УДК 621.11

Yaroslav VERSHYLO
Svitlana NYKYPORETS

RELAY PROTECTION. RELAY CLASSIFICATION, PRINCIPLE OF WORK AND MAINTENANCE IN THE CONDITIONS OF TECHNICAL OPERATION

Анотація
В статті розглядається призначення релейного захисту, класифікація релейного захисту, принципи роботи та технічне обслуговування. Техніка безпеки при ремонті та експлуатації релейного захисту також наводиться.
Ключові слова: реле, АПВ, РЗ, струм, напруга, час спрацювання, трансформатор, автоматика.

Abstract
The article considers the purpose of relay protection, classification of relay protection, principles of operation and maintenance. Safety precautions for repair and operation of relay protection are also provided.

Keywords: relay, AR, RP, current, voltage, operating time, transformer, automation**.**

Purpose of relay protection devices

All electrical installations are equipped with relay protection devices designed to disconnect the protected part of the circuit or element in case of damage, if this damage causes failure of the element or the electrical installation as a whole. Relay protection also works when there are conditions that threaten to disrupt the normal operation of the electrical installation.

In relay protection of electrical installations, protective functions are assigned to relays that serve to apply a pulse to automatically turn off the elements of the electrical installation or a signal of violation of the normal mode of operation of equipment, electrical installations, lines, etc.

A relay is a device that responds to changes in any physical quantity, such as current, voltage, pressure, temperature. When the deviation of this value is above the allowable, the relay is triggered and its contacts, closing or opening, make the necessary switches by applying or disconnecting voltage in the control circuits of the electrical installation.

The following requirements are put forward to relay protection:

- ✓ selectivity (selectivity) – disabling only the minimum part or element of the installation that caused the violation of the regime;
- ✓ sensitivity – a quick reaction to certain, predetermined deviations from normal regimes, sometimes the most insignificant;
- ✓ reliability – trouble-free operation in case of deviation from normal mode.

Reliability of protection is provided both by the correct choice of the scheme and devices, and by the correct operation providing periodic preventive checks and examinations.

The required speed of the relay is determined by the project depending on the nature of the technological process. Sometimes, to minimize damage from damage, the relay protection must provide a complete shutdown within a hundredth of a second.

According to their purpose, relays are divided into control relays and protection relays. Control relays are usually included directly in electrical circuits and they are triggered by deviations from the technological process or changes in the operation of mechanisms. Protection relays are included in electrical circuits through measuring instruments transformers and only sometimes directly. They work in informal or emergency modes of operation of the installation. The relay is characterized by the following indicators:

- ✓ setpoint – current, voltage or time for which this relay is adjusted for its operation;
- ✓ voltage (or current) of operation – the smallest or largest value at which the relay is fully activated;
- ✓ release voltage (or current) – the highest value at which the relay is turned off (returns to its original position);

- ✓ return factor – the ratio of voltage (or current) of the release to the voltage (or current) of operation.

According to the time of operation, there are instantaneous and time-delayed relays.

The following protections are installed on transformers:

- ✓ protection against short circuits, which acts to disconnect the damaged transformer and is performed without delay (to limit the size of the damage, as well as to prevent disruption of the uninterrupted operation of the power supply system). Longitudinal differential current protections are used for protection of large transformers, and for low-power transformers – current protections with step characteristic;
- ✓ shutter speed. In addition, non-electric gas protection is used for all damage inside the tank and oil level drops;
- ✓ protection against external short-circuit currents, the main purpose of which is to prevent the long-term passage of short-circuit currents. In case of failure of switches or protections of adjacent elements by disconnecting the transformer. In addition, protection can work as the main one (on low-fashion transformers, as well as on short circuits on tires, if there is no special protection of tires). Protection against external short circuit is usually performed by current or (much less often) remote – with shutter speeds;
- ✓ overload protection performed by means of one maximum current relay, as overload is usually a symmetrical mode. Since overloading is permissible for a long period of time, overload protection in the presence of on-duty personnel must be performed with an effect on the signal, and in the absence of personnel – on unloading or disconnecting the transformer.

