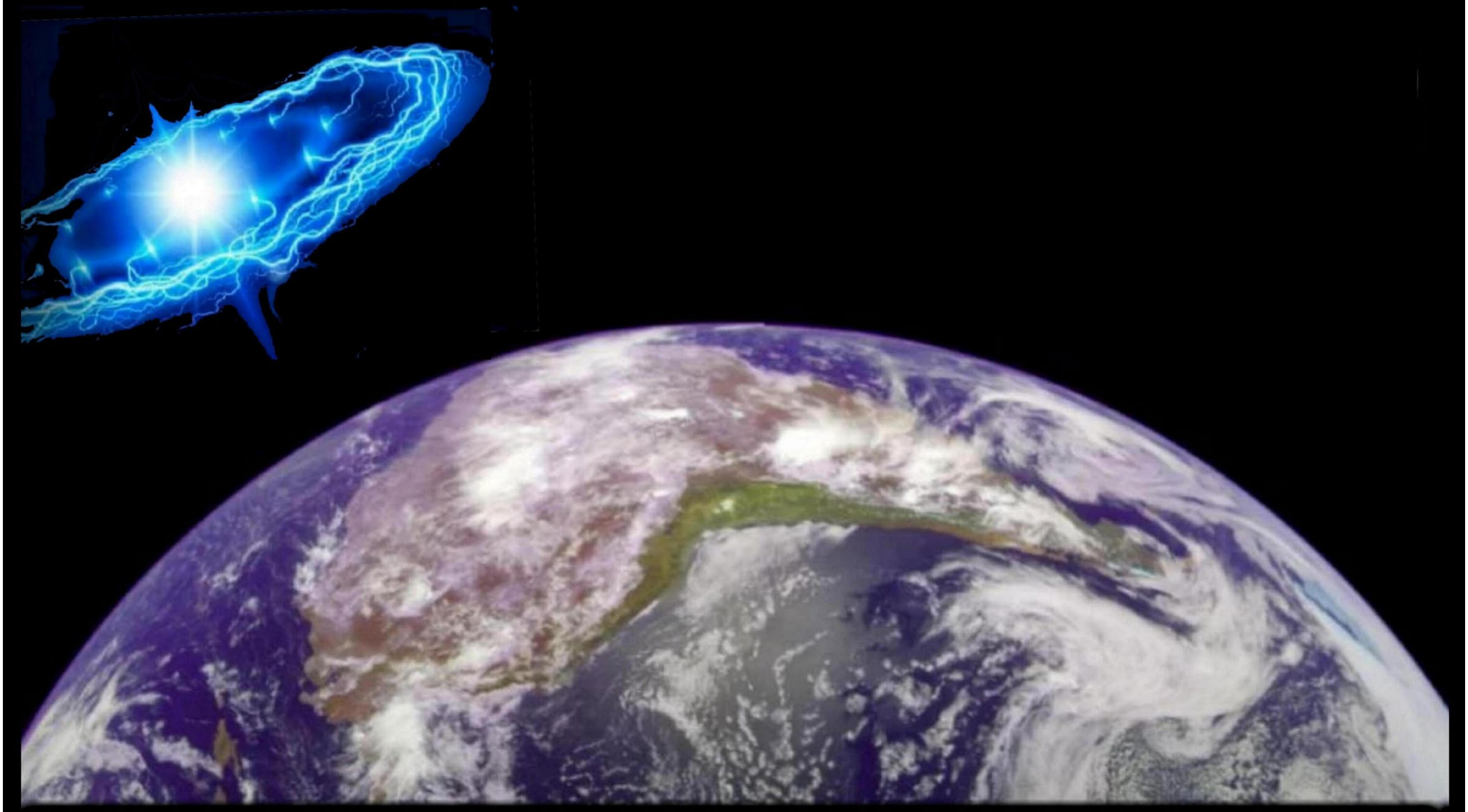


Industrial EMP Solutions
Civilian Critical Infrastructure Protection

CATALOG
of HEMP Protection Means for Critical Electrical Equipment of Critical Civil Infrastructure

2026

Debebis optare optima, cogitare difficillima

Marcus Tulliis Cicero

We can’t expect God do all the work

Joshua Graham
(“Fallout: New Vegas”)

Periculum in mora

Titus Livius
(“The History of Roma”)

CONTENTS

INTRODUCTION

A New Strategy is Needed to Solve the 60-year-old Problem - HEMP Protection of Critical Civilian Infrastructure

The ability of the powerful electromagnetic pulse, generated upon the high-altitude electromagnetic pulse - HEMP (or simplified EMP) to destroy all electronics, has been known to nuclear physicists since the first nuclear explosion was performed in 1945 on the Alamogordo range, New Mexico (project “Trinity”). Upon the explosion, all apparatus that was meant to monitor the explosion parameters became inoperative. Upon all further test explosions performed in all countries, that electromagnetic pulse was registered precisely and was followed with the analysis and study of the parameters.

Additional experimental high altitude nuclear explosion named “K-3” was performed in the Soviet Union (at Kazakhstan, 180 km west of Dzhezkazgan town) on October 22, 1962 (300 kt yield, at altitude 290 km). According to data, published by V. M. Loborev [1], Fig. 1. EMP impact caused failures in the operation of Air Defense radar located about 1,000 km away. An underground power cable with a length of 1,000 km, passing at a depth of about 1 m and connecting towns Tselinograd and Alma-Ata, was put out of action. Breakdowns of ceramic insulators resulting in short-circuit were observed on 35 kV electric overhead power lines, in some areas. The insulators were so damaged that the wires fell to the ground. Electromagnetic pulse caused fires due to short-circuit in electric appliances. A power generator which was connected to an underground power cable was knocked out of service at one of power plants in Karaganda town, relay protection (even old electromechanical type, not modern EMP sensitive microprocessor based!) was triggered resulting in switching the power generator off at another power plant. A slow geomagnetic component of EMP induced a short current pulse with an amplitude of several thousand Amps, as well as a long (more than 20 sec) current pulse, rated 4 Amps. This led to diesel-generator damage and triggering of protection devices mounted over a 570 km above-ground telephone line. There is also information about some breakages of electronic equipment, occurred at Baikonur Cosmodrome.

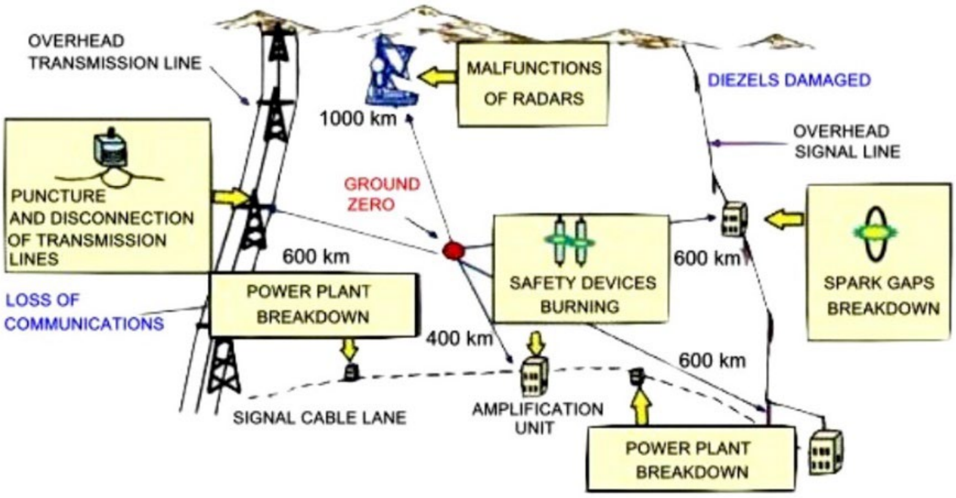
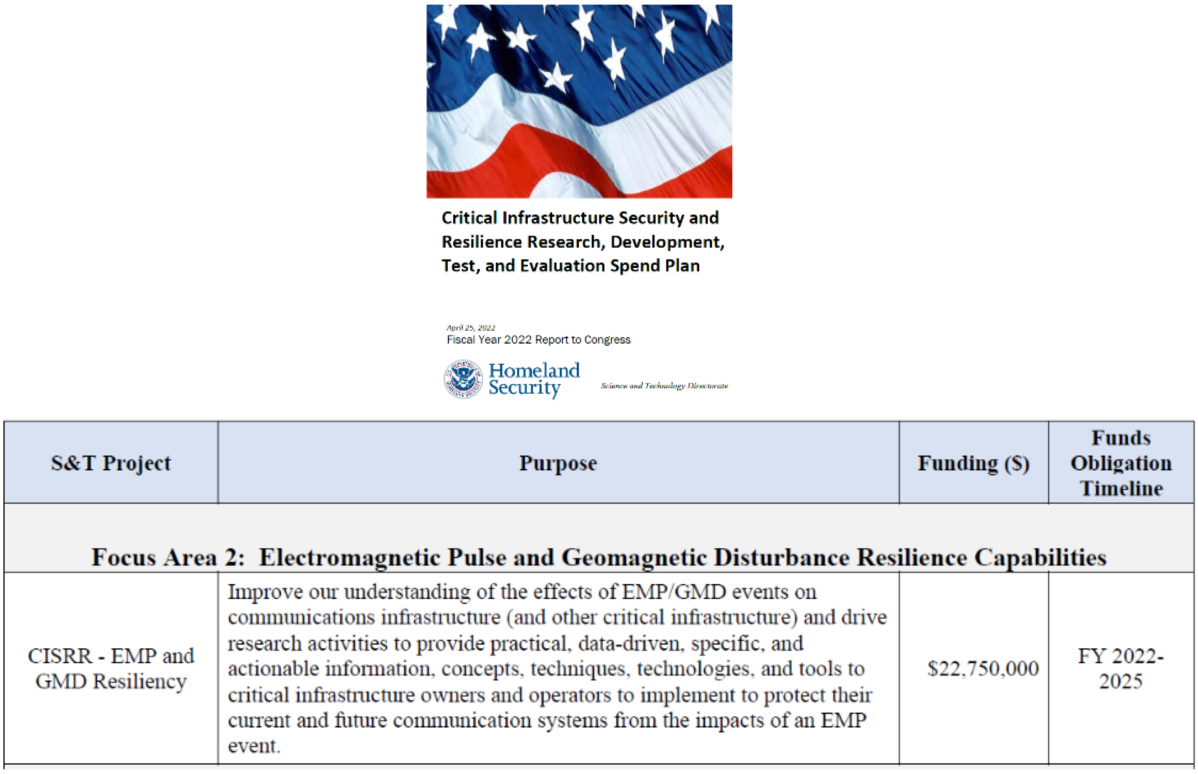


Fig. 1. Damaged electric equipment affected by HEMP during nuclear high-altitude test explosion performed under “K-3” project in Kazakhstan in 1962 (based on data published in V. M. Loborev’s report presented at EUROEM International conference in France in 1994).

At the same time, it should be taken into account that the level of electronics in the USSR in 1962 was incomparably lower than in the West today. That is, the breadth of application of electronics, its sensitivity (i.e., susceptibility to EMP) were incommensurate with today. If such a test were carried out today, it would lead to the complete collapse of a large part of the country.

Beginning in the 1970s (almost 60 years ago), that subject has been unclassified. At that time, dozens of Western scientific and technical reports, prepared by numerous military and civilian organizations (working at the military request), were devoted to different aspects of EMP impact on electrical equipment and electronics. Since then, the electromagnetic pulse had been officially recognized as one of the damage effects of nuclear weapons, along with the detonation wave, the temperature, the light and the radioactive emission. At the same time, the first recommendations for the protection of electronic and electrical equipment from HEMP appeared, which, of course, were primarily intended for military equipment [2, 3].

