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NEW DESIGN PRINCIPLES OF THE OVERCURRENT PROTECTION BASED ON MAGNETICALLY EXCITED CONTACTS (MEC)

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The popularity of the overcurrent protection based on the magnetically excited contacts grows very rapidly. Industry produces MEC-based current relays of the CTG series for the low voltage circuit applications. The high voltage protection circuits can utilize a MEC located in the insulation-wise admissible vicinity to a high voltage current-carrying bus [1-4]. However, in many cases, the MEC sensitivity is not sufficient even for the power network relay protection and automation needs, let alone less powerful HV electric and radio-electronic equipment.

Besides, MEC application in the AC protection circuitry is associated with MEC plate vibration which exceeds the network frequency by a factor of two. The output signal is, therefore, not compatible with the DC input requirements of the standard control and protection systems, and also drastically reduces the commutational capacity of a MEC.

Hercotrones are the high volatge isolating interfaces, which have an enforced insulation level (up to 100 kV) between the control coil and the output circuitry represented by a MEC [5,6]. Their invention made it possible to find a conceptually new approach to the control and protection issues of the low current (0.5 .. 5 Amps) high voltage radio-electronic equipment.

The present paper lays out the new principles of the overcurrent protection design based on the non-coil hercotrones for the range of the operational currents between 25 and 5000 Amps.

Fig. 1 features the cross-sectional design of the overcurrent protection system (OPS), based on the non-coil hercotrone and the build in solid-state converter. The OPS is mounted directly on a HV bus of the protected equipment, while its output is serially connected through an auxilarry relay to a DC low voltage power source.

The magnetic field of the current carrying bus excites the MEC whose pulses are then converted into a standard binary signal compatible with the relay protection devices.

Fig. 2a shows the solid state transducer circuitry with a MEC as a triggering component. The sensitivity of this module is directly proportional to the sine of the angle α between the longitudinal axes of the MEC and the HV bus and is inversely proportional to the distance *h* between these axes. Keeping in mind that for the MEC operating in the field of the current carrying bus, the operative (F_{op}) and the release (F_{rel})magneto-motive forces are respectively adequate to the operative and the release current in the bus, one can say:

$$I_{op} = F_{op} (K_h \sin \alpha)^{-1} \quad (1)$$

$$I_{rel} = F_{rel} (K_h \sin \alpha)^{-1} \quad (2)$$

where I_{op}, I_{rel} are the values of the current in the bus causing the triggering and the release of the MEC, respectively;

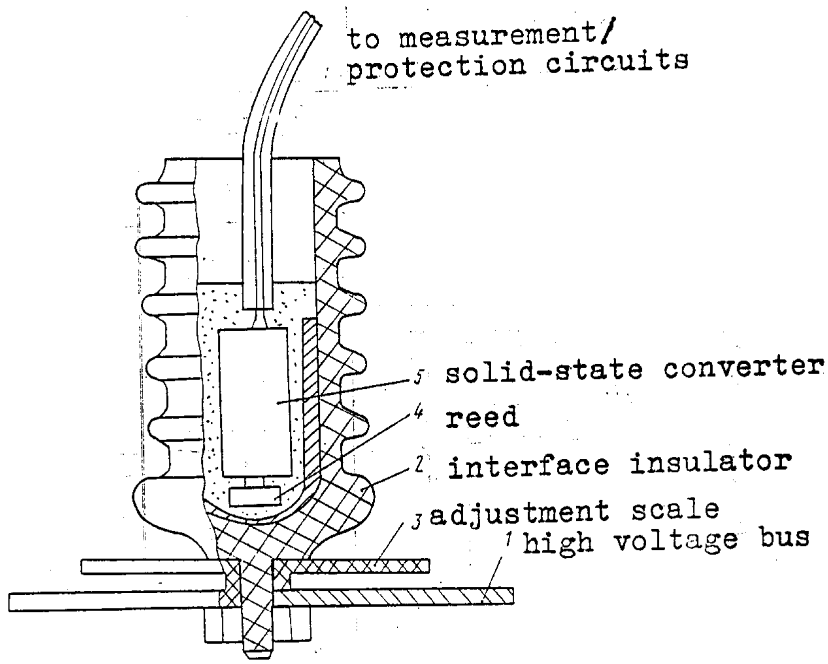

Fig. 1. An Overcurrent Protection System.

