Designs for Mounting Reed Switches in Closed Complete Current Conductors and on Cable Lines

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Abstract—**A brief consideration of the current sensors with the magnetosensitive elements. The use of reed switches as current sensors in relay protection is advised. The principle of building protections on reed switches is stated. The disadvantages of the known designs for mounting the reed switches in closed complete current conductors are analyzed. Four designs for mounting reed switches near three-phase closed complete current conductors with dividing barriers and on cable lines are proposed. In the first one, the bracket with reed switches is attached to two dividing barriers of the current conductor, in the second to its shell and passes through the dividing barriers, in the third, the reed switch is mounted on a rotary drum located in a housing attached to the cable, in the fourth – on an inclined bracket. Further we speak about how the response parameters of magnetosensitive elements are controlled using these designs.**

Keyword—magnetosensitive elements, reed switches, mounting designs, cable lines, current conductors

I. INTRODUCTION

It is known that most modern relay protection (RP) devices obtain data on the protected electrical system from bulky and expensive current transformers [1–3], which, as has been repeatedly noted, have a number of well-known disadvantages. Alternatives to the widespread use of current transformers are current sensors on magnetically sensitive elements [4–8], such as Hall sensors, Rogowski coils, magnetic current transformers, simple inductors, reed switches (sealed contacts), reed relays, etc. Each of these sensors has its own advantages and disadvantages. We have chosen reed switches, as they can simultaneously perform the functions of analog-discrete and measuring transducers, as well as of a measuring protection element; they are not affected by ambient temperature; they do not need amplifiers; they transmit signals through control circuits [9–11]. Moreover, they have a low cost and relatively small size. At present, RP devices with reed switches for almost all types of electrical installations have already been developed [6, 12–16]. However, all these RP devices need appropriate designs for mounting the reed switches near the phases of the protected electrical installations. Therefore, in this article, we propose new unique designs for mounting reed switches in three-phase closed complete current conductors and on cable lines.

II. THE CURRENT SENSORS ON REED SWITCHES OPERATION PRINCIPLE

Reed switch is two (three) ferromagnetic plates (contacts) contained in a glass flask filled with an inert gas or vacuum (Fig. 1) [9, 10]. Ferromagnetic plates (contacts) overlap each other, while maintaining an air gap between them.

Reed switch trips under the influence of a magnetic field with a triggering induction B_{tr} [17]:

$$B_{tr} = \mu_0 F_{tr}/l_c = \mu_0 w I_c / l_c, \qquad (1)$$

where μ_0 is the air magnetic permeability; I_c and F_{tr} is the minimum value of current and magnetomotive force in the reed switch coil, at which it is triggered; w and l_c is the number of turns and length of the reed switch coil.

In RP devices, a reed switch is mainly used as a sensor of a change in the current value in the current conductor, with contacts that close and open with each half-wave of alternating current at $I_{tr} \ge k_{offs} I_{rat}$ (k_{offs} is selected depending on the required sensitivity). In this case, the t_{tr} reed switch response time for a current multiplicity of $1 < K \le 4$ does not exceed 6 ms, and for $K \ge 1.5$ it is less than 1.5 ms [6]. This indicates that when designing RP on reed switches, it is necessary to take into account the current multiplicity influence on the t_{tr} reed switch response time.
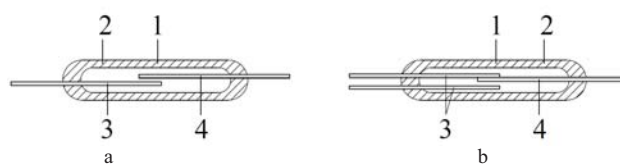

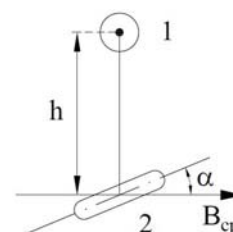Fig. 1. The reed switch structure: a – closing, b – switching

Fig. 2. Reed switch location under the installation phase: 1 - electrical installation phase 2 - reed switch

Relay devices have already been developed for low and high voltage networks, with the reed switches installed both directly on the bus and at a safe distance h (according to safety conditions) from the current conductor (Fig. 2). The reed switch trips under the influence of a magnetic field created by the current flowing through the current conductor [17]:

$$I_{tr} = \frac{2B_{tr}\pi h}{\mu_0 \cos\alpha} = \frac{2F_{tr}\pi h}{l_c \cos\alpha}, \qquad (2)$$

where I_{tr} is the minimum current value in the phase of the electrical installation at which the reed switch trips; B_{tr} is the magnetic field induction, directed along the reed switch contacts, and created by the tripping current I_{tr}; α is the angle between the reed switch longitudinal axis and the plane parallel to the current conductor.

