EE

Application of EVI and GDI in Electronic Equipment

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Reed Interface Parameter Correction

A new method to adjust the threshold level of the hercotrone parameters is considered. Hercotrones is a new family of electrical apparatus for the remote control and protection systems of the high power electric-vacuum devices. The paper also addresses the issues of the temperature compensation of the hercotrone threshold parameters.

Hercotrone Threshold Parameter Adjustment Methods

The first design solutions of the hercotrones [1-3] had no threshold adjustment unit. Further theoretical and experimental investigations showed, however, that under a mass production of hercotrones, their threshold parameters are subject to a sensible statistical noise. Besides, the parameters of the protected HV devices (high power electric-vacuum UHF units, X-Ray electronic tubes, etc.), or those of the associated circuitry have been found not stable either. These factors stimulated the R&D activity on developing an adjusted threshold level hercotrone to provide for a possibility to regulate the threshold level under particular operational conditions.

As of today, there exist several strategies to adjust the hercotrone threshold level (see Fig. 1).

The 50 kV hercotrone design employs an adjustment method based on the axially displaced MEC (the sealed magnetically excited contact). The simplest version of it contains two hermetically sealed cylinder insulators, one of which (the stationary) encapsules the control coil, while the other (the dynamic) encapsulates the MEC. The insulated couple is placed into the joining unit, which is equipped with a fixation module providing the relative fixation of the two dielectric cylinders.

The modifications derived from this base design are simple and reliable in operation and include a multichannel hercotrone with an independent threshold control on each of the channels. The control characteristic curve of this adjustment method can be approximated by this non-linear polinomes:

$$I_{thr} = 0.021\,(0.01\,|\,s\,|)^3 + 0.42 \qquad (1)$$

$$I_{thr} = 0.258\,(0.01\,|\,s\,|)^2 + 0.53 \qquad (2)$$

here

(1),(2) - the threshold current values for a MEC with and without ferromagnetic screening, respectively; *s* - distance between the longitudinal axes of the MEC and the control coils.

This method is limited by applications requesting not a wide range of the threshold adjustment, since the latter would require to displace the MEC off the coil field limits, which would, in turn, reduce the interference immunity of the device. This shortcoming can be eliminated either by extending the existing ferromagnetic screen (along with the stationary insulator), or by adding another screen, which would move with the dynamic insulator and (in combination with the first screen) create a zone of uniform screening, irrespective of the stationary cylinder displacement [4]. This action, albeit, may lead to the considerable increase of the device dimensions, which gets to be critical for a number of applications.

An adjustment method based on the longitudinally displaced MEC with respect to the U-shaped magnetic system is implemented in the in the design for the operational voltages higher than 50 kV (see Fig. 2). This design provides for an increased diameter shell, which will at minimum be equal to the double insulator wall thickness plus the length of a MEC. This provides for larger diameters of the electrostatic screens of the MEC and the control coil, respectively, which, in turn, reduces the electric field intensity between them. The described method is not as effective under the lower operational voltages, since the dimensional requirement remains almost the same causing the disproportion between the size and the operational voltage level.

Another threshold regulation methods calls for the displacement of the ferromagnetic core with respect to the MEC and the control coils. The MEC and coils, in this case, can be switched via a HV cable, which ensures their fixation. Practical realizations of this technique require limited, though., since they require a high complexity design to provide for the HV requirements.

The relative fixation of the MEC and the control coils is also achieved in the hercotrone with the isolated permanent magnet control unit [5]. The field intensity of the magnet is computed to be at such a level, which is not sufficient to trigger the MEC but strong enough to impact the field intensity in the MEC vicinity. Again, the adjustment range of this method is limited by the correlation between the magnitude of the magnet field vector and the initial magnetomotive force of the MEC. It is quite effective, though, to lower the MEC sensitivity by the counter directed fields of the electric and permanent magnets.

Another appropriate application of this latter design is the "memory" unit hercotrone, where the MEC (once triggered) stays in the closed condition under the field of the magnet.

The most effective threshold adjustment method for a wide range of applications is shown in Fig. 3, a.

