

## MULTILAYER MAGNETIC SHIELDING: AN INNOVATIVE OVERLAPPING STRUCTURE

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### ABSTRACT

*The paper deals with magnetic shields for distribution systems mainly devoted to MV/LV substation. In the category of passive system, a new multilayer shielding plate is presented. The main purpose of the proposed solution is the reduction of the gap between the ferromagnetic sheets by a proper overlapping in order to reduce the local leakage fluxes. Plates characterised by different conductive and ferromagnetic thicknesses have been realised and tested. The effect of the welding of the conductive part is finally analysed.*

### INTRODUCTION

The protection from exposure to electromagnetic field is a problem that can regards people and sensitive devices. In the first case a big differentiation is done in the case of population and workers and different approach to the protection policy can be found in the different countries [1-2]. On the contrary, the protection of devices to external magnetic field is an objective problem which has common aspect all over the world [3].

In recent decades, many studies have been developed with the aim of providing methods to mitigate the magnetic field (MF) generated by power-frequency electrical installations (overhead lines, underground power cables, substations, etc), whether they are destined to reduce interference on sensitive equipment or to avoid possible harm to human health. Several solutions have been proposed for a variety of sources, where conductive/ferromagnetic shields and passive or active loops are the most common solutions [4].

In particular, talking about passive shielding, the combination of ferromagnetic and conductive materials allows to reach interesting performances close to the shield, and so to the source, and a significant magnetic attenuation also far from the shield [5]. Two different installation strategies can be adopted: the installation of the two materials separately or the installation of pre-assembled multilayer plates. The second solution requires and industrial process which cut and fix together the different slices of conductive and ferromagnetic materials but allows to obtain an high modularity. For example starting from plates of different dimensions (e.g. 1mx1m, 2mx1m, 0,5mx0,5m etc.) it is possible to realize many shielding configurations. A drawback of the modularity is the conductive and ferromagnetic discontinuity among the

plates. The solution to overcome this problem is based on the welding of the conductive plates and the overlapping of the ferromagnetic parts. This two operations can be complicated on field and can require additional installation time. In this paper a new solution of multilayer magnetic shield that simplify the restoring of material properties is presented.

### OVERLAPPING STRUCTURE

The solution is based on a partial overlapping of the shield plates (e.g. 5 cm) which can be obtained by particular plates where two edges are properly warped as shown in Fig. 1. This design allows a junction between the neighbored plates as reported in Fig. 2.

This solution allows to solve in the same time several problems. On the conductive point of view the overlapping of two closed plates allows to mitigate the end effect drawbacks because the two opposite currents in the edges of the plates tend to compensate ones with the others (as shown in Fig. 3). Of course, to restore the conductivity between two neighbored plates it is necessary to weld them but also in this case the overlapping allows this process during the installation on field. On the magnetic point of view, even if the two ferromagnetic shields are not in contact due to the conductive layer, the magnetic reluctance between the two plates is strongly reduced thanks to the increase of the ferromagnetic area of the two plates that overlook (see Fig. 3).

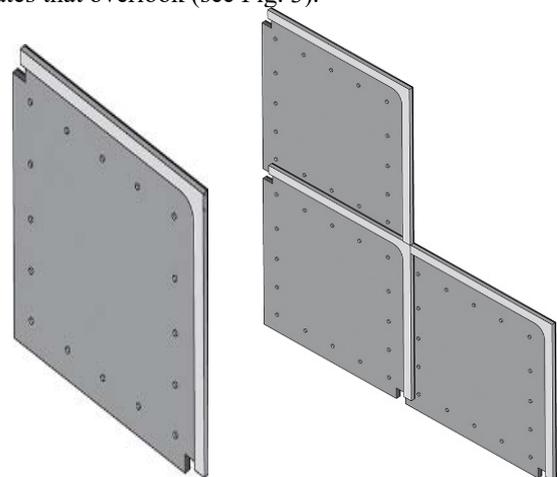


Fig. 1 Multilayer plate with overlaps and principle scheme of installation

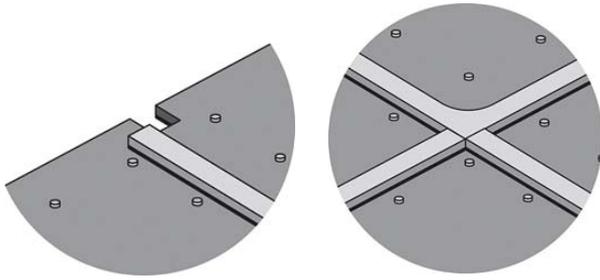


Fig. 2. Particular of the overlapping zone between two and among four plates

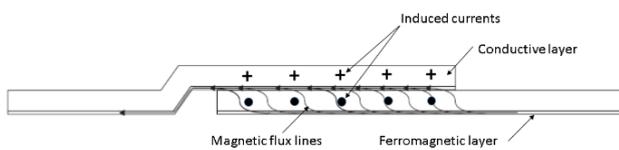


Fig. 3. Scheme of the overlapping showing the continuity of the magnetic flux and the edge effect compensation of induced eddy currents in the shield

