Improvement of HEMP Resilience of Automatic Fire Suppression System

Vladimir Gurevich

Central Electric Laboratory, Israel Electric Corp., POB 10, Haifa 31000, Israel

***Abstract* - Automatic fire suppression systems, employing microprocessor-based equipment and microelectronic components connected via long cables with numerous sensors branched on a large area, are very sensitive to High Altitude Electromagnetic Pulse of nuclear explosion (HEMP). Unpredictable actuation of these systems, with prior automatic disconnection of electric equipment as a result of HEMP impact, can lead to serious accidents in power systems. The article discusses the ways to improve resilience of automatic fire suppression systems of critical electric equipment.**

Keywords-Fire Suppression Systems; High Altitude Electromagnetic Pulse; HEMP; Protection.

I. INTRODUCTION

Explosion of nuclear ammunition at an altitude of more than 30 km results in occurrence of an electromagnetic pulse near the earth surface with the field gradient of up to 50 kV/m. Due to extensive and expanding use of low-voltage highly-sensitive microelectronic and microprocessor-based equipment in power industry, the electromagnetic pulse of high-altitude nuclear explosion (HEMP) is perceived by many world armies as a perspective weapon to destroy the foundation of any country's infrastructure, i.e. the power industry. Thus, many countries have recently started developing safety equipment to protect electric power equipment from HEMP [1, 2]. However, apart from electronic and electrical equipment, which is directly involved in generation, transmission and distribution of electric power, there is another type of highly-sensitive electronic equipment that is not directly involved in these processes, but can disrupt them. These are fire suppression systems installed at any power plant and electrical substation.

II. FIRE SAFETY SYSTEMS USED AT POWER INDUSTRY FACILITIES

There are many different systems: from fire alarm only, to automatic fire suppression. Obviously, a faulty fire alarm system will not cause any disaster to occur. However, this is not true for automatic fire suppression systems as in case of their self-actuation, some of them will disconnect electric equipment first and then deliver a fire extinguishing agent. As a rule, fire extinguishing of electric equipment in low-voltage (up to 0.4 kV) electric cabinets is performed by delivering pressurized low-conductive powder, gas or fine water spray, into the burning area (Fig. 1) and does not require voltage disconnection. These systems are also very diverse: from local systems, containing one gas container and intended for a single cabinet or a group of cabinets (Fig. 1) to centralized systems, which consist of rather sophisticated and branched systems (Fig. 2). Local systems based on a single gas balloon and a simple temperature sensor do not consist of sophisticated electronic components, and thus it is unnecessary to protect them from HEMP.

Fig. 1 Local gas and spray fire suppression systems for low voltage control cabinets

However, centralized fire suppression systems that employ microelectronic control equipment are susceptible to HEMP. Moreover, both types of damage are dangerous, i.e.: failure of a fire suppression system to actuate and its faulty actuation. The latter is not just about high cost of such wasted gas. In fact, gas wasted during faulty actuation will not be available to extinguish fire, which can start after breakdown of insulation of many types of electric equipment upon the impact of a high-voltage pulse.

When extinguishing fire on large high-voltage equipment (where intensive cooling of the burning zone is necessary in addition to deoxygenation), water is usually delivered though a previously mounted piping system surrounding the unit and sprayed by sprinklers, Fig. 3. Disconnection of power before spraying is compulsory; it is performed upon a signal of an automatic fire suppression system.

Fig. 2 Components of centralized gas fire suppression system

Control panels (cabinets) of a fire alarm and automatic control are very sophisticated. They consist of microprocessors and many different microchips (Fig. 4), connected through dozens of cables that create a branched antenna system (hundreds-meter long), which absorbs the HEMP energy from a large area and delivers it directly onto highly-sensitive electronic components.

Fig. 3 Fire extinguishing for power transformers: above – red fire piping with sprinklers; below – fire extinguishing in progress.

Fig. 4 Control panel (cabinet) of fire alarm (a) with three control units (1, 2 and 3) and accumulators (4, 5); 6 (b) - external multi-core cables, connected to internal electronic circuit of the cabinet; c - microelectronic "internals" of one of three control units of the cabinet.

Fig. 5 Power electronic devices to control electrical motors of centralized fire extinguishing system's pumps.

These systems are built based on network technologies at large facilities. Thus, firefighting control panels are equipped with RS422 or RS485 interfaces; they can also communicate via Ethernet or by means of modem transmission over a dial-up telephone channel, which makes it even more susceptible to HEMP and complicates their protection.

Among other things, centralized systems of fire extinguishing control contain power electronic devices, such as soft start systems of powerful electric motors of pumps, which supply water into a hydraulic fire extinguishing system. These power electronic devices are connected into a common power supply network of an electric energy facility, where HEMP induced pulse overvoltage can reach as high as dozens of kilovolts. At the same time, my analysis of standards and other regulatory documents [3 – 6 and others], which determine certain features, parameters and guidelines for testing of fire extinguishing systems and their use, showed that they neither address, nor consider the HEMP impact at all and thus, they do not require implementation of special measures, which improve immunity of these systems to HEMP.

