The study of the logical mode of function choice of digital protection on the railway control

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Abstract. The article analyzes the existing protection systems for the traction substation - traction network - electric stock system, including digital terminals having several levels of digital protection used in the Russian Federation. Their vulnerabilities were described. Based on the analysis, a protection system responding to a number of signs of the transition process and having a built-in logic function used to select a mode was developed.

1. Introduction

The articles [1 ... 2] provide analytical data on all methods for protecting individual elements of the traction substation - traction network - electric stock system which are used at the stage of experimental studies. A variety of patents have been not implemented. Significant contribution to the study of ways to protect elements of this system was made by Radchenko V.D., Sukhoprudskiy N.D., Sokolov S.D., Markvardt G.G., Kuchma K.G., Pupynin V.N., Figurnov E.P., Kosarev B.I., Kuznetsov S.M. et al. According to the research conducted by these scientists, the protection system responds only to changes in one sign and its parameters in normal and emergency modes. These signs are as follows: current, voltage, temperature, resistance, etc.

The protection scheme does not provide for the control of combined changes in the parameters [1, 2, 3, 7] which are often close in normal and emergency modes. This circumstance violates selectivity of the protection system. In order to ensure the protection, a number of false alarms [2, 6] deviating from the requirements of electrical installation rules are allowed.

Among other things, all elements of the traction substation - traction network - electric rolling stock system with the exception of the traction substation contain only one protection system. In accordance with the rules of electrical installation, it is necessary to protect all the elements.
The combination of these shortcomings can be eliminated or limited using various methods of indirect control of individual elements of the system (the traction network) analyzed in [4, 10]. Due to the lack of a systematic approach, the problem cannot be solved using new parametric protection systems. [5, 8, 9, 11, 12].

2. Methods and materials

The general requirements for protection devices are described in [1, 2]. The study of electromagnetic processes [1, 2] allows us to conclude that the most effective solution to the problem of quick and selective disconnection of short-circuit current is a protection system that responds to the time coincidence of several signs of the transient process caused by a short circuit. These signs are as follows:

- a change in the spectrum of high-frequency oscillations in electromagnetically coupled circuits parallel to the traction network;
- a change in impedance of the traction network;
- a change in current and a current increment;
- an increase in the variable component of voltage of the contact network;
- a contact wire temperature increase;
- a multi-parameter control over a large number of parameters and a continuous analysis of their changes in comparison with limit values.

In addition, indirect methods can be used:

- monitoring of integrity of the contact wire to protect it from external effects and adjust the frequency of the control current for each section of the traction network [1, 12];
- potential protection with high and low currents of an emergency mode [1, 2, 7];
- TV signals about the state of any element of the traction substation - traction network system transmitted via TV control channels to the central processor for continuous analysis and decision making;

The protected element of the traction substation - traction network - electric rolling stock system is a protection object of the device (a feeder of the traction network, sectioning points or parallel connection point, electric rolling stock and its individual blocks). The action of a a protection device that causes output signals (disconnection of the protected object or a signal) is a protection triggering.

The standard mode of the system which does not require protection is a watchdog mode of the protection device or a standby mode of the request for operation.

A short circuit affects neighboring (intact) elements and their relay protection.

Therefore, the mode of operation of this relay protection as well as the relay protection of a damaged element is an alarm mode.

It should be noted that as a result of operation of the entire protection system, only the damaged element should be disconnected. This action is called selective, and disconnection of the damaged element is called correct.

In the alarm mode, intensive input signals (spurious signals) may occur in the protection device of undamaged elements which can cause them to be triggered. Triggering of the ultrasound of any intact element in an alarm mode is called a false alarm.

To ensure the selective action of a protection device, a slowdown of the response which is called a time delay can be used. This process is called Q launch of the protection device. Signals from sensors can be shifted in time. This slowdown is called a delay in response which can cause a protection failure [1].

Each protection device responds to the above signs, according to which it distinguishes the alarm mode from the duty mode.

