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Active Protection of Electronic Equipment against the HEMP

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Abstract: *In the article proposed the method of active protection of electronics against high altitude electromagnetic pulse (HEMP). The proposed solution involves the remote tripping (by radio, cellular communication GSM, or Ethernet) of power source and shortening of all inputs and outputs during the standby periods when the electronic equipment must remain inoperative.*

Keywords: *Electromagnetic pulse, HEMP, protection of electronic equipment, active protection*

1. Introduction

The ever-growing use of high-sensitive computer and microprocessor equipment within the control and automation systems applied in all major national infrastructures and, particularly, in electric power systems, results in the constant increase in vulnerability of infrastructure to high-altitude electromagnetic pulse (HEMP) [1]. Since this hazard is well known to military experts continuously working to increase the electromagnetic energy component of the high-altitude nuclear explosion, the proper methods capable of ensuring adequate electronic equipment protection against HEMP must be available.

Essentially, the electronics located inside the screened body (or inside the well protected cabinet) is virtually invulnerable to HEMP, provided that it is switched off and all its inputs and outputs are shorted.

On the other hand, a complete set of special means, including special construction materials, screened rooms, screened cables, surge arresters, filters, chokes, and special grounding systems [1], is required to ensure the HEMP protection of permanently operating electronics. Such means are deemed as passive. Each mean provides only the partial protection of equipment, therefore to ensure complete protection, the full set of all such means must be applied.

Thus, HEMP immunity of enabled and disabled electronics (with shortened inputs and outputs) differs dramatically. The only problem is that the disabled equipment with shortened inputs and outputs does not operate! Is this true? Certainly, the disabled equipment cannot operate. However, there are many types of on-line electronic equipment performing only certain functions within the very short periods of time. For example, there are devices measuring the parameters and duty cycles upon the equipment monitoring. Devices of this type can be active during one or more minutes of each hour or even once a day, or a month. During the remaining time they are in standby mode. Some kinds of such devices are not critical and do not require HEMP protection since they are not able to cause a disaster if damaged upon the HEMP impact. However, many diagnostic and monitoring devices of this kind use factory installed main controllers of basic equipment to gather the data of such basic equipment.

Therefore, such controllers must remain operational, even when the equipment is inactive to maintain the periodic operation of auxiliary monitoring electronics. This principle, for example, is used in systems consisting of wide apart 500–1000 kW emergency diesel generators, monitored from the remote control center on a continuous basis. This signifies that in order to ensure the periodical monitoring (once a month) the main controller of diesel generator must operate permanently, so it is not adequately protected against HEMP. Upon the main controller damage, the modern diesel generators cannot be started, so in an emergency, (after the HEMP impact) the standby power sources will not be operational.

The suggested method of active protection can help to solve this problem.

2. Active Protection Method Of Electronic Equipment

Initially, the author suggested a method of active protection of electronics against external electromagnetic effects in 1996 [2]. Later, in [3, 4], it was amended and clarified.

Active protection of electronics means that the devices designed for periodic operation are disabled remotely and all their inputs and outputs are shortened for the standby periods. When needed, the devices are remotely enabled (by radio, cellular communication or computer network) and their inputs and outputs are unlocked. Therefore, during the standby periods (i.e. most of the time) the device is provided with the highest HEMP protection (disabled rarely and for a very short time period).

It is quite clear that in order to prevent the protected electronics from penetrating HEMP during the standby phase, the unprotected remote control device must be provided with high voltage insolation from the protected electronics. As for the protecting device, including the remote control unit, there are no specific requirements to the HEMP immunity of such a device, since it does not directly impact the operability of the main equipment (the main equipment can be activated when the protecting device is disabled) after HEMP impact, such a protecting device must be dismounted and discarded.

3. Active Protection Device For Electronic Equipment

The proposed active protection device for electronics (APD), see Fig. 1, is basically a compact unit consisting of three components: multicontact low-voltage electromechanical relay LVR, two high-voltage relays HVR1 and HVR2, and a remote control unit RCU.

