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Investigation of the Properties of Reed Switches in Devices for Resource-Saving Relay Protection of the Electrical Part of Power Plants

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Abstract. Resource conservation issues are relevant in the energy sector, for example, the development of relay protection devices without the use of metal-intensive current transformers. For the construction of relay protection devices, it is proposed to use reed switches. However, it was determined that the parameters of the reed switches are not constant and can vary with the magnitude of the acting magnetic flux. Additional research is needed to improve relay protection devices using reed switches.

INTRODUCTION

Power plants, which are designed for the production or conversion, transmission, distribution or consumption of electrical energy, are called electrical installations [1]. It is possible to happen damage and abnormal conditions in electrical installations [2, 3]. To identify a damaged area and disconnect it from the electric power system, it is necessary to have devices relay protection that continuously monitor the state of all elements of the electric power system [4-7]. Classically, relay protection devices receive information about the flowing current and voltage from measuring current and voltage transformers. However, current transformers have several disadvantages. They are metal consuming, have large errors in transitional regime, and when their secondary circuits break, a dangerous voltage is created [8]. These disadvantages can be avoided by using other primary converters to obtain information [9], for example, reed switches [10-12].

THE PRINCIPLE OF DEVICE OPERATION AND RESEARCH OF OPERATION

There are developments which use the reed switches. They are located near the busbars of the protected electrical installation, to obtain information about the magnitude of the current [11]. Methods for determining the magnitude of the steady-state current short circuit using reed switches are as follows. Reed switch 1 in accordance with Fig. 1 or reed switches 1 and 3 are installed near conductor 2 at a distance h, admissible for safety reasons.

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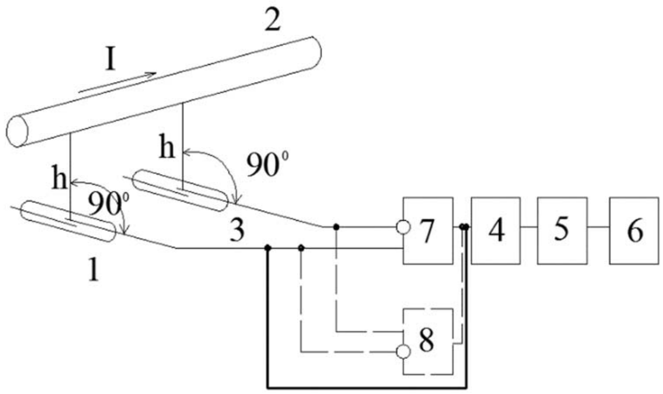


FIGURE 1. Block diagram of the implementation of methods for determining the magnitude of the steady-state short-circuit current

When the electrical installation is switched on, a sinusoidal current with an amplitude I_m flows through the conductor in accordance with Fig. 2. Its magnetic field impacts on the contacts of the reed switch 1 or the reed switches 1 and 3 [11].

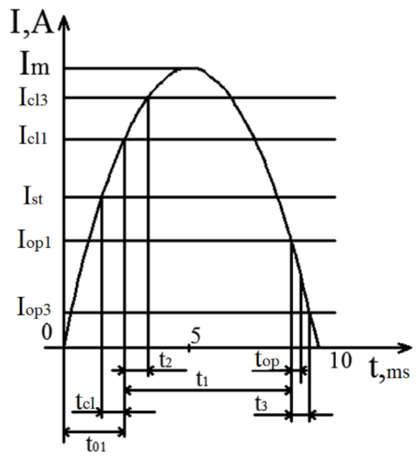


FIGURE 2. Currents of operation and return, and the time between them

Normally open reed switch contacts close when the current in the conductor to a value sufficient to create a certain magnetomotive force. The current changes in time according to a sinusoidal law, therefore after reaching the amplitude I_m value in accordance with Fig. 2, it decreases. When its instantaneous values decrease, the reed switch contacts will open. The instantaneous value of the current in the conductor, at which the closure (opening) of the reed switch contacts occurred, is called the actuation current I_{cl} (I_{op} return) of the reed switch [13]. Using elementary knowledge about the sinusoid, it is possible to express the instantaneous values of the operating currents I_{cl1} and return I_{op1} of the reed switch through the amplitude I_m of the current in the conductor, the time t_{01} from the transition of the sinusoid from the negative half-wave to the positive one until the reed switch is triggered, and the time interval t_1 from closing to opening its contacts in accordance with Fig. 2. The return current I_{op1} of the reed switch can be represented using the formula

$$I_{op1} = I_m \cdot \sin(\omega \cdot t_{01} + \omega \cdot t_1), \tag{1}$$

where: t_{01} is the time from the transition of the sinusoid through zero to the moment of operation; ω - angular frequency of alternating current.

