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PASSIVE LOOPS TECHNIQUE FOR ELECTROMAGNETIC FIELDS MITIGATION: APPLICATIONS AND THEORETICAL CONSIDERATIONS.

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ABSTRACT

The paper illustrates the innovative technique of passive loops, used for electromagnetic field shielding of HV and EHV cable lines and adopted to overcome the concern arising whenever an existing or planned underground cable line crosses densely populated areas, where restrictions of the electromagnetic field (EMF) are requested. This method is an alternative to the use of copper plates, but it is as if they have now been made flexible and with a variable thickness. A careful cost-benefit analysis shows that passive loops are a simple and effective solution that can be tuned to achieve the required Shielding Factor (SF), exploiting the technology of low voltage commercial cables.

KEYWORDS

EMF, passive loops, electromagnetic fields, shielding factor, HV cables, EHV cables.

INTRODUCTION

The method, generally used to slightly reduce the electromagnetic field, is to adjust the laying parameters such as interaxial distance between the phases, laying depth and geometry. If a greater reduction of the EMF is requested, a common solution can be the adoption of special shielding apparatus external to the cables such as ferromagnetic raceways, metallic plates and grids of insulated conductors. The installation and the thermal problems linked to the losses are also presented, with a careful analysis in order to properly balance the shielding efficiency to achieve the required field mitigation with negligible impact on the rating.

A new technique ids presented in this paper which uses simple loops of standard LV power cables to mitigate the magnetic field for both cables, joint bays and manholes.
The Shielding Factor (SF) of a given mitigation technique is defined here as the ratio between the magnetic field modulus before and after the adoption of the mitigation measure at 1 metre above ground on the axis of the circuit.

THEORETICAL CONSIDERATIONS

The passive loop is an innovative technique with SF that can reach the value of ten with standard practice. The passive loops are easily placed in the trench together with HV cables, with negligible impact on the installation operations of the main cable circuit: standard practice is to limit the over temperature to a few tenths of a degree centigrade, with a careful choice of the section and of the position of the loops. The first application of passive cables technique has been in Vienna in 2005 to reduce the EMF of the joint chambers of a 5.2 km long 400 kV double circuit [1].

As it is known, the electromagnetic field is directly proportional to the circulating current and to the cable interaxial separation but decreases rapidly with distance.
A general criterion is that symmetric dispositions of the main cables results in a symmetrical arrangement of the passive loops, so that only an even number of cable is presented here.
The phase sequence of a single three phase circuit has no influence on the modulus of the resulting magnetic field, but becomes fundamental with two or more circuits laid in parallel.

A careful choice is necessary to select the section and the position of the passive cables: the calculation is not simple and needs dedicated software, which has been developed and tested by the authors. Passive loops can be easily tested in the laboratory: the position of cables can be varied and the total number increased by simply adding more cables. One of the most important aspects is to minimize the resistance and the reactance of the passive system. Low voltage cables are normally installed, due to the very low tension induced into the cables. They are arranged in the trench of the HV cables, either on the surface of the compacted backfill, at the same level or even below the HV cables.

Shielding of cables in flat formation is easier because optimum disposition of passive cables can be in flat formation; for a trefoil arrangement, the passive cables should have a triangular structure. The solutions depend also on the dimensions of the trench and on the acceptable over temperature: high voltage, high current systems are more difficult to shield and require larger passive conductors.
The study considers the optimum disposition of the passive loops around the power cables or the joints, where the position of the passive cables can be, a priori, continuously varied. In order to limit the otherwise enormous number of cases, the investigated area is here limited to the accessible volume of the trench and the distance between adjacent cables is varied in steps of 50 mm or 100 mm, respectively for small and large trench widths. A test on the validity of this simplifying assumption has been done on the joint bay in configuration “E”, shielded with 8 passive copper cables of 240 mm^2.The differences in the computed SF are less than 1% and justify the assumption of the step variation of the position of the cables.
The experience demonstrates that the dispositions of the shielding cables presented here have the property to be “optimum solutions” in a mathematical sense: when one or more cables are slightly displaced from the position of best shielding, there is only a minimal decrease of the SF. Due to this property, the passive cables can be installed with standard care and do not require particular technologies.
The following table 1 reports the main layout schemes for HV and EHV cable trenches and joint bays: the nominal current is 870 A for 150 kV and 1500 A for 380 kV. The ground thermal resistivity is assumed to be 1 K*m/W and the unperturbed