Designs for Mounting Reed Switches in Vicinity of AC and DC Buses

Mark Kletsel
dept. Electrical Power Engineering
S. Toraighyrov Pavlodar State University
Pavlodar, Kazakhstan
mkletsel@mail.ru

Alexandr Barukin
dept. Electrical Power Engineering
S. Toraighyrov Pavlodar State University
Pavlodar, Kazakhstan
alexbarukin@mail.ru

Bauyrzhan Mashrapov
dept. Electrical Power Engineering
S. Toraighyrov Pavlodar State University
Pavlodar, Kazakhstan
bokamashapov@mail.ru

***Abstract*—It is noted that the use of reed switches makes it possible to solve the urgent problem of building relay protection devices without current transformers. It is emphasized that for their fastening and regulation of the response parameters of these devices by changing the position of the reed switches in the vicinity of live buses, special structures are necessary. Four new designs are offered for mounting reed switches close to AC and DC buses. The first of them differs from the known ones by the availability of a clamp covering the bus, a plate on which n reed switches are fixed and a strap fastened with this clamp. The second one differs by a double ear clamp and two rotary arcs with ratchet drums with a reed switch. The third one differs by a L-shaped plate with reed switches and mounting angles. The fourth one differs by two rectangular beams with four through holes. The article describes how to control the parameters of protections tripping on the reed switches using these structures.**

Keywords*—protection, reed switch, design, fastening, bus, current lead

I. Introduction

One of the ways to solve the problem of building protections without current transformers (traditionally used to obtain information about current, including the newest protections [1–6]), which was repeatedly referred to at the CIGRE sessions as an unsolved problem of world power engineering [7, 8], can be the use of reed switches. To fix and change the position of the reed switches (they are the measuring tools of the new short circuit protection of electrical plants [9, 10]), special structures should be installed in the vicinity of current-carrying buses. There have been already made 20 patented models of such structures (for example, [11]). However, the work in the area has not been completed, and it will be necessary to build numerous structures for mounting the reed switches, since the possible options for their building largely depend on the location of the phases of the electrical plant, its voltage, type of switchgear (for example, [12–20]) and the design of current-carrying buses in the vicinity of which a reed switch should be installed. In this paper consider the designs developed by the authors for mounting reed switches, which make it relatively easy to place them near AC and DC buses of all types, and build measuring tools for current protection of various electrical plants.

II. Designs for Mounting Reed Switches in the Vicinity of AC Buses

A. First Design

The design [21] contains a plate 1 (Fig. 1), on the surface 2 of which clamps 3 fix n reed switches 4 in parallel and at the same distance from each other. One end of the plate 1 (Fig. 1, 2) is glued into the slot of the strip 5, attached with a bolt 6 to the clamp 7. The clamp 7 is put on a current-carrying bus 8 mounted on insulators 9 inside the sheath 10 of the closed conductor. The plate 1 is located so that its surface 2 coincides with the plane of the cross section of the bus 8. In plate 1, 2n holes 11 were made (Fig. 2), through which insulated wires 12 were fed from the contacts of the reed switches 4 to the opposite surface 13 (Fig. 3) of the plate 1. Insulated wires 12 with the help of clamps 14 and 15 are attached to the surface 13 of the plate 1. The insulated wires 12 through the connector 16, mounted on the surface 13 of the plate 1, with the help of the cable 17 are put through the hole 18 in the sheath 10 of the closed conductor and connected to the timing unit 19. The executive device 20 input is connected to the timing unit 19, and the output is connected to the circuit breaker.

As reed switches 4 MKA-20101 type reed switches can be used. The plate 1 and strap 5 are made of STED sheet fiberglass. The timing unit 19 can be made on a microcontroller series 51 of the manufacturer Atmel AT89S53. As the executive device 20, an intermediate relay of the RP-251 series can be used.