III. IMPROVEMENT OF AUTOMATIC FIRE SUPPRESSION SYSTEM' RESILIENCE TO HEMP

Is it possible to protect all these sophisticated systems from HEMP and how?

The answer to this question is rather complicated. Indeed, tampering with internal electronic circuit of fire suppression and an automated control system is prohibited, even for such a good reason as HEMP protection. For example, installation of any additional filters in RS422 or RS485, in order to establish Ethernet or modem communication, is an example of such tampering.

Still, there is a feasible solution. For example, it is possible to briefly disconnect the electronic fire extinguishing system using a remotely sent command upon obtaining immediate information about the danger of impact by a nuclear-tipped missile. Use of a high altitude nuclear weapon (even with the aim to damage infrastructure and not the population) cannot be too spontaneous and unpredictable. As a rule, a number of collisions signifying aggravation of environment occur prior to impact, in which case the state agencies become alert to unfavorable unfolding of a situation, including the danger of HEMP impact. In this situation, it is not unusual that while the nuclear-tipped missile approaches, advanced information about HEMP danger will come, and this time will be sufficient for remote switch off the critical fire extinguishing systems located at various remote power system facilities. Deenergized systems are known to be much less susceptible to internal damages by HEMP. Moreover, a damaged deenergized system cannot adversely affect other systems.

In practice, remote switch off of automated fire suppression systems can be achieved using various tools readily available in the market. These can be relatively expensive (200-300 USD) remote power switches installed in separate casings (Fig. 6) and controlled via Ethernet. These switches are equipped with network interface and output electromagnetic relays, which respond to a special code, transmitted by network. The terminals of these relays can switch external devices either off or on.

Fig. 6 Remote power switches

The so-called "network relays" (Fig. 7) are much cheaper (20 - 30 USD), but are equivalent to those described above.

Fig. 7 Network relays with different number of channels and output electromechanical relays.

The GSM remote controller (Fig. 8), which costs 100 - 150 USD, can be used as a device for remote switch off the fire extinguishing systems.

Fig. 8 Remote switches controlled via Global System of Mobile Communications (GSM).

Use of these systems does not suppose intrusion into the internal circuit of fire extinguishing systems, since they are inserted into the external power supply circuit only and break of this external circuit. However, they have some specific features of use. First of all, apart from external power supply, the fire suppression control systems contain an additional back-up power source. As a rule, this power source is designed as accumulator batteries (4 and 5 in Fig. 4), so it is necessary to disconnect both power supplies. Secondly, in order to ensure remote return of the fire extinguishing control system back into an operational state (after the attack is over), the power sources need to be disconnected in a certain order: first – the back-up battery, and then – the supply mains. Returning to an operational state is performed in a reverse order. Thus, the remote switch (relay) should have at least two independent channels with two independent output relays. It is noteworthy that the OFF/ON codes of the fire suppression system, as well as the order of these procedures, should be clearly defined in the Emergency Guidelines and the employees involved must be familiar with these guidelines. As for the remote return into the operational state, it is possible only in case there was no HEMP impact. Otherwise, the automatic fire suppression system should be thoroughly checked before returning it into an operational state.

Apart from relays in power supply circuits, another "permissible intervention" is installation of special filters into both the circuits of the external power supply of a fire suppression control system and all other power control devices' power circuits (such as those controlling the pumps' motors, Fig. 5). These filters need to consist of elements, which limit the voltage amplitude and the current induced by HEMP. Metal-oxide varistors (MOV) and chokes are very convenient for low-voltage electronic control systems. There are standard units that protect single-phase AC supply circuits from over-voltage. These units are mounted in small casings that will be installed on a DIN-rail and contain two varistors and a gas discharge-tube (Fig. 9a). The majority of single-phase protection units are engineered according to this design, which ensures good lightning protection, but not HEMP protection. This is due to a long time response of the gas discharge tube (GDT) to pulses of this kind and sharp increase of its breakdown voltage, as affected by a short pulse with high steepness of the leading edge (such as that of HEMP).

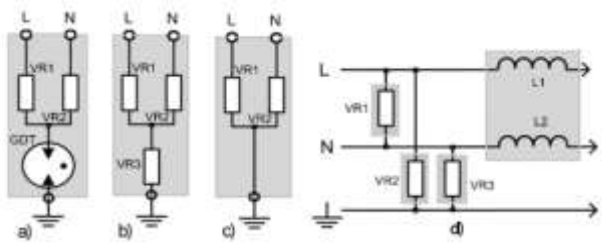

Fig. 9 Various protection units (a, b, c) and suggested connection of protection elements (d). VR1 – VR3 – metal-oxide varistors (MOV); GDT – gas discharge tube; L1 – L2 – current-limiting chokes.

