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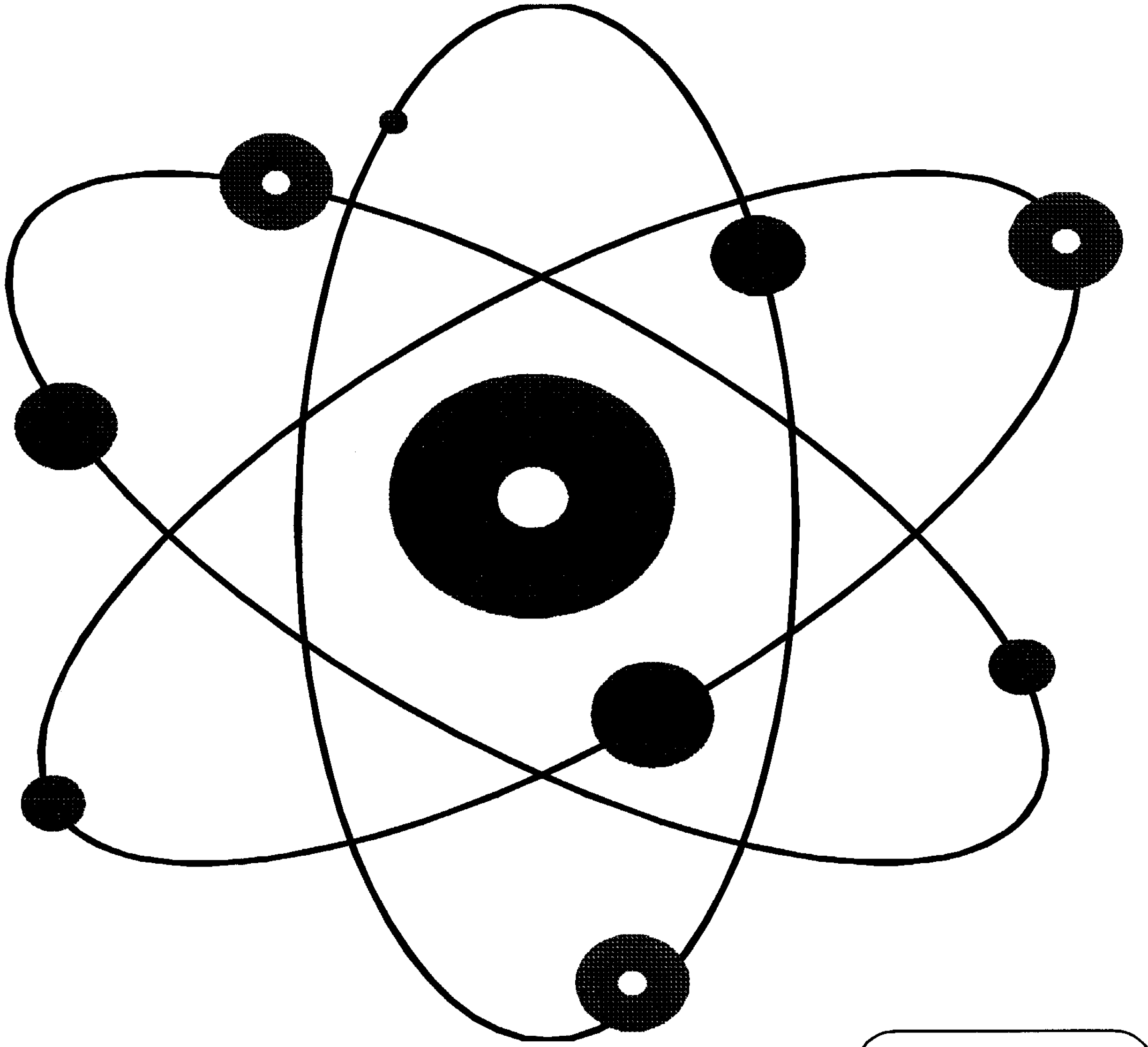

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New Relay Technology
for the Power Network System Automation

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Tendencies in the relay technology development. Maximum current protection relays are the basic components of the network control and protection systems. Their usage in power supply systems is overwhelmingly large, so the problem of improving their cost and performance indices is quite essential.

Analysis of the tendencies in the domestic relay technology development shows that the major relay developers do not share a solid and consistent direction of the current relay design improvement. For instance, the leading experts of the VNIIR research institute [1] reason that the certain families of electric-mechanical relays, currently in mass production, need to be replaced by the static IC relays. At the same time, they claim that regular electric-mechanical relays (including the maximum current relays) are most reliable and affordable for many electric utility companies, and will, therefore, be used in majority of control and protection systems. The VNIIR specialist also agree that the same tendency is typical for the major foreign competitors (ASEA, «AEG-Telefunken», BBC, «GEC-Measurement»).