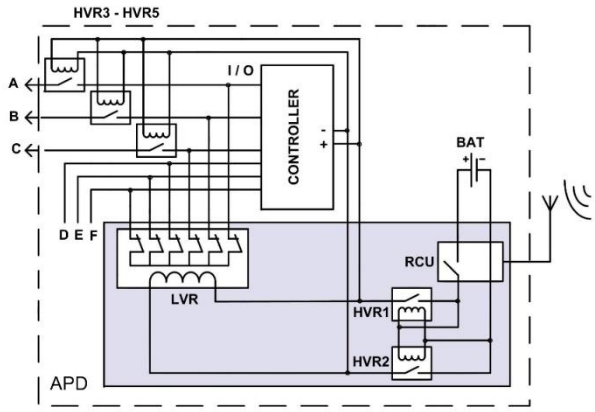

Figure1. *Active protection device for electronics (APD); LVR – multicontact low-voltage electromechanical relay; HVR – high-voltage relay; RCU – remote control unit; A, B, C – inputs and outputs of electronic equipment connected to a long cables run beyond the protected area; D, E, F – inputs/outputs used within the protected area.*

Its principle of operation is simple and clears (Fig. 1). In standby mode, all inputs and outputs of the protected device (such as the controller) are shortened (shunted) and its power supply is disconnected. In order to protect the internal circuits of such a device against high-voltage pulse penetrating through the permanently enabled remote control unit, HVR1 and HVR2 relays are provided with their own internal isolation. Alone, the remote control unit does not require protection, since it is designed to operate only under the normal conditions and its damage by HEMP does not influence the operability of the protected electronics.

If there is a hazard of high-voltage pulse penetration through the long cables connected to the electronics and run beyond the protected area, (such as cabinet enclosing the equipment) such cables must be connected to electronics inputs/outputs through the contacts of additional high-voltage relays (HVR3- HVR5).

Upon the remote instruction, the remote control unit activates the high-voltage relay, energizing the controller and feeding the multicontact relay coils which unblock the controller's inputs and outputs. At this time, the controller is ready for operation. After an operation, the device reverts to the original state upon the remote instruction. If some external circuits connected to the controller inputs cannot be shortened, the changeover contacts of multicontact relay may be used instead of normally closed relay contacts, see Fig. 2. These contacts will disconnect the external circuit before the controller inputs/outputs are shortened.

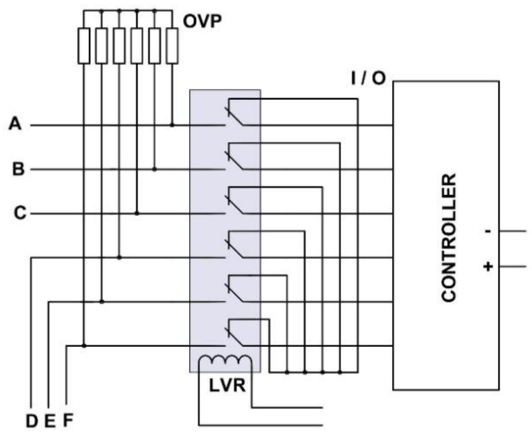

Figure2. *Application of LVR changeover contacts when external circuits are not allowed to be shortened. OVP – over voltage protection components (such as varistors) ensuring relay contacts protection against the HEMP high-voltage pulse entering the device through the external cables A, B, C.*

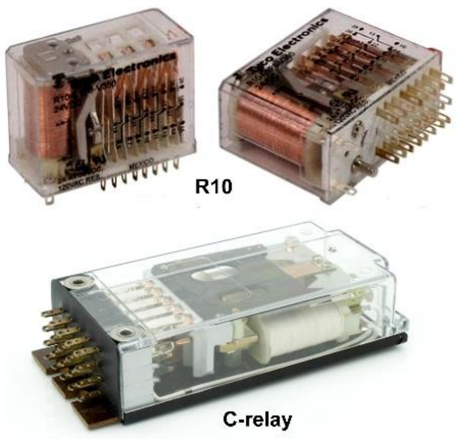

Figure3. *Multicontact electromechanical relays (8 or 9 changeover contacts) type R10 (Tyco Electronics) and type C (Mors Smitt).*

The number of contacts on the LVR relay must correspond to the number of inputs and outputs on the protected electronics. Usually, the proposed electromechanical relays contain a maximum of 8 – 9 changeover contacts, see Fig. 3, such as relay type R10 (Tyco Electronics); relay type C and relay type D8-U200 (Mors Smitt), etc. Where applicable, several relays with its control coils connected in parallel can be used.

