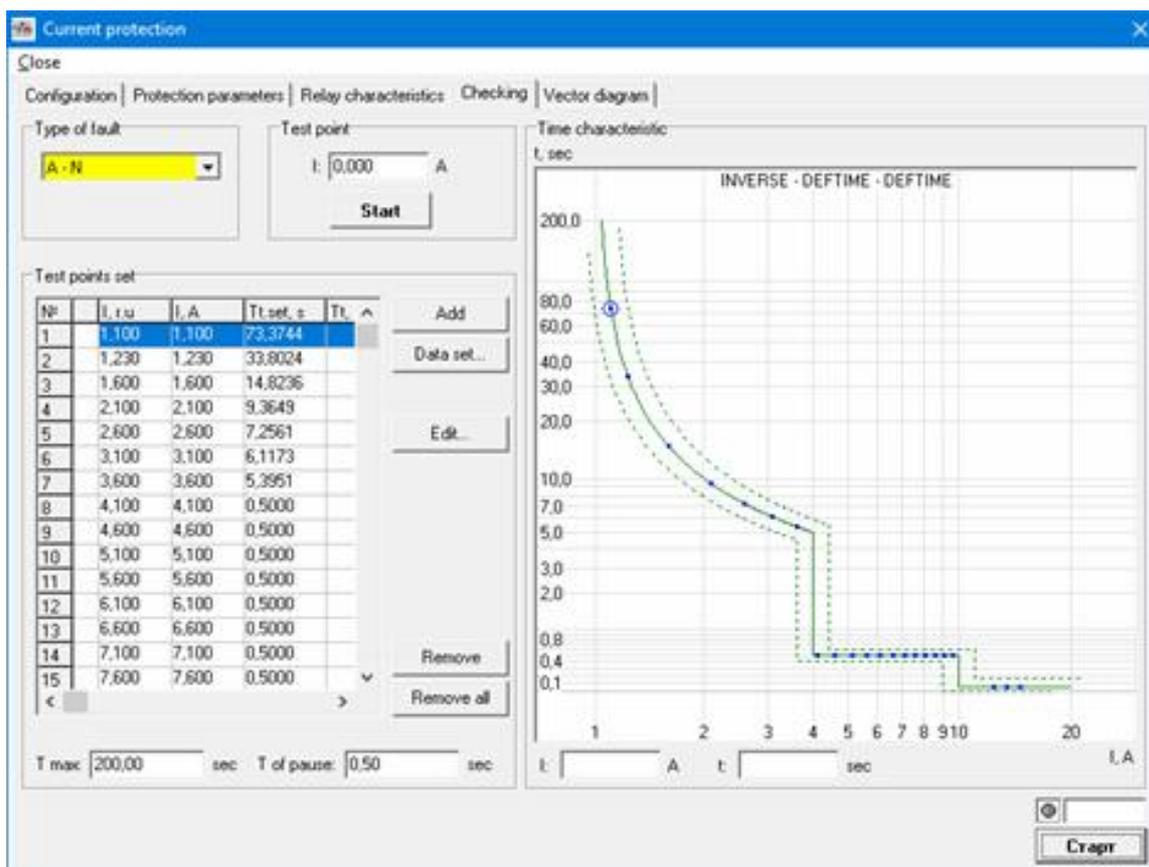
Fig. 3. Page of "Checking" of the module "Current protection".

In the field "Type of fault" of this page, we specify the type of fault – three-phase s/c, all types of double-phase s/c, single-phase s/c, and (if necessary) currents of negative sequence and zero sequence. Depending on the type of fault, the corresponding time characteristic of the current protection is displayed in the "Time characteristic" field.

The protection check can be performed either for separate specified points or for a pre-set array of the check points (complex check).

In the first case the current value is given in the field "Test Point" to check the operating time of current protection. The current value can be set in the appropriate field or by using the "mouse" manipulator on the time characteristic of protection in the "Time characteristic" field. When the "Start" button is pressed, the device starts to generate a given current until the protection is actuated. After the protection has been actuated, in the "Time characteristic" field, a point corresponding to the given current and the actual operating time is fixed.

For a complex check of the characteristic of current protection, it is necessary to form a set of test points. These points are formed in the field "Test Points Set". This array can be generated automatically or manually. When the "Start" button is pressed, the device starts to alternately, according to the table "Test Points Set", generate the given values of the current. In case the protection is actuated, in the field "Time characteristic" we shall see the points, which correspond to the protection operation coordinates. In the first column of the table "Test Points Set", information about the test results for each point will be displayed: "+" – successful; "-" – unsuccessful; "+/-" – undefined. A result analysis is carried out on the basis of a comparison of the expected operating time with the actual one, given the specified permissible errors.

The "Vector Diagram" page displays vector diagrams of the currents and voltages generated by the device. The values of currents, voltages and their phases depend on the type of fault specified on the "Checking" page, the test current and the nature of protection — directional or non-directional. The vector diagram is passive, that is, on this page it is impossible to set and adjust the values of currents and voltages calculated by the checking module.

For example, Fig. 4 shows the check scheme of a microprocessor current protection device MRZS-05M produced by "Kyivprylad", production association.
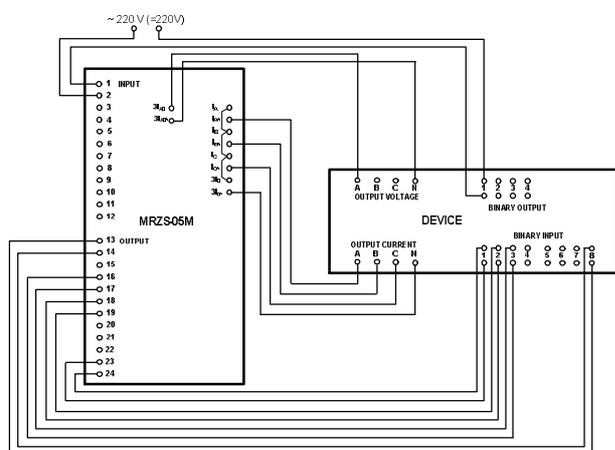

Fig. 4. Check scheme of current protection of MRZS-05M type.

4. Conclusion

The algorithm developed by the authors became the basis for the creation of a specialized module intended for setting up and checking current protection

It is possible to form current protection time characteristics of any complexity and store them in the library.

Checking the current protection characteristics for a set of points makes it possible to check the operation of all current protection stages in a single cycle and significantly reduce the time of its testing.

In addition, the editor developed for the creation of complex time characteristics of current protection allows characteristics to be used in the international formats DCC and RIO that ensures the versatile utilization of the module designed.

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ПЕРЕВІРКА СТРУМОВИХ ЗАХИСТІВ ІЗ ЗАСТОСУВАННЯМ ЦИФРОВИХ СИСТЕМ ТЕСТУВАННЯ

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Вітчизняні технічні засоби налаштування та перевірки струмових захистів виконані переважно на аналогових пристроях, які не забезпечують необхідної точності перевірки та потребують суттєвих часових затрат. Із появою цифрових систем тестування перевірку захистів можна автоматизувати. Для автоматичної перевірки характеристик струмових захистів з використанням цифрових систем тестування розроблено відповідні алгоритми та їх цифрову реалізацію. В результаті створено модуль цифрової системи тестування пристроїв релейного захисту та автоматики, за допомогою якого в автоматичному режимі здійснюється перевірка основних характеристик струмових захистів будь-якої конфігурації.

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