Well, what about civilian critical infrastructure protection? Today, at least a hundred organizations around the world are dealing with this problem (there are more than 50 of them in the United States only), dozens of detailed reports have been published on this topic, which are freely available on the Internet [4], as well as hundreds of articles and books. Dozens of standards (civilian and military) describe how to protect critical infrastructure equipment against HEMP [4].



Critical Infrastructure Security and Resilience Research, Development, Test, and Evaluation Spend Plan

April 25, 2022
Fiscal Year 2022 Report to Congress

Homeland Security
Science and Technology Directorate

S&T Project	Purpose	Funding ($)	Funds Obligation Timeline
Focus Area 2: Electromagnetic Pulse and Geomagnetic Disturbance Resilience Capabilities			
CISRR - EMP and GMD Resiliency	Improve our understanding of the effects of EMP/GMD events on communications infrastructure (and other critical infrastructure) and drive research activities to provide practical, data-driven, specific, and actionable information, concepts, techniques, technologies, and tools to critical infrastructure owners and operators to implement to protect their current and future communication systems from the impacts of an EMP event.	$22,750,000	FY 2022-2025

Fig. 2. The budget of the Department of Homeland Security to "improve understanding" of the problem of critical infrastructure resilience after 60 years of careful study.

But if everything is so good, then why is critical civilian infrastructure still unprotected anywhere in the world? Why, after 50 years of careful study of the problem and hundreds of recommendations, is the Department of Homeland Security asking Congress for tens of millions of dollars to "*improve understanding*", Fig. 2?

And this is just one organization out of many dozens (more than 50!) "studying" this problem in the United States alone! One can only imagine how much money from the budget is "sawn" under the guise of this problem…

OPINIONS

To date, we have four opposing concepts on the problem of protecting the civil critical infrastructure, which are reflected in the statements of the apologists of these three concepts [5]:

Concept A: Everything has been known for a long time, there are no technological problems:

"The problem is not the technology. We know how to protect against it. It's not the money, it doesn't cost that much. The problem is the politics. It always seems to be the politics that gets in the way".

Dr. Peter Vincent Pry,
Executive Director of the Task Force on National and Homeland Security

“The U.S. military already has EMP protection approaches that are practical, affordable, tested and well understood that can be translated directly to electric power grid control facilities and supervisory control and data acquisition electronics and networks.”

Dr. George H. Baker,
Prof. Emeritus James Madison University, Director Foundation for Resilient Societies

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Concept B: We have neither the knowledge nor the resources to protect infrastructures:

"*Much of the available information is not specifically applied to electric utilities, making it very difficult for utilities and regulators to understand effective options for protecting energy infrastructure*".

Robin Manning,
Vice president for transmission and distribution for the Electric Power Research Institute (EPRI)

"Managing that kind of threat right now — no one really has the resources to do that"

Richard Mroz,
President of the New Jersey Board of Public Utilities

Concept C: There are no solutions to the problem, so you need to leave everything as it is

“I don’t mean to be so flippant, but there really aren’t any solutions to THIS, so I would just leave it at that”.

General M. V. Hayden
Ex-Director of the National Security Agency (NSA);
Ex-Director of the Central Intelligence Agency (CIA)

Concept D: Effective defenses against HEMP are a national anti-missile defense system only into which more budgetary funds should be invested

Representatives of Military-Industrial Complex (MIC)

This last concept seems to be quite effective. After all, the military and representatives of the military-industrial complex should know this problem better than anyone else. But, let's understand this concept.

First, this concept, which was adopted by representatives of the military-industrial complex, would be quite understandable if the cost of developing and producing an effective multi-layer anti-missile shield that would protect the entire country would be lower than the cost of defensive measures to protect critical elements of the country's infrastructure and its systems from cannabis. But this is not so, but quite the opposite!

Secondly, it appears that it is not that simple and that missile systems have been in existence for some time that an anti-missile system is not capable of defending against, that is to say it is not possible to protect the national infrastructure from HEMP attacks. What sort of systems are these then? First of all, these are theatre ballistic missile (TBM) systems which can be equipped with a nuclear warhead, Fig. 3. The danger of such systems is that they can be as close as possible to the borders of any country. With a small area of a country (for example, such as Israel), the flight time of such a missile can be so small that the missile defense system will not be able to effectively counteract. Especially dangerous are modern container-type missile systems, which are made in the form of an ordinary container with missiles hidden inside. Such a system is, for example, the Israeli LORA system (Long-Range Artillery Weapon System).

Fig. 3. Soviet/Russian theatre ballistic missile (TBM) systems which can be equipped with a nuclear warhead (explosion yield up to 200 kt).

Fig. 4. A conventional shipping container (left) and a LORA missile system container (right)

The launcher of such a system differs very little from a conventional shipping container, Fig. 4. Today there are hundreds of millions of sea containers in circulation across the world, Fig. 5. Nobody knows which of them are genuine and which are filled with missiles…

Developed by IAI's MALAM division, LORA is a sea-to-ground and ground-to-ground system which comprises a long-range ballistic missile, a unique launcher, a command-and-control system, and a ground/marine support system. LORA missile has a length of 5.2 m, a diameter of 625 mm and weight of 1,600 kg. It can engage targets at a short range of 90 km and at long ranges up to 430 km. High explosive (HE) warhead (up to 600 kg) can be equipped with a nuclear charge.

Fig. 5. An ordinary civilian container ship loaded with hundreds of standard containers and a LORA rocket, launched from a ship with containers during a test launch.

This rocket is capable of going up to an altitude of 45 km and above, that is, to an altitude optimal for the production of HEMP.

No missile defense system is capable of neutralizing a missile that unexpectedly launches vertically from one of the hundreds of containers standing in the cargo port of a container ship, Fig. 5.

The LORA missile system is not entirely unique. Similar systems are also being developed and manufactured by other countries. That is the actual situation is such that the Army is not in a position to provide a sufficiently reliable defense of the civilian infrastructure facilities and population centers from HEMP and as such it is the electrical engineering specialists themselves that need to be concerned with this defense ahead of time.

The lack of clear, understandable, technical-effective and cost-effective solutions to the problem of protecting civilian critical infrastructure, suitable for practical application (and not for scientific reports only) for more than 60 years, indicates the existence of a very serious problem.

THE PROBLEM

Today, indeed, there is all the data on how and how critical infrastructure can be protected. Therefore, no one does anything in practice to develop new protection means specially for civilian infrastructure. And why, if everything has long been known and the market is full of all kinds of protective equipment (EMP filters, shelters, etc.)? That is, everyone is right and everything is correct, but this does not prevent the situation that for 50 years not a single substation in the world has been protected as it should be (two substations in the United States, partially protected do not count).

Well, the problem exists or does not exist, that is the question?

In the previous section, the author points out the existence of a serious problem, and in this section, he writes that everything has been known for a long time and the market is full of protective equipment! The author only confused the situation and made it completely incomprehensible!

Alas, it is precisely such kind of confusion that exists in the protection of civilian infrastructure. After all, it is not for nothing that one of the leading experts in this field, Dr., Prof. Emeritus of James Madison University writes: “*The current state of EMP protection is random, disoriented and uncoordinated”.*

But what is the reason for all this confusion and lack of solution to the problem for more than 50 years?!

The main and only problem is the attempts to use military technology to protect civilian critical infrastructure for all these 60 years.

The author argues that the well-known concepts of protection of military equipment and the means of protection against EMP available on the market, made according to military standards, are not suitable for the protection of civilian infrastructure.

But where is the way out of this paradoxical situation?

There can be ***only one way out of this situation: the development of new protection strategy and new protective equipment specifically designed for civilian infrastructure.*** But for this it is necessary to know well the structure and features of civilian infrastructure, including control cabinets with electronic equipment, relay protection, power transformers, DC power auxiliary supply system, grounding systems, Ethernet networks and much more. Therefore, it is not easy to develop protection for such a diverse range of equipment. In addition, in order to understand what means of protection are needed for civilian infrastructure, it is necessary to understand why the known military means of protection are not suitable.

Unfortunately, it is not possible to describe within the framework of this article the problems that arise when trying to apply military technology to civilian equipment without resorting to very specific technical details and features of electronic and electrical equipment. But all these technical details are described by the author in [7] and are intended for technical specialists.

It is important to reiterate here that this is not only a question of new means of protection, but also of a new strategy for the protection of civilian infrastructure against EMP.

Dr. V. Gurevich's NEW STRATEGY:

From the foregoing, we can conclude that suitable strategies and technologies intended for the civilian sector do not exist now. Therefore, a new absolute different strategy and means are required for the protection of the civilian infrastructure.

The main principles of the author's strategy (reviewed in detail and substantiated in [7] with all technical and scientific evidence) are:

- *It is fundamentally impossible to formulate clear technical requirements for EMP protection of equipment that would be universal for all types of civilian facilities and equipment;*

- *it is impossible to ensure absolute protection for every piece of electronic equipment employed at civilian critical facilities;*

- *any available level of protection which can attenuate (at least partially) EMP impact on electronic and electrical equipment is useful for civilian critical infrastructure.*

- *The cost of protection devices budgeted during the design stage (in case of new equipment and facilities) will be much lower compared to upgrading the existing equipment.*

- *Due to technical and economic reasons, protection should only be provided to the most important (critical) types of electronic equipment installed at critical facilities of the power industry, rather than to any and all types of equipment employed at the power industry.*

- *Critical types may include equipment which is directly involved in electrical energy generation and transmission, as well as main types of relay protection, control and automation systems, AC and DC power supply systems.*

- *Consequently, measuring systems, communication (but not telecommunications used by digital relay protection devices), remote control and remote signaling systems do not belong to equipment without which temporary generation and distribution of electrical energy will be hampered in emergency situations.*

- *EMP protection of equipment is multi-layered:*
  - *The first (top) layer includes protected buildings and structures.*
  - *The second layer includes protected rooms (halls) where equipment is installed.*
  - *The third layer includes protected cabinets with electronic equipment.*
  - *The fourth layer includes protection input and output terminals of the equipment itself placed into control cabinets.*
  - *Some additional "layers" of protection may include means for attenuation electromagnetic interferences penetrating into the equipment through the input and output cables (grounding, control and power).*

  However, the use of all these "layers" in any situation is not feasible. In some cases, it is feasible to use just some of the "layers" in various combinations.

- *Instead of protecting specific types of employed electronic equipment, it is sometimes feasible to use back-up equipment of the same type stored in a metal container directly at the facility being protected.*

- *Existing EMP-simulating test benches provide insufficient information at immunity testing of the power system's electronic equipment and thus testing such equipment (e.g. each cabinet with electronic equipment) on such test-benches is not feasible.*

In other words, the ***general strategy*** should be based on maximum use of maximum amount of known nonmilitary protection means (selected based on the above-mentioned strategy), with restrictions to be determined by technical and economic capabilities of a specific infrastructure object, only because any level of protection which can attenuate (at least partially) EMP impact on electronic and electric equipment is useful.

KEY FINDINGS

1. The actual situation is such that the Army is not in a position to provide a sufficiently reliable defense of the civilian infrastructure facilities and population centers from EMP and as such it is the electrical engineering specialists themselves that need to be concerned with this defense ahead of time.

2. The EMP parameters affecting civilian infrastructure equipment depend on so many factors that they should be considered as uncertain.

3. The difference in the constructions, properties and characteristics of various types of civilian equipment used in critical infrastructure facilities, their different location inside the buildings, the differences in the buildings themselves, the presence of long cables connecting different types of equipment, make their levels of resilience to EMP (and therefore the required levels of their protection) completely uncertain.

4. The real level of EMP protection and the real level of resilience will be determined by the technical and economic capabilities allocated for a particular infrastructure. But, based on research described in [7], it follows that any level of protection is desirable and any level of resilience increases the resistance of critical infrastructure to EMP. Naturally, with this approach, some of the equipment may be damaged when exposed to EMP, but most of the equipment will remain in good condition and will be able to continue to function. The more protective means is installed on a particular infrastructure object, the higher its degree of protection will be. This approach to the problem differs significantly from the requirements for military equipment.