The following automation devices are provided on transformers:

- ✓ automatic restart, designed to restart the transformer after it is turned off by maximum current protection. Requirements for APV (automatic reconnection) and methods of its implementation are similar to the previously discussed devices APV lines. The main feature is the prohibition of APV transformers in case of internal damage, which is disabled by differential or gas protection;
- ✓ automatic switching on of the reserve transformer, intended for automatic switching on of the section switch at emergency shutdown of one of working transformers or at loss of power of one of sections for other reasons;
- ✓ automatic disconnection and inclusion of one of the parallel transformers, designed to reduce the total electricity losses in the transformers;
- ✓ automatic voltage regulation, designed to ensure the required quality of electricity for consumers by changing the conversion factor of step-down transformers of substations supplying the distribution network.

For change under load, transformers are equipped with on-load tap-changer devices (regulator of switching of soldering of transformer winding under load). Automatic change is carried out by a special regulator of the transformation factor (ARKT), which affects the on-load tap-changer.

2 MECHANICAL PART

2.1 General information about relay protection

In power systems, problems and abnormal modes of operation of electrical equipment of power plants and substations, power lines and electrical installations of electricity may occur.

To ensure the normal operation of power systems, it is necessary to quickly identify and separate the fault location from a working network, thus establishing the normal means of their work and stop the destruction at the fault location. In this regard, there is a need for automatic mechanisms. Initially, soft fuses are used in such protections. But as the power and voltage of electrical installations and the complexity of their switching circuits, this method became insufficient, due to which protective devices were created with the help of automatic devices – relays, called relay protection.

Relay protection is the main type of electrical automation, without which the normal and reliable operation of modern power systems is impossible. It carries out continuous monitoring of the condition and mode of operation of all elements of the power system and responds to problems.

When abnormal protection modes appear, it detects them and, depending on the nature of the violation, performs the operations necessary to restore the mode or gives a signal to the staff.

In modern electrical relay protection systems are closely reinforced with electrical automation, designed for rapid automatic establishment of normal mode.

2.2 Design and principle of operation of relays of different types

Electromechanical relays, relays on semiconductor devices (diodes, transistors) are used in relay protection and electrical automation circuits.

But the presence of such shortcomings of electromechanical relays, such as large size, high demand for power from current and voltage transformers, problems in ensuring the reliability of the contacts prompted the search for better principles of relay manufacturing. New principles of relay manufacturing with the help of semiconductor devices allow to improve the parameters and characteristics of relays and to switch completely or partially to contactless protection circuits.

In addition to relays that respond to electrical quantities, relays that respond to non-electrical quantities are used to protect electrical machines and devices, thus characterizing the occurrence of problems or abnormal modes in them. For example, we have a relay that responds to the appearance of gases or an increase in pressure in the casings of oil-filled transformers and reactors. The relay reacts to increase in temperature of transformers in electric cars.

Relays that respond to electrical quantities are divided into 3 groups:

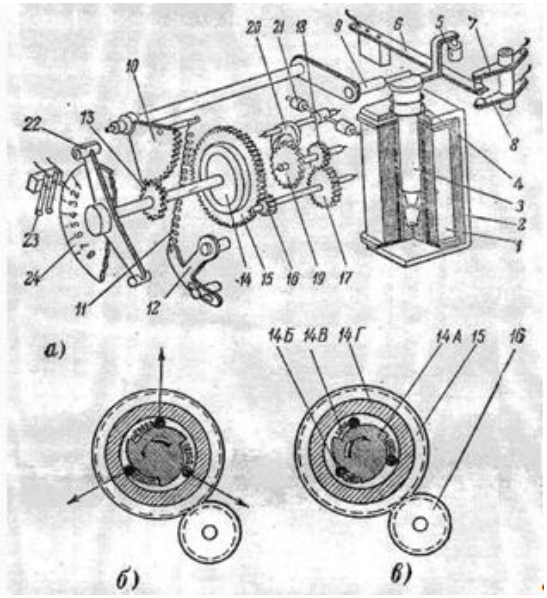
- ✓ relay that responds to one electrical quantity current or voltage;
- ✓ a relay reacting to two electrical quantities current and voltage, or two voltages U1 and U2 which of which is a linear function of current and voltage of the network;
- ✓ a relay that responds to three or more electrical quantities, such as three currents and three voltages or several voltages, a linear function of currents and voltages.