K_h is a remoteness factor accounting for the distance between the longitudinal axes of the MEC and the bus.

Therefore, by rotating the OPS with respect to its longitudinal axis, one can set up the opreative current at different values. The limb scale 3 (see Fig. 1) provides the refernce point for the fixation of the pre-set oprative current.

The solid-sate converter is based on a transistor filter with a peculiar parameter vector, which is explained below. Excited by an AC magneto-motive force, the MEC generates rectangular pulses, duration of which is t_p and the space is the t_s see Fig. 2b). Capacitor C_k is supposed to gain the full charge during period tp, i.e. the full charge time must satisfy the following condition:

$$\pi \mathbf{R_H} \mathbf{C_k} \leq \mathbf{t_p},$$

which defines the capacity:

$$\mathbf{C_k} \leq \mathbf{t_p} (\pi \mathbf{R_H})^{-1} \quad (3)$$

During the discharge period of C_k, the transient voltage free component attenuation on the $R_б$ resistor is not supposed to exceed a given load pulsation factor Kп.

$$\mathbf{Kп = U(t_s) / U,}$$

where U, $U(t_s)$ - nominal voltage and voltage drop on the load at the end of the pulse space, respectively.

(If the load R_H is represented by a control coil of an auxiliary relay, than this pulsation factor can be expressed trough the relay reset ratio).

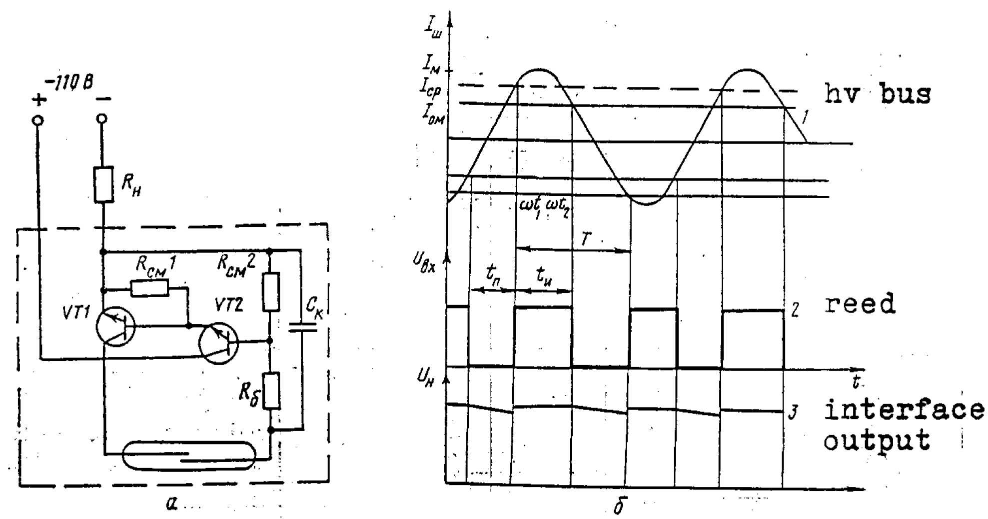

Fig. 2. a) The solid-state converter circuitry with a MEC as a triggering component; б) The AC operational oscillogram.

The above requirement can formally be expressed as

$$\mathbf{Kп \geq Exp(-t_s / (R_б C_k)),}$$

where $\tau = R_б C_k$ - the discharge time constant.