5. Military standards should not be used to determine the requirements for the level of protection of civilian infrastructure equipment.

6. The numerous EMP protection means available on the market, made according to military standards, are not suitable for use in civilian equipment. For civilian equipment, other EMP protection means should be used, such as those described in this article.

7. For civilian infrastructure, it is necessary to use a completely different strategy and different principles of protection than for military equipment. Such a strategy and such methods of protection are described in this article.

8. The most common types of test benches - EMP simulators (guided-wave type) designed for testing military equipment according to military standards, are not suitable for testing civilian equipment. Therefore (and on the basis of [7]), it can be concluded that there is no point in such tests at all and no significant conclusions can be drawn from the results of such tests.

9. The transition to fiber optical communication lines for the transmission of telecommunication commands between cabinets with electronic equipment is not a panacea and, in some cases, only exacerbates the situation.

10. To the frequently asked question: "*Is it possible to consider an infrastructure object completely protected from EMP if the recommendations described above are followed?*" - the answer is NO! But it can be assumed that this object will be much more resistant to EMP, and the probability of its damage will be much lower.

Dr. V. Gurevich's SOLUTIONS FOR PROTECTIVE MEANS:

In accordance with the specific strategy for the protection of civilian infrastructure previously proposed by Dr. V. Gurevich, this catalog presents various means of protecting critical civilian infrastructure, developed by Dr. Vladimir Gurevich. These protection means are installed in trial operation and have already been tested in several electrical substations during 2 – 3 years.

"… should not wait for the federal government to take action, we need to take action now to protect our portion of the grid."

David Gregory,
Chairman of the Special Committee on Government Accountability,
member of the Missouri House of Representatives

"The time for research is running out; we have the data we need. It's time for bold action"

R. James Woosley,
Former Director Central Intelligence Agency (CIA)

REFERENCES

[1] **Loborev V.** Up to Date State of the NEMP Problems and Topical Research Directions. - Electromagnetic Environmen`ts and Consequences: Proceedings of the EUROEM 94 International Symposium, Bordeaux, France, 30 May – 3 June 1994, pp. 15-21.

[2] **Gurevich V.** Cyber and Electromagnetic Threats in Modern Relay Protection. – CRC Press, 2015, 205 p.

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

[4] **Gurevich V.** EMP and Its Impact on Electrical Power System: Standards and Reports. - "International Journal of Research and Innovation in Applied Science (IJRIAS)", 2016, Vol I, Issue VI, pp. 5 – 10.

[5] **Gurevich V.** Protecting Electrical Equipment: GOOD Practices for Preventing High Altitude Electromagnetic Pulse Impacts. – De Gruyter, 2019, 386 p.

[6] **Gurevich V.** Protecting Electrical Equipment: NEW Practices for Preventing High Altitude Electromagnetic Pulse Impacts. – De Gruyter, 2021, 204 p.

[7] **Gurevich V.** EMP Protection of Civilian Critical Infrastructure: Opinions, Problems, Strategy, Solutions. Third Edition. Haifa, 2023. (https://www.researchgate.net/publication/375088787_Gurevich_V_EMP_Protection_of_Civilian_Critical_Infrastructure_-_Third_Edition)

Enough talk about EMP!
It's time to act!

EMI
Protective Modules
Specially Designed for Ungrounded (IT system) with zero leakage requirements DC/AC Electrical Auxiliary Power Networks (10-Series)

- For civilian critical infrastructure protection
- For DC/AC electrical power networks ground-insulated (IT system, IEC 60364-1) and equipped with insulation monitoring devices (IEC 61557-8) for zero leakage requirements
- For facilities: medical, explosive, with high humidity, safety applications, special production processes, ungrounded auxiliary DC power network of substation and power plants
- For nominal voltages 12V to 250V and loads 50W to 3000W
- For effective limit the amplitude of the high-voltage high power EMI pulse (residual voltage amplitude not more than 520V at current amplitude up to 6 kA)
- Panel-mounted, PCB-mounted or DIN-rail 35 mm mounted
- Special inductors for high DC saturation currents are used
- High insulation level to ground (> 200 MΩ at 500V)

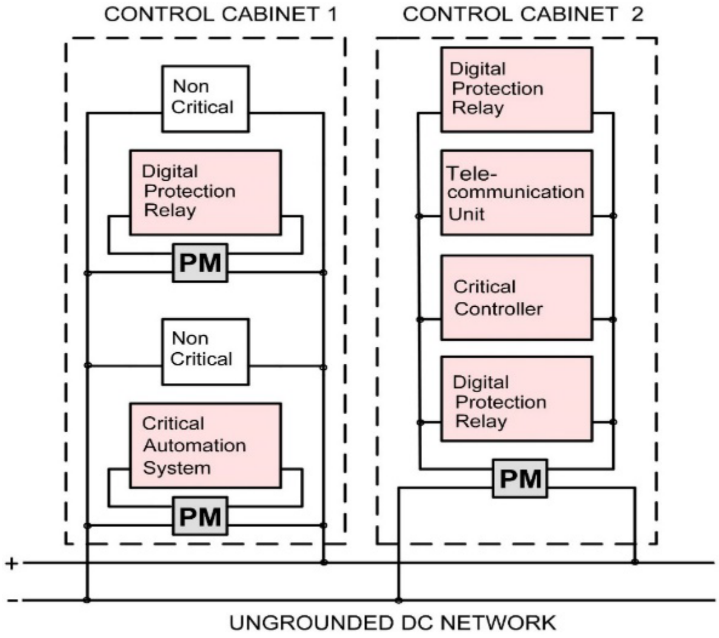
Specifications

Cat. No.	**Power Network Type**	**Current: Nominal/ Maximal/ Overcurrent for 1 sec, A**	**Case Type**	**Internal DC Resistance and Impedance For 50 Hz, mOhm**	**Case Dimensions (without fasteners), mm** **Weight, g**
11 **12** **13**	Ungrounded (IT) 125-250VDC or 115-230VAC	4/5/50	**Plastic** panel mounting (11) DIN-rail (12) PCB mounting (13)	15 25	105x65x40 250
14		8/12/100	**Aluminum** panel mounting	10 21	130x120x55 1100

All critical electronic devices are equipped with their own embedded EMI filters and surge voltage suppressors in their internal power supplies. The basis of such protective circuits are common-mode chokes and varistors, connected between the protected circuits and the ground. However, when such an apparatus is powered by fully insulated ungrounded DC (or AC) electrical network, then such built-in elements of protection against electromagnetic impacts turn out to be ineffective. In completely ground-isolated electrical networks (e.g., in the internal auxiliary DC network in substation and power plants), there is practically no conductive interference of the common type (wire-to-ground). However, there is a lot of powerful interference caused by switching inductive loads (circuit breaker's trip coils, lockout relays, auxiliary electromagnetic relay coils, solenoids, motors, etc.). These are very powerful interferences not related to the ground potential, (i.e. not being a common type interference), that propagate over such a network and are induced into critical control circuits, relay protection, etc. In addition to this, there is also interference produced by switching power supplies, DC-DC convertors, etc. Such interference also has nothing to do with the earth's potential and is not common mode interference. An additional problem is associated with the use of varistors to limit the voltage amplitude in the load. Varistors' so-called "clamping voltage" given in reference materials refers to very small values of pulse current through the varistor. And at high pulse currents (1 to 10 kA), for which varistors are designed, the residual voltage on it ("clamping voltage") can reach several thousand volts and is generally not standardized.

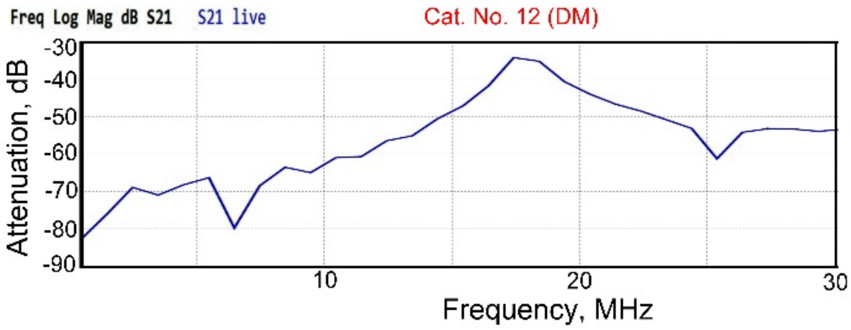
The use of additional EMI filters, connected at the input of critically important electronic devices, also does not solve the problem. Commercial EMI filters are built on the same basic scheme using common-mode chokes, which are not only ineffective for noise that does not have a potential relative to ground, but also tend to saturate quickly and lose their properties when DC passes through them. As practice shows, even those filters that are advertised as intended for DC are made according to the same classic scheme. Moreover, conventional commercial EMI filters are designed to protect against interference such as electromagnetic noise and do not protect against surge voltages, and in addition, their own intrinsic immunity to high-amplitude surges is very limited. As a result, sensitive electronic equipment, even equipped with such filters, often fails.

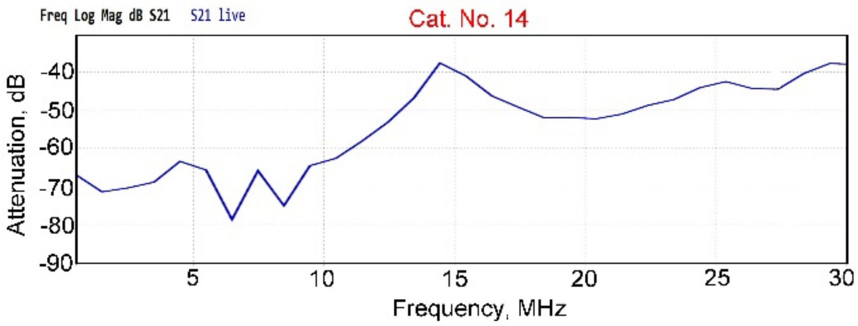
Zero leakage EMI protective modules (**PM**) 10-series are specifically designed to protect critical electronic equipment from powerful electromagnetic impacts distributed over ungrounded DC power supply networks 125V/250V in power plants, substations, industrial plants, such as switching interference and surge voltages, induced interference, etc., from which conventional protect ion elements cannot protect and can also be used to power single-phase AC 125-230V equipment.



Series 10 PM can be installed in electrical control cabinets as individual protection elements for individual types of equipment, or for group protection of all critical electronic equipment available in the control cabinet.

Attenuation for differential mode (DM)



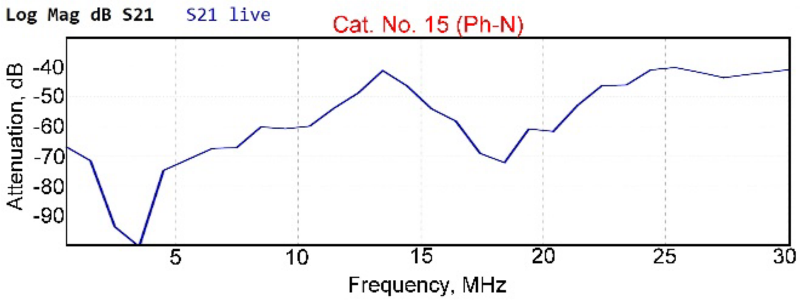


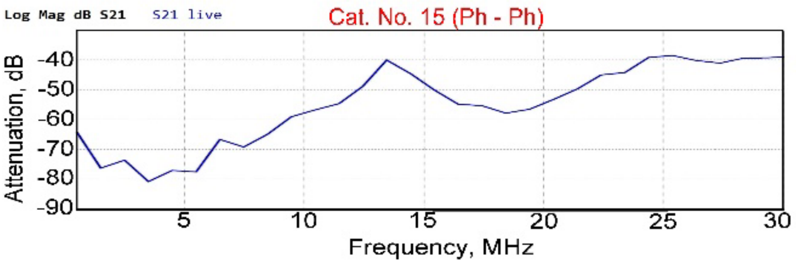
Module Cat. No. 15 designed for three-phase ungrounded AC network 230/400V.