A device for maximum current protection with a measuring body in the form of a plate with reed switches works as follows. Before the protection tripping one of the n reed switches 4 is selected, by the tripping of which one identifies the presence of interphase short circuits (short circuit) at the end of a closed conductor or on the extending connections. To do this, determine the current I_{tr} in the current-carrying bus 8, at which the reed switch 4 is triggered. All reed switches 4 are mounted on the plate 1 in such a way that they have maximum sensitivity. So, in Fig. 1, all reed switches 4 are located at the angle $\alpha = 90^0$, where α is the angle between the longitudinal axis of the reed switch and a line perpendicular to it, located on the surface 2, connecting

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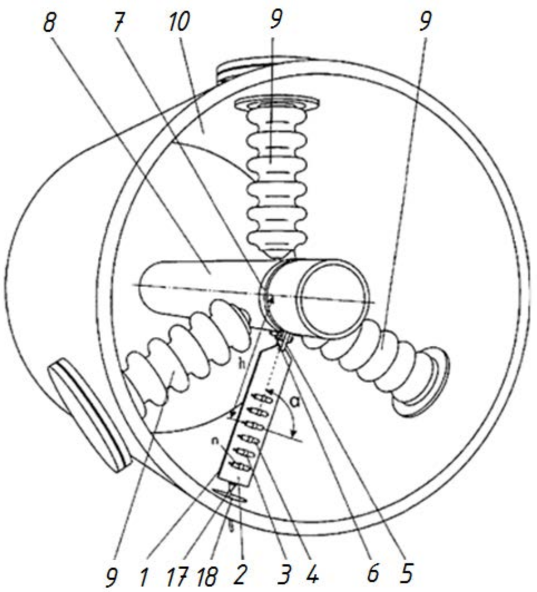

Fig. 1. Design for Mounting Reed Switches in the Vicinity of the AC Bus of a Closed Complete Conductor

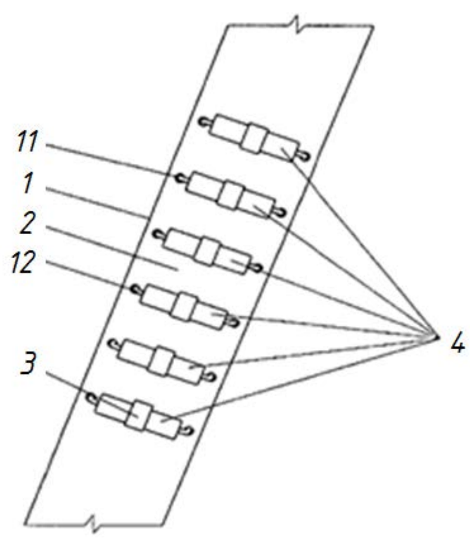

Fig. 2. View of the Plate from the Side Where the Reed Switches are Installed

the center of gravity of the reed switch 4 and the axis of the current-carrying bus 8. Therefore, the value I_{tr} is determined by the known distance h (Fig. 1) to the reed switches 4 and the magnetomotive force of tripping (m.m.f.) of the reed switches F_{tr} is determined according to the formula:

$$I_{tr} = 2\pi \frac{F_{tr} h}{l_c}, \tag{1}$$

where l_c is the length of the coil of the solenoid in which the m.m.f. is measured

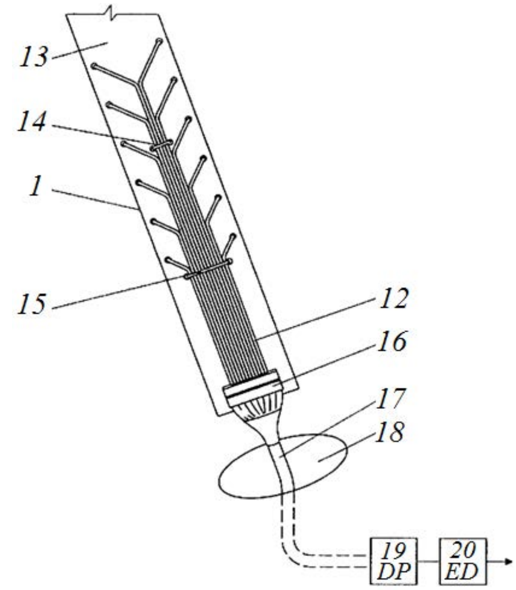

Fig. 3. View of the Plate from the Side Where the Wires are Fixed

It should be noted that for a more accurate calculation I_{tr} by (2), one should use the correction factors given in [22].