With a short circuit (SC), the current in the phases of electrical installations increases several times, so the reed switches can be used to identify the short circuit mode.

It should be noted that for a more accurate calculation of the RP on the reed switches response parameters according to formula (2), the correction factors given in [18] should be used.

III. Reed Switches Mounting Designs

A. Reed switches mounting designs in three-phase closed complete current conductors

A number of designs for mounting reed switches in closed complete conductors already exists [19–21]. However, the designs [19, 20] cannot provide a smooth and precise operation parameters adjustment of the reed switches used in RP devices, and the design [21] is too complicated to make. Moreover, designs [19, 20] are intended for complete single-phase current conductors with tubular buses. We offer designs that do not have these restrictions.

The design for mounting the reed switches in a closed three-phase complete current conductor with dividing barriers [22] contains reed switches 1 (Fig. 3, 4), mounted on the first bracket 2 with clamps 3 and screws 4. The second bracket 5, with two lugs 6 with holes for the screw 7 on the front side, is attached to the first bracket 2 with the pivot pins 8. Two guide plates 9 are mounted in parallel on the dividing barriers 10 with bolts 11 and nuts 12.

The first 13 and second 14 brackets with recesses are mounted in parallel on two guide plates 9 with bolts 11 and nuts 12. The hollow cylinder 15 is fastened to the second bracket 14 with recesses. Rod 16 is equipped with a wing 17. The first bracket with recesses 13 has a hole for the rod 16 with the wing 17, while the base of the rod 16 is integrated into the hollow cylinder 15. On the shaft 16, a nut 19, glued to the back of the second bracket 5, is statically fixed. Also two guide rails 18 are glued to the same bracket along the guide plates 9 (not shown in Figs. 3, 4). All structural parts are made of dielectric material.
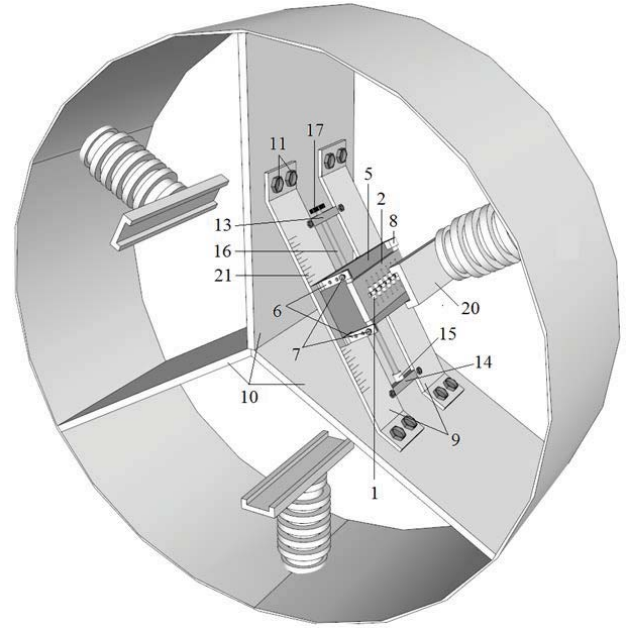

Fig. 3. The reed switches mounting design, fastened inside the three-phase closed complete current conductor casing
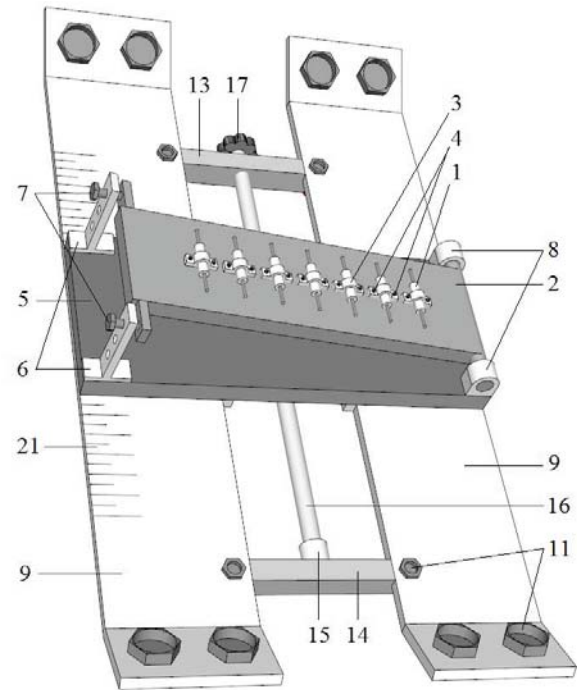

