**ANNOTATION**

**of the dissertation of Mashrapova Rizagul Megdaniyatovna "Development of the methods to protect parallel lines and their implementation on reed switches", presented for the degree of Doctor of Philosophy (PhD) in the specialty 6D071800 - "Electricity**

**Relevance**

In recent decades, much more attention has been paid to resource conservation than before, especially in Kazakhstan and Russia. In relay protection, in terms of resource saving, there are great opportunities if you replace the current transformers, from which they receive information about the current, with some miniature (in comparison with current transformers) sensors. The largest number of works in this direction is devoted to the creation of protection on reed switches, which are fixed at a safe distance from the current-carrying buses of the electrical installation. This direction is developing due to the fact that reed switches have a number of known advantages over other magnetically sensitive elements. The overwhelming majority of developments were made at Toraigyrov University under the leadership and with the direct participation of Doctor of Technical Sciences Kletzel M.Ya. A number of protections have already been developed, and they basically meet the requirements. As for the protection of parallel lines, then, as shown by a thorough patent study and analysis of publications in well-known journals, for the receiving side of the lines connected to the bus bars through separate switches, no protection without transformers has been developed, and for the supply side there is only one proposal. However, this protection is difficult to implement, can be falsely triggered by short-term interference, and has some other disadvantages. Based on the foregoing, it follows that the development of protection for parallel lines on reed switches is relevant.

**The object of the research** is the relay protection of power lines**.**

**The subject of research** is relay protection of parallel power transmission lines with a voltage of 6-35 kV.

**Connection of the topic of the dissertation with general scientific (state) programs.** The work was carried out in accordance with the scientific directions of the subcommittee B5 "Relay protection and automation" of the international organization CIGRE.

**The aim of the work** is to create protection on reed switches without current transformers for the supply and receiving sides of parallel lines with a voltage of 6-35 kV with one-way power supply.

**To achieve the goal, the following tasks were set and solved:**

* protection analysis of parallel lines;
* development of ways to protect parallel lines from supply and receiving sides;
* development of protection devices on reed switches that implement these methods.

**The validity and reliability of scientific statements, conclusions and recommendations are confirmed by:** the validity of the initial assumptions arising from the foundations of the used theories and laws; competently performed research; experimental verification of the developed operating principle; obtaining two patents in the Republic of Kazakhstan and three in the Russian Federation.

**Scientific novelty of the work:**

1. A method and device for protection of parallel lines from short circuits from the supply side have been developed, based on the control of the sequence of reaching the set value by instantaneous currents in the eponymous phases.

2. A method and device for protecting parallel lines from short circuits from the receiving side have been created, based on monitoring the presence of an instantaneous current value in the line greater than or equal to a given value after a certain time after it reached this value in the previous positive (negative) half-wave of the alternating current industrial frequency.

3. A method for protecting parallel lines from the receiving side Has been created, in which adjacent positive (negative) half-waves of AC power frequency are considered and being controlled the time between the moments when the instantaneous value of the current in the phase of the line reaches a given value during its rise.

4. Methods have been developed for calculating the response parameters of protection of parallel lines against short circuits on reed switches and assessing their sensitivity, which differ from the known ones taking into account the influence of reed switches with control windings installed side by side on each other.

5. A method has been developed to ensure the actuation of a reed switch in one of the alternating current half-waves, in which an additional magnetic flux is created in the other, acting on the second reed switch, opening the contacts and blocking the output signal of the first reed switch.

**New scientific results of work:**

1. Two methods of constructing protections for the receiving side and one for the supply side (two parallel lines with one-way power supply) have been developed. For the supply side, it is proposed to control the sequence of reaching the instantaneous values of currents in the phases of the same name of the given value in both half-waves of the alternating current. For the receiving side: in the first method - to control the presence of a current greater than or equal to a given value after a certain time after it has reached this value in the previous positive (negative) half-wave of the alternating current when it rises; in the second - to control the time between the moments of reaching the instantaneous value of the alternating current in the phase of the line of a given value when it rises into adjacent positive (negative) half-waves. Methods are patented.

2. Protection devices on reed switches on the supply and receive sides of parallel lines with one-way supply have been developed. Circuits on semiconductor elements and functioning algorithms are proposed.

3. New formulas for determining the size of the cascade zone action and the scope of protection on reed switches have been obtained, respectively, from the receiving and supply sides.