The design (that implements this principle for a range of applications with the operating voltage from 10 to 50 kV) has the best mass and dimension indices, a very high sensitivity and can serve as a base solution for a whole family of interface relays, including but not limited by the following:

- relay with a multiplication module of the output channels (up to 6 channels);
- differential interface relay;
- relay with a three-phase thyristor control unit;
- relay with an output power amplifier module;
- quasi-analog current meeter.

One can reach additional functionality by adding a coil to a low voltage potential MEC, which ensures an automatic, as opposed to a manual, threshold level adjustment. The signal to this additional coil can be supplied either by a pre-programmed controller, or depending on the mode of the protected circuit. As such, the threshold current level will be defined not only by the hercotrone coil at the HV potential, but also by the low voltage correction input.

Some applications require hercotrones capable of providing a vector of predefined features. The threshold adjustment implementation in these cases can be rather involved, so a separate adjustment module have been developed in [6]. It is compatible virtually with all base designs and provides a wide adjustment range. The dimensional characteristics of a hercotrone system with this module, however, are not as good as those of the above described configurations.

Temperature Compensation Methods of the Hercotrone Parameters

It is know that the circuit current under the constant voltage and variable ambient temperature is changing according to the following equation:

$$I = (1 + \alpha t)^{-1} U / R_0 \qquad (3)$$

here

R_0 - control coil resistance under ambient temperature of 0 °C;
α - temperature coefficient of resistivity;
t - ambient temperature.

Experimental investigations have shown that the operational condition temperature range for hercotrones lays between -50 and +70 °C. Another sensible factor is the coil overheating coefficient. With this in mind, it becomes apparent that the hercotrone threshold current can vary by as much as a factor of two! This problem has stimulated the research and development of the methods of the threshold current correction to compensate for the temperature impact.

One of the most obvious schematic resolutions is a serial/parallel inclusion of a negative /positive TC into the hercotrone control coil. The negative TC can only be used if the coil is not subject to the overload current conditions (which is, alas, not the case in many practical applications), since it has a very narrow overload margin. The operational coil current has to be low too because of the limited active power that can be dissipated by the TC. The positive TC decreases the sensitivity of the device.

Another solution is the magnetic system

with the temperature dependent magnetic conductivity (see Fig. 3b). The horizontal part of the U-shaped core has to be fixed just in the center point and is combined with memory element (made of titanium nickelid or copper alloys). Theoretically, onecan use a usual bimetal alloy. This configuration, however, is not stable in the high mechanical impact or vibration environment.

The most efficient method involving no dynamic parts is based on the temperature dependent magnetic permeability of the hercotrone magnetic system core. High permeability *Mn-Zn* ferrite (e.g., 6000 HM type) possesses this particular permeability-temperature property (see fig. 5). The magnetic system resistance $R\mu$ as well as the Ohmic resistance of the coil now changes in an inversely proportional law with a change of temperature:

$$R\mu = l / (\mu\ S) \quad (4)$$

here

l - the length of the magnetic system;

S - the length of the magnetic system;

$\mu = f(t)$ - magnetic permeability of the core.

The $\mu = f(t)$ relationship for the material in question can be well approximated by

$$\mu = 54.69\, t + 5000 \quad (6)$$

which turns (4) into

$$R\mu = l / S\, (54.69\, t + 5000)^{-1} \quad (7)$$

To provide a constant magnetic flow in the system:

$$\Phi = I\, W / R\mu = U\, W / (Z\, R\mu) \quad (8)$$

where

W, U, Z - number of turns, impedance and operational voltage of the control coil, respectively,

one has to meet the condition, which is a combination of (3), (7) and (8):

$$UW = k\, I\, R_0\, (1 + \alpha\, t)\, (54.69\, t + 5000)^{-1}\ / S \quad (9)$$

here

$k \sim \Phi$ - proportionality factor, derived experimentally.

It can be shown that based on (9), onecan find an optimal vector of the hercotrone static and operational parameters, which would ensure the constant flow in the core irrespective of the ambient temperature. Resolving (9) with respect to t:

$$t = k(IR_0 - 5000UWS/k)(54.69UWS - kIR_0\,\alpha) \quad (10)$$

we can introduce a condition:

$$5000UWS = (IR_0\,\alpha)^{-1} = k \quad (11)$$

Equation (10) in the light of (11) takes the form of:

$$(I\, R_0 - 1)(54.69UWS - 1) = k^{-1}\, t \quad (12)$$

which shows that k is merely a proportionality factor between the hercotrone parameters and the temperature and therefor is independent of the latter.

