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Alexandr V. Neftissov, Alexandr P. Kislov, and Oxana A. Andreyeva

The Resource-Efficient Device for Protecting the Electrical Part of Power Plants

Alexandr V. Neftissov[1, a)], Alexandr P. Kislov[1, b)] and Oxana A. Andreyeva[1, c)]

[1]*Pavlodar State University, 140000 Pavlodar, Kazakhstan.*

[a)]Corresponding author: neftisov.a@psu.kz
[b)]kislovpsu@mail.ru
[c)]andreyeva.oa@mail.ru

Abstract. Issues of resource saving are relevant in the field of energy, for example, the development of relay protection devices without the use of metal-intensive current transformers. As a result of the study, it was determined that reed switches can be used to build relay protection devices that do not need current transformers and allow you to compare phases of two electrical quantities. The error in comparing the phases of electrical quantities did not exceed 10%. There is no dead zone in the presented device, when the phase of the first electrical quantity changes by 180 degrees. The sensitivity is increased and the field of application is expanded due to signal amplification and ensuring the polarity of switching.

INTRODUCTION

The power supply apparatus is a complex of interconnected equipment and facilities intended for the production, conversion, transmission, storage, distribution or consumption of energy [1, 67 p.].

Safety and emergency shutdown of the electrical part of these apparatuses, such as generators, transformers, power lines, etc. are provided by relay protection devices [2, 188 p.].

The problem of creating relay protection devices that do not use information from current transformers (CT) was considered at international scientific conferences [3], [4, 39 pp.]. Because CT's of 6-220 kV electrical installations contain up to 90 kg of high-quality copper and steel.

To increase resource efficiency (without using CT), it's possible to build relay protection devices that can operate on new principles. For instance, the development of optical CT's [5, 24 pp.] that do not contain copper, as well as relay protection devices that receive information from Rogowski coils [4, 39 pp.] and others [6, 116 p.], [7, 157 p.]. One of the promising projects is the use of reed switches as sensitive elements [8, 88 pp.], [9, 210 pp.].

According to the basic principles of action, relay protection devices are divided into current, distance and phase-comparison types. Phase-comparing circuits are used in current directional, distance directional and phase-comparison protection systems.

In this paper, a device is presented for phase-comparison of two electrical quantities using reed switches and a microprocessor [10, 1 p.].

DEVICE DIAGRAM

The presented device (Fig. 1) contains reed switches 1 and 2, AND gate 3, actuator 4, inductors 5 and 6, phase-shifting circuits 7 and 8, amplifiers 9 and 10, windings 11 and 12 of the reed switch control, diodes 13 and 14, parallelepiped-shaped housings 15 and 16, and the microprocessor 17. The terminals of the first coil 5 connected to the first phase-shifting circuit 7 through the first amplifier 9. The terminals of the first phase-shifting circuit 7 are connected to the terminals of the first control winding 11 of the first reed switch through a series-connected first diode 13. The terminals of the second coil 6 are connected to the second phase-shifting circuit 8 through the second amplifier

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10, and the terminals of the second phase-shifting circuit 8 are connected to the terminals of the second control winding 12 of the second reed switch through the second series-connected diode 14. Phase-shifting circuits 7 and 8, amplifiers 9 and 10, control windings 11 and 12 with reed switches 1 and 2, diodes 13 and 14 are fixed in shielding parallelepiped-shaped housings 15 and 16, respectively. One contact group of reed switches 1 and 2 is connected to the microprocessor 17 through the AND gate 3. Other group is connected to the power supply. Parallelepiped-shaped housings 15 and 16 are shown in the open for clarity of content.