The threshold (boundary) value of the parameter at which the protection starts is called a trigger parameter. After disconnecting the damaged element of the system, the protection device is switched to the duty mode. The threshold value of the parameter at which the protection device switches from the alarm mode to the duty one is called a return parameter. The ratio of the return parameter to the trigger
parameter is called the return coefficient. The value of the triggering parameter is set by a measuring body (a threshold device) – a protection device.

3. Results
The measuring body or a sensor of the monitored parameter (D) is the main body of the protection device designed to detect the sign of damage. The controlled parameters of the protected circuit are specified above.

Relay measuring elements of the protection devices are the main part of the relay protection devices. They control the mode of the protected object of the electrical system and operate when the controlled electrical parameters (current, voltage, power direction, frequency, resistance) are in a certain specified range of values. Under the influence of any sudden changes in the electrical system mode (short circuit, commutation), transients occur in individual elements of the electrical system, current and voltage measuring transformers, secondary relay circuits, accompanying the transition from the values of the parameters before the disturbance to their new values. At the same time, significant delays in the operation of the relay in case of internal damages and false actions in case of external damages and commutations are possible. This is due to the fact that in the transition mode, the monitored parameter is different from the steady-state value due to the free components of transients in the electrical system and instrument transformers. Transients in the circuits of the measuring body with jump-like changes in the input monitored parameter cause a similar effect. An increase in capacities of the energy systems and single objects, an increase in the length of power transmission lines increase requirements for speed and accuracy of the response of the measuring bodies in conditions of intensive transients.

The structure of any protection device includes the following components: a microprocessor unit and an output unit, sensors, analog-to-digital converters.

Based on the analysis of stability of the internal short circuit mode, the structure of the algorithm limited by spurious signals caused by external short circuits is formed.

The purpose of algorithm development is stable identification of signs caused by internal short circuits. Therefore, the structure of the algorithm should include systems used for identifying the useful signal and determining and neutralizing false signals.

![Figure 1](image-url)

**Figure 1.** The power supply circuit of the traction network with disabled PS: F1 - F4 - feeders of the traction substation A and B; SI - sectional insulator; T - current collector passing through SI
Let us analyze a typical double-track section of the direct current traction network (Fig. 1). Along with the current-pulse protection device, a distance protection device will be installed on each feeder of the traction substation. Thus, instead of one of protection device, a protection device that includes four types of protection systems will be used.

Based on this concept, it is necessary to use a number of signs of short circuits. These signs should be recognized by sensors; parameters of the signs should be analyzed by such parameters as an amplitude and transmitted to the microprocessor.

In the unit of amplitude and logical analysis, blockings taking into account changes in the parameters of the protected circuit should be installed. In order to improve noise immunity, it is necessary to transmit signals along the circuit path.

The appropriate solution will be the use of microprocessor sets of large integrated circuits. This will make it possible to create a microcomputer and adapt a microprocessor software to a specific application: by changing the program and functions of the information control system. It will make it possible to determine optimal characteristics of the microprocessor.

If the level of software of microprocessors does not allow for developing an effective system, the next level is available. By changing the RAM contents, one can adjust them to more specific features of the information processing system. By changing the firmware, the hardware level of the system does not change. Technical and economic consequences are associated only with limited intervention of microcomputer control units.

The change in the hardware level of the information control microprocessor system simultaneously with the specification of the microprogram and program levels makes it possible to meet the requirements for the system and protect it from possible destructive effects of current and voltage parameters.

4. Conclusion
The analysis of transients in the traction network allowed us to determine a set of features and parameters that characterize the short circuit mode and occur during normal operation of the system. If there are coincidences of several signs, it allows us to identify a short circuit more accurately and disconnect the fault location. In some cases, when the sectioning point is disconnected, the length of a feeder zone increases. In this case, reliability of the system can be maintained by using a combination of other indirect actions, such as telelocking. In addition, the use of microprocessor kits makes it possible to improve reliability of the system and protect it from destructive effects.

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