Therefore, if the hercotrone parameter vector is chosen in such a way that (11) holds, the threshold current becomes independent of the temperature.

Technical solutions described above provide a reliable ground for the correction of the hercotrone parameters in the wide functional range, which helps to considerably expand their field of application.

REFERENCES

1. New Schematic Solutions for the HV Control Systems Based on Hercotrones / V.P. Gerasimov, V.I. Gurevich, A.G. Nechaev et al. // Problems of Nuclear Science and Technology. Series: Electrophysical Equipment. - 1985. - No. 22. - pp. 33-38.
2. V.I. Gurevich, P.I. Savchenko Gercotrones Are New Devices for the Remote Control of the HV Circuitry // Electronic Engineering. Series 4. Electrovacuum and Gas Discharge Devices. - 1984. - No. 4(103). - pp. 57 - 59.
3. V.I. Gurevich. Fundamentals of the Hercotrone Design / Magnetic and Solid-State Components for the Conversion Technology // Ryazan Radio Technology Institute. - 1983. - pp. 73-79.
4. USSR Patent 1196967. A High Voltage Commutation Device / V. I. Gurevich, K.K. Namitokov, et al. // Discoveries, Inventions. - 1985. No. 45.
5. USSR Patent 1130916. A Reed Switch Relay / V. I. Gurevich, A.G. Mnukhin, P.I. Savchenko, et al. // Discoveries, Inventions. - 1984. No. 47.
6. USSR Patent 1130916.A High Voltage Commutation Device / V. I. Gurevich, P.I.

Savchenko, et al. // Discoveries, Inventions. - 1986.
No. 37.

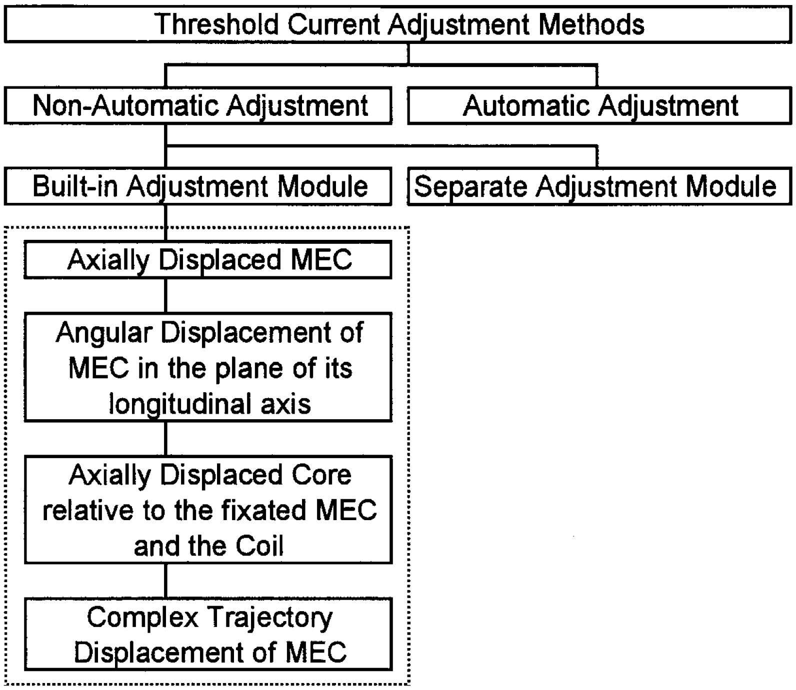

Fig. 1. Classification of the hercotrone threshold current adjustment methods.

