EMF CONDUCTOR MANAGEMENT OF UNDERGROUND CABLE SYSTEMS

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ABSTRACT

Conductor management is an efficient way to reduce electromagnetic fields (EMF) directly at the source, acting on the geometry and phase arrangement of the cables.

A user-friendly software application has been developed to help the cable engineer to assess the influence of EMF basic parameters. The tool is very convenient to report the optimal arrangement of multiple circuits, to assess the efficiency of phase-splitting or to evaluate innovative geometries. Two and three-phase circuits can be mixed, and DC systems (static field) can be studied as well.

The paper presents typical and complex cable configurations or curiosities, and solves some recurrent problems.

KEYWORDS

Underground cable systems, electromagnetic fields, EMF mitigation techniques, conductor arrangement, current rating calculation.

SCOPE OF WORK

Conductor management aims at designing a cable system with respect to a reduced magnetic field, acting on the installation but without modifying the cable construction itself.

The paper deals with AC & DC systems, assessing the influence of EMF basic parameters (position of conductors, magnitude and direction of currents, phase sequence, elevation of measurement above ground surface).

Neither circulation nor eddy currents are taken into account in metal screens (solid bonding will be discussed in a further publication).

No mitigation device is considered (neither passive loop, nor high conductivity foil or ferromagnetic structure).

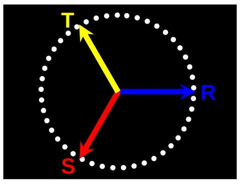
GENERAL ASSUMPTIONS

Cable circuits are considered as infinite horizontal straight parallel wires, along *z*-axis. The value of the magnetic field is given by Biot-Savart formula [1]. We study a system of *N* cables. Each cable of index *k* at a location (x_k, y_k) is transmitting a current of magnitude I_k and phase φ_k. At time *t*, the magnetic field components along the *x* and *y*-axis at a point P of (x_P, y_P) coordinates are:

$$\begin{cases} B_x(t) = \frac{\mu_0}{2\pi} \sum_{k=1}^{N} \left[I_k \cdot \frac{(y_P - y_k)}{(x_P - x_k)^2 + (y_P - y_k)^2} \cos(\omega t + \varphi_k) \right] \\ B_y(t) = \frac{\mu_0}{2\pi} \sum_{k=1}^{N} \left[I_k \cdot \frac{(x - x_k)}{(x_P - x_k)^2 + (y_P - y_k)^2} \cos(\omega t + \varphi_k) \right] \end{cases} \quad [1]$$

Magnetic field measuring instruments usually consist of a 3-axis sensing device that determines the root-mean-square (rms) value of the field. Our calculations are performed in the same way:

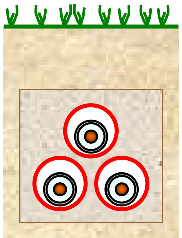
$$\|B_{rms}\| = \sqrt{\frac{1}{T}\int_T B_x^2(t) + B_y^2(t)} \quad [2]$$



For a three-phase balanced system, we will use a colour code to mark conductors: blue for *R*-phase ($\varphi_k = 0$), red for *S*-phase ($\varphi_k = -2\pi/3$) and yellow for *T*-phase ($\varphi_k = -4\pi/3$).

Cables marked on charts with the same colour transmit currents of same phase.

European authorities [3] recommend that the power frequency magnetic field should not exceed 100 µT in areas where the public may spend a significant time. This threshold considers average exposure all over the body. As a consequence, standardised measurement protocols [2] specify that the magnetic field must be measured at **1 meter above ground**. Our calculations to design power link systems are carried out with this value of h_m = 1 meter, agreed as a reference height for checking compliance with the recommended exposure threshold.



Calculations are illustrated with a three-phase circuit, 1200 mm² copper 225 kV, cables laid in ducts embedded in concrete, in non touching trefoil formation:

- D_d = 192 mm / Do = 200 mm, internal and external diameter of duct.
- *s* = 240 mm, axial separation of conductors.
- t_c = 100 mm, thickness of concrete around ducts in the bank.
- L_b = 1.51 m, distance from the soil surface to the bottom of the duct bank.

From which:

- *L* = 1.281 mm, depth of laying, to centre of cable trefoil.
- L_{low} = 1.350 mm, depth of laying, to centre of lowest cable.

All calculations in this paper are performed with a **current rating *I* = 1000 A**. Since magnetic field is proportional to the current into the conductor, it is very easy to extrapolate the field magnitude corresponding to other values of current ratings.

OVERVIEW OF INFLUENT PARAMETERS

The influent parameters for the computation of magnetic field generated by an underground cable system are: