ABSTRACT

of thesis research of Neftissov Alexandr Vitalyevich "Determination of current value and phase for building of relay protection with reed switches and microprocessors" for the degree of Doctor of Philosophy (PhD) in specialty 6D071800 - "Electrical Power Engineering"

Relevance of the topic. Over the last 15 years at international conferences of the European Committee of CIGRE has been noticed repeatedly the relevance of development of relay protection based on magnetosensitive elements, that does not use the information from current transformers as they are metal-intensive and in some instances have poor accuracy. According to the researches conducted in Pavlodar State University by Kletsel M.Ya. and his students, one of the ways of solving the problem is the building of relay protection with reed switches, which are superior to other magnetosensitive elements in some properties. However, developed protections with reed switches do not use a microprocessor (MP), which limits the feasibility of known and new protection algorithms. Ways of obtaining information with the use of reed switches and microprocessor proposed recently allow to determine current value in steady-state short-circuit condition, but current phase and its value in transient states remain unknown. In this thesis research we made an attempt to fill these gaps.

The object of the research is protective relays.

The subject of the research is the methods of conversion of primary current by using reed switches and MP.

Connection between the theme of thesis research and general scientific (state) programs. The theme of this thesis research corresponds to one of the scientific areas of the European Committee of CIGRE (subcommittee B5 "Relay protection and automation" of the Russian National Committee).

Work objective: To develop methods and devices for determination of alternating current value and phase in order to construct relay protection based on reed switches and MP without the use of current transformers.

The following tasks were set and solved to achieve the objective.

1. The choice of the method for determination of value of steady-state short-circuit current with the use of reed switches and MP and its implementation.

2. Development of the method of determination of value of initial short-circuit current using reed switches mounted near electrical busbars.

3. Obtaining information about the phase of steady-state short-circuit current in the primary circuit with the help of reed switches and MP.

4. Development of microprocessor-based power direction relay on reed switches.

Research methods. In solving tasks we used fundamental provisions of theoretical basis of electrical engineering, electromagnetic transients, electronics and relay protection, full-scale experiment, mathematical and physical modeling.

Scientific novelty.

1. Proposed method of obtaining information about the phase of steady-state short-circuit current on reed switches and MP is distinctive in that the astronomical time of tripping and reset of reed switches (the first is located near current conductor of the protected electrical installation, the second - in control winding, connected to the voltage transformer) is recorded, time intervals of closed state of their contacts are measured, current amplitude values in the primary circuit and current in control winding are calculated from them, as well as instantaneous values of current of tripping of the two reed switches (according to the formulas derived as a result of recalculation of approximated dependencies, which are read in laboratory conditions with the use of inductor), and then the moments when current sine waves and voltage cross zero are defined

2. The suggested method of determination of value of initial short-circuit current is distinctive in that in laboratory environment we measure resetting current of four reed switches, which are mounted near current conductor of the primary circuit, then we measure time intervals between resets and find out periodic and aperiodic components of short-circuit current by solving four equations made up on the basis of the formula of total transient short-circuit current and known instantaneous resetting current values of these reed switches.

3. A device for determination of value and phase of short-circuit current in steady-state condition with the help of reed switches and MP without the use of information from current transformers (CT) is developed.

4. Proposed (together with Kabdualiyev N.M.) method of providing polarity of reed switch tripping, unlike already known, is based on compensation of one of the half-waves of the magnetic flux affecting reed switch by supplying current to its control winding from inductor mounted just like reed switch near the conductor with primary current.

New scientific results:

1. Methods to obtain information about the phase of steady-state short-circuit current and the value of initial current through the use of reed switches and MP;

2. Method for providing polarity of reed switch tripping.

3. Dependence of reed switch tripping current I_{CP} on multiplicity $K = \frac{I_{K3}}{I_{CP}}$ of short-circuit current I_{K3} in primary circuit.

4. Power direction relay on reed switches and MP, made without the use of CT.

Practical relevance of the scientific results.

1. Developed methods create opportunity for building of microprocessor-based protection on reed switches without the use of CT.

2. Dependence of I_{CP} on multiplicity K allows to implement the method of determination of the phase of steady-state short-circuit current.

Practical value of the work.

1. The device that implements the method of determination of value and phase of steady-state short-circuit current in primary circuit with the help of reed switches and MP allows to obtain its value in 11 ms, and the phase - in 20-25 ms. A simplified version of this device can be used to build simple protections, which are not subject of determination of current phase. Since the device does not use the information from CT, thereby it saves copper and steel.

2. Microprocessor device that implements the method of determination of value of initial short-circuit current using four reed switches allows to determine its periodic and aperiodic components in 20 ms.

3. Developed method to provide polarity and device for comparing two electrical quantities in phase (coupled with the method of determination of current value and phase) allows to build microprocessor-based power direction relay based on reed switches without the use of the information form CT.

