**Automated Calculation of Relay Protection Settings for a   
10 Kv Line**

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**Abstract**. Currently, the task of developing an integrated system for automated calculation of relay protection settings, which makes it possible to calculate short-circuit currents in maximum and minimum modes based on the initial data on the equivalent of the electrical network and the parameters of the main equipment of the substation and determine the protection settings based on various microprocessor terminals, taking into account their technical features, is relevant. This paper presents a system for automated calculation of protection settings for a 10 kV power transmission line based on microprocessor terminals manufactured by Radius Automation Joint Stock Company (JSC). The authors have investigated the developed algorithms for the automated calculation of the maximum current protection and current cut-off settings based on the specified protection terminals. A software implementation of these algorithms is also presented and an example of calculating settings using the developed software package is given. The algorithms provide for the formation of warnings for the calculator about non-compliance with the requirements for protection sensitivity, going beyond the range of setpoint control.

**Key words:** computer-aided design system, microprocessor, relay protection, setpoints, sensitivity, maximum current protection, current cut-off, setpoint control range, software, setpoint calculation.

**INTRODUCTION**

When operating the power system as a whole, we can identify the generating complex, transmission networks, distribution networks and consumer networks. Electric distribution networks are an important element in the system of electricity production and consumption, and reliable operation of enterprises largely depends on them.

Proper configuration of relay protection and emergency automation plays an important role in ensuring stable, reliable and continuous operation of electrical installations. The correct choice of operating response parameters (settings) is the most important aspect of error-free operation of relay protection. Since maximum current and differential protections prevail in distribution networks, special attention should be paid to them when calculating setpoints. Distribution networks consist of power transmission lines that supply inputs to consumers' electrical installations or transformer substations, and substations or distribution points.

In networks with a voltage of up to 10 kV serving district substations, substations of individual organizations and settlements, overloads and short circuits can lead to serious disruptions in operation, since autonomous current sources are usually absent. To prevent the consequences of short circuits and overloads, fuses or automatic circuit breakers are installed at substations. Relay protection is a type of automation that ensures reliable operation of the power system. Relay protection switches off the damaged section of the circuit, or a separate electrical installation, in automatic mode. Relay protection prevents accidents and gives a signal to the operator about a malfunction [1, 2].

The principle of operation of the relay is as follows: at a set value of electrical indicators, the relay automatically opens the circuit, if the boundary conditions are not reached, it remains in its original position, or, if set by the operator, the relay closes the circuit again automatically. By opening the main circuit, the relay closes the circuit of the alarm system, giving a sound, light or other kind of signal about the shutdown that has occurred. The setpoint of relay protection is closely related to automation designed to quickly automatically restore normal operation and power supply to consumers, for example, an automatic backup power supply (ABPS) device for category 1 electrical receivers and automatic re-activation (ARA). With the advent of modern computing systems and software complexes, the process of calculating relay protection and automation (RPA) settings has become less laborious, and the influence of the human factor has been reduced [3, 4].

**MATERIALS AND METHODS**

The purpose of this article is to study calculation techniques, awareness of the features of a particular area of relay protection, high accuracy and the absence of calculation errors.

One of the ways to solve these problems is to develop a system for automated calculation (SAC) of RPA response parameters, which includes the following tasks [5]:

1. Development of algorithms for calculating RPA settings on a microprocessor base, taking into account the functionality and features of the RP terminals.

2. Implementation and automation of these algorithms in software.

3. Presentation of this system in the form of a clear user interface.

4. Debugging the implemented SAC.

The advantages of this approach are:

1. Speed: such SAC can significantly reduce the time spent on calculating settings.

2. Versatility: the program can be used to calculate the settings of any type of protective devices and for various power supply schemes.

3. Flexibility: the ability to change the parameters and conditions of the task, which allows you to quickly evaluate various calculation options.

4. Saving time and resources: using this software reduces the need for the number of project personnel, including offloading the employment of project organizations.

5. Improving the quality of the project: SAC allows you to obtain accurate and adequate calculation results, taking into account certain calculation features, which increases the reliability of the RPA.

Much attention has been paid to this area by the scientific research society.

In this direction, an analysis of modern SAC settings of RPA devices was carried out, the conclusion of which is the low “flexibility” of the considered software complexes (SC) for the user, due to their “closed” code. Based on this, it was concluded that the most favorable and convenient is the Excel SC, on the basis of which the authors implemented a SAC of RPA settings on a microprocessor base [4].