The resistance of $R_б$ should, therefore, satisfy the condition:

$$\mathbf{R_б \geq t_s (-Ln(Kп) C_k)^{-1}} \quad (4)$$

Oscillogram in Fig. 2b shows that the duration of pulses generated by the MEC is

$$t_p = \omega^{-1} (\omega t_2 - \omega t_1), \quad (5)$$

where the current phases ωt_2 and ωt_1 are, respectively, given by

$$\omega t_1 = Sin^{-1}(I_{op}/I_m) \quad (6)$$
$$\omega t_2 = \pi - Sin^{-1}(I_{rel}/I_m), \quad (7)$$

where I_m - the current amplitude.

Based on (1), (2), (6) and (7), the MEC pulse duration takes a form of

$$t_p = \omega^{-1} (\pi - Sin^{-1}(I_{op}/I_m) - Sin^{-1}(I_{rel}/I_m)) \quad (8)$$

The pulse duration and space are related to each other by

$$t_p = T - t_s$$

where T is the pulse period, which under the sinusoidal form of the current in the bus is equal to π;

or, taking into account (8)

$$t_p = \omega^{-1} (Sin^{-1}(I_{op}/I_m) + Sin^{-1}(I_{rel}/I_m)) \quad (8)$$

By incorporating (8) and (9) into (3) and (4), we finally get:

$$C_k \leq (\pi - Sin^{-1}(I_{op}/I_m) - Sin^{-1}(I_{rel}/I_m)) (\omega \pi R_H)^{-1} \quad (10)$$

$$R_б \geq (Sin^{-1}(I_{op}/I_m) - Sin^{-1}(I_{rel}/I_m)) (-Ln (K_П) \omega C_k)^{-1} \quad (11)$$

Thus, expressions (10) and (11) define the parameter vector for the above solid-state converter.

The operational speed of the described device does not exceed a quarter of the (HV bus) operative current period. With one of the most sensitive MECs of the CEM-2 series, the minimal operative current in the bus, which can still be sensed by the OPS is about 300 Amps.

One can considerably increase the sensitivity of the OPS with the solid-state converter employing an elementary coil as a triggering device (see Fig. 3). The electro-motive force induced in this coil by a short-circuit current, is applied as the input to the amplifier-invertor VT1-VT3. The latter opens thyristor VS, which, in turn, shunts rectifier VD1 at the DC side. This causes the voltage drop at load Z_H, which, again, can be represented by the control coil of an AC auxiliary relay. To get a feeling about the sensitivity, we have used the control coil of the AR21-110 relay as the L component (see Fig. 3). The sensitivity of the device in this case is about 10 .. 15 Amps. As in the previous OPS version, the sensitivity is directly proportional to the sine of the angle between the longitudinal axes of the coil core and the HV bus.

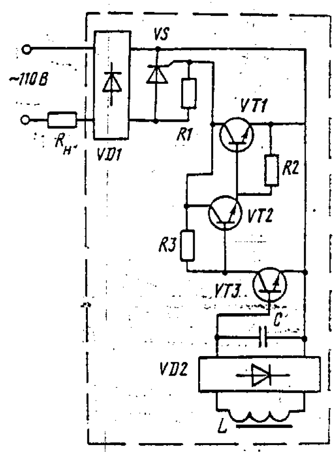

Fig. 3. The solid-state converter circuitry with an elementary coil as a triggering component.

It is well known that in most cases the current transformers are used not only for the relay protection, but also for the current measurement purposes. With this in mind, the non-transformer modules of relay protection must account for the measurement needs. We did find a couple of references [7,8] discussing this type of non-transformer measuring devices. However, these technical solutions are not applicable for the high voltage applications. Besides, they employ some non-conventional measuring devices, which are expensive and not available commercially.