Fig. 4. The reed switches mounting design in a three-phase closed complete current conductor.

The operation values adjustment of the proposed current protection on the reed switches design is as follows. As the reed switch serves as a current sensor of the RE, it is necessary to calculate the corresponding operation values, according to the method described in article [17].

To adjust the operation values, it is necessary to move the reed switch 1 in relation to the conductor bus 20, i.e. change "h" (Fig. 4). By rotation of the wing 17, the second bracket 5, fixed on the rod 16 is moved. Finally, the first bracket 2 with reed switches 1 will be exactly under the conductor bus 20, for maximum sensitivity of the reed switches. A scale 21 is applied on the guide plate 9 for fine tuning. To change the value of "h" to "h'" turn the first bracket 2 and fasten it to the corresponding holes in lugs 6 with screws 7. The use of a large number of reed switches on the first bracket 2 makes the operation values adjustment more accurate and smooth, as each reed switch is configured to its own operating current, and it is possible to choose the reed switch with operating current closer to the calculated one.

The following design for mounting reed switches in a closed three-phase complete current conductor with dividing barriers includes a bracket 1 (Fig. 5), with the first 2, second 3, third 4 and fourth 5 guide rails fixed on it at both edges. One end of the bracket 1 is equipped with a handle. The bracket 1 is fastened along the entire length to the slide 7 with the possibility of moving along and passing through the corresponding slots in the first 8 and second 9 dividing
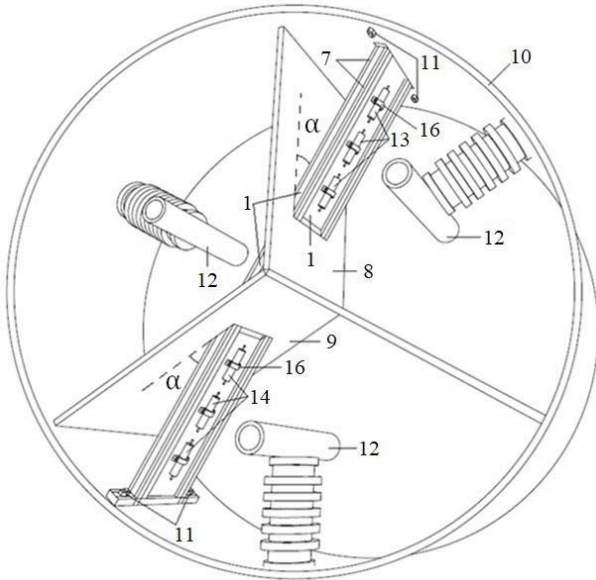

Fig. 5. Reed switches mounting design

barriers and in the conductor sheath 10 at an angle α to the planes of these barriers. In this case, the slide 7 has locking protrusions for fastening to the conductor sheath 10 with the mounting bolts 11. The first 13 and second 14 groups of reed switches are fastened to the bracket 1 near its ends from the side where two of the three conductor buses 12 are located. The third group of reed switches 15 is fixed near the middle of the bracket 1 from the side where only one conductor bus 12 is located. The reed switches of the first 13, second 14 and third 15 groups are fastened to the rail 1 with the clamps 16, fixed with mounting bolts 17.

The order and calculation of the reed switches operation parameters is carried out in the same way as in the previous

design. The bracket 1 with the reed switches is positioned by entering it through an opening in the current conductor 10 along the slide 7 until it stops. Then the design is ready to work. When the bracket 1 is positioned at an angle $\alpha = 30^0$, setting the protection operation parameters for each group of reed switches is simple and uniform, without requiring specific calculations.