The system of automated calculation of RPA settings is an urgent development in the light of modern technologies and requirements in the field of energy. The development of this SAC is an urgent and important task, which has a high potential in the field of energy and will ensure increased safety and reliability of the power supply system.

In this article, the authors present an algorithm for the automated calculation of protection settings for power transmission lines with a voltage of 10 kV and its software implementation.

The authors reviewed the developed software products designed for automated calculation of the RPA settings of substation equipment based on data on the equivalent of the power system, as well as the parameters of the main electrical equipment. The SC is designed for microprocessor terminals of Radius Automation JSC. This paper presents an algorithm for calculating the automated calculation of the protection settings of power transmission lines with a voltage of 10 kV and the value of the settings of the maximum current protection (MCP) stages, given in the secondary values of the measuring current transformer (CT) (Table 1) [6, 7].

**TABLE.1.** Secondary values of the measuring current transformer

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| The value of the MCP settings, A | The manufacturer of the RPA terminal | | | |
| Mechatronics | Radius Automation | EKRA | Schneider Electric |
| MCP-1, (CCO) | 78,85 | 72,78 | 66,72 | 66,72 |
| MCP-2 | 3,29 | 3,29 | 3,06 | 3,06 |
| MCP-3 (overload protection) | - | 1,37 | 1,16 | - |
| Sensitivity coefficient | 14,23 | 14,23 | 15,52 | 15,27 |
| The fraction of the line length of the protected current cut-off (CCO), % | 18 | 40 | 65 | 65 |

In the protection calculation modules of the 10 kV lines of the implemented system, the current cut-off (CCO) and maximum current protection (MCP) settings are calculated, the sensitivity of the protections is checked, as well as the construction of the time- current characteristics of the MTZ and the characteristics of the protection of the CCO, taking into account the characteristics of the terminals.

For automatic calculation, the user needs to set the following initial parameters:

1. The resulting resistance of the system in the maximum and minimum modes , Ohms.

2. The nominal voltage of the protected line , kV.

3. The coefficient of the circuit and the transformation of the measuring CT, the transformation coefficient of the voltage transformer (VT) installed on the protected line.

4. The maximum total load capacity of the protected heating line, , kVA.

5. The value of the base power , BA.

6. The value of the rated power of the power transformer , MBA.

7. Select the type of substation power transformer from the drop-down list and enter its short-circuit voltage , %.

8. Enter the limiting value of voltage regulation under load (RUL) of the transformer in question, RUL, %.

9. The value of the linear voltage in the conditions of self-starting of load motors after disconnecting the short circuit at the place of installation of protection , kV. In approximate calculations, it can be assumed to be equal to .

10. The value of the linear voltage in the conditions of self-starting of load motors when they are switched on from automation (automatic re-activation (ARA), automatic reserve activation (ARA)) at the place of protection installation, kV. In approximate calculations, it can be assumed to be equal to .

11. The resistivity of the cable line extending from the tires of the main step-down substation (SDS) , Ohms/km, as well as its length l, km.

12. Specify from the drop-down list whether the protected line feeds a single transformer or a group of power transformers. If the condition is positive, the value of the rated power of the supplied transformer is entered, , kVA, and the short-circuit voltage ,%. Under the condition that a group of transformers is powered, the total rated current of all power transformers powered by the protected line , A is also indicated.

13. The total load current of the undamaged elements fed from the protected line , A.

14. The largest of the protection actuation currents of one of the previous connections , A.

As an example, let's take the following model of the equivalent of an electrical system for entering input data into the system:

– the length of the protected line extending from the substation switchgear to the nearest transformer ;

– line resistivity ;

– the maximum load capacity of the line is ;

– it is known that the line supplies a group of 10/0.4 kV transformers, the nearest of which has an installed capacity of with a short-circuit voltage value of ShC ;

– in the module for the Radius Automation terminal, we will indicate the protective device installed on the line – a load switch with a rated cut-off current ;

– the resulting system resistance in the maximum and minimum modes is ;

– rated voltage of the protected line ;

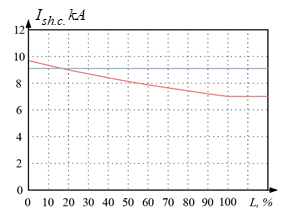
– coefficients of the scheme and transformation CT , transformation coefficient   
VT .