Further, check the possibility of using reed switch 4 to fulfill the inequality:

$$I_{SC.\min} \geq 1{,}5 I_{pr.tr} \geq 2 I_{tr}, \tag{2}$$

where $I_{SC.\min}$ is the minimum short-circuit current at the end of the protected area; $I_{pr.tr}$ is protection tripping current (on the current conductors of auxiliary needs of power plants, it is detached from self-starting currents of electric motors).

Providing that after selecting the protection tripping current $I_{pr.tr}$ and calculations according to formula (1), the right-hand part of inequality (2) is not satisfied, it is required to take information from the reed switch 4 located closer to the current-carrying bus 8, for example, at a distance h from it, calculate its trip current I_{tr} and then verify the fulfillment of inequality (2). If it is fulfilled, then the device is ready for operation.

With a short circuit between the phases at the end of a closed current path or on connections extending from it, the current flowing through the current-carrying bus 8 exceeds the protection tripping current $I_{pr.tr}$. Therefore, the selected reed switch 4 is triggered (closes the contacts) and through wires 12 via the connector 16 and cable 17 transmits a signal to the timing unit 19, which after a set time delay sends a signal to the input of the executive device 20, from the output of which a signal is sent to disconnect the damaged buses 8 from the network. In load modes, the tripping current I_{tr} is greater than the load current, and the reed switch does not work. Therefore, the device does not come into action.

B. Second Design

The design [23] (Fig. 4–7) contains two reed switches 1, a double ear clamp 2, two identical adjustment blocks 3, made in the form of rotary arcs 4 connected to the movable part of the fixed hinges 5, which are rigidly fixed on double ear clamps 2 by their stationary parts. At the end of each arc 4, a ratchet drum 6 with a catch hook 7 and with a locking screw 8 is movably fixed. A reed switch is fixed inside each ratchet 6 with a clamp 9 fastened by fixing bolts 10. A double ear clamp 2 with a bolt 11 and a nut 12 is fixed in the groove of the support insulator 13, which is attached to the current-carrying bus 14 of the complete current conductor with the sheath 15. The prototypes of structures were made by means of 3D printing, and PLA plastic was used as a consumable. For current conductors with a voltage of 15 kV, the mass of the proposed design (together with reed switches) will be 0.15 kg, and the occupied volume - $0.09 \cdot 10^{-3}\ \mathrm{m}^3$ (the mass of the current transformer and the volume occupied by it for this voltage are 25 kg and $8 \cdot 10^{-3}\ \mathrm{m}^3$, accordingly). Similar figures were obtained for the remaining designs presented in this paper.

For tripping of the reed switch placed in the vicinity of the current-carrying bus 14, the m.m.f. F_{tr} induced by the current with the value I_{tr} in the bus is required. If the reed switch is located (Fig. 7) at a distance h from the current-carrying bus 14 in a plane N, parallel to the bus (Δabc is located in the plane N), then, in accordance with the law of Bio-Savard-Laplace:

$$I_{tr} = H_{tr} / g, \tag{3}$$

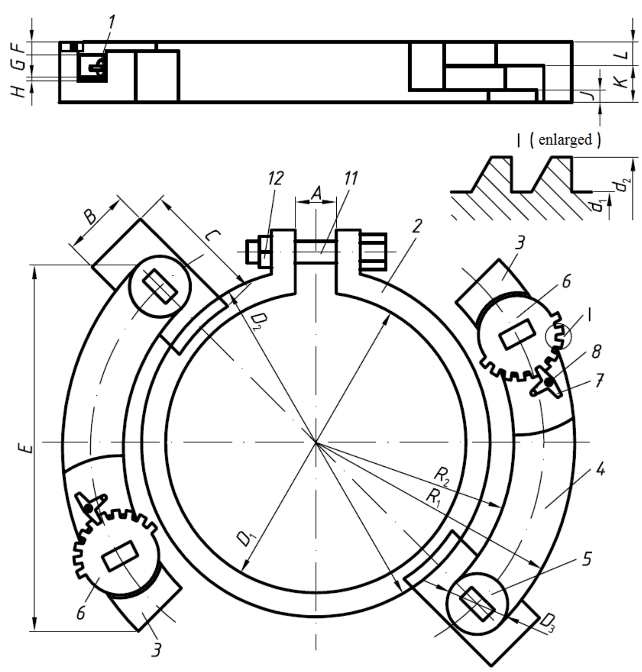

Fig. 4. Design for Mounting Reed Switches (General View)

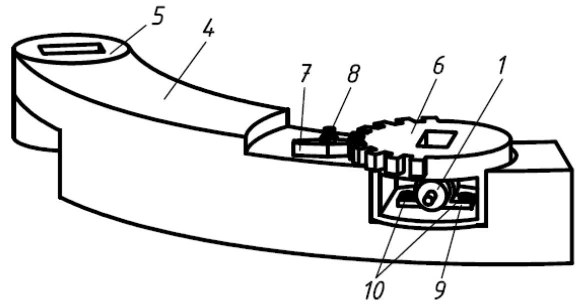

Fig. 5. Adjustment Unit

where I_{tr} and H_{tr} are the minimum values of the current in the current-carrying bus 2 and the intensity of the magnetic field generated by this current at which the reed switch is triggered (H_{tr} is directed along the contacts of the reed switch); g is the coefficient characterizing the location of the reed switch relative to the current-carrying bus 14, expressed with h, m, γ.

$$g = \frac{h \cos\gamma}{h^2 + m^2}, \tag{4}$$

where $m = \sqrt{2d^2 - 2d^2 \cos\beta}$ is the distance over which the reed switch moves as a result of changing the position of the rotary arc 4; d is arc chord; β is angle of rotation of the arc; γ is the angle between m and the longitudinal axis of the reed switch.

Fig. 7 shows two positions of the reed switch 1 - with $m = 0$ (solid line) and $m \neq 0$ (dashed line). According to (3), the minimum of the corresponding current function determines the coordinates of the reed switches at which they have maximum sensitivity.