B. Designs for mounting reed switches on cable lines

In contrast to designs for mounting reed switches in closed complete current conductors, the number of designs for mounting reed switches on cable lines is much less. One of these designs is given in [23], where the reed switch is located on the cable with a fastening block. However, the design according to [23] has a very limited range of the reed switch operation parameters adjustment, thus it is not always possible to select a reed switch for the RP of the protected electrical installation. To eliminate this disadvantage, the following designs are proposed.

The Fig. 6 shows the design with rotary drums for mounting the reed switches on cable lines [24], which consists of a housing 1 with a cover 2, made in the form of a
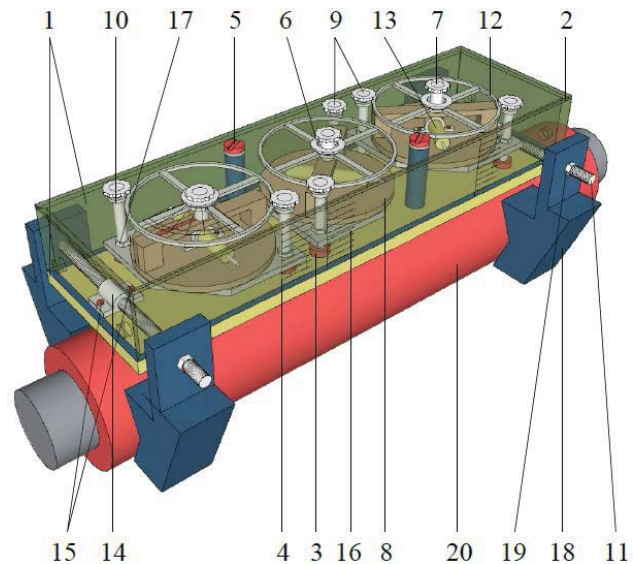

Fig. 6. Design for mounting reed switches on cable lines (general isometric view)

parallelepiped of non-magnetic material. At the bottom of the housing 1 are fixed protruding grooves 3. The housing cover 2 and one of the housing side faces 4 are made transparent. The housing cover 2 with nine holes is attached to it by two screws 5. A cylindrical hollow axis 6 and the wing 7 of the rotary drums 8 pass through these holes. The bolts 9 are passed through the remaining six holes with a pinion gear 10 at the upper parts of each.

Holes are made in the housing 1 walls near its ends, and the studs 11 are passed through them. A pinion gear 12 is installed on each cylindrical hollow axis 6, under the cover 2, and connected with two of the six gears 10. On the inner bottom side of each rotary drum 8, a reed switch 13 is fixed with a

clamp 14 and two screws 15, and the outer side of the bottom is attached to the lifting platform 16. At the edges of the lifting platform 16, holes are made and nuts 17 are attached, so that the holes in the nut 17 and the lifting platform 16 are aligned. The bolts 9 are screwed into the nuts 17 and inserted into the grooves 3 at the bottom of the housing. Each stud 11 is rigidly fixed to the bottom of the housing with a clamp 14 and two screws 15, and their ends are passed through holes in the movable guide links 18 and fixed with nuts 19. In this case, the movable guide links 18 encircle the cable 20 from two sides.

This design enables the trip current protection (reed switch) adjustment as follows. When one of the two bolts 9, interconnected by the gear mechanism of the gears 10 and the pinion gear 12, is rotated, the lifting platform 16 is moved in the vertical plane to a distance h along the bolts 9, where the rotary drum 8 with the wing 7 is located. When the wing 7 is rotated, the reed switch 13 is rotated to the angle γ (between the reed switch longitudinal axis and the conductor axis) in the horizontal plane parallel to the cable 20. Quantification of changes in angle γ and distance h is displayed by scales on cover 2 and one of the side faces 4.

The design described above enables the reed switches mounting on cable lines and smooth RP on reel switches operation current I_{tr} adjustment. This advantage is associated with the reed switches rotation in the horizontal plane and movement in the vertical one. When it is necessary to use a larger number of reed switches and the fine-tuning of the RP operation values is not required, it is recommended to use designs with reed switches on a rotary bracket [25].