Another option – out of the box relay modules consisting of 16 separate miniature relays, each with a single changeover contact, mounted on the compact printed boards provided with standard wire terminal strips, see Fig. 4.

Figure4. *Relay modules*

Alternatively, the flat thin modules of miniature relays to be installed on the standard DIN-rail makes a difference, see Fig. 5, and can be applied.

Figure5. *Flat thin relay modules to be installed on the standard DIN-rail.*

In fact, any number of such modules mounted in line on DIN-rails located inside the cabinets can be installed.

Today, the market proposes a wide choice of devices to be implemented as the remote control units RCUs. For that purpose, the enclosed remote power switches controlled over the Ethernet can be used, see Fig. 6. However, they are rather expensive (200–300 USD). The switches of this type contain network interfaces and output electromagnetic relays pickups upon the special code transmitted over the network. Contacts of such relays ensure connection and disconnection of the external devices.

Figure6. *Remote power switches*

The so-called network relays, or Ethernet relays, see Fig. 7 (20–30 USD) can also be used for the same purpose.

Figure7. *Network relays with a different number of channels and output electromagnetic relays.*

Also, the remote control can be performed using the GSM remote controllers, see Fig. 8 (100–150 USD).

Figure8. *GSM remote controllers (Global System of Mobile Communications – GSM).*

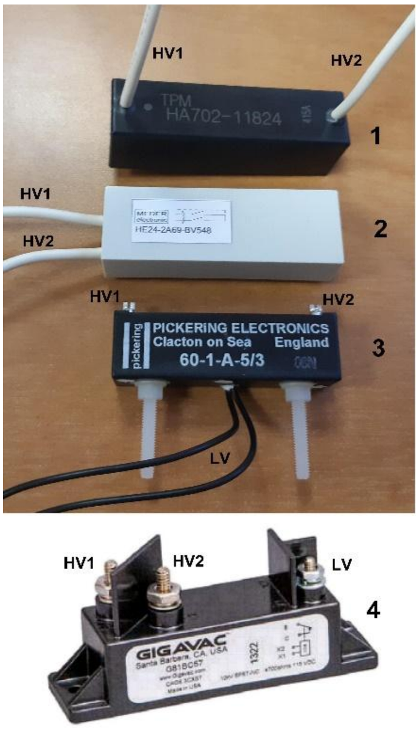

Figure9. *High-voltage reed switch relays selected for impulse insulation strength test. 1 – type HA702-11824; 2 – type HE24-2A69-BV548; 3 – type 60-1-A-5/3; 4 – type G81AB47. HV1 and HV2 – outputs of high-voltage reed switch, LV – outputs of low-voltage control coil.*

High-voltage relays (HVR) containing high-voltage contact separated with the high-voltage isolation from the control coil (10–50kV and above) are produced by such manufacturers as Meder Electronics, TPM Sanyu Electric, Pickering Electronics, SPS Electronic, Cynergy 3, Kilovac, Gigavac, Bright Toward Industrial, Gunther, Ross Engineering, Struthers-Dunn, Comus, etc. Basically, the relays of this type can be categorized as follows: low-power relays (50 W, 7.5–20 kV DC) and high-power relays (1 – 3A switching current, 35 – 70 kV DC and above). These two relay categories also significantly differ from each other in cost (60 - 100 USD for low-power relays and 400 – 1000 USD for high-power relays). Since the proposed solution does not require the high-power switching ability under the high voltage, the high-voltage miniature relays based on a vacuum sealed reed switch are the most suitable for this purpose. Sometimes, the rated breakdown strength of such relays (7.5 – 20kV) is unable to ensure the reliable isolation upon HEMP, since its electric field strength can reach 50 kV/m. However, these parameters are rated by relay manufacturers of continuous DC voltage. Moreover, it is known that the dielectric breakdown strength rises significantly under the pulse voltage, while HEMP is a very short pulse. However, neither manufacturer could not inform about the value of the impulse insulation strength of its products. Thus, the author performed its own tests.