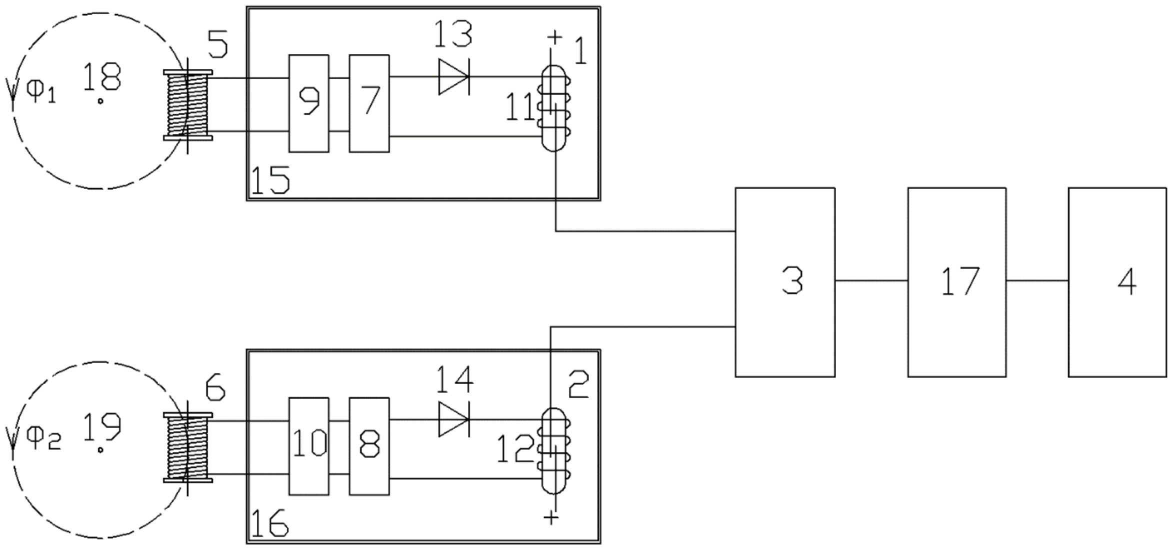

FIGURE 1. The structure of the device

Reed switches 1 and 2 are used as analog-to-discrete converter (ADC) for the compared analog values F1 and F2. These values are proportional to the currents, flowing in conductors 18 and 19, respectively. Figure 1 shows the cross section of these conductors.

THE PRINCIPLE OF DEVICE OPERATION AND RESEARCH OF OPERATION

While we do experiments with the prototype of the proposed device, the following equipment were used: the oscilloscope AKIP-4115/4A (errors along the vertical path ±3%, errors along the horizontal path ±0.01%), the multimeter FLUKE 87V (AV errors ±0.7%, AC errors ±1.0%).

Figure 2 shows Φ_1 and Φ_2 magnetic fluxes created by currents in conductors acting on inductors 5 and 6, respectively. Φ_{1amp} and Φ_{2amp} are amplified magnetic fluxes from currents in control windings 11 and 12 acting on reed switches 1 and 2, respectively. Φ_{op} is the magnetic flux when the reed switch closes its contacts. Φ_r is the magnetic flux when the reed switch opens its contacts. The signals: t_1 is the closed state time of the first reed switch; t_2 is the closed state time of the second reed switch; t_3 is the coincidence time of the closed states of both reed contacts in the AND gate.