The design for mounting the reed switches on cable lines [25] contains a housing 1 with a cover 2, made in the form of a parallelepiped (Fig. 7). Cover 2 is mounted on the housing 1 with screws 3. Holes are made in the butt wall of one side of the housing 1, and a U-shaped bracket 4 is inserted there and secured externally with a screw 5 so that the U-shaped bracket 4 flanges protrude inside the housing 1. L-part 6 is fixed below the U-shaped bracket 4 flanges on the inner side of the housing 1 butt wall. On the large sides of the housing 1, closer to its bottom, through holes (two on each side) are symmetrically made, where two threaded studs 7 are inserted. Each stud 7 is rigidly fixed to the bottom of the housing 1 with a clamp 8 and screws 9. At the ends of the studs 7 movable guide links 11 are fixed with the help of nuts 10, and shaped to cover the conductor cable 12. Inside the housing 1 there is an inclined bracket 13, with the lower end attached to a hinge 14 fixed on the bottom of the housing 1 (Fig. 7). The upper end of the bracket 13 is made for thrusting or connecting to the upper flange of the U-shaped bracket 4, or on the L-part 6. n reed switches 17 are fixed to the bracket 13 upper and lower sides at an equal distance and parallel to each other with clamps 15 and screws 16 (Fig. 8). Reed switches 17 are connected in parallel and connected with wires 18 to the terminal block 19, mounted on the bottom of the housing 1.

To place the design on the cable, unscrew the nuts 10 on the studs 7 until enough gap is formed between the guide links 11 for the conductor cable 12. Then perform the guide links 11 convergence on the studs 7 to a position that provides reliable connection of the device on the conductor cable 12. Nuts 10 are tightened to the limit.
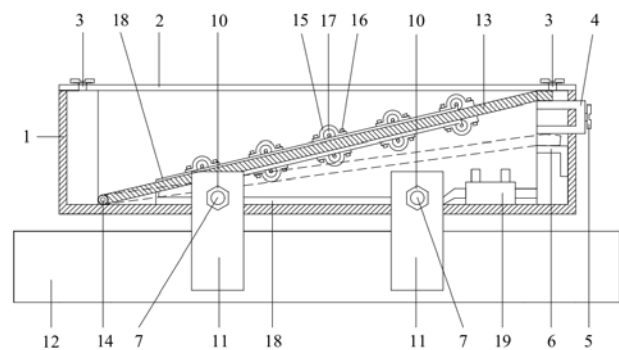

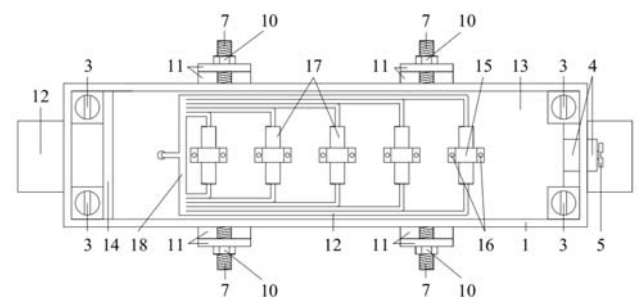Fig. 7. Design for mounting reed switches on cable lines

Fig. 8. Design for mounting reed switches on cable lines

This design provides for the trip current adjustment as follows. The protection tripping current and the tripping current of all n reed switches 17 are determined. The reed switches 17 operation current is the value of the current flowing in the conductor cable 12 during a short circuit, when the reed switches 17 close their contacts or send signals. All n reed switches 17 have different operation current values. The contacts of each reed switch 17 are connected to the individual terminals of the terminal block 19 with wires 18. Then, the closest protection trip current is selected from the obtained values of the n reed switches 17 operation currents. An output relay is connected to the selected reed switch 17 through the terminal block 19, where the signal enters the protection circuit.

The bracket 13 upper end is lifted to the upper shelf of the U-shaped bracket 4 or lowered to the L-part 6, by removing and reverse mounting the U-shaped bracket 4 (shown in dashed line in Fig. 7), thereby changing the RP trip values to increase the n reed switches 17 operation settings range.

To calculate the operating current of the reed switches used in the designs [23–25], it is recommended to use the calculation method described in [26]. This is due to the fact that when the reed switches are located at a distance of less than 4.5 cm, the calculation of the operation values according to (2) has large errors.

IV. CONCLUSIONS

1. The proposed designs enable to make the measuring elements of electrical installations with three-phase closed

current conductors with dividing barriers and cable lines relay protection without of current transformers.

2. The proposed designs for closed three-phase complete current conductors are simpler than the conventional ones, the adjustment range of the protection parameters for reed switches is wider, and there is the possibility of modifying them without electrical installations downtime.

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