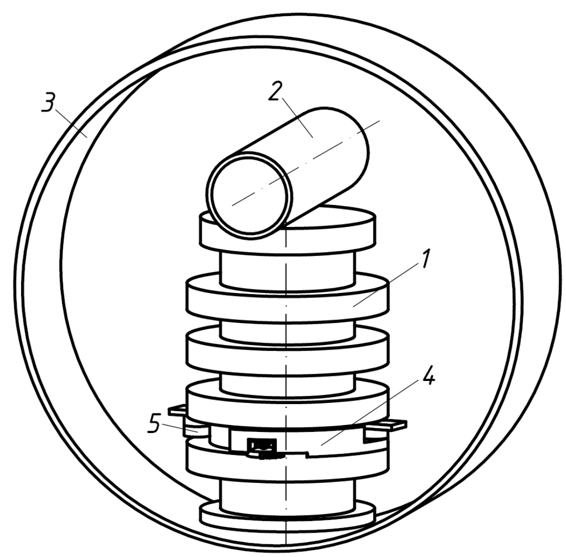

Fig. 6. Location of the Structure in the Complete Current Conductor

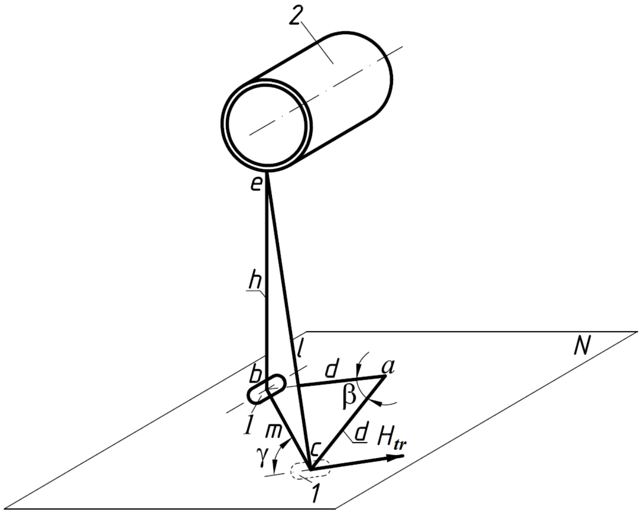

Fig. 7. Pattern for determining the m.m.f. acting on the reed switch

The adjustment I_{tr} is performed as follows. By rotating the movable part of the hinge 5 (Fig. 4), for example using a reversible screwdriver, extend the rotary arc 4 from the groove of the support insulator 1 by the angle β (Fig. 7) in the plane N. After the arc 4 has been extended (Fig. 4), the ratchet drum 6 located on it appears in the area accessible for regulation. The ratchet rotates the reed switch 1 (Fig. 7) for the calculated angle γ in the plane N after unscrewing the locking screw 8 (Fig. 4) of the catch hook 7 (then the latter is returned to its original position and tightened with a screw 8).

III. Designs for Mounting Reed Switches in the Vicinity of AC Buses

A. First Design

To mount the reed switches near the buses of closed DC conductors, a design [24] can be used that contains (Fig. 8, 9) an L-shaped plate 1, cable channels 2, covers 3 and 4, a mounting unit made in the form of mounting angles 5. On the shortened part of the L-shaped plate 1 through holes are made at the same distance from each other, inside which reed switches 6 are fixed. On the edges of this part, on the both sides of the plate 1, cylindrical protrusions with threaded holes are made, on which covers 3 and 4 are put and fixed with screws; the covers are made in the form of hollow rectangular parallelepipeds having, like the cable channels 2, located on their outer sides, through holes coaxial with the longitudinal axes of the reed switches 6 in which insulated wires 7 are fed (Fig. 10). On one end the wires are connected to the contacts of the reed switches 6, and on the other end - to the terminal block (not shown in Fig. 8-10). At the end of the elongated part of the L-shaped plate 1, angles 5 are fixed on both sides of the plate with the help of screws, making it possible to arrange the plate 1 in the magnetic field of the current-carrying bus 8 of the closed direct current conductor.

