LACK OF A STANDARD FOR FILTERS PROTECTING FROM ELECTROMAGNETIC PULSE MAKES IT DIFFICULT TO DEVELOP AN EFFICIENT PROTECTION

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Protection of digital protective relays (DPR) from a High Altitude Electromagnetic Pulse (HEMP) capable of interfering with their normal functionality or damaging their internal elements has recently gained particular relevance. This article discusses issues related to protection of DPR from HEMP by means of special filters. In the article it is shown that absence of special standard, which would stipulate the requirements to configuration and parameters of HEMP filters, procedures of their testing and performance estimation, has impeded developing an efficient protection.

Keywords: digital protective relays, HEMP, EMP, filters, MIL-STD-188-125

Introduction

Protection of modern electronic equipment, particularly in the power industry from High Altitude Electromagnetic Pulse (HEMP) is an important and relevant problem in the current stage of machinery development due to the reasons discussed earlier [1]. The main methods of protection from HEMP impact in high-sensitive equipment include thorough electromagnetic shielding of the equipment and attached cables as well as suppresion of the pulse by means of special filters, Fig. 1, which provide connection of the equipment with external units and systems.

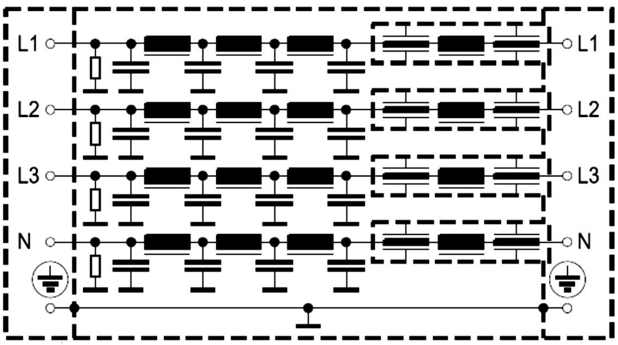

Fig. 1. Typical circuit diagram of a power HEMP filter consisting of a set of LC-circuits

There are several filters on the market manufactured by a number of companies, such as: ETS-Lindgren, MPE, Meteolabor-EMP, European EMC Products Ltd., Captor Corp., LCR Electronics, API Technologies, Astrodyne TDI Corp., Fi-Coil, EMI Solutions Pvt. Ltd, RFI Corp., and others. One would think: what's the problem: do you want to protect your equipment from HEMP? Install these filters and sleep well! But the question is whether one can really sleep well after installation of these filters?

Do the Filters Really Protect from an Electromagnetic Pulse?

When selecting a filter that can efficiently suppress HEMP, one unexpectedly faces the problem: all the above mentioned companies promote their filters as highly efficient means of protection from HEMP and declare that they conform to the military standard MIL-STD-188-125 [2]. However, parameters of testing pulses applied to the filters significantly differ from those detailed in the standard. For instance, the standard stipulates that tests should be conducted with current pulses of 20/500 nano-seconds of undetermined amplitude with applied loads of 60 Ohm, while the manufacturers test their filters at 8/20 µs with an applied load of 1 Ohm. Why? Because the pulse of 8/20 µs is a standard pulse produced by all types of testing equipment intended for testing the resistance to lightning charges, while special equipment is required in order to test by current pulses of 20/500 nano-seconds with an applied load of 60 Ohm; and the filter manufacturers do not have it. This problem is directly addressed in [3].

Another strange thing is that MIL-STD-188-125 stipulates the testing of objects by current pulses in two modes: with current flowing between all inputs that are connected together and the ground (common mode) and between each separate input and the ground (wire-to-ground mode). However, in the case of a high altitude nuclear blast a high voltage pulse can be applied not only between equipment's inputs and the ground (this mode is referred to as "common mode" in other standards), but also between different inputs insulated from the ground ("differential mode"). MIL-STD-188-125 does not contain these tests, they are addressed in other standards. Due to this, some companies promoting their filters as HEMP filters do not equip them with elements that limit pulse voltage referring to the same MIL-STD-188-125, while they declare that the filters ensure full protection from HEMP, since they were tested by current pulse with amplitudes of several thousand amperes and recognized as conforming to MIL-STD-188-125. Indeed, the standard represents the limiters of pulse voltage as absolutely separate elements, which have nothing to do with filters, Fig. 2.