### SIMULATION OF THE OVERLAPPING EFFECT

The effect of the overlapping contribution has been previously tested by numerical analysis performed by a 2D FEM software [6]. The benchmark configuration is constituted by a balanced three phase line and a multilayer shield. The distance between the conductor is 17 cm, the distance of the conductors from the shield is 25 cm and the phase current is 909 (A). The shield width is 2m. In Fig. 4 is reported the flux line distribution of the magnetic field where is possible to evaluate the shielding effect.

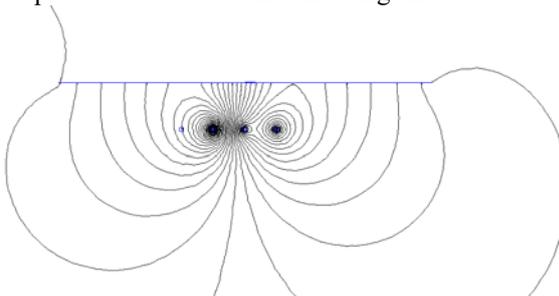


Fig. 4. Magnetic flux line distribution of a power balanced three phase line with a magnetic shielding.

Two shielding configurations are considered:

- traditional multilayer shield without overlapping
- proposed multilayer shield without overlapping

The multilayer shield is composed by:

- conductive material with  $\sigma=35$  MS/m and thickness=3mm;
- ferromagnetic shield with relative permeability of 10000 and thickness=0.7 mm

In both the shielding configurations the conductive material is welded and so can be considered as continuous material [5]. The orientation choice of the layers is with the ferromagnetic parts on the side of the source. The comparison is in terms of magnetic flux density on an inspection line at 5 cm from the shield (30 cm from the source). Without shielding the magnetic flux density in the middle point of the inspection line reaches a value of about  $450 \mu\text{T}$ . When the shield is applied a strong magnetic flux density reduction is obtained with a Shielding Factor (SF defined as the ration between the magnetic field without and with the shield) close to 90-100 times (corresponding to  $5 \mu\text{T}$ ) but in the configuration without overlapping the SF decay to 15 times (corresponding to  $30 \mu\text{T}$ ). This local increment of the magnetic flux density close to the ferromagnetic discontinuity can be clearly observed in Fig. 5 and from the same figure it is possible to see how the overlapping solution does not present such local magnetic flux density peak. This benefit is due to the overlapping of the ferromagnetic parts with make easier the magnetic flux crossing from the two layers (see Fig. 6).

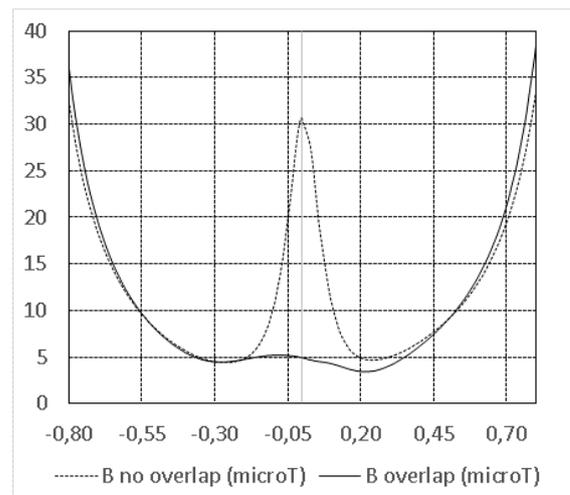


Fig. 5. Magnetic flux density along the inspection line: configuration with and without overlapping

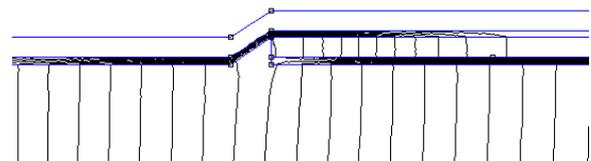


Fig. 6. Magnetic flux line distribution in the overlapping zone

### EXPERIMENTAL RESULTS

A measuring set up constituted by 4 plates (each 1mx1m) excited by a tangential and normal magnetic field has been

employed. The source is constituted by a coil supplied by a 50Hz current and is placed below the shield in the center of it at about 25 cm. A three dimensional isotropic magnetic probe is used for the magnetic field characterization in the space above the shield at 10 cm from the shield. The inspection point are distributed in a regular matrix in the plane every 10 cm (see Fig. 7). The measurement point distribution is chosen on order to consider all the significant points close to the discontinuity of the plates. In Fig. 8 is reported the picture of the facility has been built for the SF characterization.