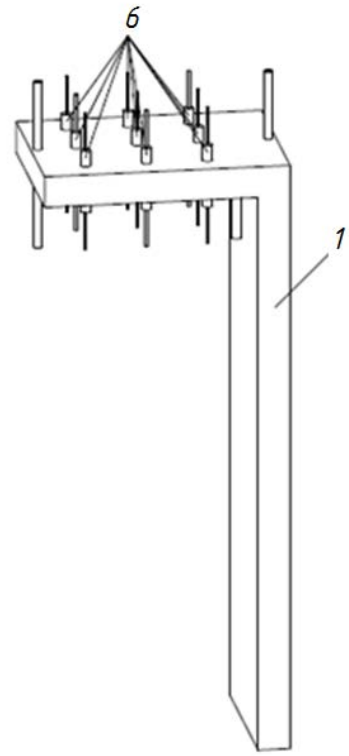

Fig. 8. General View of the Plate

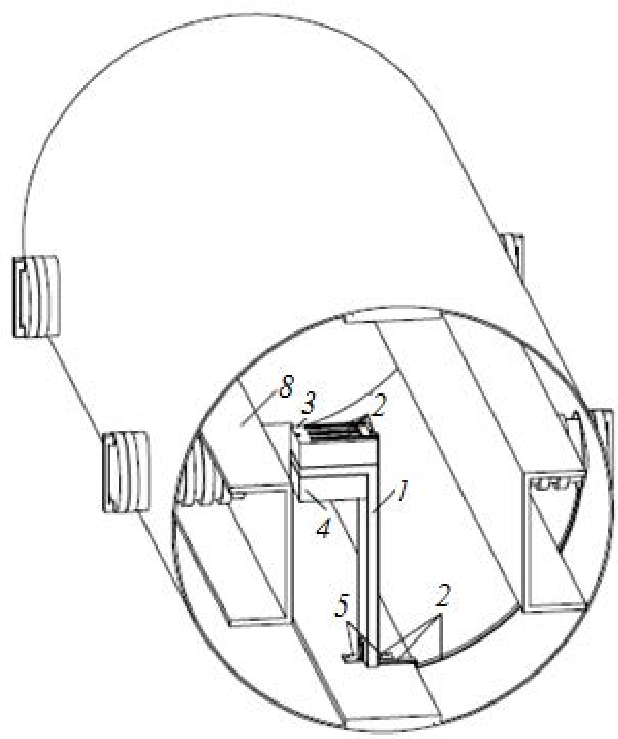

Fig. 9. Pattern for Determining the M.M.F. Acting on the Reed Switch

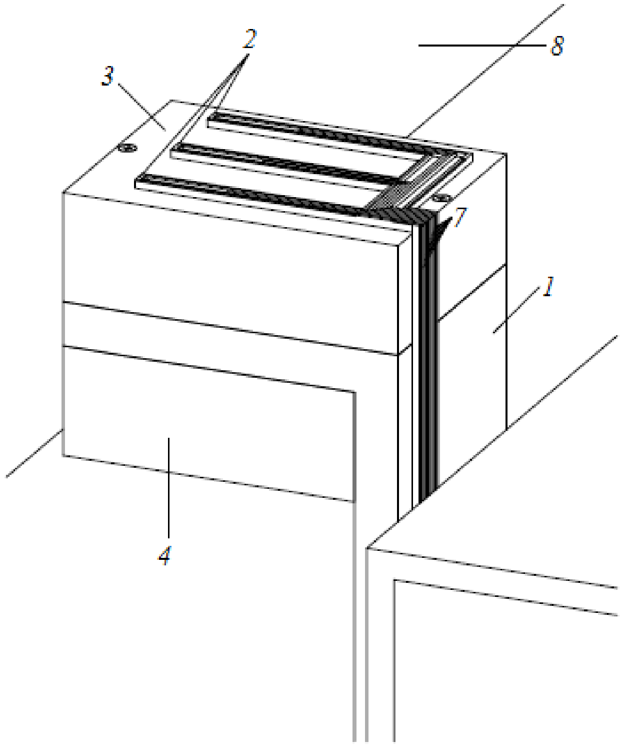

Fig. 10. The Location of the Structure Inside a Closed DC Conductor (General View in Isometry)

The proposed design can be also used for mounting magnetoresistors near the buses of closed DC conductors of converting installations. This design provides for the possibility of simultaneously mounting nine magnetic field sensors. When executing the protection circuit of a converter installation on reed switches and magnetoresistors according to the majority principle [20], this makes it possible to regulate the setpoint of its tripping by using three magnetoresistors located, in comparison with others, closer to the current-carrying bus 8, or, vice versa, farther from it. The developed design is simple and makes it possible to fix the reed switches or magnetoresistors in the vicinity of the buses of closed DC conductors, without requiring their structural changes.