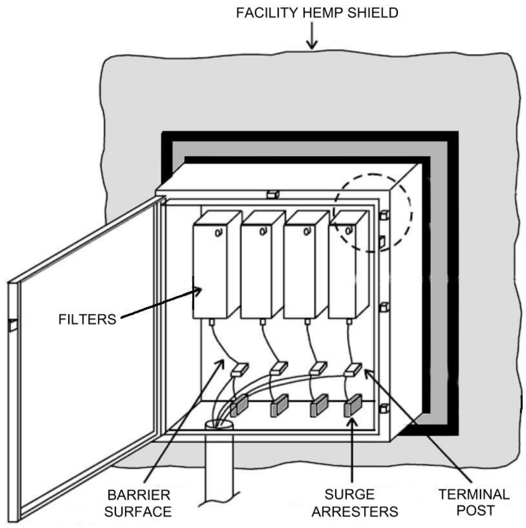

Fig. 2. Design of inlet box for connecting of external cable to a unit protected from HEMP (according to MIL-STD-188-125)

With this approach the filters really do not have to protect from overvoltage at inputs. On the other hand, is it possible to proclaim that these filters ensure full protection from HEMP? Obviously, since manufacturers understand the problem, they equip their filters with certain elements protecting from pulse overvoltage and installed at inputs. In their opinion, now these filters enjoy the full right to be called as filters protecting from HEMP.

However, a close-up examination of the protecting elements used in those filters brings into question their efficiency. The most widespread and cheapest limiters of pulse voltage used in the filters are gas-discharge tube and zinc-oxide varistors, Fig. 3. It is known that these are relatively "slow" elements, which do well suppressing standard pulses of 8/20 µs, but fail to actuate under the short high voltage E1 pulse of HEMP featuring 2/25 nano-seconds [4] (or 5/50 nano-seconds according to [5]). Having read that the selected filter is intended for HEMP protection and was tested by current pulses of 8/20 µs according to MIL-STD-188-125, it is unlikely that the consumer will look for the standard and check whether this is the required pulse rate. However, it is early to challenge the manufacturers. It is directly discussed in [6] that insufficiently slow varistors and even slower gas-discharge tubes installed in filters seem to be unsuitable for HEMP protection; they just protect from lightning charges and switching overvoltages.

Fig. 3. Filters of the MPE Company with protective elements consisting of voltage dependent resistors – VDR (zinc-oxide varistors) and gas-discharge tubes (GDT) at inputs

Oh dear, filters intended to protect from HEMP employ voltage suppressors intended to protect from... lightning, but not from HEMP! Nevertheless, some of MPE's filters with protective varistors are referred to as filters intended for protection from the E1 component in the promotional materials. However, a more detailed analysis of parameters of these filters revealed that they do not differ (except for the name in the heading) from all other filters of this company, i.e. they are protected from lightning charge rather than from E1 component of HEMP. Otherwise, it it should be accepted that parameters of lightning charge do not differ from E1 component's parameters, which is absolutely not true.

During a discussion with a representative of one company regarding the feasibility of varistor's use in filters, intended for protection from HEMP, a new argument was presented. The representative declared that regardless of the fact that a varistor itself is not deemed as a quick element, its efficiency becomes enough to protect from the E1 component when connected with L-C elements of the filters. Verification of this argument showed that it is also not accurate. Some publications [7-8] suggest that connection of short external conductors having very low conductivity to the protecting element reduced their response time. It appears that response time of the protecting element to the applied voltage pulse is very dependant both on the element's casing design and on the configuration (length) of its pins [7-8]. Moreover, [8] suggests that the configuration and length of the external pins determine the response time of protecting element. With this in mind, some manufacturers of protecting elements often indicate in their promotional materials not the response time of fully assembled element in the casing with pins, but that of the material used in the manufacturing of this protecting element [8]. At the same time manufacturers work on improvement of configuration of protecting elements and they do it rather successfully [9].

