ANNOTATION

of the dissertation for the degree of Doctor of Philosophy (PhD) in the specialty 8D07103 – «Electric power industry»

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DEVELOPMENT OF MAGNETIC CURRENT CONVERTERS FOR CURRENT PROTECTION

The proposed dissertation work is devoted to the development of magnetic current converters for current protection and was carried out within the framework of the priority directions of the development in the field of "Power Engineering and Mechanical Engineering", approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan.

The relevance. In accordance with the PUE, protections are used to protect electrical networks and electrical installations that provide power supply to cities, settlements and industrial enterprises from short circuits (SC), the operation of which is based on measuring the current in the bus of the protected electrical object or the magnetic field from this current.

Fuses, circuit breakers, maximum current relays of the type REO-401, REO-402 or REV-570, as well as current transformers (CT) with current relays are used in protections whose operation is based on current measurement. However, all these devices, except for CT with a current relay, do not always allow to implement current protection that meets the requirements of selectivity, speed and sensitivity. Protections in which CT and current relay are used are devoid of this drawback. Their main disadvantage is the high cost of CT, which increases in proportion to the square of the increase in its rated current and voltage.

In protections whose operation is based on measuring the magnetic field of the bus, a Rogovsky coil, a magnetic current transformer (MCT), fiber-optic and galvanomagnetic Hall effect current converters, a magnetic-resistive converter, as well as a reed switch can be used as a measuring element. A significant contribution to the field of relay protection related to the development of protection devices on such current converters was made by I.M. Sirota, V.E. Kazansky, A.A. Chunikhin, A.N. Novozhilov, V.V. Gurin, M.Ya Kletsel and many other scientists.

All these current converters are cheap. However, their use in relay protection has not been widely used. This is mainly caused by the complexity and high cost of implementing current protections using them. They consist in the fact that almost always the installation of such protection on a specific electrical object, due to its design features, requires the development of a new mounting design for these current converters and a device for setting its trigger threshold. In addition, to determine its trigger threshold, it is necessary to calculate magnetic fields taking into account the influence of all ferromagnetic elements located nearby, as well as those that may appear nearby during operation. All this requires a significant amount of time, additional structural materials and devices, as well as the

participation of highly qualified specialists in the implementation of protections with such measuring transducers.

To a large extent, these disadvantages are deprived of cheap and easy-to-implement current protections, which use a magnetic current converter (MCC), manufactured on the basis of elements of the RT-40 current relay. Installation of such an MCC is carried out on the tire using fiberglass impregnated with epoxy resin. Such an MCC has a built-in element for smooth adjustment of the trigger threshold. This trigger threshold is determined by the uniform tables calculated for this MCC. At the same time, the MCC contacts, due to the absence of their vibration, can be connected directly to the control circuits of the switch. Thus, the implementation of protection with MCC is quite possible for the service personnel.

However, such MCCs are designed to protect low-voltage electrical networks and electrical installations, the size of current-carrying buses with insulation of which does not exceed the size of the window of the magnetic circuit of the current relay RT-40. In this regard, these MCCs cannot be used to protect high-voltage electrical installations, as well as electrical installations with a large cross-section of supply buses and currents of more than 700-800 amperes. In addition, the protection of a three-phase electrical installation requires the use of three MCCs. All this limits the scope of the MCC. In this regard, the work on the development of MCC for current protection cannot be considered completed. Therefore, their further development **is relevant**.

The object of the study is MCC for current protection of low-voltage and high-voltage electrical networks and electrical installations.

The subject of the study is MCC for current protections, the magnetic and contact systems of which are manufactured on the basis of elements of the RT–40 current relay and reed switch.

The purpose of the work is to develop single-phase and three-phase MCCs for current protection of low-voltage and high-voltage electrical networks and electrical installations, the size of current-carrying buses with insulation, which has arbitrary sizes and shapes. To achieve this goal, **the following tasks were set and solved**:

1. Experimentally determine the dependence of the magnitude of magnetic induction in the air gap of the RT-40 magnetic relay system with a bus winding on the current in this bus at different values of the set threshold of the relay.

2. By using the ELCUT software package, simulate the dependence of the magnitude of magnetic induction in the air gap of the magnetic system of the RT-40 relay with a winding in the form of a bus on the current in this bus at different values of the set operating threshold, and also evaluate the error of this modeling.