The operating current of the reed switch is expressed in a similar way; for this, it is sufficient to remove ωt_1 from formula (1). We will not write down the new formula. Using equalities (1) and the definition formula, we obtain

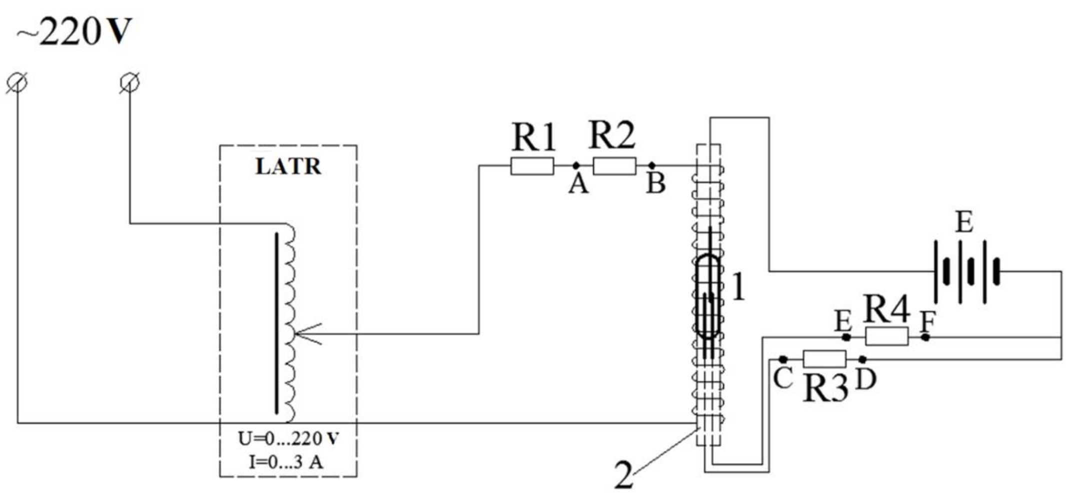
$$I_m = \frac{\sqrt{I_{cl1}^2 + I_{op1}^2 - 2 \cdot I_{cl1} \cdot I_{op1} \cdot \cos(\omega \cdot t_1)}}{\sin(\omega \cdot t_1)}, \quad (2)$$

In case you use two reed switches 1 and 3 in accordance with Fig. 1, while knowing their operating currents I_{cl1} and I_{cl3} (return currents I_{op1} and I_{op3}) and the time between the moments of closure t_2 (opening t_3) of the reed switch contacts [14], then you can also derive the amplitude I_m value of the current in the conductor. To do this, in (2) it is necessary to replace I_{op1}, t_1 with I_{cl3}, t_2 (I_{cl1}, t_1 by I_{op3}, t_3).

