ANNOTATION

on thesis of Issabekov Dauren Dzhambulovich«Development of reed switch resource-saving current protection with fault diagnosis» submitted for the degree of Doctor of Philosophy (PhD) in specialty 6D071800 - "Electrical Power Engineering"

Relevance

One of the fundamentally unresolved problems of the electric power industry is considered to be the construction of relay protection for high-voltage installations without the use of traditional current transformers (CTs), which was repeatedly mentioned at international conferences on large energy systems (CIGRE). The fact is that current transformers are very metal consuming and bulky, have expensive insulation and other disadvantages. In PSU them. S. Toraigyrova Professor Kletsel M.Ya. and his many students, as well as Russians Goryunov V.N., Gurevich V.I. and Shoffoy V.N. For several decades, protections without the use of CTs on magnetically controlled reed contacts were developed. Reed switches were selected due to the fact that they have a number of advantages important for relay protection compared to other magnetically sensitive elements. The principles of constructing current, differential, differential-phase and distance protection have already been developed (more than 100 patents and 30 publications in Moscow magazines and in Scopus databases have been received). However, for a number of electrical installations, questions regarding the very possibility of using reed switches to build protections, installing them near current-carrying buses at a safe distance, calculating relay parameters and protection settings, assessing their sensitivity, performance and reliability were not considered. And the developed devices on the reed switches are overwhelmingly not equipped with either test diagnostics of malfunctions or functional, although at present this method of increasing reliability in relay protection technology is considered almost mandatory.

In the present work, an attempt is made to solve the issues raised during the development of reed current protection of electrical installations powered by 6-10 kV switchgear. These installations are selected due to the fact that they are very widespread in the electric power industry.

The **object of study** is the relay protection of electrical installations.

Subject of study - are reed switch resource-saving current protections with fault diagnosis for electrical installations powered by switchgear 6-10 kV.

The 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 international (European) Research Committee B5 "Relay protection and automation" of the international organization CIGRE, as well as within the framework of the budget program "Development of Science", under the subprogramme "Grant funding for research" of the project "Creating a globally competitive resource-saving relay protection of power supply systems ”, funded by JSC “Science Fund”of the Ministry of Education and Science of the Republic of Kazakhstan.

The purpose of the work is the development of reed switch resource-saving current protection with fault diagnosis for electrical installations with switchgear 6-10 kV.

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

1 Construction of a noise-resistant overcurrent relay on reed switches with test diagnostics of faults, a relay and a reverse sequence current filter with functional fault diagnostics.

2 Determination of the magnitude of the magnetic field induction inside the switchgear cell with a voltage of 6-10 kV, the coefficient necessary for introducing into the Bio-Savard-Laplace formula in order to use it in the calculations.

3 Development of methods for selecting the response current of the reed contact overcurrent protection installed in the switchgear and the parameters of the reverse sequence current filter.

4 Development of structures for fastening close to current-carrying busbars of switchgear 6-10 kV, providing remote control of overcurrent protection settings.

5 Evaluation of the sensitivity, performance and efficiency, the proposed overcurrent protection on the reed switches.

The validity and reliability of scientific provisions, conclusions and recommendations is confirmed: by the competent use of the fundamental provisions of relay protection, the theoretical foundations of electrical engineering and the foundations of the design of mechanisms and machines, as well as field experiments in switchgear 6-10 kV. with developed overcurrent relays on reed switches and testing in the form of publications in a journal with impact factor 4 based on Scopus, 3 patents of the Republic of Kazakhstan, 3 patents of the Russian Federation and reports at 3 conferences, one of which is foreign.

Scientific novelty of the work:

1. The theory of the construction of shields on reed switches is developed: a) based on measuring the induction of magnetic fields in different modes and points inside the switchgear of 6-10 kV. it is proved that their values are sufficient to detect interphase short circuits in electrical installations powered by these switchgears and the dependences of these inductions on the position of the reed switch inside the switchgear under consideration are found; b) it is shown that for their calculation it is possible to use the simplest formula of the Bio-Savard-Laplace law if we add to it the coefficient obtained as a result of experiments in this switchgear; c) a procedure has been created for calculating the overcurrent protection parameters on reed switches for 6-10 kV switchgear, which differs from the known ones by using this formula and taking into account the influence of interference from currents in the metal parts of the switchgear; d) a method for calculating the parameters for the proposed reverse current filter on the reed switches; e) a method for test and functional diagnosis of current protection on reed switches is proposed, which consists in supplying current to the reed switch control winding while blocking the output circuit.

2. One maximum relay with test diagnostics, and the other with functional diagnostics, as well as two devices that allow mounting the reed switch near the

switchgear busbars with the possibility of remote control of the settings of the operation of current protection are created and patented. The first differs from the known ones by the presence of a control winding and a start button, and the second also by capacitors and intermediate relays. The third is the presence of a stepping electric motor with a belt drive, the fourth is boxes with reed switches and plates moving in two directions.