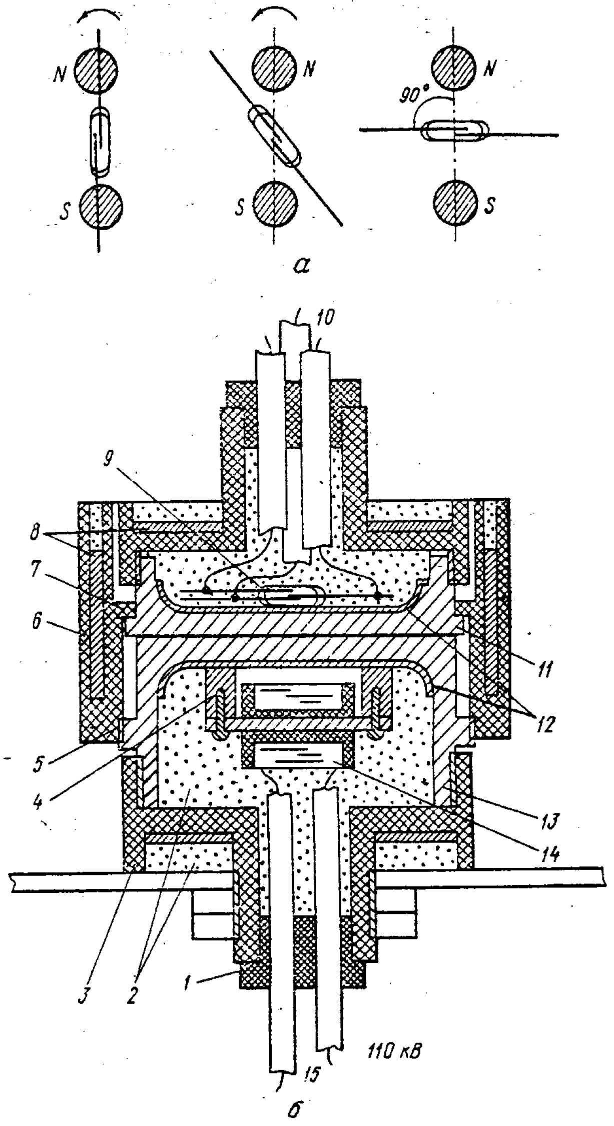

Fig. 2. The 50 kV hercotrone with the built-in adjustment module:
a - MEC displacement scheme; б - longitudinal cross-section of the hercotrone: 1 - fixator; 2 - isolating compound; 3 - insulator lid; 4 -core; 5 - thread joint; 6 - ring fixator; 7 - insulator joint module; 8 - ferromagnetic screens; 9 - MEC; 10 - HV cable; 11 - moving insulator; 12 - electrostatic screens; 13 - static insulator; 14 - control coil.