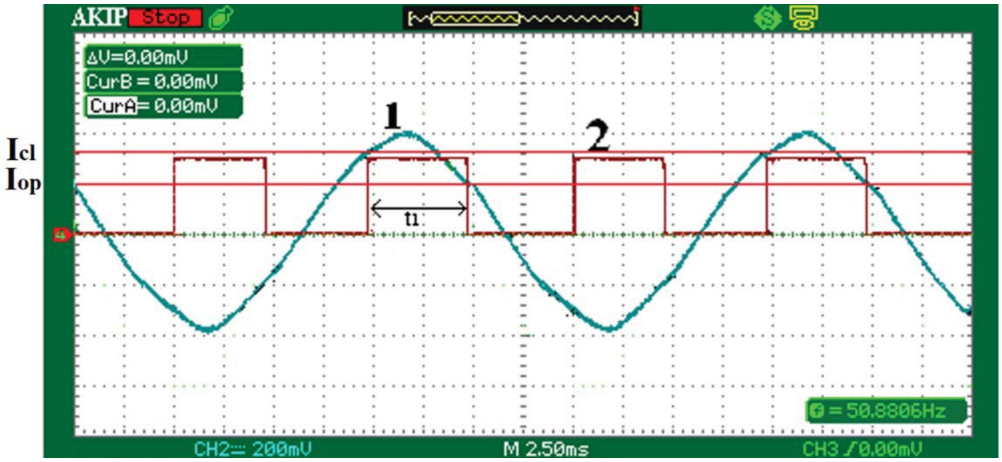
It is possible to determine I_m by measuring the response time t_{cl} of the reed switch contacts (from the moment the reed switch contacts start to move to their actuation) [15]. But for this it is necessary to know current I_{st} the starting. It corresponds to the value of current value at which the reed switch contacts begin to move when triggered. This can be done quite easily using a switching reed switch. Determination of the current in the conductor is possible in other ways, for example, using n-reed switches [16]. Thus, in order to determine the value of the current in the conductor, it is necessary to measure the time t_1 (t_2 or t_3 or t_{cl}) and know the values of the operating currents I_{cl} and (or) I_{op} return of the reed switch (es).

Traditional protection relays and current transformers have errors. Requirements are imposed on the errors of current transformers, according to which they should not exceed 10%. Since the reed switches together with the device perform the functions of current transformers, we will set the errors $\varepsilon_f \leq 10\%$ [11]. To determine the errors, experimental studies were carried out to determine the value of the steady-state short-circuit current in laboratory conditions. The experiments were carried out on reed switches MKA14103, KEM-1, KEM-2, KEM-3 from batches of different years of production. Three samples were selected.

The block diagram of the setup for the experiments is shown in Fig. 3, a. The voltage source is LATP M2, to which a series circuit of resistors R1, R2 and inductor 2 is connected. Reed switch 1 is located in the inductor, the changeover contact of which is connected to the positive terminal of the battery. The closing contact is connected through the resistor R3 to the negative terminal of the battery, and the opening contact is connected through R4. Inductor has L_K >> R and 5200 turns with a cross section of S = 0.5 mm^2. The sinusoid (in accordance with Fig. 3, b, curve 1) was monitored using the first channel of the digital oscilloscope AKIP-4115 connected to points A and B [17, 18]. Fig. 3, b shows an oscillogram that shows the operation of the closed reed switch contact. The actuation and return of the reed switch contacts (in accordance with Fig. 3, b, curve 2) was monitored by the second channel, which was connected to points C and D. The time was measured using an oscilloscope with an accuracy of 1 μs.



a)



b)

FIGURE 3. Block diagram of the laboratory installation (a) and the oscillogram of the reed switch (b)

From formula (2), it can be concluded that one of the conditions for achieving the most accurate information about the value of the current in the conductor is to ensure the stability of the response parameters and the return of the reed switch at different magnitudes of the magnetic flux effect. During the research, it was found that with an increase in the amplitude of the current in the conductor and, accordingly, an increase in the rate of rise of the sinusoid (the slope of the half-wave of the sinusoid), the operating current of the reed switch increases. The resulting characteristic for the KEM-3 reed switch is shown in Fig. 4. The fig. 4 shows that with an increase in the closed state time from 4000 μs to 9000 μs, the operating current increases 1.7 times