New scientific results:

1. It is proved that the magnitude of the magnetic field induction inside the switchgear is 6-10 kV. sufficient to detect interphase short circuits with the help of reed switches in electrical installations powered by it.

2. To calculate the magnetic field inductions inside the switchgear under consideration, one can use the formula for writing the Bio-Savard-Laplace law in the simplest form, if one introduces into it a correction coefficient obtained as a result of experiments conducted in it.

3. Methods for selecting overcurrent protection settings on reed switches for electrical installations with switchgear and calculating the parameters of the mentioned filter have been developed.

4. The two above-mentioned overcurrent relays with test and functional diagnostics of faults and two designs for their fastening were created.

The practical significance of scientific results:

1. A resource-saving current relay on reed switches without the use of current transformers with test and relays with functional diagnostics of faults has been developed, which will increase the reliability of current protections performed with their help.

2. The proposed relay with test diagnostics is capable of failing during short-term interference and sticking of contacts, and a reverse sequence current filter with functional fault diagnostics, which can be used to build particularly sensitive and reliable current protections.

3. A procedure has been developed for calculating the overcurrent protection parameters on reed switches in a switchgear with a voltage of 6-10 kV, taking into account the influence of interference from currents in metal parts in its own and neighboring switchgears, and a calculation method for the mentioned filter.

4. For the switchgear, anovercurrent protection device on the reed switches with remote control of the settings was created, which allows the tuning of the operation settings without disabling the electrical installation.

The practical value of the work.

1. It is proved that the induction of magnetic fields inside the switchgear is 6-10 kV. sufficient for the operation of the reed switches in the current protection, and to calculate these inductions, you can use the formula of the Bio-Savard-Laplace law, with the introduction of the obtained coefficient into it.

2. The developed overcurrent relays on the reed switches are more advanced in comparison with the known ones, since they have advantages, one due to the availability of simple test diagnostics for faults, the second also not to work for short-term faults, and the third due to the presence of functional diagnostics.

3. The created design for mounting the reed switches allows you to remotely and without disconnecting the electrical installation to adjust the response setting.

4. The proposed method for calculating the overcurrent protection parameters on the developed relays makes it possible to take into account the errors in the installation of reed switches inside the switchgear and the influence of currents in the phases of the protected and adjacent connections, and, very importantly, the effect of induced currents in their metal parts.

5. The developed methodology for calculating the negative sequence current filter with fault diagnosis makes it easy to implement them.

The following are submitted to the defense:

1. Two overcurrent relays with test and functional fault diagnosis.

2. The formula for calculating the magnetic field inductions with the dependences of these inductions on the position of the reed switch inside the switchgear cell.

3. Methods of calculating the parameters: a) maximum current protection of switchgear 6-10 kV. using the formula for calculating induction and taking into account the influence of interference from neighboring cells; b) reverse sequence current filter with fault diagnosis.

4. A method for test and functional diagnosis of current protection on reed switches, as well as two devices for mounting a reed switch near the busbars of a switchgear cell.

Implementation of the results of the work. Consent was obtained for the implementation of a current protection device in a switchgear unit at JSC PREC (Pavlodar).

Approbation of work. The main provisions of the dissertation were reported at the International Scientific Conference “XVII Satpayev Readings” (Pavlodar, 2017), “X Toraigyrov Readings” (Pavlodar, 2018), 47th International Scientific and Practical Conference “Actual Issues of Science” (Moscow, 2019).

Publications. The research results were published in 11 scientific works: one article in the journal included in the Scopus database: 7 publications in publications recommended by ESMC, among which 3 patents for the invention of the Republic of Kazakhstan, 3 patents for the invention of the Russian Federation, 2 of which are included in the Web of Science "; 3 publications in materials of international conferences, including 1 in materials of a foreign conference. In publications co-authored, the personal contribution of the applicant is 80%, and in article [55] - 30%.

The structure and scope of the dissertation. Conclusion and three applications. The work is presented on 95 pages of computer text, includes 45 figures. The list of sources used consists of 73 items.

The first chapter, “Analysis of existing current protections,” discusses traditional protections that receive information from current transformers with ferromagnetic cores, current protections on various converters without current transformers: on magnetic current transformers, Rogowski sensors, magnetoresistors, magnetodiodes and magnetotransistors, Hall sensors and on inductors. The current protection of the elements of electrical systems on the reed switches is described in

detail. The most important advantages of the reed switch for relay protection are indicated. Their advantages are given in comparison with other magnetically sensitive elements. It is shown that they have sufficient sensitivity for use in the relay protection of electrical installations 6-110 kV. The implementation of the maximum current protection on the reed switches with the choice of settings is presented, attention is paid to the detuning from self-starting and various interference. Methods of protection on the reed switches are indicated, including relay circuits and structures for their fastening. The importance of test and functional fault diagnosis for relay protection is emphasized. Some circuits with fault diagnostics are analyzed. The conclusions of the chapter indicate that special attention during research should be given to the development of simple current protection devices on reed switches with test and functional diagnostics of malfunctions and determination of the distribution of magnetic fields inside the switchgear cell.