Cheboksary Electrical Apparatus Plant has considerably changed the design specifications of the popular CR-40 electric-mechanical relay claiming that it does not comply with the modern network requirements and should not be further used in new control and protection circuitry. At present, they launch the static IC based current relays designed by the VNIIR back in 70s [2].

However, the operational experience with static relays shows that their reliability level leaves a lot to be desired. The IC based static relays have been reported [3] to malfunction due to the EMI from the commutation of the electromagnetic relays working in their vicinity. Unfortunately, instead of researching the ways to improve the robustness of the static relays, the VNIIR designing community recommends to equip the non-static commutational equipment with the EMI damping circuitry.

Needless to say, this kind of recommendations do not stimulate any enthusiasm with the power system maintenance personnel, who under the pressure of the plant-monopolist (reducing the production volumes of CR-40) have no choice but to use the static relay hardware. It is important to note that the CR-40 is a high speed relay, which is insensitive to the pulse and high-frequency interference and surge voltages. It exhibits a very robust behavior in overload modes and has a satisfactory reset ratio. One has to agree, though, that electric-mechanical relays usually consist of many high precision expensive components, the production of which becomes cost inefficient for the relay manufacturer, especially nowadays.

A dynamic measuring system with exposed contacts reduces the required relay reliability in dust and gas intensive environment under a constant vibration factor. Besides, the need to clean and adjust the contacts increases labor intensity of the personnel.

Static relays, however, have a lower complexity and a better assembly factor, since they consist of standard radio components mounted on PCBs. They require zero maintenance and are decently robust to an environmental and mechanical impact.

At the same time, the threshold components, such as IC triggers and comparators as well as the transformer by means of which ICs are connected to the high current circuits cause an entirely new range of problems related to the interference immunity issue [4-7]. The threshold components happen to be extremely sensitive to the high frequency signal interference, pulse peak interference coming through the feeding circuitry, etc. Therefore, it is difficult to filter out the useful signal in the wide spectrum noise background for these components.

The input relay transformer - an interface between the highly sensitive electronic module and the high current circuit - transforms the useful signal as well as the noise. Besides, in many occasions, the transformer itself becomes a source of the interference. While this issue is very critical for the static relays, the electric-mechanical relays are well compatible with transformers, that's way the transformer-based interfaces have found a wide range of applications in relay protection engineering.

The above analysis shows that in spite of a number of advantages typical for each of the considered classes of relays, they both have obvious deficiencies. This fact seemingly causes a lot of confusion among the designing community. One of the major deficiencies is the requirement for an expensive and bulky current transformer needed as interface to the high voltage buses. Keeping in mind that many types of switchgear boxes are not inherently equipped with the current and power meters, and that the current transformers are used solely for the purpose of feeding the meters, it becomes obvious that the transformers have to be replaced by less expensive and more efficient devices. More over, many experts suggest that the analog current meeter in the HV switch gear boxes do not justify the their presence and should be replaced with a discrete meter, which would differentiae between the “idle”, “norm” and “current overload” modes. This would also eliminate the need in the current transformer.

Prospective for the relay systems based on the magnetically excited contacts (MEC). We have used the above considerations as a basis for the new methodology in a current relay design to combine the advantages of the two relay concepts (electric-mechanical and static). The basic guidelines of the new methodology are as follows:

- the threshold component, which, in principle, is a measuring organ has to have an electric-mechanical structure to ensure interference immunity;
- it is expedient to use a MEC equipped with a special module to move the former relative to the control coil (analogous to the one in CR-40);
- to ensure the compatibility of the MEC specifications with the output commutation component, an interface unit should be implemented with the discrete electronic components (not ICs) having wide current and voltage margins; the number of these components has to be minimal and their schematics should not result in a threshold circuitry (such as a trigger, comparator, monostable, etc.)

Relay designers are well familiar with these technical characteristics of MECs: high level of protection from the environmental impact, extreme reliability, large commutational recourse, zero maintenance requirements. It is less known, however, that their reset ratio in the AC magnetic field is about 0.8 ..0.9, and the pickup ratio (not to be confused with its statistical variance) is relatively stable and its adjustment function has been technologically resolved. The problem of the statistical variance of the magnetomotive force becomes irrelevant with the introduction of the MEC adjustment module. The initial value of the relay can be defined at the manufacturing stage.

In [8], we have suggested a radically new resolution of the MEC based isolating interface to an HV bus without a transformer.