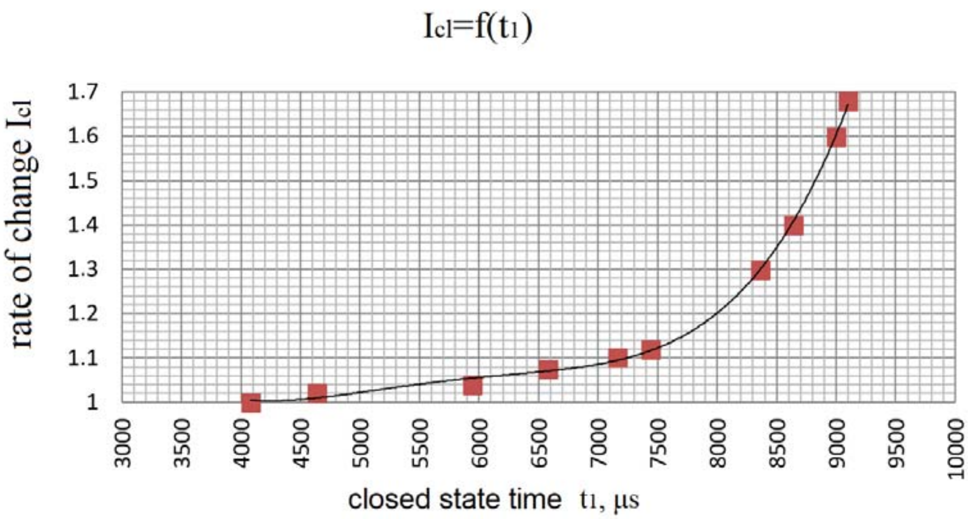


FIGURE 4. Dependence of the operating current on the value of the current in the conductor (closed state time)

CONCLUSION

From the obtained characteristics it follows that additional research is needed to determine the parameters of the reed switch at different values of the influencing magnetic flux, including the study of the change in the parameters of the reed switch relative to the number of the worked out number of actuations of its contacts.

These studies will allow obtaining more accurate information about the primary current in the conductor, and as a consequence, reducing the errors of resource-saving relay protection devices receiving information from reed switches, which will increase the reliability of the entire power supply system.

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REFERENCES

1. GOST 19431–84, *Power engineering and electrification. Terms and Definitions* (Standartinform, Moscow, 1986), p. 8.
2. A. N. Novozhilov, T. A. Novozhilov, and D. M. Rakhimberdinova, Russ. Electr. Eng. **91** (6), 403–407 (2020).
3. E. Volgina, A. Novozhilov, Y. Kolesnikov, D. Rakhimberdinova, T. Novozhilov, and O. Andreeva, News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, **5** (437), p. 26–33 (2019).
4. V. Gurevich, *Electric Relays: Principles and applications* (CRC Press, London, 2005), p. 704.
5. A. Novozhilov, Y. Kryukova, A. Kislov, O. Andreyeva, and T. Novozhilov, Life Sci. **11**, 502–505 (2014).
6. A. Novozhilov, Y. Kryukova, A. Kislov, O. Andreyeva, and T. Novozhilov, Life Sci. **11**, 116–119 (2014).
7. A. Novozhilov, Y. Kryukova, O. Andreyeva, and T. Novozhilov, Przegląd Elektrotechniczny **9**, 157–159 (2014).
8. M. Y. Kletsel', A. V. Neftisov, and P. N. Maishev, Russ. Electr. Eng. **91** (1), 34–40 (2020).
9. A. N. Novozhilov, T. A. Novozhilov, E. M. Volgina, E. N. Kolesnikov, and D. M. Rakhimberdinova, Russ. Eng. Res. **40** (9), 710–713 (2020).
10. M. Kletsel, N. Kabdualiyev, B. Mashrapov, and A. Neftissov, Przeglad Elektrotechniczny **1**, 88–89 (2014).
11. A. B. Zhantlesova, M. Y. Kletsel, P. N. Maishev, and A. V. Neftisov, Russ. Electr. Eng. **85** (4), 210–216 (2014).
12. A. Kaltayev, B. Mashrapov, and O. Talipov, ICIEAM 2020, 9111883 (2020).
13. M. Y. Kletsel' and V. V. Musin, Electrical Engineering. **4**, 11–13 (1987) [in Russian].
14. M. Y. Kletsel', P. N. Maishev, and V. N. Gorunov, Patent RF no. 2397499, 2010.
15. M. Y. Kletsel' and P. N. Maishev, Patent RK no. 21141, 2009.
16. M. Y. Kletsel', A. B. Zhantlesova, and K. I. Nikitin, Patent RF no. 2377579, 2009.
17. A. Sarinova and A. Zamyatin. E3S Web Conf. **149**, 02003 (2020).
18. S. Abimuldina, A. Sarinova, L. Sarlybayeva, and N. Akhmetova. DYNA (Colombia) **84** (202), 289–294 (2017).