4. Improved the way to ensure the polarity of the reed switch actuation - by blocking the output signal of the reed switch in one of the alternating current half-waves.

5. New protection schemes for three and four parallel lines have been developed, differing in that the timing of response of each two reed switches installed near the lines of the same name is controlled.

**Practical significance of scientific results:**

1. The proposed methods will make it possible to build resource-saving protection on reed switches for the receiving side of parallel lines that do not detune away from the currents in the intact phases and the maximum load current, and for the supply side - ensuring the correct behavior of the protection in all operating modes of the lines. The created algorithms allow performing protection on electromechanical, semiconductor and microprocessor element bases.

2 The developed formulas allow: to calculate the cascade zone action of protection from the receiving side; to determine the possibility of using protection from the supply side on certain lines, without calculating the setting of its operation.

3. The method of ensuring the polarity of the reed switches actuation allows to increase the sensitivity of the protection functioning from the receiving side.

**The practical value of the work:**

1. The developed protection devices for parallel lines will save high-quality copper, steel and insulating materials and reduce dimensions by obtaining information about the current from reed switches without using current transformers.

2. The developed methods for calculating the protection response parameters of parallel lines on reed switches make it possible to calculate the currents in the bus bars at which they are triggered and to take into account the influence on each other of reed switches with control windings located near one phase, which ensures the selectivity of protection.

3. The proposed protection from the receiving side will allow to expand the area of application of transverse protection of parallel lines due to the fact that they have a higher sensitivity than the traditional.

**To the defense are presented:**

– method and devices for protecting two, three and four parallel lines on reed switches from the supply side;

– methods and device for protection of two, three and four parallel lines on reed switches from the receiving side;

– method of ensuring the polarity of the reed switch.

**Approbation of work.** The main provisions of the dissertation were reported at the International Scientific and Practical Conference "XI Toraigyrov Readings" (Republic of Kazakhstan, Pavlodar, 2019), the 60th International Scientific and Practical Conference "Topical Issues of Science" (Russian Federation, Moscow, 2020) and at a meeting of the Toraigyrov University Department of Power Engineering.

**Publications.** The research results were published in 8 scientific works, including: 5 publications in editions recommended by CCSES, including 2 patents of the Republic of Kazakhstan, 3 patents of the Russian Federation; one publication in an international scientific journal included in the Scopus database, with percentile 38; two publications in the proceedings of international conferences. In publications in co-authorship, the personal contribution of the applicant is: in an article in the Scopus database - not less than 25%; in publications at conferences and in patents - not less than 65%.

**The structure and scope of the dissertation.** The dissertation consists of an introduction, three chapters, a conclusion, and four appendixes. The work is presented on 95 pages of computer text, includes 44 figures and two tables. The list of sources used includes 75 items.

**In the first chapter** «Analysis of parallel line short-circuit protection with and without current and voltage transformers» the well-known transverse protection of parallel lines and their disadvantages are considered. It is noted that:

1. Traditional transverse differential current directional protection of parallel lines is easy to implement, does not react to oscillations, but has a number of disadvantages, including obtaining information from current and voltage transformers. There are a number of protections to eliminate all its disadvantages, except for current transformers.

2. Reed switches can be used as current sensors for building protection, since they have some important advantages for relay protection.

3. The known transverse differential protection based on them can be used only on the supply side, triggers falsely in case of short-term disturbances, and, depending on the embodiment, can give a signal to disconnect an undamaged line in case of double earth faults or not operate in a cascade disconnection of a damaged line, and the principle of operation does not allow to eliminate most of these disadvantages.

4. Protections of parallel lines, which do not require current and voltage transformers, were not developed for the receiving side.

**In the second chapter** «Development of a method for protecting parallel lines from short circuits (from the supply side) and its implementation on reed switches» a protection method based on the control of the sequence of reaching the specified value by the current in the lines of the same name is proposed. In accordance with the method, a verbal description of the protection operation condition is also formulated in the symbols of logic algebra. Its implementation on reed switches is considered in detail. In this case, the sequence of actuation of the reed switches and the time between their actuation are monitored. The results of experiments proving the efficiency of the proposed principle of operation are presented. The schemes of protection for two, three and four parallel lines are given when they are executed on semiconductor and electromechanical element bases and block diagrams of algorithms for their operation for implementation using a microprocessor. The behavior of protections in various modes is considered in detail.