The first group includes relays of current and voltage. The second includes single-phase power and resistance relays. The third includes three-phase power relays, multi-phase resistance relays and other devices.

Time relay

The time relay serves for artificial delay of action of devices of relay protection. When closing the contacts of the current relay plus is fed to the winding of the time relay, which after a while closes the contacts and leads to the disconnection of the switch. The time from the moment the voltage is applied to the time relay winding until its contacts are closed is called the time delay of the relay.

The main requirement for time relays in relay protection circuits is accuracy. The time relay must operate reliably starting from 80% of the rated voltage and its endurance time should not depend on the possible operating voltage.



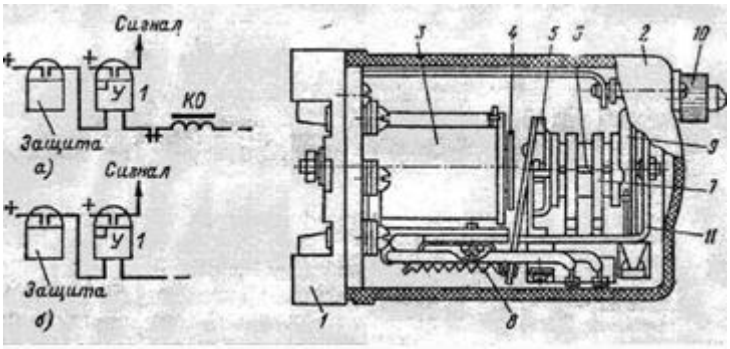
The time relay has many design types, but the principles of their devices are homogeneous and can be considered on the example of design. When current appears in the winding, the armature is immediately retracted, releasing the lever with the toothed segment. Under the action of the guide spring, the lever comes into action, which is not free, as it is released by a special device for holding time. After some time, depending on the speed of the lever, the latter closes the relay contacts.

To reduce the size of the relay, the time relay coil is not designed for long-term current.

Indicating relay

The indicating relay serves for fixing of action of protection as a whole or its elements. When the protection is triggered, a current passes through the relay winding, which drives the relay.

Due to the short-term passage of current in the winding of the indicator relays, they are performed so that the signal box and the relay contacts are closed in the triggered state until they are returned to the place by service personnel. Indicator relays are made for series and parallel connection. Serial relays are more convenient and therefore more widely used.

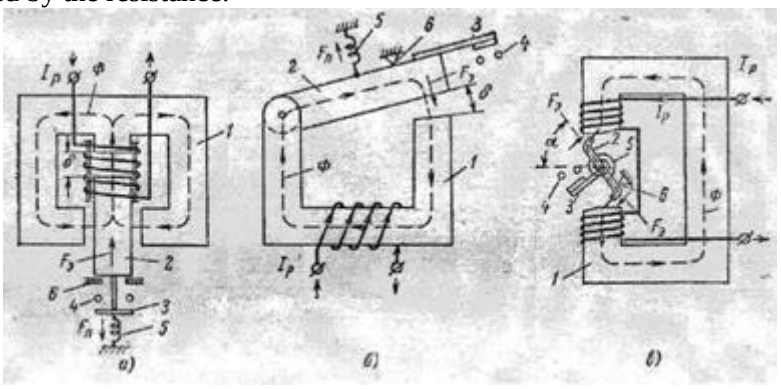


When current appears in the winding, the relay armature is attracted and the check box is released. The latter falls under its own weight, taking a vertical position.

Electromagnetic relay

Each design has an electromagnet which has a steel core and windings, a steel movable armature, a bearing mover contact, fixed contacts and a counter spring.

