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THEISSUEOFCONTROLCABLESSELECTIONFORHEMPPROTECTEDELECTRICFACILITIES

*Strictly as per the compliance and regulations of:*

# The Issue of Control Cables Selection for HEMP-Protected Electric Facilities

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## I. Introduction

Protection of electronic equipment of control, automation, and relay protection, installed at electric power facilities from an electromagnetic pulse of high altitude (30 - 400 km) nuclear explosion (HEMP),which creates electric field density about 50 kV/m at the ground surface, has recently become very relevant. Nowadays, there are technical solutions including special shielded cabinets, filters, arresters, etc., which provide HEMP protection for highly sensitive electronic equipment of power plants and substations, [1, 2]. However, local protection of this equipment at a level of an individual cabinet or even a room is facing a serious problem, evolving in wasted efforts. This this problem is called control cables. They run over long distances and act as huge antennas absorbing HEMP energy from a large area and deliver it to an interior space of protected rooms and cabinets, directly to inputs of sensitive electronic equipment. Thus, only exceptional cables should be used for HEMP-protected facilities, as otherwise all the efforts will be wasted.

## II. Design And Features Of Shielded Control Cables

The fact that low-voltage low-frequency control cables used in this application (also preferable power cables) should be shielded is obvious and doesnot require additional explanations. Indeed, there are various designs of shielded cables and not all of them provide the best protection against HEMP. So, it is appropriate to address different designs of low-voltage shielded cables and their features.

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But first of all it should be noted that there are two kinds of screens used for shielding of cables:

1. *Foil:* screens made of thin (30 - 100 μm) copper or aluminum foil or made of metal-coated (usually aluminum) plastic strip – single strip wrapped around the cable, or consisting of several separate overlaying strips.
2. *Braid:* screens made of interlaced (usually in the way of a "French braid") thin copper (usually tinned) wires, which look like a solid flexible hose, put onto a cable, Fig. 1. This screen is much thicker than that made of foil.

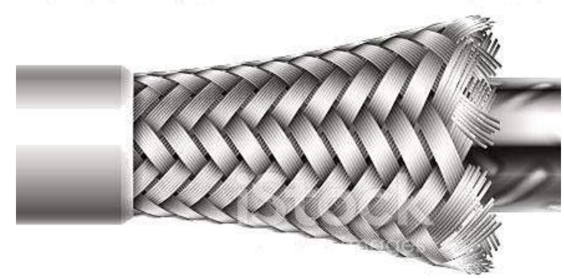

*Fig. 1:* A braided screen of a cable – "French braid".

The specifications of these two kinds of screens are different, Fig. 2.

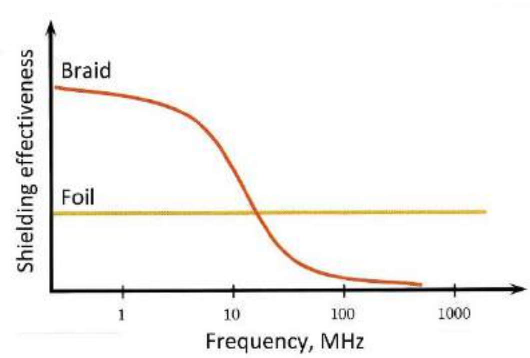


*Fig. 2:* Shielding effectiveness of two kinds of screens.

For example, a foil screen will hardly be efficient at low frequencies as electromagnetic wave penetrates much deeper into metal than the foil thickness. Whereas at higher frequencies, foil screens are much more effective than braid screens, as the surface resistance of the latter is too high for high frequency.

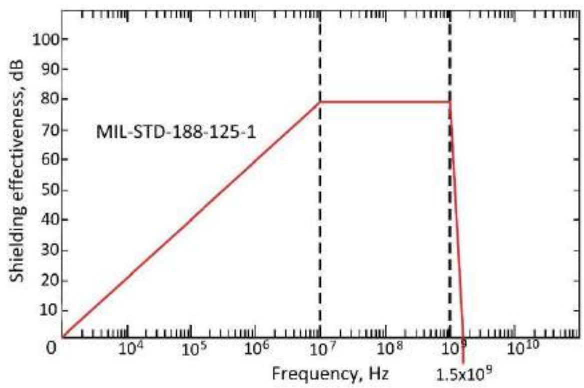


*Fig. 3:* Required shielding effectiveness of HEMP-protected equipment according to MIL-STD-188-125-1 [3].

Since STD-188-125-1 [3] (Fig. 3) requires effective shielding of HEMP-protected equipment in a quite broad range of frequencies, it is obvious that none of the above-mentioned kinds of screens meets these requirements.

Fortunately, there are many compound screens, which combine advantages of both types (Fig. 4).