The multilayer plates are made of Aluminum (Al) and Grain Oriented Electrical Steel (GOES). Several parameter and shielding configurations have been analyzed and characterized by:

- component of the magnetic field: source with axis orthogonal to the shield (normal field  $B_n$ ) and source with axis parallel to the shield (tangential field  $B_t$ )
- orientation of the material: Al or GOES facing to the side of the source;
- thickness of the shielding material: low thickness (LT) plate and medium thickness (MT) plate;
- welding of the conductive material.

The performance of the shield with overlapping is compared with the equivalent solution having the same type and weight of conductive and ferromagnetic material but without overlapping.

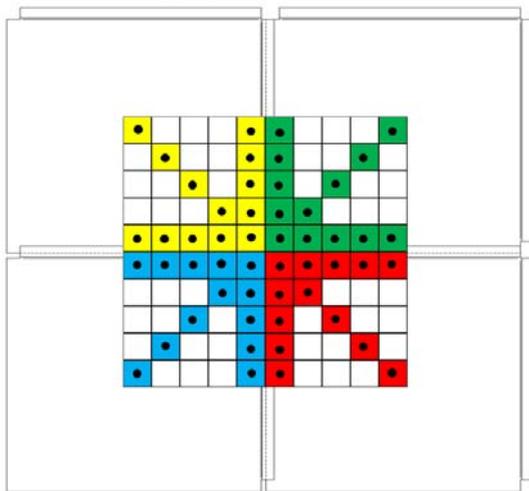


Fig. 7. Space distribution of the inspection points

### Effect of source orientation

Two different configurations are compared: a first one with traditional plates and a second one with overlapped plates. The more critical situation is when the source generate a tangential magnetic field on the shield. In Fig. 9 are reported the SF values in different points at 10 cm from the shield. As can be observed the overlapping configuration allows to reach a double performance. In all the configurations the Al is faced to the source.



Fig. 8. Facility for the evaluation of the shielding factor

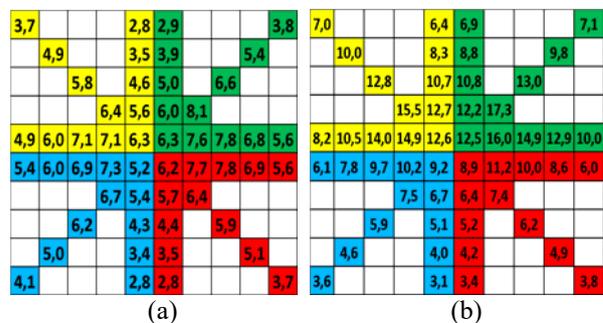


Fig. 9 SF without (a) and with (b) overlapping of the shielding plates: tangential component ( $B_t$ )

Regarding the normal component the effect of overlapping is less important even if a global increment of the SF occurs (Fig. 10).

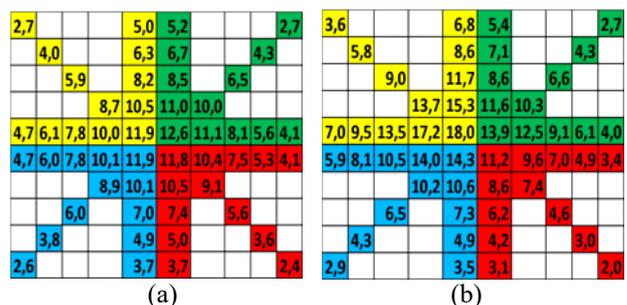


Fig. 10. SF without (a) and with (b) overlapping of the shielding plates: normal component ( $B_n$ )

### Effect of material orientation

The effect of the orientation is analyzed in this section. In Fig. 11 is reported the SF for the overlapped configuration and with a normal magnetic field. The two pictures are related to the following orientations: (a) has the Al on the side of source and (b) has the GOES on the side of the source.