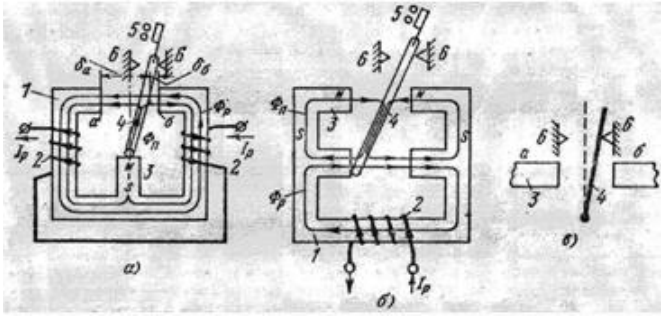
The current passing through the winding of the electromagnet creates a magnetizing force, under the action of which there is a magnetic flux, closing through the core of the electromagnet air gap and anchor. The anchor is magnetized and as a result is attracted to the pole of the electromagnet. The anchor, which has moved to the end position with its movable contact, closes the fixed contacts of the relay. The initial position of the anchor is limited by the resistance.



Electromagnetic force, attracting a steel armature to the electromagnet, is proportional to the square of the magnetic flux in the air resistance.

Polarized relay

Polarized relays are a variety of electromagnetic structures. In these relays, the armature is under the action of two magnetic fluxes, one of which is created by the current that supplies the relay winding, the other – a permanent magnet. The magnetic flux of the winding is called the working, and the permanent magnet – polarizing. The polarized relay is made in two versions: with differential and bridge systems. Both designs consist of a core, a winding, a permanent magnet, an armature and a contact system.



Polarized relays have the following advantages:

- ✓ high sensitivity and low need, reaching at the minimum current of operation;
- ✓ high multiplicity of thermal stability current.

The disadvantages of polarized relays are low power contacts, small gap between them and relatively low return coefficient.

Polarized relays are used in relay protection circuits as auxiliary DC relays, if necessary high-speed and highly sensitive, as well as responsive organs in relay circuits.

Electromechanical relay

Electromechanical relays are made on electromagnetic, induction, electrodynamic, induction-dynamic and magnetoelectric principles. Our industry manufactures electromechanical relays in general on the basis of electromagnetic and induction principles, which allow developing types of relays. Relay contacts are a very appropriate element in protection circuits. They must ensure the reliability of closing and unlocking the current in the control circuits and be designed for multiple.

Switching capacity of contacts characterized by the power at which it provides closing and opening of circuits. The relay winding must have thermal stability, which is characterized depending on the type of relay, the value of current or voltage allowed for long and short time.

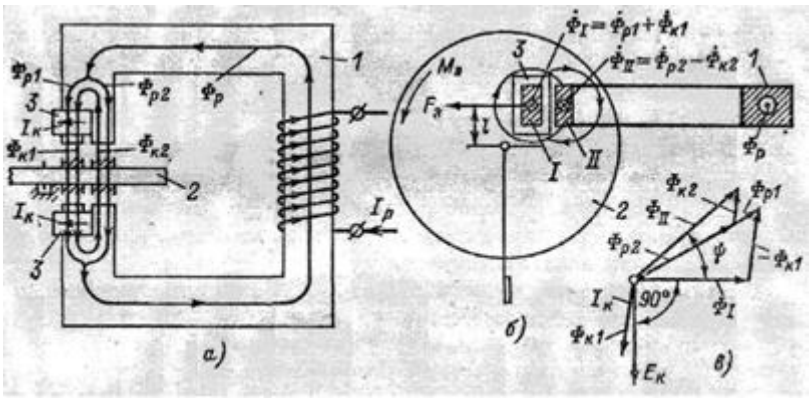
Power consumption depends on the effort that must be created by the magnetizing forces of the windings to actuate the mobile relay system and reliably close the relay contacts.

Indicating relay

The indicating relay serves for fixing of action of protection as a whole or its elements. When the protection is triggered, a current passes through the relay winding, which drives the relay. Due to the short-term passage of current in the winding of the indicator relays, they are performed so that the signal box and the relay contacts are closed in the triggered state until they are returned to the place by service personnel. Indicator relays are made for series and parallel connection. Serial relays are more convenient and therefore more widely used.

When current appears in the winding, the relay armature is attracted and the check box is released. The latter falls under its own weight, taking a vertical position.

