AMPACITY DERATING EFFECTS OF MAGNETIC FIELD MANAGEMENT TECHNIQUES USED WITH UNDERGROUND TRANSMISSION CABLES

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ABSTRACT

Magnetic field management techniques used with underground transmission cables may cause a decrease in power transfer and ampacity ratings of the lines. This decrease can be a result of increased electrical losses in cables and applied magnetic shielding devices or increased thermal resistance between the cables and ambient earth.

This paper discusses conventional cable-rating calculations, methods for quantifying losses created by magnetic field management methods and their derating effects. This paper also describes design considerations, magnetic field reduction factors, and ampacity derating of several magnetic field management applications.

Results of this paper are a compliment to the work presented by CIGRE Working Group B1.23 on "Impact of EMF on Underground Cables and Cable Systems"

KEYWORDS

Power-frequency magnetic fields; magnetic field management and shielding; transmission cables; underground transmission; ampacity derating

INTRODUCTION

Numerous methods have been developed and studied over the past ten to fifteen years for reducing above-ground magnetic fields produced by underground cable systems [1, 2, and 3]. These methods generally fall into one of the following categories:

- Optimization of cable installation geometry and conductor arrangement
- Increased installation depth of burial
- Application of passive shielding loops
- Application of magnetic shields constructed with non-ferromagnetic or ferromagnetic materials
  - Open shielding geometries such as planar, inverted U-shaped or H-shaped cross sections
  - Closed shielding geometries such as pipes, casings, or box shaped cross sections

The above magnetic field management methods have certain advantages and disadvantages. Consequently, the best method for reducing magnetic field values above ground for a given underground transmission line is application specific and depends on design requirements such as the required amount of magnetic field reduction and the locations where the magnetic field reduction is to be optimized.

Some magnetic field management methods are very effective in reducing the above-ground magnetic field but are difficult to construct for underground transmission cables. Some methods are expensive to construct or have other practical issues. They can also result in reduction of cable system power transfer rating.

Although it is known that many of the commonly used magnetic field management methods have a negative impact on the ampacity or power transfer capability of underground transmission lines, methods to quantify the derating effects of many of the magnetic field management methods have not been established in industry standards and are not well documented in technical publications. This is particularly true for magnetic field shielding with ferromagnetic materials due to their relatively complex loss mechanisms and nonlinear magnetic properties. In 2007 and 2008, EPRI funded a project to document and develop methods to calculate the derating effects of practical EMF management methods. Much of the material covered in this paper was developed as a result of that research project – *EMF Management User's Guide for Underground Transmission Systems* [4].

Pipe-type transmission cables inherently produce significantly lower magnetic fields compared to conventional single-conductor cable installations [4] and the derating effects of the ferromagnetic pipes for this cable type are included in ampacity calculation standards [5]. Therefore, pipe-type transmission cables are not included in this paper.

MAGNETIC FIELD MANAGEMENT METHODS

The following EMF management methods have been applied to reduce the above-ground magnetic flux density values in the vicinity of underground transmission lines.

<u>Cable Installation Geometry and Conductor Arrangement</u>

As is the case for overhead power lines, installation geometry of the phase conductors (cables), spacing between the phase conductors, and phase sequence have a significant impact on the above-ground magnetic field values.

Since the vector sum of the three phase currents in a balanced three-phase system is approximately zero, the above-ground magnetic field values produced by transmission cables can be reduced by installing the cables closer. Consequently, the magnetic field at all above-ground locations can be reduced by minimizing the geometric mean distance, GMD_c, between the cables. GMD_c is defined in Equation 1:

$$GMD_c = \sqrt[3]{S_{ab}\ S_{bc}\ S_{ca}} \qquad [1]$$

where:

S_{ab}, S_{bc}, *and* S_{ca} are the distances between the centers of the three-phase cable conductors.

The lowest above-ground EMF values are produced by cables in a trefoil configuration. A few common installation