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The high magnetic coupling passive loop: A steady-state and transient analysis of the thermal behavior

Aldo Canova, Fabio Freschi, Luca Giaccone*, Alessandra Guerrisi

Politecnico di Torino, Dipartimento di Ingegneria Elettrica C.so Duca degli Abruzzi 24, 10129 Torino, Italy

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A B S T R A C T

This paper deals with a new concept of technology for the mitigation of the magnetic field produced by underground power lines called "High Magnetic Coupling Passive Loop" (HMCPL). The working principle of this technique is the creation of a current with the same amplitude but opposite phase for each source conductor, in order to nullify the magnetic field in a specified region. Since the number of thermal sources in the shielding region is roughy doubled, the aim of the paper is the investigation of the thermal behavior of HMCPL directly buried in the ground, both in transient and in steady-state conditions. The study is carried out with simulations in order to verify any possible configurations of the shield. Results confirm that HMCPL is a safe technology which does not modify the thermal behavior of the power line.

1. Introduction

Electromagnetic pollution is an open subject because of the possible effects on human health and the electromagnetic compatibility issue. These are the reasons why magnetic field mitigation is an active field of research [1,2]. A special type of conductive shield is represented by the passive loops. These shields are made of electrical conductors (typically the same electric cables used for transport and distribution) connected to each other in order to create closed loops. The working principle is based on electromagnetic induction: time varying magnetic fields, produced by AC currents, induce eddy currents in conductive loops and consequently they constitute an additional field source which modifies and attempts to reduce the main magnetic field produced by the sources. This kind of shield is used both for buried cable and overhead power lines [3]. In previous papers, a new concept of passive loop called the High Magnetic Coupling Passive Loop (HMCPL) was introduced along with a description of its magnetic performances [4–8]. HMCPL technology is very suitable for magnetic field mitigation of the junction. The cables are usually arranged in trefoil configuration but, when they need to be joined, the flat configuration has to be adopted because the joint needs larger spaces [8], a simple representation is shown in Fig. 1. It is worth noting that the use of the flat configuration leads to a higher magnetic field at ground level as shown in Fig. 2. This is the reason why the junction zone might need to be shielded.

To give a short overview of the HMCPL technique, the base layout is the one which associates a shielding conductor to each power cable as shown in Fig. 3. The magnetic cores allow the induction of currents inside the shielding circuit which are equal, to a first approximation, in amplitude but in phase opposition with respect to the source currents, so that the local magnetic field vanishes. When it is not possible to reach the power lines due to practical or technical problems (e.g. the need to shield an existing power line or shield a power line arranged in a trefoil configuration) the HMCPL could be used with a layout that employs a non-unitary coupling [4]. In this layout the shielding conductors are placed far from the source and they carry a current which is determined by a proper transformer ratio [4]. Therefore the design of this layout needs to be optimized to determine the position of the shielding conductors and the value of the transformer ratio [4].

The use of HMCPL technology imposes the introduction of a new set of conductors and, consequently, new joule losses. Therefore a thermal analysis of the system is unavoidable in order to clarify whether the installation of a HMCPL leads to an ampacity derating of the power line or not.

In this paper the thermal behavior of a power line which employs HMCPL directly buried in the ground is carefully analyzed by means of steady-state, transient analysis and measurements.

2. Thermal design of a power line

The thermal design of power system components is a challenging task. Several studies on power lines can be found in the literature. The thermal equations are often analyzed by means of

* Corresponding author. Tel.: +39 0 11 090 7164; fax: +39 0 11 090 7199.
E-mail address: luca.giaccone@polito.it (L. Giaccone).

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