The results of the calculation by the system of the values of short-circuit currents (ShCC) and residual voltages with a three-phase short circuit at the end of the line are shown in Table 2.

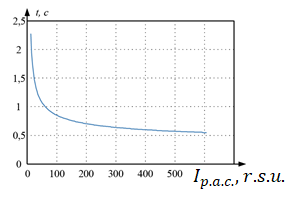
**TABLE.2** A window of results for calculating the short-circuit current and residual voltages at the end of the 10 kV line

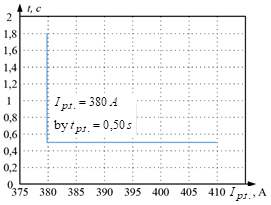
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| The calculated short-circuit point on the line extending from the switchgear of the main step-down substation | Short-circuit current at the short-circuit point, | 7.004 |  | 6.240 |
| Two-phase short-circuit current at the short-circuit point, | | | 5.404 |
| Residual maximum voltage at short circuit at point K3, | | | 3.598 |
| Reverse sequence voltage at short circuit at point K3, | | | 0.153 |

As an example, we present the generated characteristics and the setpoint map for the “Mechanotronica L” module in Figure 1-4 [8, 9].

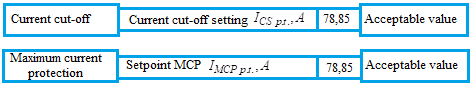


**FIGURE 1.** Characteristics of the protection of current cut-off currents



**FIGURE 2.** Dependent time-current characteristic of maximum current protection

**FIGURE 3.** Independent time-current characteristic



**FIGURE 4.** Setpoint map with the results of the protection settings of the 10 kV line

**RESULTS AND DISCUSSION**

Based on the results obtained, there is a significant difference between the values of the proportion of the line protected by the current cut-off, which is due to different values of the adjustment coefficient of one or another terminal of the RP. So, according to the MCP, in the case of terminals of the microprocessor relay protection unit (MRPU), the value of the is fixed and equal to 1.3.

It is shown that for Radius Automation JSC, the value of the is 1.2. While for NPP EKRA LLC and Schneider Electric JSC, the value of this coefficient can be taken in the range from 1.1 to 1.15 [10, 11].

The determining condition for calculating the MCP trip current for all terminals turned out to be detuning from the current during engine self-start. The differences in the values of the MCP settings are in the different values of the coefficient, as well as, in the case of Sepam, the return coefficient , which is assumed to be 0.935, in contrast to the value of 0.95 for manufacturers of other terminals. The values of the setpoint values differ by no more than 2%.

The MCP sensitivity coefficients for all modules are many times higher than the required value of 1.5. This is explained by the small length of the protected line, the magnitude of the resulting resistance of the system, affecting the value of the two-phase short-circuit currents on the line. Based on this, the inclusion of a voltage trigger in the RP circuit and the calculation of the MCP with a voltage trigger were not necessary.

According to a sample of transformers of different voltage and power classes, whose characteristics affect the value of the resulting resistance and the value of the short-circuit currents, it is unlikely to achieve a result when the MCP with current start–up does not meet the sensitivity condition. Including the self-starting coefficient in the case of a high proportion of the motor load and a rated voltage of 10 kV, as a rule, does not exceed a value equal to 5 units.

**CONCLUSION**

The existing algorithms for automated calculation of settings investigated by the authors and the software product created on its basis make it possible to calculate protection settings based on several types of terminals, compare them in sensitivity, and generate setpoint maps based on network equivalent data and protected equipment parameters. It is revealed that the system takes into account the sampling step and the limits of the settings entered into the relay protection terminal and signals in the information windows about the fulfillment of these conditions for the calculated parameters of the RP response. In the case of all terminals, the obtained setpoint values, given to the secondary circuits of the measuring circuit, are relevant and correspond to the ranges of possible input values into the terminals of the RP. This function allows you to increase the accuracy of the setpoint calculation by reducing errors on the secondary CT circuit.

Thus, the implemented system can allow the user, when designing the protection of a 10 kV line, to compare one or another RP terminal, choose the most suitable for a specific version of the electrical system, make a quick calculation in case of a change in the structure of the electrical system, and verify the adequacy of the protection response parameters received from the design organization.

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