Development of relay protection system allowing taking into account seasonality when determining operation setpoints

Olga Akhmedova*, Anatoly Soshinov, Konstantin Bakhtiarov, Olga Atrashenko, Mikhail Panasenko and Tatyana Kopeykina

Kamyshin Technological Institute (Branch), Volgograd State Technical University, Kamyshin, Russian Federation

* E-mail: epp@kti.ru

Abstract. Various manufacturers of relay protection devices only offer two options of setpoints, which should be changed manually by the operating staff at the place of protection installation. This means that these devices do not have the ability to adapt the protection response current to changing environmental parameters, which have a significant impact on overhead power lines parameters. As a result, the setpoint set on a microprocessor relay device is not always correct and can lead to failure of the relay protection or to a false positive.

Keywords: relay protection, sensitivity coefficient, microprocessor terminals, adaptive setpoint.

1. Introduction

The problems associated with relay protection devices are one of the main causes of severe accidents that periodically occur in power grids around the world. According to the North American Electric Reliability Council, in 74% of cases, the cause of severe accidents in power systems was improper actions of relay protection during the accident, therefore the reliability of the entire power system depends on the reliability of relay protection. Modern digital relay protection devices have integrated, within a single information complex, the functions of relay protection, automation, measurement, regulation and control of electrical installations. Most manufacturers of equipment for relay protection and automation devices stop producing electromechanical relays and devices and are switching to digital components. The transition to new element base does not lead to a change in the principles of relay protection and electric automation, but only expands its functionality, simplifies operation and reduces its cost. The priority direction of development of relay protection devices, as part of the transition to the “Digital Substations”, is creation of an automated system for the selection of setpoints and functions of relay protection and automation.

2. Analysis of the dependence of linear parameters of the overhead line on the weather conditions

Traditionally, maximum-current protection (MCP), distance protection (DP) and zero-sequence current protection (ZSCP) are applied as backup protection installed on power lines. In this case, MCP and DP are aimed at detecting phase-to-phase short circuits, and ZSCP are aimed at detecting single-phase and two-phase short circuits to earth [1-6].
Consider the traditional algorithm of distance protection, based on the control of resistance changes. By controlling the change in resistance, one can determine the occurrence of a short circuit and estimate the distance to the short circuit point. Soil resistance in most regions of the Russian Federation varies significantly throughout the year, but when calculating the operation setpoints, this fluctuation is not taken into account and the constant reference value is used. Figure 1 shows relationship between the wire reactive resistance at various soil resistances and seasonal fluctuations of humidity and temperature by months.

![Figure 1](image1)

At mutual projection of dependencies graphically presented in Figure 1, we observe a coincidence of trend curves change by months, therefore, regardless the soil structure, there is a clear seasonal dependence, which must be taken into account when calculating the wire resistance.

### 3. Experimental study of the influence of external weather conditions on soil resistance

Measurement of grounding resistance using the M-416 device is based on the compensation method using an auxiliary grounding switch and a potential electrode (probe). Laboratory experimental installation also comprises a unit for measuring the soil moisture. Analysis of experimental data shows a clear relationship between the soil resistance and the soil moisture, on the basis of which the following dependencies were constructed (Figure 2).

![Figure 2](image2)

### Figure 2. Relationship between soil resistivity and its moisture content.

Any type of soil in a completely dry state has a high specific resistance, since dry salts, anhydrous acids, solid bases practically do not conduct electrical current. When moistening the soil due to the...
dissolution of salts in water, acids and bases, as well as due to the conductivity of water, the resistivity of the soil will decrease by several orders of magnitude. Based on experimental data, a sharp decrease in soil resistivity occurs at a moisture content of 15-20% for sand and 20-30% for clay loam. A further increase in soil moisture (regardless of its type) practically does not affect its resistance, but when moisture content reaches 70-80%, the concentration of water-soluble substances decreases and, accordingly, the resistance slightly increases.

The analysis of relationship between soil resistance and temperature is presented in Figure 3, the experiment was carried out in the range of soil temperatures from -15 to + 15 °C.

![Figure 3. Relationship between specific soil resistance (clay loam) and temperature.](image1)

![Figure 4. Change in specific soil resistance depending on the month.](image2)

The experimental data show that with increasing temperature, the specific resistance of soil decreases, since the concentration of ions in the solution increases, but this process can be observed until the moment of moisture evaporation, and after the soil resistance increases dramatically. Rapid heating of the soil up to 100 °C occurs when a short circuit current flows. Soil drying due to the rapid evaporation of moisture leads to a sharp increase in resistance in the upper soil layer about 50-60 cm thick, therefore, it is necessary to consider the resistance of the soil as multi-layered. The analysis of the layered structure of the soil was experimentally investigated under various weather conditions and the experimental data are presented in Figure 4. To study the resistance at a depth of 2.5 meters, an insulated electrode was used over the entire surface, except for 10 cm at the end of the electrode, to make measurements of the soil resistance at the required depth without distributing the electrode immersed in the soil over the entire area.

Figure 4 presents the analysis data from July to December, for the other six months the data are similar, as there is a change of dry and wet seasons.

The decrease in resistivity was observed in fall and spring, as during these periods snow melt and heavy rains occur, which increase the moisture content in the soil. And in winter and summer, the soil resistance increases due to the freezing or evaporation of moisture. From the analysis of experimental data, it follows that the upper layers of the soil are most affected by the seasonal fluctuations, and the deeper layers have a more stable resistance.

When freezing moisture in the soil (at a temperature of 0 °C and below), the resistance of ice is higher than the resistance of water due to the salt content in water. Therefore, the ice formed in the ground in the form of thin interlayers does not conduct current, and prevents it from passing through the ground, thereby reducing the conductive cross section and extending the current flow path. A further decrease in temperature also leads to an increase in soil resistance, but with less intensity.