EMI Protective modules of the 10 series

Cat. No.	Power Network Type	Current: Nominal/ Maximal/ Overcurrent for 1 sec, A	Case Type	Internal Phase Impedance For 50 Hz, mOhm	Case Dimensions (without fasteners), mm Weight, g
15	3 Phase 3-wire or 4 wire Ungrounded IT, AC 50/60 Hz	8/12/100	Aluminum, panel mounting	21	250x160x72 1200

Attenuation for differential mode (DM)





A PM Cat. No. 12 and 14 should be mounted inside the control cabinet (relay cabinet) near the protected object, in the power circuit of which it is connected. The PM Cat. No. 15 is shielded and can be mounted both inside the cabinet and outside. In any case, the length of the wires connecting the output of the protective module with the protected object should be minimal and, if possible, shielded. According to standard safety requirements this module housing should be grounded.

The obtained attenuation characteristics demonstrate excellent results in the frequency range up to 30 MHz, characteristic of conventional electromagnetic interference (EMI) in electrical power networks (the typical frequency limit used for conventional commercial EMI filters extends to 10 - 30 MHz).

HEMP
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Specially Designed for Ungrounded (IT system) DC Electrical Auxiliary Power Networks
(20 series)

* For civilian critical infrastructure protection
* For DC electrical power networks ground-insulated (IT system, IEC 60364-1) and equipped with insulation monitoring devices (IEC 61557-8) for zero leakage requirements
* For equipment, powered by auxiliary DC power network on substation and power plants
* For nominal voltages 12V to 250V and loads 50W to 3000W
* For effective limit the amplitude of the high-voltage high power surge and HEMP pulse (residual voltage amplitude not more than 520V at current pulse amplitude up to 6 kA)
* Panel-mounted, PCB-mounted or DIN-rail 35 mm mounted
* Special inductors for high DC saturation currents are used
* High insulation level to ground (> 200 MΩ at 500VDC)

Modern electronic equipment for electrical substations and power plants is based on the extensive use of microprocessors, flash memory components, and other microchips. Moreover, their number in modern electronic equipment is constantly increasing, which is associated with the expansion of the functional capabilities of digital protection relays, automatic control, operation mode monitoring, data collection and transmission systems (SCADA), and so on.

The trend in the development of microprocessors is such that the number of elementar transistors per unit volume is constantly increasing, operating voltages are continuously decreasing, and the thickness of insulation between internal layers and components is continually diminishing.

These two vectors of development in modern power engineering lead to a constant increase in the sensitivity of electronic equipment to electromagnetic interference (EMI) and especially to High-Altitude Electromagnetic Pulse (HEMP), that is, to an increase in the vulnerability of power systems.

A wide range of special filters is offered on the market, designed to protect highly sensitive electronic equipment from HEMP, made according to military standards (MIL-STD-188-125, DEF-STAN 59-188, NATO AECTP-500, MIL-STD-461, MIL-STD-220, etc.). These filters are intended to protect equipment not only from HEMP but also from other electromagnetic effects across a wide spectrum of military applications. Therefore, the size and cost of such filters are so substantial that they make them completely unacceptable for protecting civilian infrastructure. On the other hand, the simple and inexpensive commercial EMI filters available in the market are not designed in their parameters to protect against HEMP.

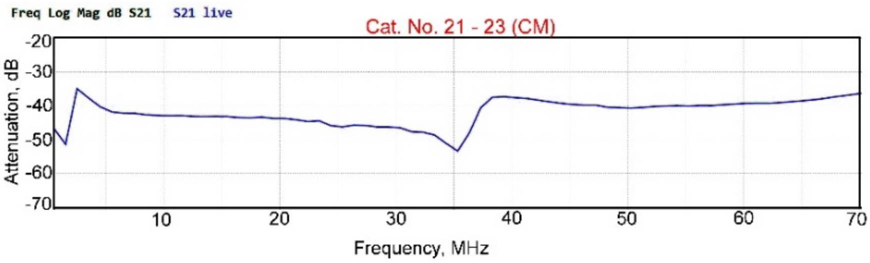
To protect civilian infrastructure against HEMP, a special protective modules (not just filters!) are needed, which are significantly more effective than ordinary commercial EMI filters, and at the same time, significantly cheaper and more compact than military filters.

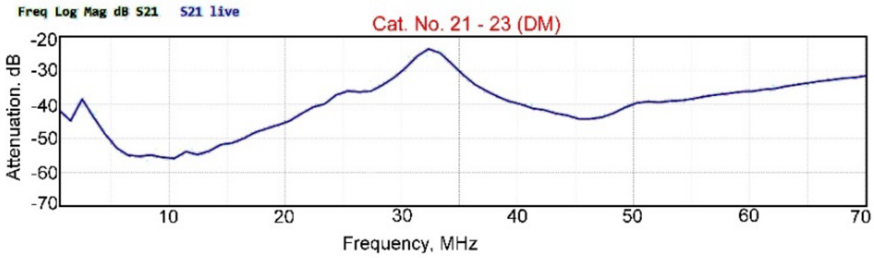
HEMP Protective modules of the 20 series

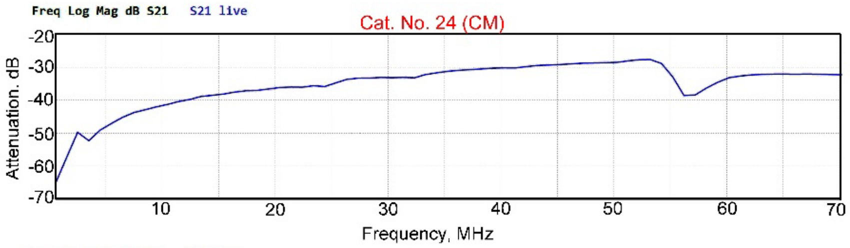
Specifications

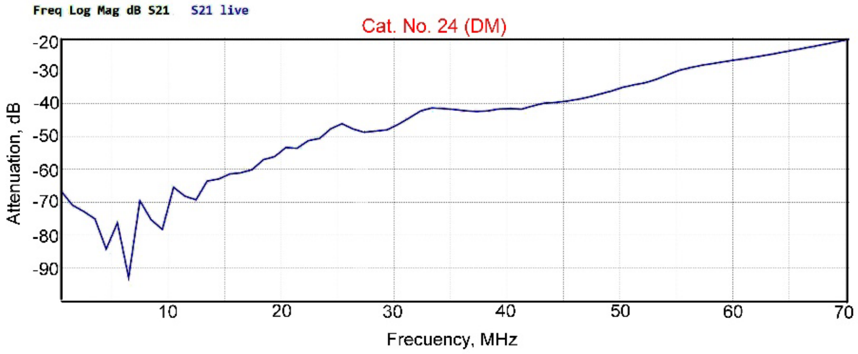
Cat. No.	Power Network Type	Current: Nominal/ Maximal/ Overcurrent for 1 sec, A	Case Type	Internal Resistance and Impedance (For 50 Hz), mOhm	Case Dimensions (without fasteners), mm Weight, g
21 22 23	Ungrounded (IT) 125-250VDC or main 115-230VAC	4/5/50	**Plastic** PCB mounting (21) Panel mounting (22) DIN-rail (23)	15/25	105x65x40 250
24		8/12/100	**aluminum** panel mounting	10/21	130x120x55 1100

Attenuation for common mode (CM) and differential mode (DM)







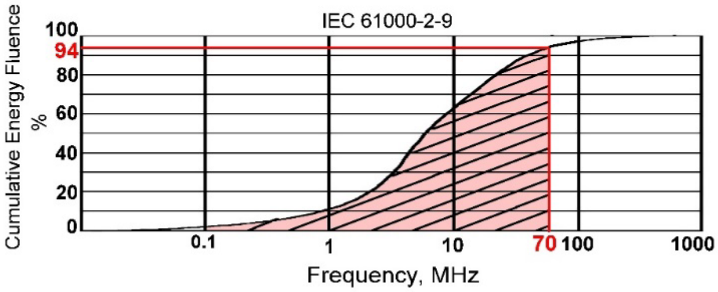


Our HEMP protective modules of the 20 series are designed to fill this existing gap. Primarily, these filters are intended to protect critical electronic equipment powered by an isolated (ungrounded, IT type) DC auxiliary power network, and they can also be successfully used in main AC networks.

Commercial EMI filters only protect against electromagnetic noise and do not protect against surge voltages. 20 series HEMP modules effectively limit the amplitude of surge overvoltages as well, which is very important for HEMP protection.

An ideal commercial solution is the widespread use of these modules for highly effective protection of critical electronic equipment from powerful electromagnetic disturbances, especially in isolated DC networks, with assurance that this equipment will also be HEMP protected.

The limitation of the frequency range with an upper boundary of 70 MHz is due to the fact that, according to the standard IEC 61000-2-9, 94% of the total energy of the E1 component of HEMP is emitted in the frequency range up to 70 MHz.



Meanwhile, the military standard MIL-STD-188-125 applies to the frequency range up to 1 GHz. However, for civilian equipment located not in open areas, but indoors, which significantly weaken the impact of a HEMP, and also excluding the need for protection against other factors (HPEM, TEMPEST), the use of the Pareto principle is quite acceptable (The Pareto Principle, or 80/20 rule, states that roughly 80% of results come from 20% of efforts. This principle of imbalance suggests focusing effort on the most impactful 20% of factors to maximize efficiency and achieve higher returns, rather than distributing effort equally).

Such a limitation of the frequency range while maintaining high efficiency allows for a significant reduction in the size and cost of the protective module, which plays a crucial role for civilian equipment.

Industrial EMP Solutions
CIVILIAN CRITICAL INFRASTRUCTURE PROTECTION
E-mail: industrial_EMP_solutions@outlook.com WEB: www.best-empsolutions.com

EMI/HEMP Protection Modules

for Analog Voltage and Current Circuits of Digital Protective Relays

(30-Series)

- For civilian critical infrastructure protection
- Specially designed for analog circuits of the Digital Protective Relays with nominal voltages 75 – 125 V and nominal current 1A, 5A
- For high power load (up to 1000 VA)
- For effective suppression of fast transient electromagnetic interference arising from the switching of high-voltage power lines and other types of interferences
- For effective limitation amplitude of the high-voltage HEMP pulse (residual voltage amplitude not more than 520V at current pulse up to 6 kA)
- Special inductors for high saturation currents and very low sinus distortion are used
- Aluminum enclosure box for wall mounting single modules and also dual modules (current and voltage in the form of a single module

Modern digital protection relays (DPR) are the most complex electronic devices that actually control the operation of the power system. Of all the variety of electronic devices available in power systems, only DPR is directly related to high-voltage circuit breakers, the position of which determines the configuration of electrical networks and the operability of the energy system. False trip of DPR can lead to disruption of the normal operation of the power system, and the lack of operation in emergency modes can lead to damage to very expensive electrical equipment of the power system.

The problem of protecting the DPR from powerful electromagnetic impacts from long (hundreds of meters) external current and voltage circuits connected to the DPR analogous inputs is a very actual. These circuits are formed by long cables passing through the territory of substations and power plants in the immediate vicinity of powerful high-voltage equipment and high-voltage power lines, which are often sources of powerful fast transient switching interferences (especially when the overhead power line is switching by disconnectors), electromagnetic radiation during corona, short circuits, and thunderstorm activity. Usually, these are unshielded cables. Even if these cables are shielded, they will still carry powerful interference from high-voltage overhead power lines.