The analog current meter module shown at Fig. 4 is free from the above deficiencies. It can be used both for the high voltage and low voltage applications and is compatible with the standard types of current meters. A proportional to the network current magnitude signal is induced in L1 and L2 and is, therefore, applied to the VT1-VT2 amplifier. The latter in combination with the rectifier VD4 forms a variable resistance in the primary circuit of the TA compatibility transformer. As such, the magnitude of the current in the bus defines the value of this resistance, and, ultimately, the reading of the current meter.

Experimental investigations have shown that the measurement accuracy is very sensitive to the angular (order of 1 .. 2 degrees) tuning of the OPS. To decrease this level of criticality, the triggering module is implemented in the form of the couple of the contra-serially connected coils. They are placed one above another, the projections of their longitudinal axes forming an acute angle and the more remote coil being switched through the voltage multiplier.

Therefore, the described current measuring module together with the above discussed devices make it possible to factor the current transformer out of the relay protection system, which considerably reduces the weight and unreliability characteristics of the latter.

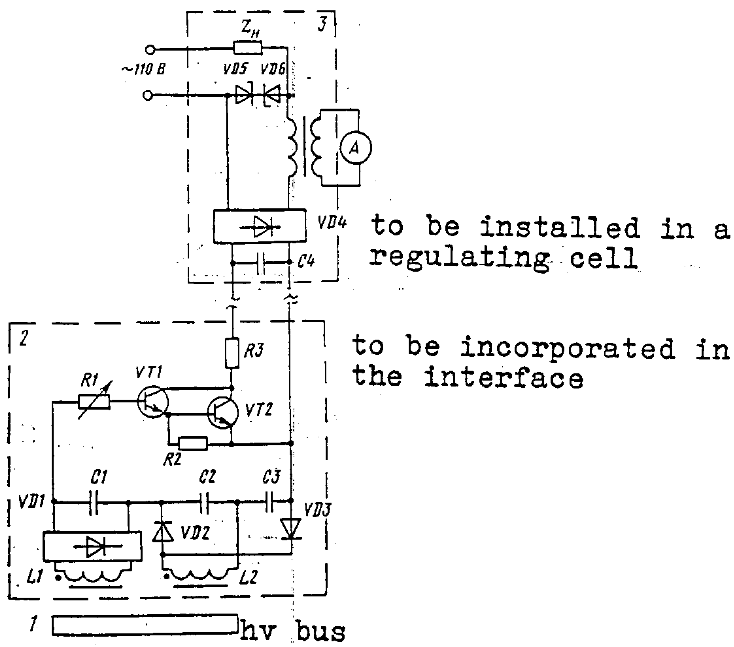

Fig. 4. A non-transformer current measuring module.

References

1. Polyakov V.E., Popov N. M. Overcurrent protection based on MECs // Industrial Power Engineering. - 1975. - No. 11. - pp. 43-44.

2. Kotlyarchuk V.A., Kluev M. Yu. MEC Current Transducers // Electrical Engineering Industry. Series: Low Voltage Devices. - 1981. - No. 2(93). - pp. 28-30.

3. Kontaktronowy czion czujnikowy na duze praudy state / Bolanoswky Boleslaw, Tarczunski Witold // Prz. electrotech. - 1988. -64. - No. 4. - pp. 11-13.

4. Kletsel M. Ya., Mussin V.V. Non- transformer Relay Protection Systems Based on MECs // Electrical Engineering. - 1987. - No. 4. - p. 11-13.

5. Gurevich V.I., Savchenko P.I. Hercotrones 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.

6. Gurevich V.I., Namitokov K.K., Savchenko P.I. Hercotrones and Their Application in Engineering // Power Engineering (News of the Higher Educational Establishments). -1989. - No. 5. - pp. 55-58.

7. USSR Patent 531087. An AC Current Transducer / A.I. Artemov // Discoveries, Inventions. - 1974. No. 21.

8. USSR Patent 1339740. A Transfomer Current Transducer / L.P. Shichkov, V.A. Trifonov, O.P. Mohova // Discoveries, Inventions. - 1987. No. 35.