

ABSTRACT
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The thesis “Development of Constructions for Securing Magnetically Operated Sealed Switches in Complete Electrical Pathways”, presented for the degree of Doctor of Philosophy (PhD) in the specialty 6D071800 - «Electric power engineering»

Topicality

For obtaining information about currents in high-voltage electrical installations current transformers are traditionally used. They are very metal-intensive (12 ÷ 120 kg of steel and copper), distort information in saturated cores and create a high voltage in the secondary circuit in the clamps. Due to these shortcomings in the twentieth century, attempts were made to build relay protection (RP) at the magneto-sensitive elements including at magnetically operated sealed switches, which are turned, in the construction of RP and have some advantages over other elements. In 2006, at the International Conference on Large Electric Systems (CIGRE), the problem of constructing devices of RP without TT was named one of the primary urgent tasks of the world power industry. By that time the principles of the current, differential and distance relay on magnetically operated sealed switch had been developed under the supervision and participation of M.J. Kletsel. Their implementation needs to strengthen the magnetically operated sealed switches near the conductors at a safe distance and to regulate protection settings. The construction for securing magnetically operated sealed switch in the open busducts has already been developed. At CIGRE conference in 2009 it had been also pointed to the need to develop constructions for securing. However, they are not designed for electrical installations with complete electrical pathways. From the foregoing it follows that the task of developing constructions for securing the magnetically operated sealed switches in the complete electrical pathways, which solution is this work devoted to, is relevant.

The object of research is the protection of electrical installations against short circuits on the magnetically operated sealed switches.

The subject of the study – the constructions for securing magnetically operated sealed switches of the protection against short circuits in complete electrical pathways.

Connection with general scientific (government) programs. The work was performed in accordance with the directions of scientific research committee B5 "Relay protection and automation» CIGRE.

The purpose of the work - to determine the possibility of the use of complete electrical pathways for the construction of relay protection for magnetically operated sealed switches and develop the constructions for their securing inside current lead casings. To achieve the purpose are set and solved the following problems:

1. The determination of the values of magnetic field induction inside complete electrical pathways.

2. The determination of the influence of parameters of tires and magnetically operated sealed switches on the definition of their current operation (current in the conductor, in which the contacts of the magnetically operated sealed switch placed near the wire).

3. The development of constructions for securing magnetically operated sealed switches in the closed three-phase bus systems with partitions.

4. The development of constructions for securing magnetically operated sealed switches, fixed parallel to the walls of closed galleries.

Validity and reliability of the results are confirmed with proper use of the basic factors of the theoretical foundations of electrical engineering, relay protection and the basics of designing mechanisms and machines carefully performed experimental research and testing by publications in journals and conference papers.

Scientific novelty:

1. The influence of magnetic field inside the casings of the complete electrical pathways on the magnetically operated sealed switch for various modes of electrical installations (including short circuits) is investigated.

2. For the first time the impact of fluctuations of the conductors in the phase of complete busducts during short circuits in the operating current of magnetically operated sealed switches has been estimated.

3. 5 patented constructions for securing the magnetically operated sealed switches of short-circuit protection in complete busduct have been offered. They differ from common constructions in the presence of a first clamp structure covering the bus, plates, on which indefinite quantity magnetically operated sealed switches and straps are fixed, bonded with the clamp; at the second - strips, attached at the center of the plate, and two uprights of the rod with a handle extending through openings in the magnetic shield plate and a third - a curved strap connecting plate with partition inside them; in the fourth - the guide rails attached to the edges on both sides of the plate attached to the casing of current lead; a fifth - the metal screen and three discs with the scale and the reed switch attached to the plates with the transverse bar in the middle and adjustable rods, fastening the screen and the plate.

New scientific results of the work:

1. It is proved that the value of the magnetic field induction inside the casing of complete electrical pathways at many points, which are at a safe distance from conductors of the phase, is sufficient to operate the magnetically operated sealed switch.

2. Variations of conductors in the phase of complete electrical pathways at short circuits on their position in the operating conditions do not significantly affect the current operation of the magnetically operated sealed switch.

3. The models of new constructions for securing magnetically operated sealed switch of protection of electrical installations against short circuits are created.

The practical significance of scientific results:

1. Determination of the values of magnetic flux induction inside the casings of complete electrical pathways showed that the sensitivity of the magnetically operated sealed switches is enough to build a complete relay protection of electrical pathways of electrical installations.

2. Definition of deviations of conductors of phase with short-circuits shows that they have no impact on the protection settings on the magnetically operated sealed switch.

3. The proposed construction provides a complete arrangement of the magnetically operated sealed switch within the complete electrical pathways, which is necessary to perform the functions of the security element reacting against short circuits.