The second chapter, "Development of current protection circuits on reed switches with diagnosis of faults and structures for mounting them in 6-10 kV switchgear", describes resource-saving current relays on reed switches with test diagnostics: a relay circuit with a pulse counter and test diagnostics, a relay circuit with test diagnostics not working unnecessarily with short-term interference and sticking of contacts. Test diagnostics is carried out by pressing a button and applying alternating current to the reed switch winding (installed under the electrical installation bus).

The results of an experimental check on the developed laboratory installation of the proposed noise-resistant relay with voltage waveforms when the reed switch and other relays are triggered are presented. The circuits of current protection devices on reed switches with functional diagnostics are analyzed. A feature of the circuit is that it gives a test signal every 2 minutes. A circuit with functional diagnostics of the filter of currents of the reverse sequence on the reed switches and inductors is proposed. The circuit of the known filter is duplicated and, using one reed switch with two windings, controls the voltage on the control windings of two filter reed switches installed under the busbars of the electrical installation.

The proposed designs for mounting reed switches in 6-10 kV switchgear are described. A feature of one of the designs is that it can be used to automatically adjust the protection settings, and the second to move the reed switches relative to the busbars in two directions. A photograph of the location of the prototype of the reverse sequence current filter in the vicinity of the switchgear buses is presented. The conclusions indicate that the developed relays on the reed switches with fault diagnosis are simple, efficient and have sufficient speed.

The third chapter, "Protection parameters with a developed relay and reverse sequence current filter", presents the features of calculating magnetic fields in switchgear 6-10 kV. It is shown that it is preferable for these purposes to use the Bio-Savard-Laplace law in the simplest form with the introduction of experimentally obtained coefficients. The results of experiments on the use of the Bio-Savard-Laplace law for calculating magnetic fields in the switchgear carried out at the Samara State Technical University are analyzed. Widely used switchgear cells in

Kazakhstan are described, on which experiments were carried out to determine the distribution of the magnetic field induction inside the switchgear.

It is shown that they (induction) are of sufficient size to build relay protection. The experimental setup is considered. The coefficients that evaluate the effect of various interference, including those generated by currents in neighboring switchgear, are determined.

The recommended methodology for conducting full-scale experiments in complete switchgears is presented. A methodology for the selection of overcurrent protection settings with a developed relay on reed switches and an example of selection are given. Particular attention is paid to determining the magnitude of the induction of magnetic fields in studies, with various short circuits in neighboring cells.

The calculation of the filter parameters of the currents of the reverse sequence with the arrangement of the phases of the protected electrical installation at the vertices of the triangle and at a horizontal arrangement is given. In this case, special attention is paid to the choice of coordinates ensuring the absence of zero sequence currents. Experimental studies of the presented filter of currents of the reverse sequence with a horizontal phase arrangement are described, which confirms the waveforms to be operational. It is shown that the introduction of a current protection device with a relay with a pulse counter and automatic adjustment of the settings can bring an economic effect of 902 tons of tenge per year. The conclusions indicate that the correction factors must be determined experimentally for each switchgear, and the developed methodology for determining the distribution of magnetic fields can be recommended for any switchgear.

The results of the work are as follows:

The tasks were solved in the work: development of a current relay with fault diagnostics, new devices and structures of current protection and methods for calculating the filter of currents of reverse sequences on reed switches, as well as an experimental study of the distribution of the magnetic field inside the cell for electrical installations with switchgear 6-10 kV. The results of the work are as follows:

1 The theory of building defenses on reed switches is developed:

a) based on the measurement of the magnetic field induction in different modes and points inside the switchgear 6-10 kV. it is proved that their values are sufficient to detect interphase short circuits in electrical installations powered by these switchgears and the dependences of these inductions on the position of the reed switch inside the switchgear under consideration are found;

b) it is shown that for their calculation it is possible to use the simplest formula of the Bio-Savard-Laplace law if we add to it the coefficient obtained as a result of experiments in this switchgear;

c) a procedure has been created for calculating the overcurrent protection parameters on reed switches for 6-10 kV switchgear, which differs from the known ones by using this formula and taking into account the influence of interference from currents in the metal parts of the switchgear;

d) a method for calculating the parameters for the proposed reverse current filter on the reed switches;

e) a method for test and functional diagnosis of current protection on reed switches is proposed, which consists in supplying current to the reed switch control winding while blocking the output circuit.

2 Created and patented one maximum relay with test diagnostics, and the other with functional, as well as two devices that allow mounting the reed switch near the switchgear with the ability to remotely control the settings of the operation of current protection.