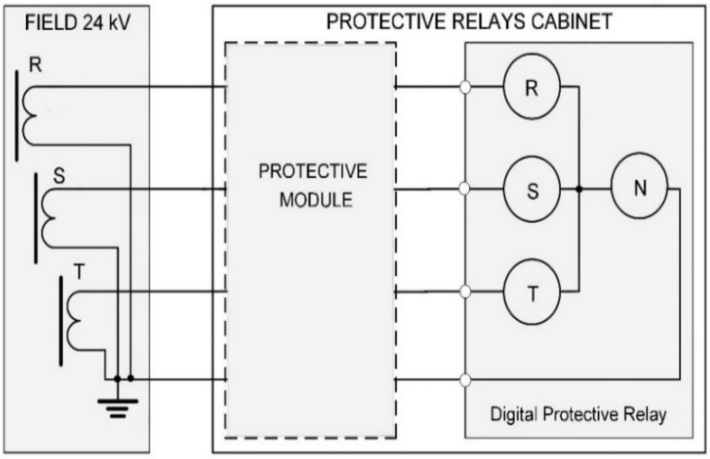
Pulsed electromagnetic impact from many kilometers of wires of overhead power lines have a wide range of frequencies up to ten and even hundreds of Megahertz, for which high-voltage current and voltage transformers are transparent due to the large capacitance between the primary and secondary windings. The fact that the electrical isolation between the primary and secondary windings of the current and voltage transformer passes the high amplitude surge voltage test is not a confirmation that high-power high-frequency interference does not penetrate this insulation and does not enter the DPR analog inputs.

While DPRs tend to withstand such conventional electromagnetic exposures, the situation is very different in the case of HEMP with an electric field strength of 50 kV/m and an electromagnetic spectrum extending up to 70 MHz there is a high probability of damage to the DPR by such a pulse. The multi-kilometer wires of overhead power lines are huge antennas that collect electromagnetic energy from a large area and deliver it through the current and voltage transformer's capacitances to the DPR analog inputs. Long cables running through the substations and connecting secondary circuits of high-voltage current and voltage transformers to DPR are also good antennas. Therefore, the protection of DPR analog current and voltage circuits from HEMP is an important task.

That's why our protective modules were developed.

Specifications

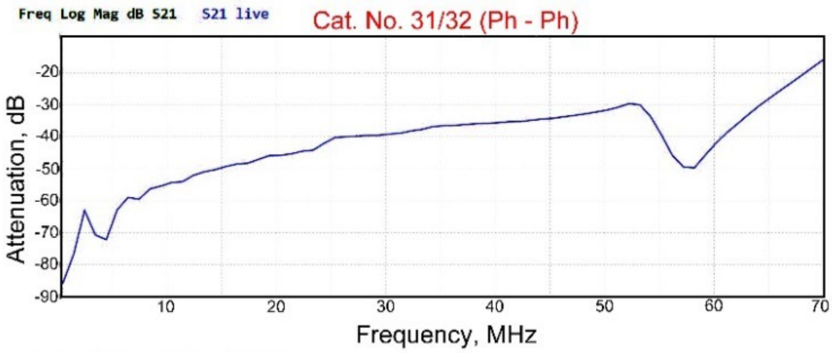
Cat. No.	Power Network Type	Overvoltage/ Overcurrent for 100 msec, A	Internal Impedance for 50 Hz, mOhm	Enclosure Dimensions (without fasteners), mm and Weight, g
31	Protection of analog VOLTAGE circuit of digital relays	300 V	22	250x160x72 1200
32	Protection of analog CURRENT circuit of digital relays	200 A	22	

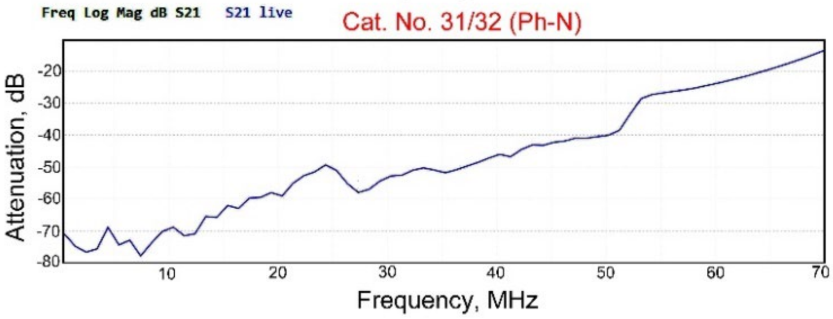


Insertion the protective modules ANLPM-series between the secondary circuits of current or voltage transformers and the analog DPR input

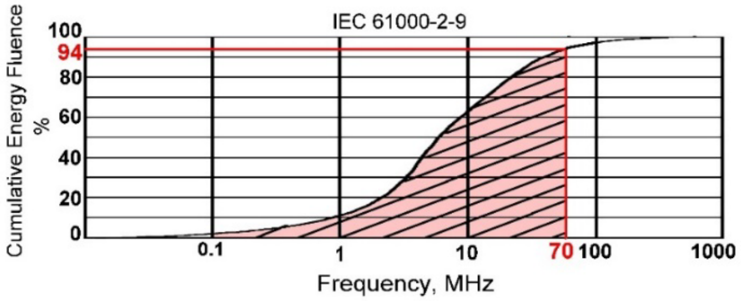
The modules 30-series are made in shielded enclosures and can be mounted both inside electrical control (or relay) cabinets and outside, e.g. in a cable duct under the cabinet.

Attenuation graphs





The limitation of the frequency range with an upper boundary of 70 MHz is due to the fact that, according to the standard IEC 61000-2-9, 94% of the total energy of the E1 component of HEMP is emitted in the frequency range up to 70 MHz.



Such a limitation of the frequency range allows for a significant reduction in the size and cost of the protective module, which plays a crucial role for civilian equipment.

EMI/HEMP
3-Phase Protection Modules
for critical electronic equipment
(40-Series)

* For civilian critical infrastructure protection
* For high power (up to 5000 VA) 3-phase powered electronic equipment
* For effective suppression of fast transient electromagnetic interference and effective limitation amplitude of the high-voltage HEMP pulse (residual voltage amplitude not more than 520V at current pulse up to 6 kA)
* Special inductors that maintain high interference attenuation efficiency even when asymmetric short-circuit currents flow through them
* Aluminum enclosure box for wall mounting single modules and also dual modules (current and voltage in the form of a single module

Specification

Cat. No.	**Power Network Type**	**Current Per Phase: Nominal/ Maximal/ Overcurrent for 1 sec, A**	**Case Type**	**Internal Phase Impedance For 50 Hz, mOhm**	**Case Dimensions (without fasteners), mm** **Weight, g**
41	3 Phase 3-wire or 4 wire AC 50/60 Hz	8/12/100	Aluminum, panel mounting	21	250x160x72 1200

Most HEMP filters available on the market are designed to protect electronic equipment powered by a single-phase AC network or a two-wire DC network. However, some types of critically important electronic equipment are also powered by a three-phase AC networks 208/120, 400/230V (and others), so there is a need for HEMP protective three-phase modules as well. Such filters are also available on the market, both for 3-circuits and for 4-circuits (with neutral). The principle of construction of such filters does not differ from single-phase filters: these are the same common mode chokes, but not single-phase, but three-phase (with three-winding or four-winding on the single ring-shaped ferrite choke).
However, such standard and widely available filters on the market have a number of serious drawbacks that limit their use for effective protection critically important civilian electronic equipment.

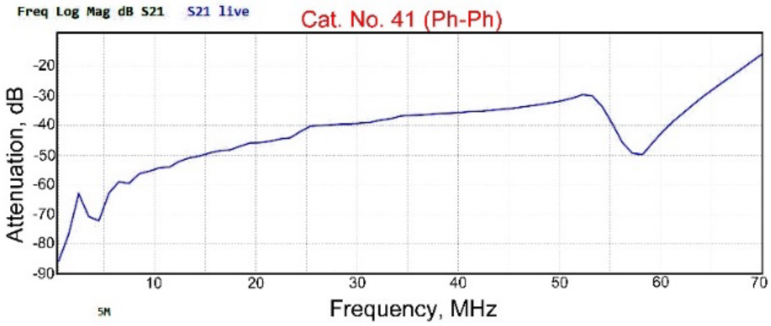
The first problem is the need for a symmetrical current load of all 3 (or even 4) coils of such a choke, since only with the same current of electromagnetic interference in all three phases and neutral, such a choke will effectively weaken it, that is, if there is interference relative to the ground in all 4 lines. If at least one of the 4 coils has a different interference current than the other 3, the filter efficiency will be significantly reduced.

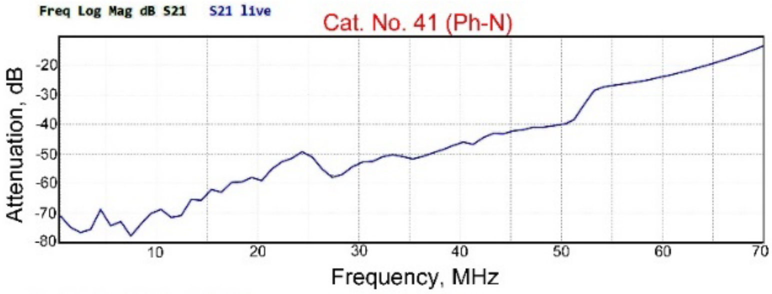
Secondly, in the event of a powerful interference the core of the standard ring-shaped ferrite chokes may enter saturation and its effectiveness drops sharply.

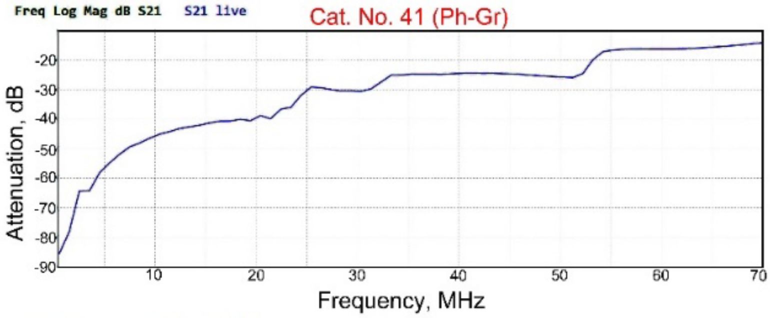
Thirdly, is related to the very limited operating frequency range of commercial three-phase filters, which are usually limited to a frequency of 30 MHz and sometimes 10 MHz, whereas the HEMP frequency range extends up to 70 MHz (*The limitation of the frequency range with an upper boundary of 70 MHz is due to the fact that, according to the standard IEC 61000-2-9, 94% of the total energy of the E1 component of HEMP is emitted in the frequency range up to 70 MHz. Such a limitation of the frequency range allows for a significant reduction in the size and cost of the protective module, which plays a crucial role for civilian equipment*).

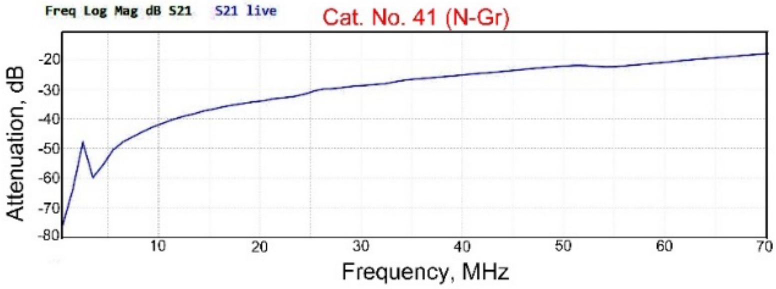
***F**ourthly*, commercial EMI filters only protect against electromagnetic noise and do not protect against surge voltages. And the three-phase HEMP filters available on the market are so expensive that the possibility of their use in civilian equipment is extremely limited. Developed 40 series HEMP modules protect against electromagnetic noise and effectively limit the amplitude of surge overvoltages as well, which is very important for HEMP protection. At the same time, they are significantly cheaper than regular HEMP filters intended for military equipment.