The above mentioned reveals that unbiased data about responsiveness of a certain type of protecting elements can only be obtained by conducting own independent trials of ready-made items offered in the market. Though some indirect data about the results of these trials [10] allow making preliminary comparative evaluation. For instance, according to [10] dynamic resistance and response time of protecting element based on avalanche diode (TVS diode) is almost 10 times lower than that of a varistor. I have not conducted my own trials of diodes and varistors responsiveness in order to confirm or contradict these data, but the fact that protecting elements based on avalanche diodes rather than varistors are used to protect electronic equipment from high-voltage electrostatic discharges (and they belong to nanoseconds range, i.e., the closest to HEMP in terms of time parameter) is self-explanatory.

Another problem related to the use of suppression elements is the circuit of connection of these elements employed in many filters, Fig. 1, where each element is connected between an input and the grounded casing of the filter. This type of connection results in closing of two elements connected in series between two input terminals of the filter. They stipulate double clamping voltage, which can be dangerous for the electronic circuit being protected.

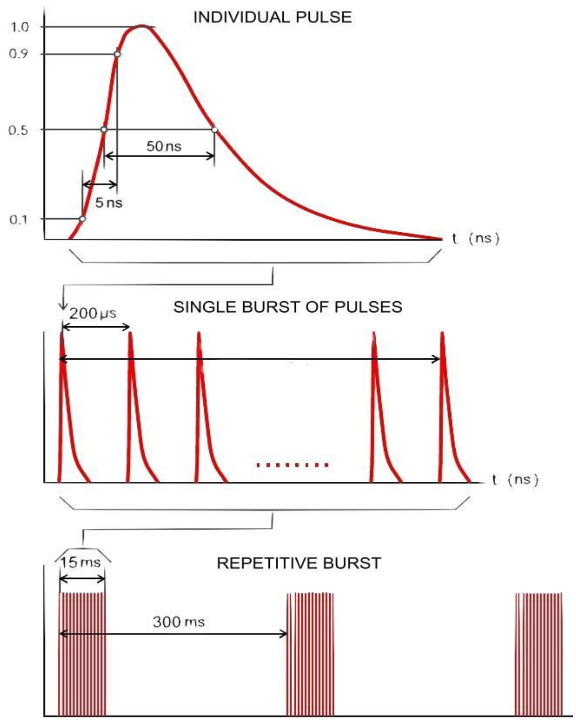

Fig. 4. Electrical Fast Transient (EFT) pulse (IEC 61000-4-4)

The technical requirements for equipment resistance to overvoltages and testing procedures are described in IEC 61000-4-4 [5] и IEC 61000-4-25[11]. Electrical Fast Transient (EFT) is meant under the testing pulse of this voltage, i.e., a quick pulse, parameters and testing procedures of which are described in IEC 61000-4-4, fig. 4. The procedure of testing pulse parameters selection based on these standards for a specific example – digital protective relays (DPR) – is discussed in [12]. For this case the amplitude of EFT pulse voltage amounted to 8 kV.

I think that these tests should be conducted on filters equipped with elements protecting from pulse voltage and intended for HEMP protection. This should be done in addition to tests stipulated by MIL-STD-188-125 and the testing voltage should be applied both between inputs and the ground and between separate inputs.

The Frequency Range of Filters

Another problem is related to the amplitude and frequency features of the filters. Typical specification of a high-quality filter intended for HEMP protection is shown in Fig. 5. Is there any relation between parameters of real filters and this typical specification?