B. Second Design

The proposed design [25] contains (Fig. 11): housing 1 with a parallelepiped cover. In one part of the housing 1, at its bottom, a rectangular protrusion 2 is made, across which a hole is made with an adjustment bolt 3 inserted into it; the bolt is passing through the groove of the first rectangular beam 4 located next to the protrusion 2. Adjusting bolt 3 is fixed with a nut 5. On the upper side of the first beam 4, a scale is applied. On the upper side of the protrusion 2 parallel to the longitudinal axis of its hole, a notch is made to visually determine the change in position of the first beam 4. On the first beam 4 with the help of a screw 6, a second rectangular beam 7 is fixed. Four through holes are made on the side of the second beam 7 at the same distance from each other; inside the holes four reed switches 8 are fixed parallel to each other.

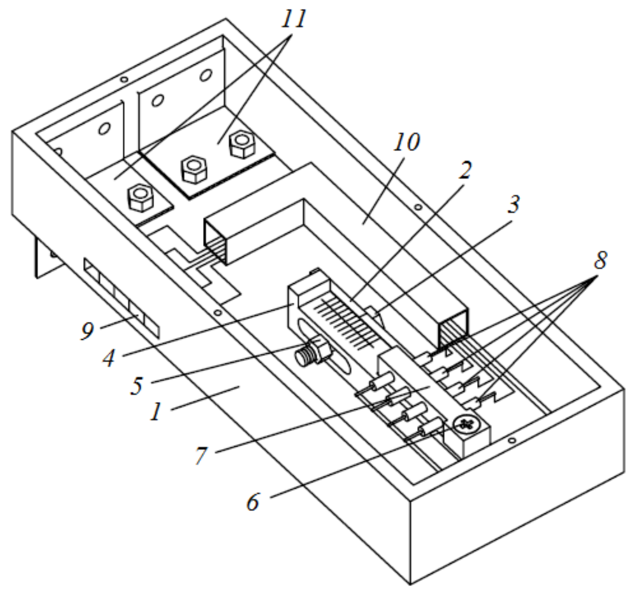

Fig. 11. General view of the structure (isometric)

A hole is made in one of the lateral walls of the housing 1, inside which a terminal block 9 is fixed, and along the second lateral wall in the central part of the housing 1 there is a cable channel 10 through which wires connecting the reed switches 8 to the block 9 are fed. In the other part of the housing 1, on the inside and outside its bottom four mounting angles 11 are fixed in pairs with bolts and nuts, designed to locate the proposed design with reed switches in the magnetic field of direct current conductors - for example, the housing 1 can be fixed to the bus with the angles 11 and clamps made of PLA plastic by 3D printing. In the same way, the housing 1, cable channel 10, the first 4 and second 7 beams can be made.

To change the range of protection tripping setpoints on the reed switches using this design, loosen the nut 5 fixing the adjusting bolt 3, move the first beam 4 within the length of its groove along the protrusion 2 of the housing 1, and then tighten the nut 5. Changing the position of the first beam 4 provides a change in the distance h from the DC bus to the reed switches 8, and consequently, a change in the currents I_{tr} inside at which the reed switches 8 will trip. Thus, the proposed design makes it possible to increase the sensitivity of the protection on the reed switches by expanding the range of their trip setpoints when the position of the first beam 4 is changed, as well as the reliability of tripping and failure by adjusting the setpoints precisely via controlling the position of the beam 4 scale relative to the notch on the protrusion 2 of the housing 1.

IV. Conclusions

The proposed designs are quite simple and make it possible to fix and change the position of the reed switches near the buses of alternating and direct current of all types. As preliminary calculations showed, in the course of implementation they (together with reed switches) should be hundreds of times lighter in weight and tens of times smaller in size than current transformers used to build traditional protections. The simultaneous use of several reed switches located at different distances from the buses in these designs provides the ability to control the response parameters of the protection in a wide range, which in most cases improves their sensitivity.

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