Inductive relay



The relay consists of a moving system located in a field of two magnetic fluxes. Magnetic fluxes are created by current passing through the winding of fixed electromagnets. The movable system is made of a copper or aluminum disk or cylinder mounted on an axis that can rotate. When rotating counterclockwise, the moving system passes the spring moment and closes the contacts.

The relay windings are powered by alternating current, which creates alternating magnetic fluxes. Penetrating the moving system, the magnetic flux creates EMF in it. Under the action of EMF, eddy currents appear in the moving system.

3 RELAY MAINTENANCE AND REPAIR

3.1 Relay repair

During operation, relay protection equipment wears out and obsolete, that is, does not meet modern requirements. Various damages due to abnormal conditions in short-circuit electrical networks, overloads, previously undetected factory defects and installation defects and damage due to incorrect actions of service personnel.

In this regard, there is a need to perform repair work and the organization of responsible services for the repair of relay protection equipment. The nature of repair work is diverse. These include: repair of relays associated with the manufacture and replacement of individual parts and components, inspection of relay equipment, repair of panels, which make new holes and earn old ones, as well as restore paintwork, connecting cable cores, soldering contact connections.

Specially equipped rooms are allocated for relay repair, which must be dry, bright, clean and heated. The production facilities include rooms for testing and adjusting relays. Auxiliary rooms are used for storage of equipment, appliances and materials. The room for inspection, adjustment and repair of relays must be equipped with stationary stands equipped with devices for smooth regulation of voltage, current and phase shift of alternating current.

At repair of relay protection use various constructional, electroinsulating, conductive and magnetic materials and also varnishes, solders with fluxes and glue. Winding wires are used for relay windings and are available with enamel and fiber insulation.

Winding wires with enamel and fibrous insulation are used for the coils of relay protection devices. Mounting wires are used for mounting electrical appliances and devices. Conductive cores are made of soft copper wire.

3.2 Relay testing and examinations

Before the exam it is necessary: to install inside the relays and kits previously removed polarized and magnetoelectric relays, semiconductor devices. Carefully inspect the objects to which the high voltage will be applied. Disconnect ground circuits from devices and apparatus with a test voltage below 1000V, shunt capacitors and coils with high inductance, short circuit semiconductor devices, relay voltage windings, electrical meters, high-impedance resistors in the circuit. Then close the relays and devices with covers and covers. In order to reduce the exams, it is recommended to connect the tested chains in one group with jumpers on the rows of clamps. Before the exam, the insulation resistance of the circuits is measured with a megohmmeter, after the exam, the measurement of the insulation resistance is repeated, but without removing the polarized relays from the circuit. To check the interaction of relays and switching equipment supply program, which indicates the sequence and method of individual testing operations on the scheme, define the order of their execution.

The test is carried out in the following order: the operating current is fed into the circuit; the polarity of the applied voltage is checked. Then check the interaction of the relay and the equipment for switching on the circuits with the help of control devices or closing and opening by hand the contacts of the relay of a sequence in accordance with the test program.

It is necessary to check:

- ✓ the correct sequence of operation of the circuit elements from the starting to the output shutdown of the relay;
- ✓ in circuits that have a separation of circuits by phases, the correct sequence of operation of the relay in phases, in addition, the lack of connection between the phases or the scheme of interconnection;
- ✓ in the presence of the relay of the direction of power of work of schemes and endurance of time depending on behaviour of the voltage relay;
- ✓ in defences that have several degrees of time, the fidelity of the interaction of elements of protection at each degree;
- ✓ in protection circuits, the operation of which depends on the type of short circuit, the fidelity of the relay interaction in the circuits;
- ✓ fidelity of locks;
- ✓ in circuits that have switching current and voltage circuits, switching accuracy;
- ✓ fidelity of operation of the scheme at possible positions of switches, overlays, blocks, keys of switches, endurance of time;
- ✓ the absence of bypass circuits in the circuits, in the absence and presence of power supply of the operating current of the devices interacting with the tested device;
- ✓ fidelity of action of the alarm schemes and the specified relays.

In the final stage make checks of protection and the full scheme at supply of voltage of an emergency mode from a by-source at the assembled circuits, at the closed relays and devices, overlays of switches, the blocks established in working position.