For testing 4 types of high-voltage reed switch relays of different makes were selected and presented by different manufacturers for the tests, see Table 1, Fig. 9.

Table1. *Basic parameters of high-voltage reed switch relays tested upon the pulse voltage*

Type/Parameters	60-1-A-5/3	HA702-11824	HE24-2A69-BV548	G81AB47
Manufacturer	Pickering	TPM Sanyu Electric Inc.	Standex-Meder Electronics	Gigavac
Dielectric strength between contacts, kV peak	15	18	20	11
Dielectric strength contact to coil, kV, peak	-	-	25	-
Max. switching current, A	3	3	3	-
Max. carry current, A	3	4	5	5 (10)
Max. switching power, W	50	50	50	-
Contact capacitance, pF - in data sheet - measured in whole device	0.15 4.0	- 4.5	0.8 4.5	- 3.6
Cost, USD	60	100	104	190

4. Test Results

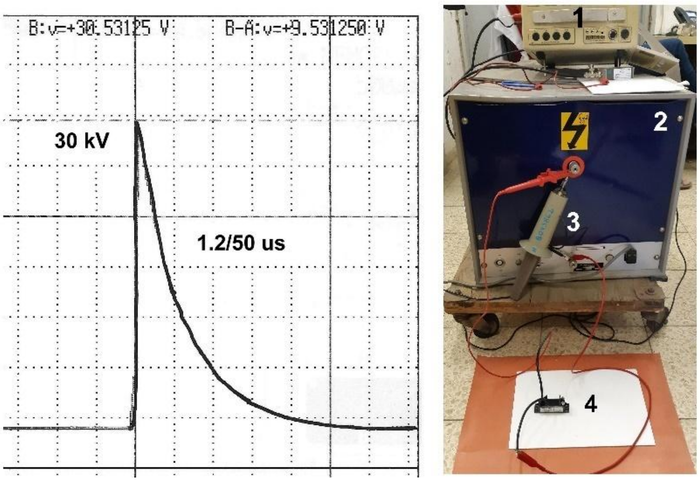

Figure10. *Test pulse and test bench. 1 – memory oscilloscope type Hioki 8835; 2 – high-voltage pulse generator type P35 (Haefely); 3 – high-voltage divider with output ratio 1000:1; 4 – tested relay.*

All relays were tested with the pulse voltage of 1.2/50 µs and amplitude of 30 kV, see Fig. 10, applied to the open contacts as well as between the contacts and the control coil.

All relays successfully passed the test and confirmed our initial suggestion that the high-voltage relays with rated insulation strength of 10 – 15 – 20 kV were capable of withstanding much higher pulse voltages. It means that they can be used for ensuring effective protection of electronics against HEMP.

Due to the significant difference in cost, the final choice of the relay may depend on the consumer budget and the required reliability. For example, the relatively expensive relays type HE24-2A69-BV548 produced by the German company Standex-Meder Electronics contain two in-series high-voltage reed switches and ensure the largest rated isolation value. Accordingly, it can be suggested that they can withstand the larger amplitude of pulse voltage compared to the relays of other types, therefore they have the significant advantage in terms of HEMP protection.

5. Conclusion

The proposed solution for active protection of electronic equipment against HEMP can be fully implemented with the components available on the market and easily integrated into the HEMP protection projects realized for the certain equipment types.

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Vladimir I. Gurevich, was born in Kharkov, Ukraine, in 1956. He received an M.S.E.E. degree (1978) at the Kharkov Technical University, named after P. Vasilenko, and a Ph.D. degree (1986) at Kharkov National Polytechnic University. His employment experience includes: teacher, assistant professor and associate professor at Kharkov Technical University, and chief engineer and director of Inventor, Ltd. In 1994, he arrived in Israel and works today at Israel Electric Corp. as a senior specialist and Head of section of the Central Electric Laboratory.

He is the author of more than 200 professional papers and 15 books and holder of nearly 120 patents in the field of electrical engineering and power electronics. In 2006 he was Honorable Professor with the Kharkov Technical University.

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