**Annotation**

The dissertation "Development of protection of electrical installations with phase conductors in a common shell" by Musaev Zhasulan Bakytzhanovich, is submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D071800 – "Electric power engineering".

**Relevance**

The problem of constructing relay protection devices that do not need current transformers (CT) has been considered relevant since the 60s of the twentieth century. Currently, the International council for large high-voltage electrical systems CIGRE considers it as one of the unsolved problems in the global energy sector [5]. One of the way to solve it, as it has been shown by the analysis of publications and patent study, is the construction of protections based on inductors. I.M. Sirota, M.Ya. Kletsel, A.N. Novozhilov, V.V. Borodenko and others contributed to the development of this direction. The principles of constructing filters of symmetrical composing currents, differential protection of the generator, current protection of electrical installations of electrolysis and ore-thermal production, protection of three-winding transformers are already have been developed on the basis of inductance coils (IC). At the same time, the issue of building protection on the IC of electrical installations with complete current lines with phases in a common shell has not been considered yet. Therefore, the development of protection of these electrical installations (EI) is relevant.

**The object of the study** is the relay protection of electrical installations that do not need current transformers.

**The subject of the study** is the maximal current protection of electrical installations with complete current lines (CL) with a voltage of 6/10 kV.

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

**The goal** is to create current protections on inductors for electrical installations with phase conductors in a common shell.

**Tasks:**

– to investigate the magnitudes of magnetic field inductions outside the shells of current conductors;

– determine the points on the shell of the current line in which it is preferable to install the IC;

– develop maximum current protection based on them;

– create models of structures for fixing the IC on the shell of the current line.

**The validity and reliability of the results of the conducted research is confirmed by:** competent application of the basics of higher mathematics, qualitatively conducted field experiments and modeling, as well as publications in journals from the list recommended by CQASES.

**Scientific novelty of the work:**

1. MCP has been developed for EI with CL without the use of current transformers based on three IC, which differs from the known ones in that they are located on the shell of the current pipeline near phases A, B, C.

2. An attachment to the specified MCP has been developed, which has increased sensitivity to two phase short circuits by controlling the differences between each two electromotive forces (EMF) induced at the terminals of these three IC.

3. Using the results of experiments and modeling, it is proved that in most cases, when choosing the MCP trigger setpoint, it is possible to ignore interference from currents in the adjacent current line if you set the CI to a point with coordinates calculated according to the above methodology and use a cylindrical screen made of electrical steel with a height h = 5÷25 cm and a wall thickness d =2÷4 mm, covering the CT shell.

**New scientific results of the work:**

1. A formula has been theoretically derived for calculating a coefficient that takes into account the influence of currents in its neighboring phases on the induction acting along the longitudinal axis of the IC installed opposite the phase of the current line of the protected EI.

2. A method for determining the coordinates of the installation of an inductor has been developed and experimentally tested, which differs from the known ones in that the geometric shape of the complete current line, the presence of the shell and the location of the tires inside it are taken into account.

3. Models of structures for mounting inductors on the shell of a complete current line have been created and patented.

4. On the basis of experiments and computer modeling, a method has been developed for selecting the MCP actuation settings on the IC and the prefix to it, which differs from the known ones by taking into account the distortion of the external MF by the shell of the current line of the protected EI.

**Practical significance of scientific results:**

1. Recommendations are given for installing the IC on the shell of the current line in the presence of an adjacent current line and without it.

2. The coefficient that takes into account the influence of currents in neighboring phases of the protected electrical installation (EI) makes it possible to simplify the calculation of the actuation setpoint of the developed MCP on the CI for EI with a single current line.

3. It is proved that the induction magnetic field (MF) acting along the longitudinal axis of the CI, created by currents in the busbars of the protected EI, can be calculated according to the Bio-Savar-Laplace law (the simplest form of recording) by introducing the shielding coefficient of its shell obtained experimentally and with the help of modeling, and the induction from currents in in the adjacent current line – by also introducing a coefficient that takes into account the distortion of the field by the specified shell.

**Practical value of the work:**

1. The developed MCP on IC allows you to build protection of EI with three-phase complete current lines from short circuit, without using CT, with increased sensitivity to two phase short circuit.

2. The created designs make it possible to place the inductors on the surface of the shell of the current line and adjust the protection response parameter.

**The following are presented for protection:**

– maximal current protection on inductors (IC) for electrical installations with complete current lines with phases in a common shell;

– results of research of MF acting on the IC fixed outside the shell of the current line, based on computer modeling and field experiments;

– designs for mounting inductors on the ends of current lines.

**Approbation of the work.** The main provisions of the dissertation were reported at the meeting of the Department of "Electric Power Engineering" of Toraigyrov University.

**Publications.** The research results have been published in 5 scientific papers, including: 5 publications in publications recommended by the Committee, including 1 patent of the Republic of Kazakhstan, 2 patents of the Russian Federation included in the Web of Science database, 2 articles in journals. In publications, the applicant's personal contribution ranges from 45 to 70%.

**The structure and scope of the dissertation.** The dissertation consists of an introduction, three sections, a conclusion and an appendix. The work is presented on 73 pages of computer text, includes 44 drawings. The list of sources used consists of 60 titles.