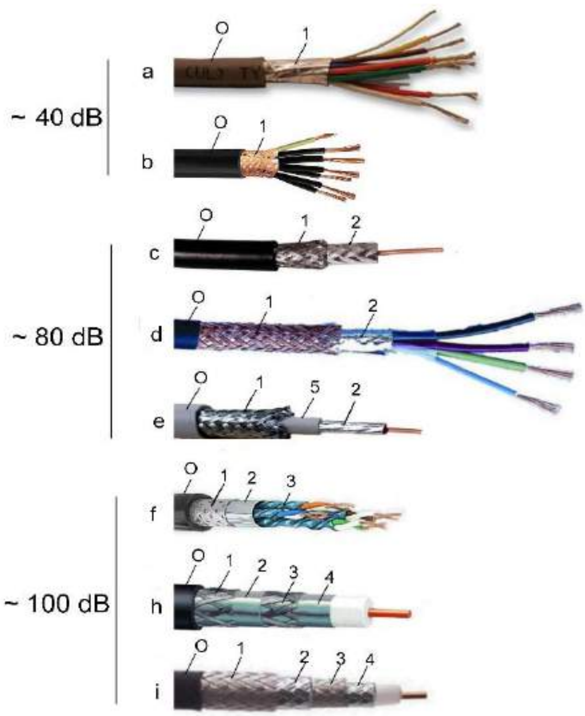


*Fig. 4:* Different designs of shielded low-voltage cables and approximate averaged and generalized values of shielding effectiveness.

a, b – with a single-layer screen (1); c, d, e – with double-layer compound screen: with foil (2) and braid (1); f – with triple-layer and (h) – with four-layer compound screens; i - with four-layer braid; 0 – outer casing of a cable, 5 – internal inter-screen insulation.

Apart from design differences, they also differ in the way of placement of individual insulated cores inside the cable, as this can also affect the cable's protection from electromagnetic interference.

*Fig. 5:* Shielded control cable with twisted pairs.

To enhance protection, individual pairs of cables are twisted with each other many times along the whole length of the cable (Fig. 5).

The above-mentioned design features of cables are often reflected in their marking:

- UTP - Unshielded Twisted Pair;
- F (Foiled) – a cable with common outer foil screen;
- F/UTP (Foiled/ Unshielded Twisted Pair) – a cable with common outer foil screen and unshielded twisted pairs;
- FTP (Foiled Twisted Pair) – a cable without outer screen, but with foiled twisted pair;
- U/FTP (Unshielded overall/ Foiled Twisted Pair) – same as above;
- STP (Shielded Twisted Pair) – a cable without the outer screen, but with braid shielded twisted pairs;
- S/FTP (Screened overall/ Foiled Twisted Pair) – a cable with common outer braid screen and with twisted pairs with individual foiled screens;
- F/FTP (Foiled/ Foiled Twisted Pair) – a cable with common outer foiled screen and with twisted pairs with individual foiled screens;
- SF/FTP (Screened Foiled/ Foiled Twisted Pair) – a cable with a double screen (braid + foil) and with foiled twisted pairs.
- SF/UTP (Screened Foiled/Unshielded Twisted Pair) – a cable with a double outer screen (braid + foil) and with unshielded twisted pairs.
- SF (Screened Foiled)same as above.

Other designs are very rare; they do not control cables, but rather coaxial high-frequency cables.

There are two other design features of shielded control cables, applying to the quality of the outer braid, which can be more or less filling (Fig. 6).

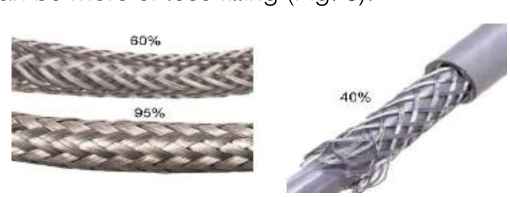


*Fig. 6:* Outer cable braids with different filling thickness (in percent).

Apparently, the higher the braid thickness, the better the shielding capacity. The maximum thickness of braid filling is 95%.

The second design feature of the braid is related to its surface resistance: the lower the resistance, the higher the shielding capacity. This is the reason why high-quality braids are made of tinned copper, which is distinguished (tin color) from non-tinned copper (copper color).

Due to high diversity of designs and because different types of cables are used at electric power facilities, a question arises if shielding effectiveness can be measured.

## III. Measuring Shielding Effectiveness of Control Cables

The method of measurement of shielding effectiveness is described in IEC 62153-4-4 [4]. It is based on measuring the correlation between the power of a high-frequency signal delivered from an external generator to a conductive core of a cable, and the power of a signal emitted from the outer surface of the cable's screen to a special enclosed chamber.