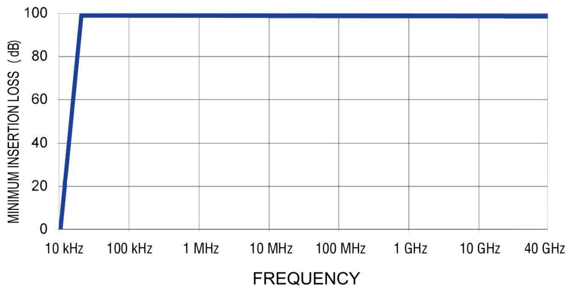

Fig. 5. Typical insertion loss performance of high-quality HEMP filters

Some companies, e. g., Meteolabor, do not mention any data about frequency range and attenuation in the technical specifications of some of their filters. Others, e. g., MPE, mention only typical specifications, which should pertain to filters according to MIL-STD-188-125 (frequency range of 14 kHz – 40 GHz, attenuation in the whole range of 100 dB) and immediately give real specifications of manufactured filters with the following parameters: 10 kHz – 1 GHz with 80 dB attenuation for ordinary quality filters and the same frequency range, but with 100 dB attenuation for improved quality filters. Where is the range of 1 GHz – 40 GHz? Employees of Astrodyne (LCR Electronics, Inc.) turned out to be even more cunning. They wrote in the technical specifications for their filters that they ensure attenuation of 100 dB in the frequency range of 14 kHz – 10 GHz according to MIL-STD-220 [13], however, if their filters are well shielded and insulated (in other words: installed in the "Faraday cage"), their frequency range can be expanded to the required value of 40 GHz. Oh dear, in order for the filter to ensure HEMP protection, it should initially be protected from HEMP itself! As the phrase goes: "It speaks for itself".

Frequency specifications of filters of leading manufacturers

Manufacturer of HEMP filters	Frequency interval		Attenuation, dB	Notes
	Min	Max		
LCR Electronics	14 kHz	1 GHz	100	-
MPE	10 kHz	1 GHz	80	for standard filter
MPE	14 kHz	18 GHz	100	for improved filter
Fi-Coil	14 kHz	1 GHz	100	-
Captor Corp.	14 kHz	10 GHz	100	-
ETS-Lindgren	14 kHz	40 GHz	100	-
MeteoLabor	200 kHz	1 GHz	80	for filter PLP type
MeteoLabor	-	-	-	for filter USP type

The comicality of the situation is shown in table, where frequency specifications of filters of leading manufacturers are compared: all filters have the same intended purpose and all of them correspond to requirements of MIL-STD-188-125 and simultaneously all of them have significantly different parameters. How can this be?

Another feature of adopted connection schedule (between each input and the ground) of some separate internal elements of the filters is characterized by not only double clamping voltage on the suppressor (as mentioned above), but also by double capacitance and double inductance connected between two inputs compared to inductance and capacitance between each input and the ground. This leads us to conclude that the frequency specifications of filters for a pulse applied between to inputs will not be the same as those for a pulse applied between an input and the ground. How far will these specifications be applicable for HEMP protection?

Conclusions

Who of the consumers will be "digging" so deeply? Why should the declarations of the manufacturer about high efficiency of their products not be trusted? Even if a consumer believes the manufacturer, the consumer will not be able to check the real efficiency of operation of such filter. It is not clear, how efficient will they be in protecting certain equipment by the filter, if it fails to protect from HEMP in a critical situation.

Today's situation requires that each manufacturer should make their own decisions whether to include limiters of pulse voltage in the filters' configuration or not; whether to use cheap and unsuitable (in terms of parameters) elements or not; whether to test filters with a standard lightning pulse or a pulse with parameters stipulated in the military standard or not; whether to mention the frequency range or not mention it at all and use the one given in MIL-STD-188-125 or MIL-STD-220 [13] or maybe indicate their own frequency range and refer to a known military standard. Who on the earth will check the reliability of this information!

This situation is a result of the lack of a special standard, which would stipulate the requirements to configuration and parameters of HEMP filters; to procedures of their testing and quality of their performance. In my opinion this situation is unacceptable considering the relevance of the problem and requires urgent addressing.

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ОТСУТСТВИЕ СТАНДАРТА НА ФИЛЬТРЫ ДЛЯ ЗАЩИТЫ ОТ ЭЛЕКТРОМАГНИТНОГО ИМПУЛЬСА ЗАТРУДНЯЕТ СОЗДАНИЕ ЭФФЕКТИВНОЙ ЗАЩИТЫ

В.И. Гуревич

Аннотация: Защита микропроцессорных устройств релейной защиты (МУРЗ) от электромагнитного импульса высотного ядерного взрыва (ЭМИ ЯВ), способного нарушить их нормальное функционирование или привести к повреждениям их внутренних элементов в последнее время приобрела особую актуальность. В статье рассматриваются проблемы, связанные с защитой МУРЗ от ЭМИ ЯВ посредством специальных фильтров. В статье показано, что отсутствие специального стандарта, оговаривающего требования к составу и параметрам таких фильтров, методов их испытаний, оценки результатов испытаний, препятствует созданию эффективной защиты.

Ключевые слова: микропроцессорные устройства релейной защиты, МУРЗ, электромагнитный импульс, ЭМИ ЯВ, фильтры.