A complete check of the current circuits is performed by the primary current from the side source. The devices are checked by operating voltage and load current and then the direction of protection is checked.

4 SAFETY PRECAUTIONS WHEN REPAIRING AND OPERATING RELAYS

All relay protection devices must comply with the PUE. Relay protection devices are operated by relay protection services.

In cases where the operation of high-frequency equipment and communication channels we distinguish responsibilities under local regulations.

Relay protection settings at consumer substations, consuming from the power system. When choosing the relay installations of the consumer's protective electrical equipment must ensure the selectivity of action from the devices AVR and WUA.

All relay protection settings are checked for sensitivity in the conditions of the minimum loading of the enterprise and power system at the power supply scheme. The operation creates conditions for the normal operation of relay protection equipment provided by DUST and TU. Relay protection devices that are in operation must always be ready for operation, are taken out of operation when the equipment is turned off.

In case of danger of incorrect operation of relay protection devices, work must be carried out without the permission of superiors, but with a subsequent report to him. The alarm must always be ready for operation. Particular attention is paid to monitoring the availability of operating current, the safety of fuses.

Relays and relay protection devices must be sealed, except for those whose parameters are changed by operating personnel depending on the mode of operation and the scheme of primary connections or which do not have special means to change their settings.

Relays, auxiliary devices of relay protection can be opened only by service personnel or operational personnel according to his instructions with an entry in the operational log.

In the presence of high-speed relay protection and redundancy devices in case of failure of switches, all operations on switching on the line, tires and electrical equipment after repair or downtime, as well as switching disconnectors and air switches are performed with these protections.

Work in relay protection devices is performed in compliance with the rules of safety of personnel who have undergone special training and allowed to self-test devices. When working on the panels and in the control relay protection networks, safety measures are taken against erroneous shutdown of the equipment, the work is performed only with an insulated tool.

Execution of these works without execution of schemes is forbidden. At the end of the work is checked the serviceability and accuracy of the connection of current, voltage and operational circuits.

Relay protection control panels and panels alternately clean dust from specially trained personnel. The panels of the relay protection equipment, on which the operating personnel perform switching with the help of keys, pads and other devices, must have tables of positions of the specified switching devices for all used modes. Operations on these switches must be recorded in the operational log.

The maximum allowable loads of the network batteries according to the conditions of setting the relay protection and taking into account the possible operating modes are agreed by the company with the dispatch service of the power system and periodically reviewed.

СПИСОК ВИКОРИСТАНОЇ ЛІТЕРАТУРИ

1. Атабеков В.Б. Монтаж електричних мереж і силового електроустаткування: Підруч. / Пер. з рос. Т.А. Сиротинко. – Вища шк.; 1995.

2. Вернер В.В. Электромонтер-ремонтник: Учеб. для профессион. обучения рабочих на производстве. – 7-е изд., перераб. и доп. – М.: Высш. шк., 1987.

3. Корнилов Ю.В., Бредихин А.Н. Слесарь-электромонтажник: Учеб. пособ. для СПТУ. 2-е изд., перераб. и доп. – М.: Высш. шк., 1988. – 256 с.: ил.

4. Принц М.В., Цимбалістий В.М. Освітлювальне і силове електроустаткування. Монтаж і обслуговування. — Львів: Оріяна-Нова, 2005.
5. Электротехнический справочник. Т. I, "Энергия", 1971.

Вершило Ярослав Сергійович — студент групи 1ЕС-21м, факультет електроенергетики, електротехніки та електромеханіки, Вінницький національний технічний університет, Вінниця, e-mail: vershilo998@gmail.com

Науковий керівник: **Никипорець Світлана Степанівна** — викладач англійської мови, кафедра іноземних мов, Вінницький національний технічний університет, м. Вінниця, e-mail: fotinia606@gmail.com

Vershylo Yaroslav Serhiyovych — 1EC-21m, Department of Electricity and Electromechanics, Vinnytsia National Technical University, Vinnytsia, email: vershilo998@gmail.com

Scientific supervisor: **Svitlana S. Nykyporets** – Teacher of English, a department of foreign languages, Vinnytsia National Technical University, Vinnytsia, e-mail: fotinia606@gmail.com