Attenuation graphs









HEMP
Protection Module
for Telecommunication
(50-Series)

- * For civilian critical infrastructure protection
- * For typical industrial, power substation and power plant Ethernet systems
- * Very low losses and capacitance
- * Small dimensions and easy installation
- * High efficiency of protection

Telecommunications are widely used in relay protection systems and other important systems at substations, power plants, and water supply systems. As a rule, it is based on 10 Base-T and 10/100 Base-TX Ethernet (IEEE 802.2).

Complex equipment that provides transmission an important data in such a system contains microprocessors and other electronic chips operating at very low voltages, that is, it is very sensitive to electrical influences. This is the most vulnerable part of the infrastructure, which requires special high-effective HEMP protection. Moreover, such protection should not affect the work of telecommunication.

Such a protective module was developed and tested for compliance with standards IEC 61000-4-25, IEC 61000-4-4, IEC 61000-4-5 and ITU K.78.

Specification

Parameter	Value
Peak pulse discharge current for (E1) very short rise time (less than 0.2 µs)	300 A during 20 µs
Peak pulse discharge current: - for E2 HEMP component (25/1500 µs) - for lightning (8/20 µs)	 1000 A 5.000 A
Max. surge voltage amplitude L-L, L-G (for E1 & E2 HEMP components), at clamping voltage not more than 15 V	8 kV
Insulation level between input and output circuit (rms)	5 kV
Internal series resistance L-L, L-G	30 Ohm
Max. losses: - for 10 Base-T - for 100 Base-T	 3 dB 5 dB
Pins protected	1-2, 3-6
LAN Protocol	10 Base-T (10 Mbps) 100 Base-TX (100 Mbps)
Typical Capacitance (1 MHz) L-L/L-G	30/40 pF
Punch-Through Voltage	4.5 V
Clamping voltage at current 300 A	15 V
Dimensions: - without mounting plate - mounting plate	 115 x 75 x 40 mm 145 x 75 x 2 mm
Weight	280 g
Operating temperature, ˚C	-20+50
Max. Humidity non-condensed, %	95

Additional tests were carried out when pulses 5/50 ns and 1.2/50 µs were applied to the input of an industrial telecommunications equipment with an amplitude of 1 to 8 kV without the protective module and with the protective module connected at the input of equipment. In the first case, the telecommunications equipment was always damaged even at the smallest amplitude of pulses, and in the second case it remained fully operational even at the largest amplitude of pulses.

To confirm the absence of the influence of the protective module on the operation of the Ethernet network, such a module has been used for a long time when inserting between a computer network and a personal computer. During the test period, no side effects of the module on the operation of the computer were detected. The measured data transmission and receiving speed also did not change.

UPS and Static Switch Tester
(for express test after HEMP impact)

* For civilian critical infrastructure protection
* For express-test industrial uninterruptable power supplies (UPS) performance and serviceability
* Simplicity and ease of use
* For a quick check of the industrial UPS functionality after exposure to HEMP, as well as for use in a normal situation
* Replaces the complex test that previously required special equipment
* Significantly reduces testing time to a few minutes

Some types of electric consumers in critical infrastructure systems (computer servers, medical equipment, communication systems, and other critical applications where even millisecond power interruptions are unacceptable) are powered through very high quality industrial Uninterruptable Power Supplies (UPS) with a capacity from several kilowatts to hundreds of kilowatts. But the UPS itself is a very complex electronic unit that uses many microelectronic components and microprocessors, that is, it is a type of equipment that is very vulnerable to HEMP.

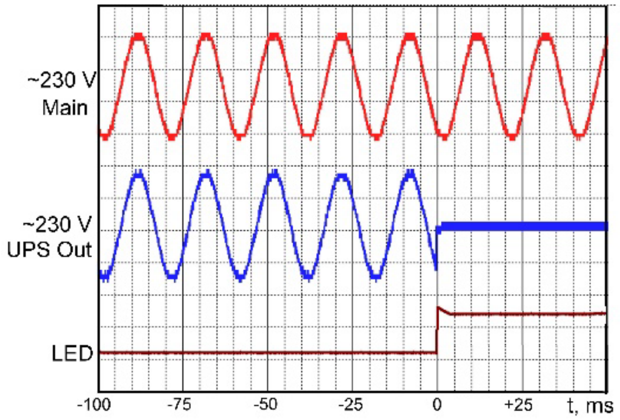
A possible situation when, after HEMP impact and shutdown of many types of electrical equipment and power supply networks, a gradual return of all electrical equipment to a working state is required. In this case, it will be necessary to check its performance. In accordance with the IEC62040-4, 2024 standard, a very wide range of tests is provided for UPS, involving long and rather complex measurements of UPS characteristics using special equipment.

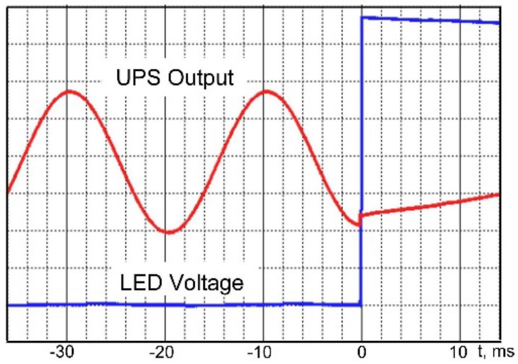
Although all these parameters and tests are undoubtedly important, there are only a few basic characteristics, adherence to which ensures at least a minimal ability of the UPS to perform its functions (which is very important, for example, after the UPS is subjected to a HEMP).

One of the main functions of the UPS is its ability to very quickly switch the power supply of the critical load from the main AC supply network to battery power or a quick switch to bypass. Without special technical means (such as a storage oscilloscope equipped with special active voltage dividers, for example), it is not easy to check the serviceability of such UPS functions. Such equipment requires skill in setting up and working with it.

Our UPS tester allows to solve this problem and very easily and very quickly test this parameter and also most important addition parameters of the UPS such as the frequency and level of the output voltage (in accordance with the requirements of the IEC 62040-3 standard, deviations from nominal values are allowed at the UPS output: voltage ±10%, frequency ±2%.

The tester can be used for testing single-phase UPS or three-phase UPS with phase-by-phase testing of each phase. For testing, one of the inputs of this instrument is connected to the main AC network (to ordinary electrical outlet) using a regular cable with a regular 2-pin or 3-pin plug, and the second – to the electrical network intended for critical loads (to specific electrical outlet). When the operator disconnects the UPS from the main AC network (by external CB only and not by internal CB at the UPS input!), the LED in the instrument should not turn ON. This will confirm that the voltage at the UPS output was not interrupted (or its interruption did not exceed 1.0 ms). This function of the device is explained below in the oscillograms.





As can be seen from the presented oscillograms, the device's reaction time to a voltage break at the UPS output is much less than even one millisecond.

The device is also equipped with a voltage and frequency meter, which complements its functional capabilities. With the help of the switch, this meter can be connected either to the main power supply or to the UPS output voltage.

The device is also equipped with two green indicators for the presence of the main voltage and the output voltage of the UPS, as well as a switch for synchronizing the voltage polarity in the outlets belonging to the main power supply network and belonging to the UPS output network intended for critical loads (the connection of the phase and neutral wires in these outlets does not always match).

Specification

Nominal voltage on the tester inputs, VAC	230 ±10%
Measurement range:	
-for voltage, V	100 – 300
-for frequency, Hz	45-65
Power consumptions, W	<5
Accuracy measurement for voltage and frequency	1% ± 2 dig.
Reaction time for voltage interruption, msec	0.5
Dimensions, mm	175 x 150 x 75
Weight, kg	1.2

The developed device can find wide application for express testing of UPSs, Transfer Switches, Bypass Switches, etc., whether in operation, during commissioning, or after repair, also independently of HEMP.

Important Note:
The device must be turned ON immediately before conducting the test and turned OFF immediately after the test is completed. Prolonged operation of the device in the on state is not allowed.

HEMP Protected
Automatic Emergency Backup Industrial Battery Charger

for Auxiliary DC Critical Power Network

* For civilian critical infrastructure protection
* For nominal DC network voltages 125V and 250V
* Automatic activation in case of failure of the main charger
* Automatic return to standby mode upon restoration of voltage in the DC network
* The compact size and relatively light weight make the charger easy to transportation
* Floor-mounted installation and wall-mounted

Direct current auxiliary power system (DCAPS) is the most important component of any substation. All other substation systems and equipment (such as power equipment, relay protection, automation, control, communication, emergency, etc.) rely upon its operability. DCAPS failure makes the whole substation completely inoperable and “invisible” for the central control room. Therefore, DCAPS above all others needs the special facilities to ensure its operation upon HEMP. Primarily, the special protection measures are required for electronic battery chargers supplying power to DC current carrying buses, feeding numerous consumers and ensuring battery floating charge. A regular charger contains many electronic elements connected with long cables (input AC supply cable, output DC cable and signal cable). Such equipment is particularly sensitive to the effects of HEMP.

The backup automatic charger allows the entire DC network (including batteries) to maintain normal operation in case the main charger fails. This charger continuously monitors the voltage level in the DC network. In this mode, the charger is completely HEMP protected. When this voltage falls below the set level due to the failure of the main standard charger (after HEMP impact), the backup charger activates and returns the voltage in the DC system to normal levels.

After two hours of operation, the backup charger deactivates automatically but continues to monitor the DC voltage. If the problem persists, the charger automatically reactivates. If the issue has been resolved and the voltage has returned to normal levels, the charger automatically goes back to standby mode. This is a very important function because the charger can be activated for various reasons related to emergency situations that periodically occur in the power network. However, after activation, the charger's HEMP protection does not disappear completely, but its level decreases. Therefore, it is very important that the charger automatically returns to HEMP full protected mode (that is standby mode) after the fault in the network has been eliminated. But this function can be turned off using a toggle switch **S2** located on the control unit. In this case, the charger remains in an on state constantly after first activation and operates parallel to the standard charger operating at the substation.

Under normal condition the charger operates with natural ventilation, which is provided through two ventilation openings covered by honeycomb vent panels that prevent the penetration of electromagnetic waves into the internal space of the charger. Usually, chargers at substations operate most of the time with a small load (about 20-30% of the maximum capacity) and therefore do not require forced cooling. However, with prolonged operation after activation at maximum current (for example, after a deep discharge of the battery), the temperature inside the charger (which has very limited free internal space) may rise. To increase the thermal time constant of power supplies, their casings have good thermal contact with the main mounting board and an additional metal board. In addition, the device is equipped with a current monitoring relay that automatically turns on the intake and exhaust fans when the load exceeds 70% in order to prevent overheating of the power modules. When the temperature inside the charger increases, unrelated to operation at maximum current, another system based on a temperature monitoring relay comes into play. The temperature monitoring relay turns on the intake and exhaust fans automatically when the temperature in the upper part of the cabinet rises to 35-37°C (at the same time, the temperature inside the closed power units can be much higher) and turn off when the temperature drops to 30°C. As a backup redundant element needed in case of failure of the electronic systems for monitoring current and temperature, a simple mechanical thermostat switch is used, which turns on the fans at around 45°C and turns them off at around 30°C.