4. Analysis of relationship between relay protection operation setpoints for various types of damage and the soil resistance
In distance protection, the measuring body is the resistance body, the characteristic value to which it reacts is the ratio of the applied voltage and current. The executive body of resistance is minimal and
works when the characteristic value $Z_p$ decreases down to the response resistance $Z_{resp}$, and returns when $Z_p$ increases up to the resistance of return $Z_{ret}$. The realization of the minimum resistance measuring body is determined by the change in the characteristic value when the mode changes from operating to short-circuit mode. [6].

Figure 5. Distance protection block diagram

During single-phase short circuit the resistance at the input of the resistance measuring body is greater than during multi-phase short circuit at the same point, therefore, the resistance measuring body cannot operate unnecessarily [7]. But the question arises whether the protection will work in this type of damage correctly, if its setpoint directly depends on the resistance, i.e. under certain conditions, is proportional to the distance from the place of protection installation to the short-circuit location, assuming that variative external environmental parameters are neglected? The dynamics of protection setpoint resistance at a single phase short circuit at variation of soil resistance is presented in Figure 6. By analyzing the obtained data, it becomes clear that the resistance change ranges from 14% (soil resistance of 20 Ohm·m) to 28% (soil resistance of 1000 Ohm·m) relative to the resistance calculated for symmetrical damage, therefore, the distance protection that is minimal may not work with asymmetric short-circuit in case of the soil drying and increase of its resistance.

Figure 6. Relationship between setpoint protection resistance at single-phase short-circuit and soil resistance for OHL "PS KrasnyiYar - Rudnya".
The dependency analysis revealed the need to develop an algorithm for the operation of relay protection devices, which allows one to calculate the setpoints of the response current depending on the damage type, as well as to select short circuits to determine the damaged phases.

5. Development of relay protection control system device with adaptive setpoint

The structural circuit of the relay protection system with an adaptive setpoint is shown in Figure 7.

![Diagram](image)

**Figure 7.** The structural circuit of microprocessor protection relay system with adaptive setpoint.

The microprocessor module receives analog current and voltage signals from the block of intermediate transformers, as well as from the data transfer unit with sensors for ambient air monitoring connected to it. Using the common bus, the microprocessor relay unit receives in digital form the state of discrete input signals from the input discrete signals block, the status of the control buttons from the display and control unit, requests from the upper level system from the communication unit; control and alarm signals are issued to the input relay unit, LED alarm signals to the display and control unit and responses to the request of the upper level system to the communication unit; information exchange via a serial channel with a top-level system through a communication unit.

6. Conclusions

The article proposes a solution to the problem of more accurately determining the operation setpoints of overhead transmission lines protection, due to the multiparameter calculation system, as well as the possibility of determining the short-circuit type during accident using new algorithms for the protection functioning.

References

[1] Rubinchik V A 1985 Reservation of short circuits turn-off in electrical networks. Moscow: Energoatomizdat 120

[2] Figurnov E P, Zharkov Yu I, Petrova T E 2006 Relay protection of AC power supply networks: textbook for students of railway transport universities. Moscow: Publishing House Marshryt 272

[3] Figurnov E P 1981 Relay protection of power supply devices of railways: textbook for students of railway transport universities. Moscow: Transport 215.

[4] Figurnov E P 2004 Relay protection: textbook for students of electrotechnical and electromechanical specialties of transport and other universities. Kiev: Transport Ukrainy
565.

[5] Chernobrovov N V, Semenov V A 1998 Relay protection of energy systems: textbook for technical schools. Moscow: Energoatomizdat 800.

[6] Bass E I, Doroguntsev V G 2002 Relay protection of electric power systems: Textbook / Ed. A.F. Dyakov. Moscow: Publishing House MEI 296.

[7] Kryuchkov I P, Starshinov V A, Gusev Yu P, Piratorov M V 2008 Transients in electric power systems: a textbook for universities Moscow: Publishing House MEI 416.

[8] Kulikov Yu A 2003 Transients in electrical systems: Textbook. - Novosibirsk: NSTU, Moscow: Mir AST Publishing House 283.

[9] Akhmedova O O 2017 Review of the algorithms for sensitive protection systems Modern Science Progress 4(4) 68–71.

[10] Akhmedova O O 2018 Development of the algorithm of functioning of the managing system of high–speed relay protection of the air-line of the electricity transmission Modern Science Intensive Technologies 3 7–13.

[11] Akhmedova O O 2016 The specified algorithm of calculation of active resistance of the air-line of the electricity transmission taking into account weather conditions International applied and fundamental research journal 12(3) 387-98

[12] HaiYang Zhang, ShanDe Li 2011 Design of adaptive line protection under smart grid International Conference on Advanced Power System Automation and Protection 1 599–603

[13] Zapata-Castro J, López-Lezama J M 2014 Optimal coordination of directional overcurrent relays operating as backup protection in electrical power system IEEE Central America and Panama Convention (CONCAPAN XXXIV), pp. 1–6

[14] WenHao Zhang, LiJun Jin, ShuJia Yan 2011 An adaptive relaying algorithm for the protection of distribution networks integrated with wind farms International Conference on Advanced Power System Automation and Protection 1 564-7

[15] Ming-yu Yang, Yong-li Zhu 2005 A Cooperative Protection System with Multi-Agent System,” IEEE/PES Transmission & Distribution Conference & Exposition: Asia and Pacific, pp. 1–4

[16] Akhmedova O O 2017 The analysis of running parameters of air-line of the electricity transmission in case of the accounting of finite conductivity of the Earth Modern science and education success 4(4) 130-2

[17] Gurevich V I 2011 Microprocessor protection relays. The device, problems, prospects. Moscow: Infra-Ingeneriya 336