Notably, MEC based convertors can e implemented both as a discrete and an analogous transducer. A MEC exposed to a sinusoidal magnetomotive force generates pulses, interval of which is proportional to the amplitude of the primary current [9]:

$$t = (\pi - 2\sin^{-1}(\,Ip/Im\,))\,/\,\omega\ ,$$

t - pulse duration
Ip - expected pickup value of the primary current
Im - amplitude value of the primary current
ω - circular current frequency

These pulses can be easily integrated by an RC-circuit, and the total integrated signal is an indication of the current magnitude in a HV bus. We have also found a technical resolution of the MEC based DC transducer [10,11].

Implementation of the new design concepts. The described new principles have been implemented in a whole new family of relays including the CR-40 maximum current relay and the VR-53 maximum voltage relay equivalents, the non-transformer interface relay (having no analogous), and a new switch gear protection relay for the short circuit open arc protection. The issue of the effective and reliable arc protection development is as important as that of the maximum current protection improvement. Conventionally used arc protection relays are based on the photo- or gas pressure transducers, which fail to provide the required level of reliability and interference immunity.

The base module shared by all the mentioned relays is show in fig. 1.

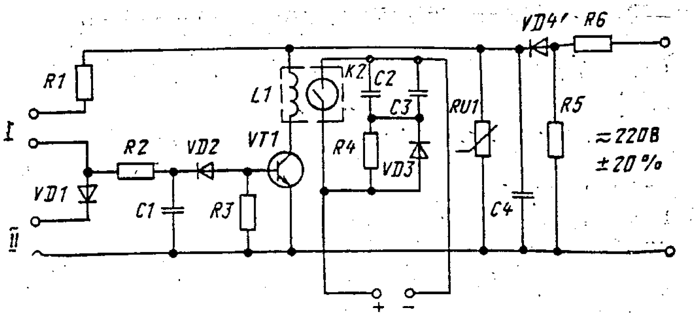

Fig. 1. Quasi electronic transducer.

Maximum current protection relay. As the circuit configuration implies, it does not contain an IC; its active solid-state component (transistor) does not constitute a threshold element and is merely used as an amplifier. An interface between the electronic circuit and the outside network bus is implemented via a MEC based relay (fig. 2), which consists of the input coils *L1* and *L2* and the *K1* MEC connected to the input *I*. The MEC is encapsulated into an isolating cylinder (which, virtually, isolates the whole electronic module from the HV bus). *K1* also plays a role of a threshold element, which starts vibrating with the double network frequency when the relay trips. The contact-erosion-free resource of the MEC (about 10^7-10^8 operations) along with the short period of the maximum current relay's on-state, ensure the required commutational resource of the relay.

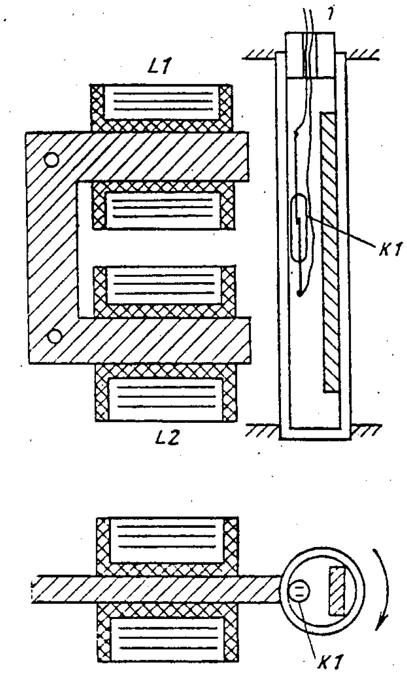

Fig. 2. An isolating interface based on a MEC.

The amplifying module of the base circuit (fig. 1) is nothing but a compatibility link between the integrating couple *L1C1* and the output relay *K2*, which provides for the stability of the on-state of the relay under the *K1* vibrating condition.

The feeding voltage of *VT1* (KT 605BM series) does not exceed 50 .. 70 V, the operating voltage range being 250 V. The control coil current under the tripping relay condition is as low as 7 mA, while the maximum collector current limit is 100 mA. This magnitude of the current and voltage margins ensure a high level of the relay operational reliability.

The high frequency and short pulse interference at the relay input cannot migrate to the electronic module, since *K1*, being the interface link, due to the inherent inertia, does not react to the high frequency control signals. Neither does it respond to the to the transient interference from the power circuit commutation. Therefore, the whole relay turns to be very robust to the power circuit pulse interference.

The effect of the magnetic component of the dissipation fields can be neutralized by introducing the ferromagnetic screens into the relay design. The 1 mm screen shields the MEC in the fields with the intensity much higher than that of the dissipation fields under the actual operation conditions. The output relay *K2* also includes a MEC because of the specific operational mode of a protection relay: which can be in hot redundancy for months (if the protected circuit remains normal).