3. To develop an MCC with two magnetic conductors of arbitrary shape and with a contact system from a current relay of the RT-40 type for single-phase current protection of low-voltage and high-voltage electrical networks and electrical installations.

4. Develop an MCC for three-phase current protection of low-voltage electrical networks and electrical installations, the contact system of which is based on the elements of the RT-40 relay.

5. Develop an MCC for single-phase current protection, the magnetic system of which is based on the elements of the RT-40 relay, and the contact system is a reed switch.

The tools in obtaining research materials are:

- fundamental principles of mathematics and mathematical modeling;
- theoretical foundations of electrical engineering and relay protection;
- theoretical research using the ELCUT software package;
-physical modeling and field experiment.

The scientific novelty of the work is determined by the fact that:

1. Experimentally, the dependence of the magnitude of the magnetic field induction in the air gap of the RT-40 magnetic relay system with a bus winding on the current in this bus at different values of the set threshold of the relay is obtained.

2. The possibility of using the student version of the ELCUT software package to simulate the dependence of the magnitude of the magnetic field induction in the air gap of the RT-40 magnetic relay system with a bus winding on the current in this bus at different values of the set trigger threshold is investigated, and the error of this simulation is estimated.

3. Three designs of single-phase MCC with two magnetic conductors of arbitrary shape and with a contact system from a current relay of the RT-40 type for current protection of low-voltage and high-voltage electrical networks and electrical installations have been developed.

4. A three-phase MCC has been developed for current protection of low-voltage electrical networks and electrical installations, the contact system of which is based on the elements of the RT-40 relay.

5. A single-phase MCC for current protection has been developed, the magnetic system of which is based on the elements of the RT-40 relay, and the contact system is made in the form of a reed switch.

The practical value of the work lies in the fact that:

1. The experimentally obtained dependence of the magnitude of the magnetic induction of the magnetic field in the air gap of the magnetic system of the RT-40 relay with a bus winding on the current in this bus at different values of the set threshold of the relay operation makes it possible to develop an MCC with a similar magnetic system and evaluate the errors of modeling this dependence in an arbitrary way.

2. Investigation of the possibility of using the student version of the ELCUT software package to simulate the induction of a magnetic field in the air gap of the RT-40 magnetic relay system with a bus winding, depending on the current in this bus at different values of the set threshold of operation, that the error of its modeling in this case does not exceed 15.5%. which fully satisfies the requirements of relay protection.

3. The developed single-phase MCC with two magnetic conductors of arbitrary shape and with a contact system from a current relay of the RT-40 type, allow performing current protections that are capable of protecting low-voltage and electrical networks and electrical installations from short circuit at operating

currents of this MCC equal to 200-750A, as well as high-voltage electrical networks and electrical installations with a voltage of up to 10 kV at The actuation currents of this MCC are equal to 4400-30000A.

4. The developed three-phase MCC, the contact system of which is made on the basis of the elements of the current relay RT-40, allows you to perform current protection capable of protecting low-voltage electrical networks or electrical installations from short circuit at operating currents of this MCC up to 500A.

5. The developed single-phase MCC, the magnetic system of which has two parallel magnetic cores, and the contact system is made in in the form of a reed switch, it allows to implement current protection capable of protecting low-voltage electrical networks and electrical installations from short circuit at the actuation currents of this protection 127-733A.

The connection of the topic of the dissertation with general scientific (state) programs. Research on the topic of the dissertation was carried out within the framework of the priority directions of the development of science "Energy and mechanical Engineering", approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan.

Implementation of results.

Theoretical and practical results of the work can be successfully used in the design of current protections, in production and in the educational process of bachelors, masters and PhD doctors.

Approbation of research results:

The main provisions and scientific results of the dissertation were reported and discussed at the LXXVI International scientific and practical conference "Technical Sciences: problems and solutions/ Internauka, Moscow 2023".

Publications. According to the work, 8 printed works have been published, including in journals recommended by COKSON – two, patents of the Russian Federation – two, patents of the Republic of Kazakhstan - two. Also, one article was published in the journal Bulletin of Mechanical Engineering and one article in the journal "Russian Engineering Research" (No. 6, 2022), which is indexed in the SCOPUS database.

The structure and scope of the dissertation. The dissertation consists of an introduction, three sections, and a conclusion. The work is presented on 88 pages of computer text, includes 60 drawings. The list of sources used includes 49 titles.