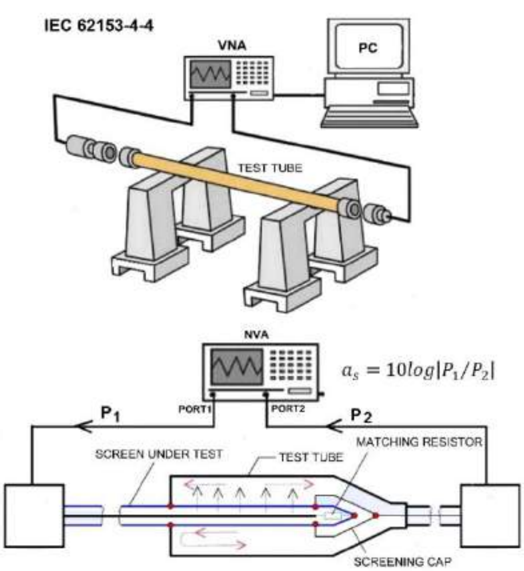


*Fig. 7:* Layout for testing effectiveness of cable shielding according to IEC 62153-4-4 standard.

The Vector Network Analyzer (VNA), which consists of a high-frequency signal generator (port 1) and a receiver (port 2) of a signal weakened by the screen, is very convenient to measure the correlation between delivered (on to a cable) and measured emitted signals (Fig. 7).

The cost of one of the cheapest VNAs (type Planar TR 1300/1) which works with an external PC (it is necessary to work both with VNA and with special software calculating attenuation caused by the cable's screen based on data transferred from VNA) is $ 2,900.

Based on the layout of the testing bench shown in Figure 7 (indeed, this is a metal tube with two special locks and connectors at both ends), its cost should not be significant.

*Fig. 8:* A kit of testing tubes (type CoMeT 90/1) with a kit of locks and connectors manufactured by the Bedea (Rosenberger) company to test cable shielding effectiveness with an outside diameter from 6 through 22 millimeters.

But the reality turned out to be different. A kit of tubes of various lengths, along with a kit of connectors (Fig. 8) and PC software to calculate attenuation imposed by the screen is sold at $ 20,000. Apparently, this high cost results from the lack of competitors in the market, as this measuring kit is manufactured exclusively by the Bedea company (Germany) in cooperation with the Rosenberger company (also Germany). There is something similar promoted by the Japanese company Keycom (SEM03 trademark), but they donot reply to requests for information regarding this equipment.

Thus, the total price of the testing kit (with VNA and PC) makes the feasibility of this purchase very questionable. Is it so important to know the effectiveness of cable shielding, provided that the standard measuring method and the formulas used for it stipulate testing of a symmetric coaxial cable with a single conductive core with one screen? What will be the accuracy of measurement of a compound cable, which contains the screens of twisted pairs in addition to the outer screen?

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Thus, considering all the above mentioned would suggest to use an approximate estimating of cable shielding efficiency based on cable designs and their features described earlier.

## IV. Choosing Of Control Cables

It is obvious that facilities being designed should employ exceptionally new cables with double (at least) shielding capacity, such as *S/FTP, SF/FTP*, *SF/UTP* or *SF* with the filling thickness of outer braid (compulsory tinned!) of not less than 85%. Cables of such kind are manufactured by many large companies, such as Belden, Hosiwell, DDA, Helukabel, Elettrotekkabel, Huanghe Cable Group and many others. In addition to that, many cable companies offer customized cable production. If it was impossible to pick up a cable from one of the manufacturers mentioned above (with the required section and the number of cores), it is possible to have this cable individually produced.

For old facilities with existing old cables that are not planned to being replaced, the approximate estimating of shielding effectiveness of these old cables can be taken into account. This estimation may be based on the above-mentioned criteria (for critical sites with critical equipment only). Additional protection means will be planned, taking intoconsideration the estimation of existing shielding effectiveness of these cables.

At the same time, it is unacceptable to use both protected and unprotected cables connected to different input terminals of the same piece of equipment or lead into the same control cabinet.

Another important parameter, which is not connected with shielding effectiveness, but which is one of the important indicators of the cable's reliability, (needs to be considered during cable selection) is the electric strength of the cable's insulation. For HEMP-protected electric facilities, insulation of a cable should sustain one-minute test voltage of not less than 2 kV AC between conductive cores, and between them and the common outer screen. As a rule, this insulation sustains short pulses of less than 1 μsec and the amplitude of up to 8 kV (such as HEMP's pulse) without any damage.

According to IEC 61000 -4-25 [5] requirements, a pulse voltage of this amplitude should be used for testing equipment located inside ordinary reinforced concrete production facilities upon HEMP impact.

## V. Conclusion

Use of shielded control cables in electric units, which need to be protected from HEMP, is very important. Due to a high diversity of shielded cables available in the market, the problem of proper cable selection becomes very relevant. The choice can be based either on accurate measurements of shielding effectiveness of various cable samples, (use of special measurement tools) or an approximate evaluation based on information regarding unique features of different cable designs. Due to the high cost of tools and devices measuring shielding effectiveness and imperfect correspondence of the standard measurement method to some important cable designs, the second method of evaluation is preferable. Information regarding shielded cables' designs, their features, marking and estimated screens' efficiency provided in this article allows a customer to browse through the diversity of types and kinds of control cables available in the market and to make a correct choice.

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