The mechanical and electrical micro erosion along with the humidity, dust, and active atmosphere gases creates low conductivity films on the surface of a (ordinary) relay with exposed contacts, which drastically decreases its commutation capability. The MEC family is free from these deficiencies. The only weak point of a MEC is its low compatibility with the inductive load commutation requirements (a typical example of the latter is an auxiliary relay control coil). The contacts tend to get "welded" even under a low intensity arc condition that normally follows an inductive commutation process. That is why we have equipped the output CEM of the DC interface relay with an effective arc suppression circuit, which makes it possible to switch on up to 10 parallel auxiliary relays of the AR-23 type without an arc. The AC MEC interface relays are equipped with the TC112-10-7 thyristor. The computational principles of the MEC parameters and those of the integrating circuit and the transistor, as well as the compatibility issues between the MEC and the thyristor switch are covered by us in [9].

The relay threshold level adjustment is achieved through the angular displacement of the dielectric capsule (containing the eccentrically mounted MEC, see fig. 2) with respect to its longitudinal axis. This changes the spatial position of the MEC with respect to the poles of the magnetic system (comprised by the core and the *L1*, *L2* coils, similar to those of CR-40). The new relay can be implemented in the CR-40 body.

Maximum voltage relay. The implementation of this relay is identical to the previous one with the exception that the current coils are replaced with the voltage coils .

Current relay with the a non-transformer interface. This relay employs a special transducer (the so called windingless hercotrone) instead of *L1, L2* and *K1*. The transducer is mounted directly onto a HV bus and does not require the current transformer [9]. The threshold level adjustment is achieved through the angular concentric displacement of the inner insulator with respect to the outer one. The MEC is switched to the *I* terminals, while the *II* terminals remain idle.

Arc protection relay for unit substations (US). The *I* and *II* terminals of the base module are now switched to the MEC outputs of the HV transducers (see fig. 3), mounted, respectively on the two feeder buses of the US input circuit as well as on all the US outputs. Under short-circuit condition that happens outside of the US boxes the short circuit currents trip both the input and (at least one of) the output MECs. As a result, a signal is applied both to the tripping terminals *I* and the prohibiting terminals *II*, the combined effect of which provides a zero signal at the output of the electronic module.

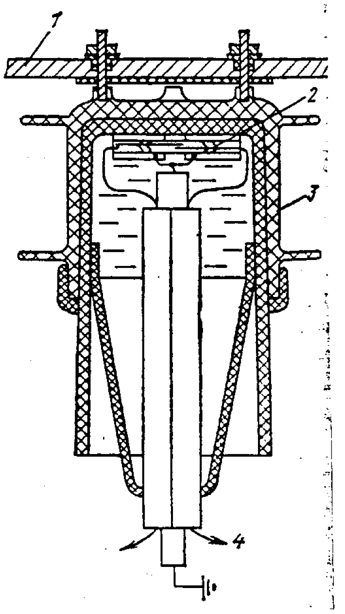

Fig. 3. A HV transducer for the US arc protection relay: 1 - HV bus, 2 - MEC (K1), 3 - interface body, 4 - relay output.

However, under an arc short-circuit condition, at the SU buses, the short-circuit current trips only the input MECs (i.e. terminals *I* get a signal, while terminals two get no signal). As a result the output of the electronic module is one, thus triggering the commutation component with an approximately 0.1 sec delay, which, in turn, gives a signal to turn off the main circuit or blocks the time relay of the maximum current protection of the US.

For the cable feeders based arc protection , the described relay is modified to include a transducer, which is mounted onto a tree-phase cable with the enforced armor (fig. 4).

The described relay family is being designed and investigated at the «INVENTOR» Science and Technology Enterprise (Kharkov, Ukraine).

The new relays significantly improves the reliability of the control and protection systems for the low and medium voltage power distribution networks.

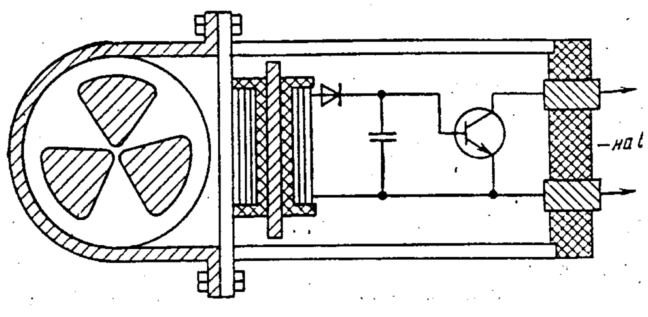

Fig. 4. A modified transducer for the cable feeders protection.

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