The introduction substantiates the relevance of the topic of the dissertation work, defines the goals and objectives of the research, reflects the scientific novelty and practical significance of the results obtained, and indicates ways to implement the tasks formulated in the dissertation.

In the first chapter, the issues of using different voltage classes in solving almost all issues of power supply and protection from emergency modes of operation of industrial enterprises are considered. The operation of three-phase networks with isolated and grounded neutral in normal operational and emergency operating modes is considered, a characteristic feature of which is a significant increase in currents in all emergency and some normal operating modes.

It was found out that to protect electrical objects from emergency modes, protections are used, the operation of which is based on measuring the current in the bus of the protected electrical object or the magnetic field from this current. The first include fuses, circuit breakers, as well as current transformers (CT) with current relays. However, protection with CT with a current relay is expensive, due to the high cost of CT, which increases in proportion to the square of the increase in its rated voltage. Protections with other devices do not always allow you to implement current protection that meets the requirements of selectivity, speed and sensitivity.

In protections based on measuring the magnetic field of the bus, a Rogovsky coil, a magnetic current transformer (MCT), fiber-optic and galvanomagnetic Hall effect current converters, a magnetoresistive converter, as well as a reed switch can be used as a measuring element. All these current converters are cheap. However, their use in relay protection has not been widely used mainly due to the complexity and high cost, as well as due to the need to take into account the influence of external magnetic fields.

All this led to the need to develop a new device for current protection, devoid of these disadvantages.

In the second chapter, the parameters of the magnetic system of the RT-40 series current relay are investigated, the dependence of the magnitude of magnetic induction in the air gap between the ends of the magnetic circuit and the anchor of this magnetic system, which causes the relay to trigger, on the magnitude of the current in the bus, obtained experimentally, is constructed.

Based on this, the designs of five magnetic current converters (MCC) have been developed, which are based on the magnetic and contact systems of the RT-40 current relay. These magnetic current converters differ in the ways they are fixed and the threshold is set, as well as ways to protect against voltage in the current-carrying bus. This makes it possible to implement simple and cheap, single-phase and three-phase current protection for low-voltage electrical networks and electrical installations, as well as high-voltage electrical installations with a voltage of up to 10 kV.

In order to simplify the determination of the trigger threshold, the possibility of using the student version of the ELCUT software package to simulate the induction of a magnetic field in the air gap between the ends of the magnetic circuit and the anchor of a magnetic current converter, depending on the magnitude of the current in the bus, was investigated, which showed that this software package allows calculating this magnetic induction with an error not exceeding 15.5%. This error fully satisfies the requirements of relay protection.

The third chapter is devoted to the construction of four current protections on magnetic current converters, which are able to provide the required speed, sensitivity and selectivity.

The construction of current protection for voltages up to 1000V with actuation currents equal to 160 – 320A is based on the use of a single-phase MCC, the magnetic and contact systems of which are based on the elements of the RT-40 current relay. To implement protection with such an MCC, schemes have been

developed in which an automatic switch is used together with this MCC, as well as a method for determining and setting the trigger threshold.

The construction of current protection of low-voltage and high-voltage electrical networks and electrical installations with voltages up to 10 kV and with actuation currents up to 10kA is based on the use of a single-phase MCC with two arbitrary-shaped magnetic cores and a contact system from a current relay of the RT-40 type. Such an MCC is installed on an electrical installation using a system of special racks. To implement this protection, its schemes for operational alternating and direct current, as well as a method for determining and setting the threshold, have been developed.

The construction of a three–phase current protection for voltages up to 1000V with actuation currents equal to 160 - 320A is based on the use of a three-phase MCC, the magnetic and contact systems of which are based on the elements of the RT-40 current relay. To implement three-phase current protection with such an MCC, schemes have been developed in which an automatic switch is used together with this MCC, as well as a method for determining and setting the trigger threshold.

The construction of current protection of low-voltage and high-voltage electrical networks and electrical installations with voltages up to 10 kV and with actuation currents from 130A to 700A to 10kA is based on the use of a single-phase MCC with two magnetic cores and a contact system in the form of a reed switch. Such an MCC is fixed on an electrical installation also with the help of a system of special racks. To implement this protection, operational AC and DC circuits have been developed, as well as a method for determining and setting the threshold.