Validity and reliability of the work results are supported by: careful application of fundamental provisions of theoretical basis of electrical engineering and relay protection, conscientiously performed modeling and full-scale experiments, as well as publications in journals included in the SCOPUS database, and conferences reports.

The following is presented for the defense:

1. Developed by the author methods to determine the phase of steady-state short-circuit current and the value of initial current on reed switches and MP.

2. Devices, performing functions of current transformer and power direction relay, built on the base of reed switches and MP.

Work approval. The key provisions of this thesis research were reported and discussed: at the XX international scientific and technical conference for students and post-graduate students "Radio electronics, Electrical engineering and Power engineering" (Moscow, Russia, 2014) and four other.

Publications. 13 works (including 4 patents) corresponding to the requirements imposed by the Committee for Control of Education and Science adapted from the thesis research were published.

Personal contribution. Main scientific results and provisions, set forth in the thesis research, goals setting and methods of their solving were developed and derived by the author himself.

Structure of the thesis research. Thesis research includes an introduction, three chapters, conclusion and appendices, contains 50 figures and 4 tables.

The first chapter "Fundamentals of building of relay protection on reed switches without the use of current transformers" is devoted to the results of patent studies and analysis of literature on the theme of thesis research. It contains the description of principles of construction of protective relays, including microprocessor-based ones, that use CT for obtaining information, as well as without them (made with reed switches). Strengths and weaknesses of microprocessor type protective relays are considered. Analysis of devices on reed switches has shown that they do not use MP. One of the reasons for this is the lack of methods to obtain information about current in primary circuit with the help of reed switches necessary for reproduction of current sine wave in MP, which limits the possibility to build relay protection on them. Attention is drawn to the fact that the vast majority of principles of relay protection building is based on the control of current value and phase in the primary circuit.

On the basis of the foregoing we came to conclusion about the relevance of development of such control methods with the use of reed switches and MP.

The second chapter "Determination of current value by means of reed switches and microprocessor" considers the known methods to determine the amplitude of steady-state short-circuit current, developed by the author method to

determine initial short-circuit current and microprocessor device that implements one of these methods.

Here is shown how by using reed switch(-es) located near the current conductor of protected electrical installation one can determine the value of steady-state short-circuit current by measuring the time between tripping of two reed switches or their resets or time of closed state of the contacts and calculation using the formula derived after approximation of dependence of the value of steady-state short-circuit current on the measured time, read in laboratory environment with the inductor.

It contains inaccuracy of methods for determination of the amplitude of steady-state current in the primary circuit with the use of reed switches without the use of CT. The method with one reed switch is implemented in the form of microprocessor device. Determination inaccuracy when current multiplicity K≤80 does not exceed 10%, performance - 11 ms. The device program code is presented.

It was theoretically substantiated and experimentally proved that it is possible to determine to a tolerance of ≤15% the value of initial short-circuit current with the help of MP and four reed switches located under busbars of protected electrical installation, by measuring time between their resets and simultaneous solution of four equations, in which the values of resetting currents of these reed switches are took as instantaneous values of current sine wave and expressed by the formula for determination of total transient short-circuit current through the time between their resets.

The third chapter "Determination of current phase with the help of reed switches and microprocessor" presents the developed method to determine the phase of steady-state short-circuit current and microprocessor-based power direction relay with reed switches. It contains the relay operation algorithm, program code and main characteristics.

It is shown that to determine the phase of steady-state short-circuit current with the help of reed switches it is necessary: to record astronomic time of contacts operation and release of two reed switches; to measure time of closed states t_1 and t_1^{OY} of their contacts; to define the moments when current sine waves and voltage cross zero by calculating current amplitudes I_m in the conductor, I_m^{OY} in the control winding, I_{CP} of tripping of the first reed switch and I_{CP}^{OY} of tripping of the second reed switch according to the formulas, which were derived from approximation of

dependences I_m, I_m^{OY}, I_{CP}, I_{CP}^{OY} of these reed switches on measured time t_1 and t_1^{OY} of closed state of their contacts, that were read in the laboratory with the use of inductor. The efficiency of the device implementing the method was proved. Corresponding oscilloscope records are presented. Inaccuracy in the determination of the phase of steady-state current in primary circuit does not exceed 25%.

It was proved that the device developed on the basis of the method to determine of phase of steady-state short-circuit current with reed switches and MP performs the functions of power direction relay and does not need CT.

The results are as follows.

The developed methods and devices allow to determine the value and phase of short-circuit current in the primary circuit with the help of reed switches and microprocessor, which offers the opportunity to build microrpocessor-based protections without the use of information from current transformers. One of these devices is expected to introduce at CHPP-3 of PAVLODARENERGO JSC and substations of PREK JSC.