Main Parameter	**Value**	
Type	**230/125-40-x***	**230/250-20-x***
Nominal Output DC Voltage, V	125	250
Power, W	5000	
Max. Output current, A	40	20
Input AC Voltage Range, V	187 – 253	187 – 253
Output Ajustable DC Voltage*, V	95 – 150**	190 – 300**
Threshold reduced voltage at which the charger should be activated*, V	75 - 120**	170 - 270**
Output Voltage Deviation, %	± 0.5	
Ripple, V	≤0.1	
Unbalance current at parallel connection, %	± 3%	
Working Temperature, ˚C	+5˚C to +30˚C	
Natural cooling (see p. 3)	Yes	
Automatic Current Limiting	Yes	
Overvoltage protection	Yes	
Short circuit protection	Yes	
Dimensions, mm	300x800x800	
Weight, kg	60	

*   *x =* ***F*** *for floor mounting; x =* ***W*** *for wall mounting*

*** The voltage within the specified range is set by the manufacturer as factory default setting* ***at the request of the consumer****, but cannot be changed by the consumer. Factory default setting for charger 230/250-20 type is 237V in float mode and 225V for activation.*

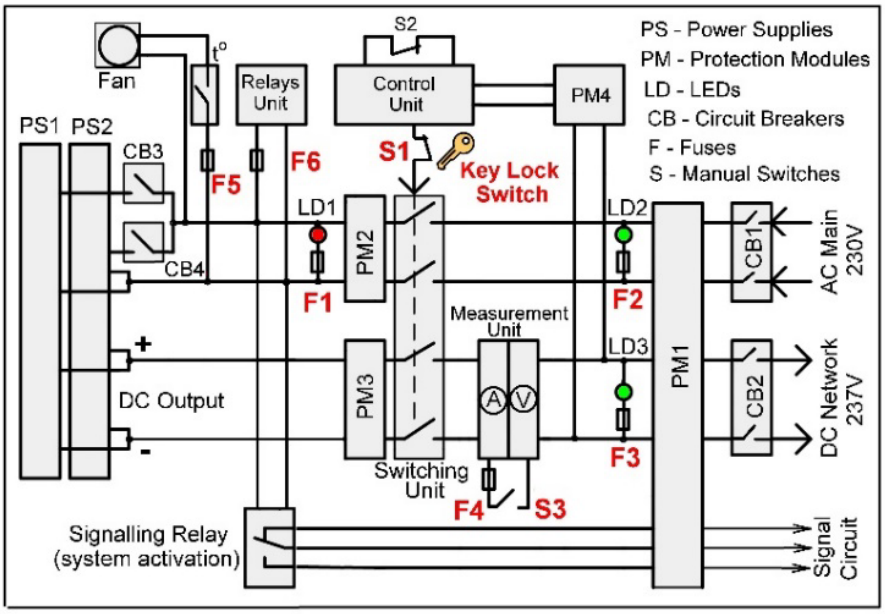
The automatic operation mode (automatic activation and deactivation) of the charger can be completely turned off at the request of the consumer using a switch **S1** located inside the charger. When the switch **S1** is moved from the "Protected" position to the "Unprotected" position, the automatic control function is completely disabled, and the device starts to operate as a regular charger. In this mode, the charger remains well protected against ordinary electromagnetic interference, but has a reduced level of protection against HEMP. Therefore, it is very important that this feature is not disabled without authorization. To prevent unauthorized disabling of this feature, switch **S1** is equipped with a mechanical lock, the key of which cannot be removed after the feature is disabled. In a normal situation the key is stored in a container on the charger door.

The charger is equipped with signal lights, as well as an DC ammeter and voltmeter, which are activated by pressing a push button switch **S3**.

The Control Unit with sensitive electronic components inside (as critical part of the system) is placed in an additional metal enclosure and connects to the DC network through addition special protective module (PM4), using triple-shielded cables.

External cables enter the charger from below through metal glands in the floor of the charger.

Simplified Functional Diagram



The charger is built in such a way that damage and failure of auxiliary electronic systems and even one of the internal power supplies do not stop its operation, but only reduce its output power. For this purpose, all secondary electronic devices and electrical circuits are equipped with 6 fuses and 2 addition thermal magnetic circuit breakers that prevent short circuits in the internal circuits when a specific internal electronic module is damaged and a short circuit occurs. These fuses allow for the isolation of the damaged module and its impact on other circuits before the main (input) circuit breaker trips and shuts down the entire charger.

To increase the output power two or three times, two or three chargers can be used with their outputs connected in parallel, while the inputs are connected to different phases of the main AC power network. In this case, the separate chargers are installed one on top of the other and fastened to the wall. The independence of each individual part of such a combined charger ensures the redundancy in reliability and survivability necessary for backup emergency equipment.

The charger is intended for operation in a control room with a controlled temperature between +5°C to +30°C and humidity up to 85% and can be transported by any means of transport, but only in a horizontal position, with the door facing up.

As a rule, the substation's own AC power supply system is more resistant to HEMP than the DC system, since it does not contain electronic components (as battery chargers, for example), however, it can also be damaged by an intense HEMP. Therefore, for comprehensive protection of the DC system at critical substation, it may be necessary to install a small diesel generator with a capacity of 5–10 kW, equipped with a special starting and protection system, as described in this catalogue.

Mobile Backup Power Supply
for auxiliary DC power system simulation

- For civilian critical infrastructure
- HEMP protected
- For testing electronic equipment after HEMP affecting before actuating
- For commissioning of new equipment at a substation and power plants and repair works
- For use in electrical laboratories as a voltage source simulating the DC network of power plants and substations

After exposure to HEMP, there is a need to check the serviceability of electronic equipment before actuating. To do this, will need a power supply that simulates a conventional auxiliary DC power system.

Since to include equipment that may have failed and has an internal short circuit in a normal auxiliary DC network of a substation or power plant means to endanger this network. In addition, after exposure to HEMP, the DC network may not function, but you still need to know about the condition of the equipment. In this case, such a DC power source is the only solution to the problem.

And not only for such an application. A mobile power supply-simulator of a DC network is also necessary for commissioning of new equipment at a substation and repair works.

This compact mobile backup power supply protected from HEMP when it is not in use and is stored in a warehouse.

Such a compact, inexpensive backup power supply, simulating a standard DC power network, should be at every substation, in every laboratory.

Among other things, such a power supply is very convenient to use when checking, repairing and adjusting the equipment of power stations and substations.

Specification

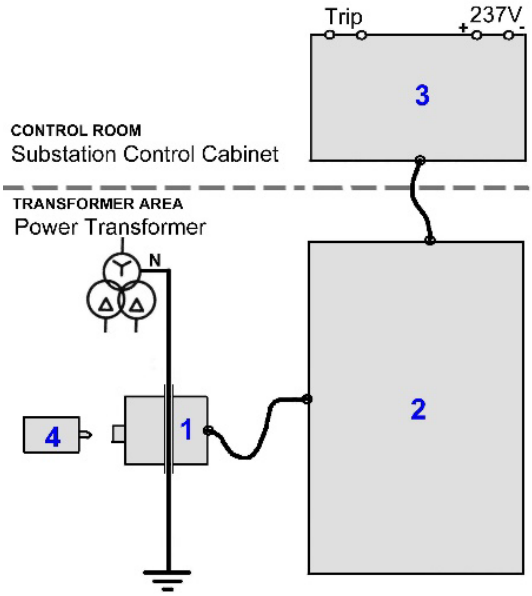
Nominal output voltage, VDC	250	Short circuit/overload protection	Yes
Rated output voltage, VDC	237	Ripple in output voltage, V peak	0.5
Max. output current, A	24	Weight, kg	12
Main power, VAC	230	Dimensions, mm	400x300x200
Amperemeter accuracy, %	2.5	Operating temperature range, ˚C	-10+40
Voltmeter accuracy, %	2.5	Humidity non-condensing, %	20 - 95

HEMP(E3) Protection System of High-Power Transformer

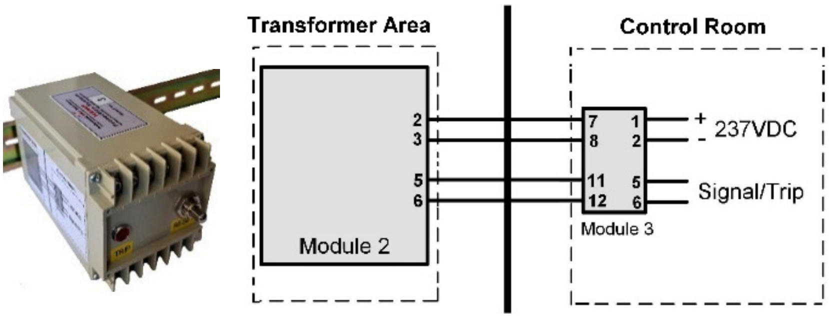
- For civilian critical infrastructure protection
- The E3 HEMP sensor is mounted on the neutral conductor (ground bus) without breaking it and without turning off the transformer
- The system is protected against overload from short-circuit currents flowing through the neutral of the transformer
- All internal electronic components protected against E1 HEMP
- Suitable for all types and classes of transformers with grounded neutral
- High reliability of protection is combined with negligible cost of the system relative to the cost of the transformer

One of the components of the HEMP is a component called "E3". It is a quasi-DC current reaching several tens to several hundred Amperes flowing ground system and leads to saturation of the transformer core, a sharp decrease in its impedance and unacceptable overheating. In addition, there are a bulk of harmonics in the network, generated by such transformer with saturated core. These harmonics disrupt the operation of relay protection, affect capacitor banks and other critical equipment.

The Transformer Protection System (TPS) consists of 4 separate modules:
No. 1 – E3 sensor placed in a protective shell,
No. 2 – HEMP protected electronic relay,
No. 3 – auxiliary substation module,
No. 4 – tester-simulator E3.
This protection system must be installed on all type transformers with a grounded neutral.



TPS flowchart



Substation Module (No. 3)

Electronic Module (No. 2)

When a dangerous DC component (about 20A) of the current (E3 component of the HEMP) appears in the neutral circuit of the transformer, the electronic module (No.2) with a slight delay (2-3 sec), which excludes false trip, gives a command to turn off the transformer. After 2-3 minutes, the flow of current in the neutral circuit from the component E3 stops and the transformer can be returned automatically to normal operation by standard substation auto-reclosing system. The entire system returns to its original standby state when the “Reset” button is pressed on the auxiliary substation module (No. 3).

The sensor (module No.1) and electronic unit (module No. 2) are protected from radiated electromagnetic interference by an aluminum enclosure and using shielded external connecting cables. These modules are protected against conducted electromagnetic interference by special HEMP filter; transient voltage suppressors and using HEMP-resistant components. The most critical elements in the electronic module are duplicated.

TPS Specification (for disconnected internal transient voltage suppressors:

Nominal sensor input current, A DC	25	Magnetic field immunity, A/m, 50 Hz	30
Over-range without damage, A	>8000	Response time (max.), s	3
Power voltage for modules:		Trip current accuracy, A DC	± 5
- No. 2, VDC ± 10%	240	Dimensions, mm:	
- No. 3, VDC ± 10%	240	-sensor (No.1)	180x180x150
- No. 4, VAC ± 10%	230	-electronic module (No.2)	180x180x70
Withstand overvoltage:		-auxiliary substation module (No.3)	115x65x65
- input sensor window, VDC	2200	-tester-simulator (No.4)	175x150x75
- power to output contacts, VDC	1000	Weight, kg:	
Total power consumption standby, W	3	-sensor (No.1)	1.8
Total power consumption max., W	5	-electronic module (No.2)	1.2
Max. switching voltage, V DC/AC	250	-auxiliary substation module (No.3)	0.2
Max. switching current, A DC/AC	5	-tester-simulator (No.4)	1.3
Breaking capacity (for DC1, 250V), A	0.25	Operating temperature, °C (%/°C)	-20+50 (0.5)

This protection system should be used not only for transformers with direct neutral grounding, but also for neutral grounding through a Petersen coil, since the Petersen coil cannot limit the direct current flowing through it.