Practical value of the work. It is proved that the magnetically operated sealed switches, commercially available, can be used to construct with complete protection of electrical installations, without using a current transformer (CT) by fixing them inside the casing of complete electrical pathways via developed constructions. These constructions make it possible to set the magnetically operated sealed switch at a given point by moving it in the vertical and horizontal planes with respect to the tire that provides the ability to control the current protection on the magnetically operated sealed switch without using current transformers. In addition, they are $40 \div 100$ times lighter in weight, at $10 \div 25$ times smaller in size and of $8 \div 12$ times less expensive than current transformers.

To defend represented:

- The results of experimental studies of the influence of the magnetic fields on the magnetically operated sealed switches inside the casing of the complete electrical pathways.

- The constructions for securing magnetically operated sealed switches in the complete phase-screened and three-phase busducts with partitions, as well as in bus, fixed parallel to the walls of the closed gallery.

- The results of the effect of fluctuations of conductors in the phase of complete electrical pathways during short-circuit currents at the operating current of magnetically operated sealed switch.

Implementation of the results. An agreement on the implementation of the device for protection with the construction for securing the magnetically operated sealed switch, installed in a complete electrical pathway of 100 MW generator at TPP-3 in Pavlodar is given.

Testing of work. Key provisions of the thesis were presented at the VII International Scientific Conference "Electrical Engineering. Electronics. Energy" (Russian Federation, Novosibirsk, 2015) and a further two international conferences in Russia and two- in Kazakhstan.

Publications. The results are published in 15 scientific works that meet the requirements.

Structure and volume of thesis. The thesis consists of introduction, three chapters, conclusion, 4 appendixes and list of the used publications. The volume of thesis is of 90 pages of the computer text of which placed 40 figures, and list of 70 used publications.

Chapter 1 "Relay protection on the reed switch" describes the known conventional current and differential protection of electrical installations, types of magnetic sensing elements, protection on the magnetically operated sealed switch, as

well as the attachment structure and regulation of relay protection in the electrical magnetically operated sealed switches with open electrical pathways.

It is stated that due to the shortcomings of the current transformers and the transition to microprocessor technology, when to increase the reliability of relay protection systems must use the principles of redundancy (including CT), actual development of relay protection, does not use current transformers, for example, magnetically elements. The use of magnetically operated sealed switch for these purposes is justified.

Attention is drawn to the fact that the work to implement the already proposed principles of various constructions of defenses on the magnetically operated sealed switch is constrained due to the lack of constructions for securing and concludes on the relevance of the topicality of these constructions for electrical installations with complete electrical pathways.

Chapter 2 "Complete electrical pathways and the possibility of their use for the detection of short circuits in electrical installations" presents the possibility of the use of complete electrical pathways to detect short circuits in electrical installations using magnetically operated sealed switches.

The conductors are considered. The common data about magnetic fields outside the casing of complete electrical pathways are shown. As a result of field experiments it is proved that the magnetic field inside the casing of the complete electrical pathways has a short-circuit induction, significantly superior induction, necessary for operation of magnetically operated sealed switches produced by Russian industry, and it is concluded that they can be used for the construction of relay protection.

The calculation of electrodynamic forces in the conductors of phase of phase-screened wireways with short circuits is given. It is shown that the maximum deflection (1.3 mm) of tires in complete electrical pathways such as TEKNE-20-12500-400-U1 at a shock current $i_{ud} = 140$ kA and installation of the magnetically operated sealed switch at a safe distance of 10-13 cm changes the magnetic flux acting on the reed switch, not more than 1%, which is quite acceptable.

Chapter 3 "The proposed constructions for fixing the magnetically operated sealed switch in the complete electrical pathways" describes the construction for securing the magnetically operated sealed switch in bus systems with complete electrical pathways in the phase-screened and in bus, fixed parallel to the walls of the closed gallery. The estimation of the possibility of using the construction with a clamp is given. The calculations of the economic efficiency of construction are presented. We describe all of the proposed constructions and the following conclusions are given:

The proposed construction allows securing the magnetically operated sealed switch at a safe distance from the busbars inside the casing of complete electrical pathways and adjusting protection settings, setting the magnetically operated sealed switch at a given point by moving it in the vertical and horizontal planes, or installing multiple magnetically operated sealed switches in a plane perpendicular to the busbar. The most profitable (several times cheaper than current transformers) are constructions for conductors with partitions and constructions for phase-shielded conductors.

The results are as follows:

1. It is proved that the induction of the magnetic flux in a number of points within a complete short-circuit conductors is sufficient to trigger the magnetically operated sealed switch, and fluctuations of conductors in the phase during short circuits have practically no effect on the induction.
2. The proposed construction allows fixing the magnetically operated sealed switch in the considering points inside the casing of complete conductors.
3. The problem of creating constructions for securing magnetically operated sealed switches and regulation of protection settings, which do not use current transformers to complete electrical pathways, has been solved.