**In the first chapter,** "Overview of proposals for the creation of relay protections that do not use traditional current transformers", well-known proposals for the construction of resource-saving protections based on magnetosensitive sensors and their disadvantages are considered. It is noted that:

1. The problem of building resource-saving relay protection devices that do not need TT remains unresolved, since currently such devices are not being mass-produced yet.

2. One of the promising magnetosensitive sensors that can be used as a current transformer is an inductor, since it has some significant advantages over other elements.

3. There are a number of proposals for the construction of protections for various electrical installations based on magnetically sensitive elements. However, the protection of electrical installations with complete three-phase current lines in a common shell has not been developed.

**In the second chapter,** "Investigation of magnetic fields outside the shell common to three phases of a closed complete current pipeline", the results of field experiments and computer modeling in the Ansys Maxwell program are presented, as well as the designs of current pipelines and their scope of application are considered. Recommendations are given on the choice of installation points of inductors (CI) on the shell of a single current line. A method is proposed for calculating the coordinates of the fixing points of the CI in the presence of a neighboring current line, which allows to reduce the influence of currents in its shell and tires by 7,2 times on the CI. Experimentally and with the help of modeling, coefficients were determined that allow calculating the inductions of magnetic fields acting on CI, according to the simplest formula of the Bio-Savar-Laplace law. The shape and overall dimensions of the screen are proposed to protect the KI from external magnetic fields.

The conclusions of the chapter indicate that:

1. To calculate the induction of MP from the currents in the busbars of the protected EI, the correction factor kpr= 1,4 and the shielding coefficient of the shell ks = 0,14-0,22 must be introduced into the formula of the Bio-Savar–Laplace law, and the coefficient k1 from the currents in the neighboring EI, which also takes into account the distortion of MF by the presence in it of the shell of the protected EI.

2. On a singly laid current line, it is convenient to place the CI opposite phases A, B, C, and if there is a neighbor, at points with coordinates calculated according to the proposed methodology.

3. It is advisable to use a screen made of electrical steel in the form of a hollow cylinder with a height of 5-25 cm and a wall thickness of 2-4 mm. At the same time, it reduces the induction of the external MF by 1,2-12 times, and the induction of MF from currents in the protected current line by 10-16%.

**In the third chapter,** "Current protections on inductors for electrical installations with complete three-phase current lines in a common shell", the method of selecting actuation parameters and models of maximum current protection (MCP) and its prefixes with increased sensitivity to two-phase short circuits are considered. The latter is provided by controlling the differences in the absolute values of the EMF induced on the CI. A model of autonomous protection is presented, which receives power from additionally installed on the shell of the current line. It is shown in which cases it is possible to choose the MCP trigger setpoint without taking into account interference, tuning it only from the self-start current, as in traditional protection.

The designs for fixing the CI on the shell of the current line are presented. Two of them are for a single current line, and three are for cases when there is a second one nearby. The latter allow you to change the position of the CI in space.

The conclusions of the chapter are as follows: the proposed MCP in most cases has the same sensitivity as the traditional one, but is 6 times lighter; the prefix to it allows you to increase the sensitivity of protection to two-phase short circuits; the developed designs are simple and allow you to fix the CI at any point on the shell of the current line.

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

1. The created experimental setup makes it possible to study the magnetic field outside of complete current lines with phases in a common shell. Studies have shown that this field can be used to build protections without receiving information from current transformers by placing inductors (CI) directly on the shell of the complete current line (CL). At the same time, if there is a neighboring CL, then it is advisable to set the IC at points with coordinates calculated according to the above method, and if there is not one, then at points opposite phases A, B, C.

2. To determine the induction of the MF at the installation point of the IC according to the simplest formula expressing the Bio-Savar-Laplace law, it is necessary to enter into it: a) the correction coefficient kpr = 1,4 and the shielding coefficient of the shell ks = 0,14-0,22 (depends on the diameter of the shell), if the MF is created by currents in the CL buses of the protected electrical installation; b) coefficient k1 (in addition to kpr and ks), which takes into account the distortion of the MF by the CL shell of the protected EI, if the MF is created by currents in the tires of the adjacent current line.

3. The developed maximal current protection (MCP) in most cases has the same sensitivity as the traditional one, but is 3-7,5 times lighter (taking into account the weight of current transformers). The prefix to the MCP allows for higher sensitivity to two-phase short circuits by controlling the differences in absolute EMF values induced at the terminals of the IC.

4. The MCP trigger setpoint can be selected without taking into account interference from the currents in the tires of the neighboring CL with their multiplicity k4≤5÷20 to the rated current of the protected EI, if the CI is installed at the identified points, and at k4≤6÷66, if you also use the screen. Computer modeling has shown that it is advisable to use a screen made of electrical steel in the form of a hollow cylinder with a height of 5-25 cm and a wall thickness of 2-4 mm. When selecting the parameters for the operation of the prefix to the MCP, consideration of interference is mandatory.

5. Designs have been developed and patented for fixing the IC outside the shell of the current line, which allow you to adjust the EMF value at their terminals by changing the position in space.