Substitution of the gas discharge tube by a varistor (Fig. 9b) could have improved the situation, but such units are very rarely produced for 230/400 VAC circuits. Instead, there are hundreds of designs of protecting units that consist of two varistors and a jumper instead of VR3 varistor (Fig. 9c). The disadvantage of this circuit is double actuation voltage and double clamping voltage between the line (L) and the neutral (N) terminals, compared to voltage relative to the ground. However, the ground does not represent the zero-potential area (relative to which the over-voltage pulse is applied to the circuit under protection and to which this pulse should be diverted by the protection device) during HEMP (unlike lightning discharge). Thus, this layout is not suitable for HEMP protection as its high voltage pulse is very likely to be applied between the line and the neutral. At the same time, there are single-pole protection units with a single varistor inside, which can be successfully used to protect a single-phase AC circuit with nominal voltage 230 V (Fig. 9d). In order to increase the efficiency of HEMP suppression, the layout is supplemented by the current-limiting chokes L1 – L2.

Single-pole protection varistor units DS71R-400 type manufactured by Citel and I^2R SA277-50 type units manufactured by Transtector (Fig. 10a) can be recommended for certain circumstances. These units feature perfect specifications and include an additional built-in element, which disconnects the varistor in case of its damage, a visual indicator of damage and a contact for a remote alarm.

A unit of chokes DSH 2x16 manufactured by Citel is recommended as current-limiting chokes L1 – L2. This unit consists of two chokes rated 16A each, located in a small casing, which can be mounted on a standard DIN-rail (Fig. 10b).

Fig. 10 Single-pole protection units with varistors (a) and a unit with two current-limiting chokes (b).

Powerful varistor blocks R1 – R6 (e.g. B40K460 type) and also powerful chokes L1 – L4, manufactured by CWS (Fig. 11) are more suitable for power three-phase circuits and other powerful loads. This type of varistor block can tolerate pulse currents rated up to 40 kA and are intended for long-time operation under 460 VAC. Upon the varistor's actuation under HEMP impact, its clamping voltage will not exceed 1240 V. This is acceptable for power equipment, which (according to IEC 61000 group of standards for EMC requirements) must tolerate pulse over-voltages of not less than 2 – 4 kV, and features either built-in elements, protecting from this level of over-voltage, or corresponding levels of insulation. Small chokes (L1 – L4), with a helix coil and special powdered cores encapsulated by epoxy resin, are manufactured by the American company CWS and designed for currents from 40 to 200 A.

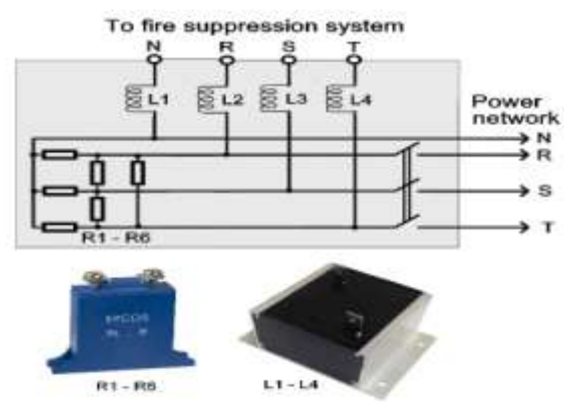

Fig.+ 11 Design and components of a filter for power circuits of powerful automatic fire extinguishing control systems. R1-R6 –varistor blocks; L1-L4 – special chokes.

Similar sets of varistors should be connected both where the power three-phase cable penetrate to the automatic fire extinguishing control system, and at all the output cables' from this system, plus on the other end of these cables, i.e. close to the motors of water pumps.

IV. CONCLUSIONS

Critical automatic fire suppression systems of critical types of electric equipment require adoption of special measures to improve their HEMP resilience. These measures should be based on the principle of non-interference into the internal circuit of fire suppression systems. Remote switching off of these systems, in case of danger of HEMP impact with their further return into an operational state (also remotely), as well as installation of HEMP filters described above, are examples of these measures.

REFERENCES

[1]. Gurevich V. Protection of Substation Critical Equipment Against Intentional Electromagnetic Threats. – Wiley, 2017, 228 p.

[2]. Gurevich, V., Cyber and Electromagnetic Threats in Modern Relay Protection. – Taylor & Francis Group, Boca Raton, 2015, 205 p.

[3]. BS EN 50130-4:2011 Alarm systems. Electromagnetic compatibility. Product family standard: Immunity requirements for components of fire, intruder, hold up, CCTV, access control and social alarm systems.

[4]. IEC 62599-2:2010 Alarm systems - Part 2: Electromagnetic compatibility - Immunity requirements for components of fire and security alarm systems.

[5]. NFPA 15, 2017 Standard for Water Spray Fixed Systems for Fire Protection.

[6]. NPB 88-2001 Fire-extinguishing and alarm systems. Designing and regulations norms –, Decree No. 31, Ministry of Interior of Russia, June 4, 2001.