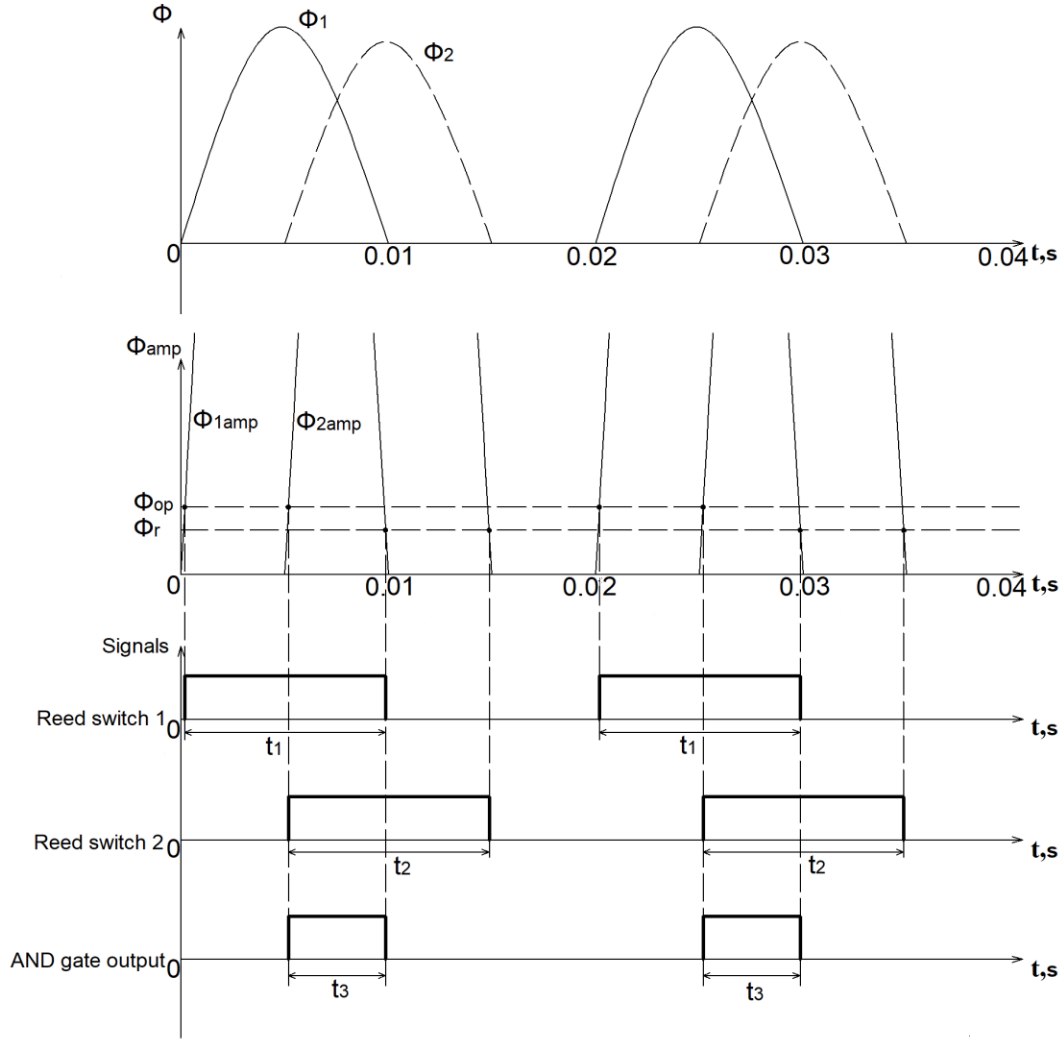

FIGURE 2. Magnetic fluxes on the inductors and reed switches

The currents in electrical installation current leads create magnetic fluxes Φ_1 and Φ_2, which induct voltages $E_1 = -d\Phi_1/dt$; $E_2 = -d\Phi_2/dt$ on coil terminals 5 and 6, respectively. Voltages E_1 and E_2 are applied to the inputs of amplifiers 9 and 10, where they increase. The time of the closed state of the reed switches should be at least 90% of the half-wave duration. In phase-shifting circuits 7 and 8 E_1 and E_2 are shifted in phase by 90 degrees, so magnetic fluxes Φ_{1amp} and Φ_{2amp} coincide in phase with Φ_1 and Φ_2. The polarity of the connection of the windings 11 and 12 to terminals of phase-shifting circuits 7 and 8 through series-connected diodes 13 and 14 should provide collinearity of magnetic fluxes Φ_{1amp}, Φ_{2amp} and fluxes Φ_1 and Φ_2, which were inducted by currents in conductors. Diodes 13 and 14 pass only the positive half-waves E_1 and E_2 into the windings 11 and 12. Thus, currents I_{w11} and I_{w12} and fluxes Φ_{1amp} and Φ_{2amp} appear in the windings only in these half-waves.

We fixed the inductors 5 and 6 and housings 15 and 16 with the above-mentioned circuit elements near the current leads (Figure 1) and then we turn the device on. The reed switches 1 and 2 are constantly in operation and are triggered (close the contacts) only in the positive half-waves of the supplied magnetic fluxes Φ_{1amp} and Φ_{2amp}, due to the diodes 13 and 14 (Figure 2). The contacts of the reed switches are connected to the inputs of the AND gate to determine the coincidence time of the triggered states of the reed switches 1 and 2. The output of the AND gate is connected to the microprocessor, which calculates the duration of the coincidence time and compares it with the setting. If the setting is exceeded, the microprocessor gives a signal to the actuator. Due to the amplifiers, the time of the closed state of the reed switches is at least 90% of the half-wave duration, i.e. not less than 9 ms. Thus, the error of calculating the phase between two values by the coincidence time will be up to 10% of the half-wave duration, i.e. upward error up to 18 degrees.

CONCLUSION

A relay protection device was presented that does not need a current transformer to receive information. In contrast to the well-known samples [11, 1 p.], the dead zone is excluded when the phase of one of the electrical quantities changes by 180 degrees. The sensitivity is increased and the field of application is expanded by amplifying the signal and ensuring the polarity of switching. It allows us to compare two electrical quantities in phase with an error up to 10%. Built on the presented principle these devices will allow to build a new resource-efficient (due to the lack of the need for current transformers) relay protection in future. However, only after further research and trial operation of the devices, it will be possible to talk about the successful development of resource-efficient technology for creating relay protection devices and their preparation for implementation. Application of this principle will make it possible to build such devices, for example, as power and current directional relays.

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