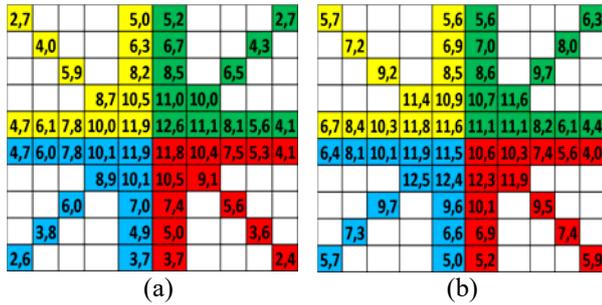


Fig. 11 SF with Al faced to source and with GOES faced to the source: normal component (Bn)

In Fig. 12 is reported the SF for the overlapped configuration when a tangential magnetic field is present.

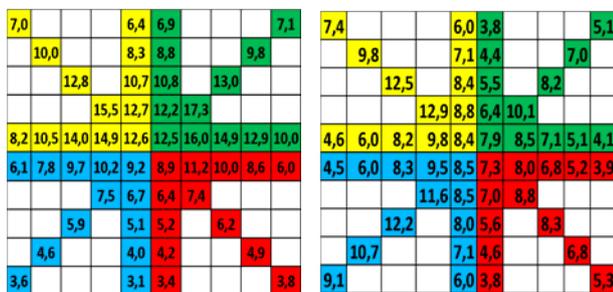


Fig. 12 SF with Al faced to source and with GOES faced to the source: tangential component (Bt)

### Effect of conductive material welding

In the last presented results the conductive part are welded. The material orientation is with GOES faced to the source and Al versus the probe. Figs. 13 and 14 report respectively the SF when a normal of a tangential magnetic field is applied. As can be seen a significant increment of the performance of the SF is obtained.

### CONCLUSION

In the present paper a new concept of multilayer shield for extremely low frequency magnetic field is proposed. The innovation is related to the reduction of the local magnetic flux leakage in the interface area among neighbored plates. A first prototype has been realised and tested and very good results are obtained. Future activity will regard the implementation of the proposed solution in real applications.

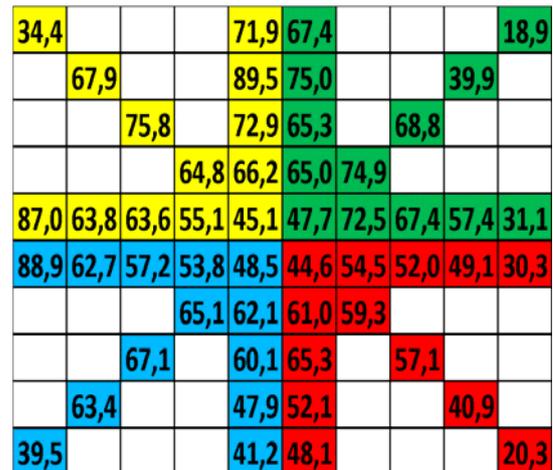


Fig. 13. SF with overlapping and conductive material welded: normal component (Bn)

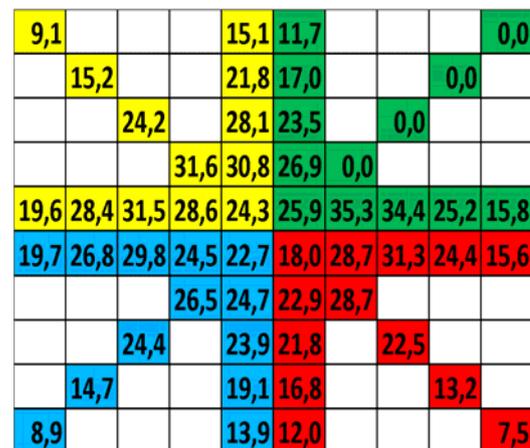


Fig. 14 SF with overlapping and conductive material welded: tangential component (Bt)

### REFERENCES

- [1] <http://www.who.int/peh-emf/project/mapnatreps/en/>
- [2] ICNIRP, Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz–100 kHz), *Health Phys.* 99 (6) (2010) 818–836.
- [3] IEC 61000-4-8:2009, Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test.
- [4] Mitigation techniques of power frequency magnetic fields originated from electric power systems, Tech. Rep. Working group C4.204, CIGRE' (2009).
- [5] D. Bavastro, A. Canova, L. Giaccone, M. Manca, Numerical and experimental development of multilayer magnetic shields, *Electric Power Syst. Res.* 116, (2014) 374–380.
- [6] <http://www.femm.info/wiki/HomePage>