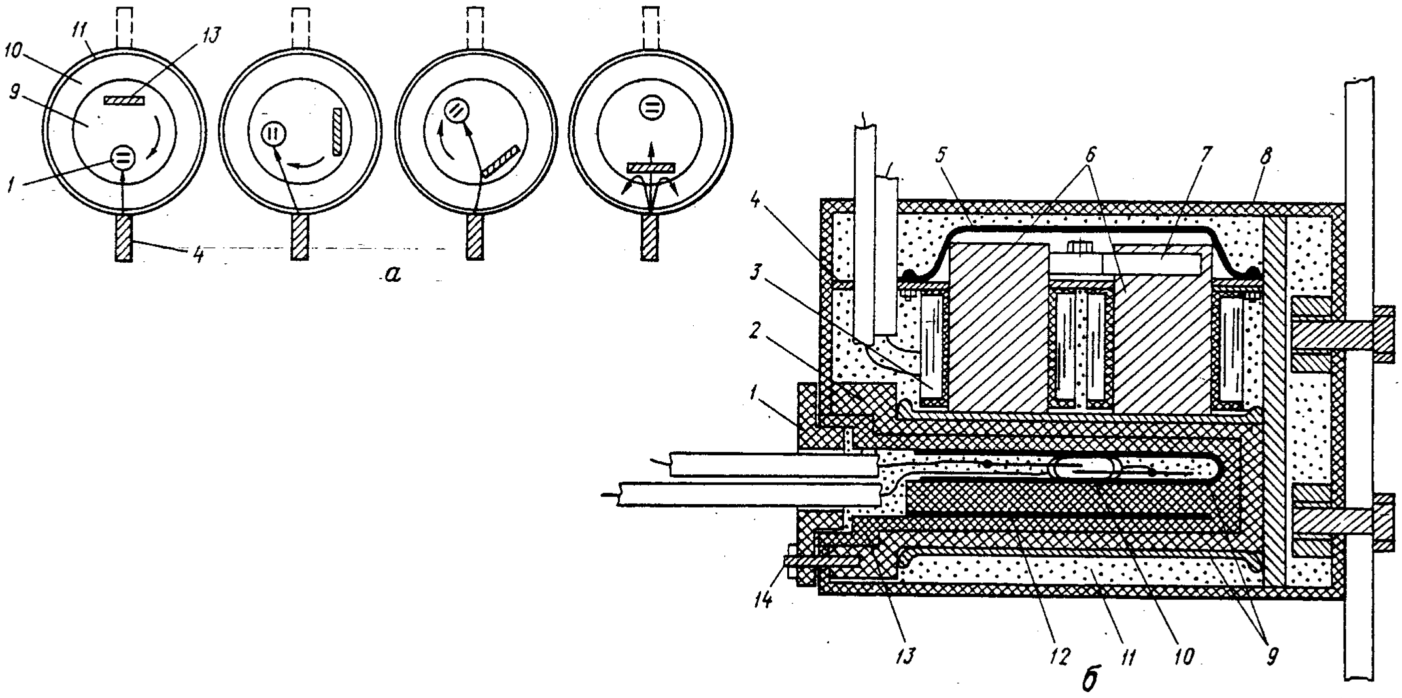

Fig. 3. The 10-50 kV hercotrone with the built-in adjustment module:

a - MEC displacement scheme; б - longitudinal cross-section of the hercotrone: 1 - limb; 2 - static insulator; 3 - control coil; 4 - plate; 5 - insulating lid; 6 - static core; 7 - moving core; 8 - hercotrone body; 9 - electrostatic screens; 10 - MEC; 11 - insulating compound; 12 - ferromagnetic bypass; 13 - moving insulator; 14 - fixating screw.

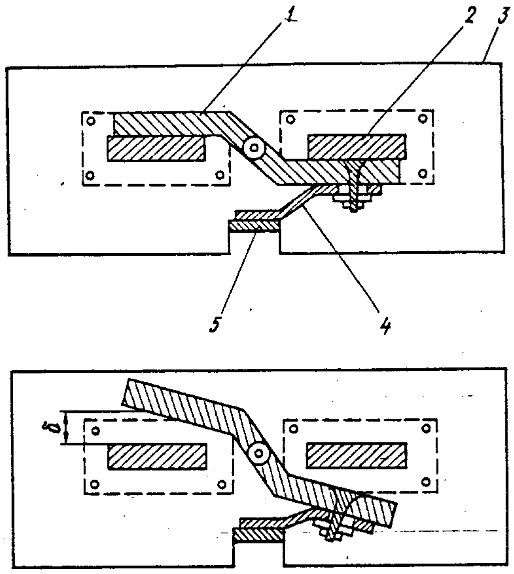

Fig. 4. Temperature compensation module: 1 - moving core ; 2 - static core; 3 - plate; 4 - temperature sensitive component; 5 - shelf.

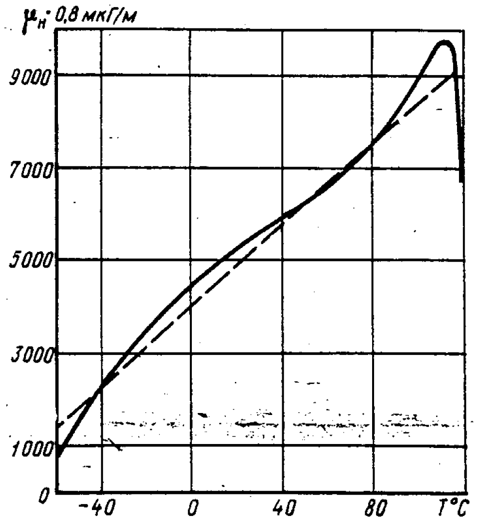

Fig 5. Permeability-temperature relationship for the 6000 HM ferrite.