A method is presented for calculating the response parameters of the protection and assessing its sensitivity, taking into account: the configuration of the arrangement of the wires of the lines on the support (when determining the induction of magnetic fields acting on the reed switch); calculation errors when using the Biot-Savart-Laplace law; influence on the reed switch of magnetic fields created by currents in the phases of both lines. Presented formulas with which you can determine the possibility of using protection.

The conclusions indicate that: a) the developed method of protecting parallel lines from the supply side, in contrast to the known ones, allows them to be built without using CTs and voltage circuits on various magnetosensitive elements for 6-35 kV lines; б) the protections developed on the basis of reed switches do not work in case of short-term interference and behave correctly in various operating modes of the lines, and for their construction, the reed switches must have a response time and a difference in response induction of no more than 2 ms and 6%, respectively.

**In the third chapter** «Development of methods for protecting parallel lines from short circuits (from the receiving side) and their implementation on reed switches» considered two ways of protection. The first is to control the presence of a current greater than or equal to a given value after a certain time after it has reached this value in the previous positive (negative) half-wave of the alternating current when it rises. The second is in controlling the time between the moments when the instantaneous value of the alternating current in the phase of the line reaches a given value when it rises into adjacent positive (negative) half-waves. For the first method, the protection actuation condition is formulated in the form of a verbal description and in the symbols of logic algebra. The schemes of protection on reed switches and algorithms of their functioning for two and three parallel lines, which implement this method, are presented. In this case, the presence of a signal from a reed switch is monitored after a certain time after its previous operation in a positive (negative) half-wave of an alternating current. The behavior of the protections in various modes of operation of the lines is considered in detail and shown.

A method of ensuring the polarity of the reed switch operation is presented, which, unlike the known one, consists not only in compensating one of the half-waves of the magnetic field induction acting on the reed switch, but also in blocking its output signal in the same half-wave.

A method for determining the response parameters of the protection from the receiving side is considered, taking into account the influence of reed switches with control windings located near the same phase on each other. The formula for determining the size of the cascade zone action of protection is presented.

The conclusions note that the proposed protection devices on reed switches for the receiving side of two and three parallel lines have a higher sensitivity than those produced by the industry, since they do not detune away from the maximum load current and do not use voltage circuits.

**The results of the work are as follows:**

1. Two protection methods have been developed for the receiving side of parallel lines with one-way supply, and one for the supply. The first is to control the presence of a current in the line greater than or equal to a given value after a certain time after it has reached the specified value in the previous positive (negative) half-wave, the second is to control the time between the moments when the current in the line phase reaches a given value when it rises in neighboring positive (negative) half-waves, and the third - in the control of the sequence of reaching the set value by currents in their phases of the same name. They will make it possible to build protections without CTs, and for the receiving side for the first time in the world.

2. Protection devices for two, three and four parallel lines are proposed, which implement the first and third methods on reed switches without CTs. All of them, unlike traditional ones, behave correctly in all modes of operation of the lines and do not use voltage circuits, and the protection from the receiving side also has a higher sensitivity. Unlike the analogue on reed switches, the protection from the supply side does not work in case of short-term interference and are easy to implement.

3. When constructing protections from the supply side, the reed switches should have a response time of 0.3-2 ms and a difference in response induction of no more than 6%. These protections can be used if the multiplicity of the minimum short-circuit current on the bus bars of the receiving substation to the rated load current is greater than or equal to 5.2, and the multiplicity of the total maximum short-circuit current at the border of the cascade zone action satisfies the inequality we obtained. Protections from the receiving side can be applied on 35 kV lines if the minimum load current amplitude exceeds 60 A, and on 10 kV lines if it exceeds 30 A. The value of their cascade zones is determined by the developed formula.

4. The developed methods for calculating the response parameters of the proposed protection devices make it possible to determine the currents in the EI buses, at which the reed switches are triggered, and take into account: the mutual influence of reed switches with control windings installed near one phase on each other; configuration of the arrangement of the wires of the lines on the support; calculation errors when using the Biot-Savart-Laplace law; influence on the reed switch of magnetic fields created by currents in the phases of both lines.

5. The developed method of ensuring the operation of the reed switch in one of the alternating current half-waves makes it possible to increase the sensitivity of the protection from the receiving side by creating an additional magnetic flux in the other half-wave.