The system is protected against overload from short-circuit currents flowing through the neutral of the transformer.

In order to be sure of the serviceability of the HEMP protection system of the power transformer, it is necessary to systematically (once a year or once every two years) check it. A simple procedure is provided to check the health of the system using a simple tester, which can be purchased separately or as a bundle with the system.

Tester-Simulator E3 (No. 4)

This test consists of applying a DC current to the sensor of less than 20 A (the system should not trip) and a current of more than 20A (the system should be triggered).

Usually, in control cabinets on large transformers there is always a standard outlet with a standard auxiliary AC voltage. Such standard AC mains can be used to power the simulator-tester.

Tester-Simulator Specification

Nominal output current, ADC		Max. current consumption, A	
-in NON-Trip mode	18-20	-at 230VAC	1.5
-in Trip mode	22-25	-at 115VAC	3
The max. time spent in the ON-		Short circuit protection	Yes
state with an output current, s	10	Weight, kg	1.3
Amperemeter accuracy, %	3	Dimensions, mm	175x150x75
Main power, VAC	220/115	Operating temperature, °C	-20+50

Long-term operation of the system in real conditions on a 160/24 kV high power transformer has confirmed its high reliability. During this time, multiple periodic simulations of the E3 component were carried out using the mentioned tester, during which the correct operation of the system was recorded.

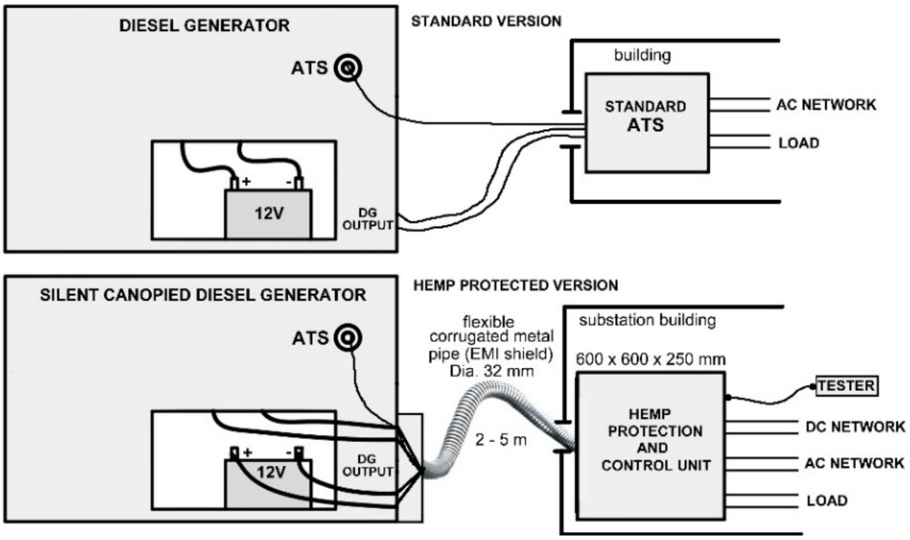
HEMP
Protection and Control System
for an Emergency Diesel Generator Powering Critical Substation Auxiliary Electrical Network

- **For civilian critical infrastructure protection**
- **Available for AC 120V/230V and DC 125V/250V networks**
- **Automatically starts the DG when problems are detected in the AC and also DC**
- **Automatically return to standby mode upon restoration of the AC and also DC**
- **Easy to transportation**
- **Floor-mounted installation and wall-mounted available**

Direct current auxiliary power system (DCAPS) is the most important component of any substation. All other substation systems and equipment (such as power switching equipment, relay protection, automation, control, communication, emergency, etc.) rely upon its operability. DCAPS failure makes the whole substation completely inoperable and “invisible” for the central control room. Therefore, DCAPS above all others needs the special facilities to ensure its operation upon HEMP. The HEMP-Protected Automatic Emergency Charger we developed earlier solves this problem.

The next problem is the possibility of loss of AC power, which aforementioned Charger is supposed to receive. Existing backup power systems based on DG and Automatic Transfer Switches (ATS) do not solve the problem, as both the DG and the ATS (containing microprocessors and other sensitive microelectronics) are not protected against HEMP, and, moreover, they only focus on the condition of the AC network and do not take into account the state of the substation's DC network with a powerful battery capable of sustaining the DC network for several hours without AC power.

The developed DG Protection and Control System (DGPCS) differ in its structure from the standard scheme with ATS. DGPCS is not only fully protected from HEMP itself but also provides protection for the electronics of DG.



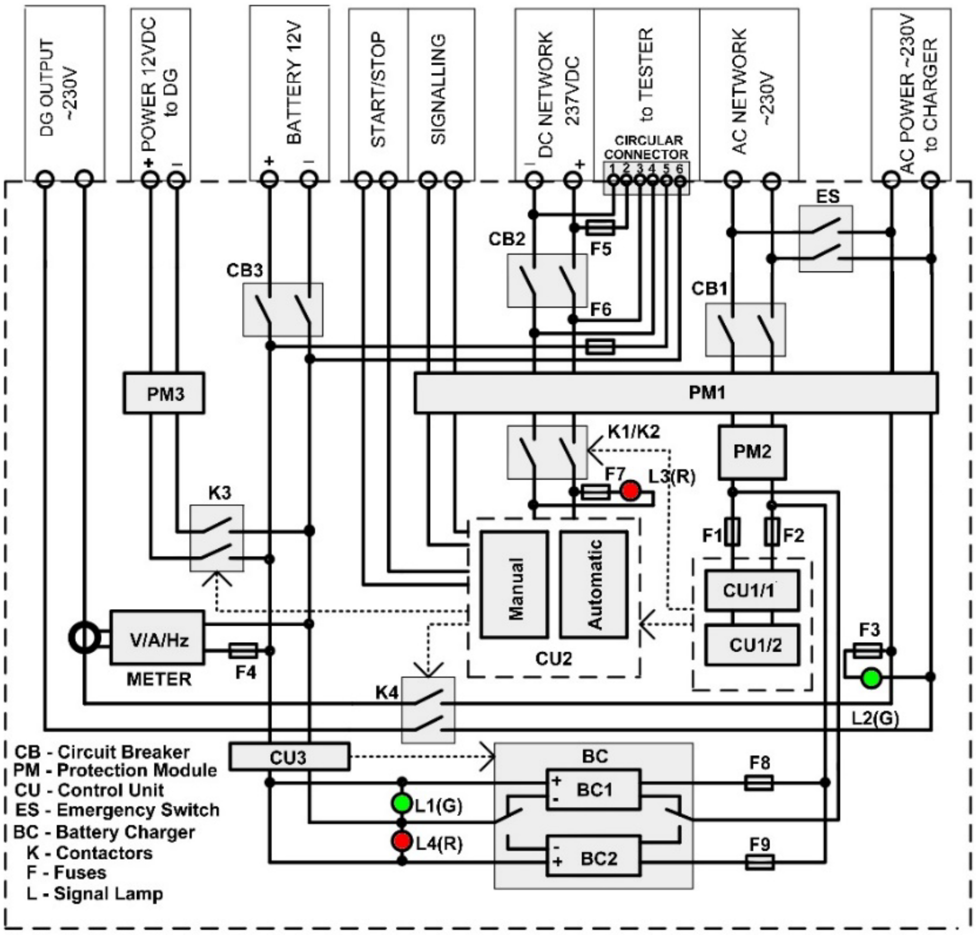
Standard ATS and new DGPCS

In normal operating mode, the AC mains voltage is supplied from the output of the DGPCS to the substation charger. In such standby mode, DGPCS continuously monitors the presence of AC voltage using two HEMP protected sensors. When AC voltage disappears, the DC voltage monitoring system of the substation DC auxiliary network is activated inside DGPCS. After several hours, if the voltage in the AC network has not been restored and therefore the voltage level in the DC network drops (below 225V in a system previously set to 237V), an automatic staged start of the generator begins, ensuring an optimal start-up process, including its idle operation mode for several dozen seconds. The operation of the diesel generator continues until the AC mains voltage is restored. After the AC mains is restored, the output circuit of the DGPCS switches from the diesel generator to the mains, but it continues to operate for a few more dozen seconds, and then (if during this time the AC mains voltage does not disappear again) the optimal diesel generator shutdown process is initiated, including its idle operation mode for several dozen seconds.

DGPCS is equipped with 3 current protection circuit breakers; 10 fuses; a manual start unit; and a manual emergency transfer switch, which allows to disconnect all internal DGPCS circuits and supply power to the substation charger directly from the AC mains. The DGPCS is also equipped with a reserved dual charger for continuous charging (float mode) of the diesel generator's starting battery. There are also red and green indicator LEDs, as well as a meter for the generator's voltage, current, and frequency.

DGPCS is equipped with a Manual Control Unit for DG starting, using three rotary switches, which are activated sequentially with a time delay of 20-30 seconds between each subsequent switch. ***Before this operation, switches CB2 and then CB1 must be turned off.***

The DGPCS is protected from radiated electromagnetic interference by a steel enclosure with electrically conductive seals around the perimeter of the door, honeycomb vent panels, as well as additional aluminum housings for electronic units inside the main steel shell, using shielded wires and cables. The DGPCS is protected against conducted electromagnetic interference by special HEMP filters; transient voltage suppressors; using HEMP-resistant components; as well as by specific original circuit design solutions.



Simplified functional diagram of the DGPCS

The DGPCS is equipped with a special compact tester, which can be connected to the DGPCS using a control cable and connector. This tester can simulate an emergency mode in the DC network and activate the DGPCS and diesel generator to check their operability. Before turning on the tester, CB2 must be switched off, followed by CB1. The tester is also equipped with two separate voltmeters to monitor the voltage of the diesel generator's starter battery and the DC voltage at which the DGPCS is activated. ***Before this operation, switches CB2 and then CB1 must be turned off.***

Tester-simulator with cable 2m to DGPCS connection
158 x 90 x 60 mm

The DGPCS is intended for operation indoor at temperature +5°C to +40°C and humidity up to 85%. To prevent condensation inside the cabinet, DGPCS is equipped with a heating element and a thermostat. The DG can be installed outside the substation building or inside, but with a sealed exhaust pipe leading outside. The distance between the DG and the DGPCS should not exceed 5 meters.

For the power supply of a medium substation, a DG with a capacity in the range of 5 - 8 kW is usually sufficient. This is a relatively small single-phase generator, equipped with wheels for easy mobility. The DGPCS, operating on the same principle, can be used in conjunction with a DG of higher power or together with a three-phase generator. In this case, only the size of the DGPCS cabinet will increase.

Main parameters of the DGPS intended for a single-phase diesel generators:

DGPS Type / **Parameter**	**DGPCS-120/125-5**	**DGPCS-120/125-10**	**DGPCS-230/250-5**	**DGPCS-230/250-10**
Network Voltage AC/DC, V	120AC/125DC		230AC/250DC	
DG Power, kW	5	10	5	10
Dimensions, mm	600 x 600 x 250 mm			
Weigh, kg	30			
Cooling Type	natural convection			
Installation (for DGPS unit only)	Indoor, at temperature +5°C to +40°C and humidity up to 85%			

The DGPCS is designed for use with any brand of silent DG (that is, with enclosed canopy), equipped with an internal controller and an input for connecting an external ATS with a dry contact for generator start.

The DGPCS can be supplied separately or as a package with a DG of the required capacity. In the event that the customer independently purchases the DG, it will be necessary to install a protective aluminum shield covering the DG control panel, as well as to install a metal gland on it for routing the cables connecting the DG to the DGPCS.

The DGPCS can be transported by any means of transport, in a horizontal position, with the door facing up.

A Fresh Look at a 50-Year-Old Unsolved Problem

Industrial EMP Solutions

Civilian Critical Infrastructure Protection