HVAC-CABLES WITH FERROMAGNETIC SHEATHINGS

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ABSTRACT

This paper analyzes three phase systems with ferromagnetic sheathings. A single-core cable system, shielded by external steel pipes as well as a three-core cable with integrated electromagnetic shielding is discussed. Details about the shielding properties of both shielding approach are discussed. It is reported about the first cable route, equipped with a shielded three-core cable.

KEYWORDS

IES cable, ferromagnetic shielding, ferromagnetic sheathing, shielding tapes, integrated shielding, steel pipe, steel pipe losses

INTRODUCTION

To provide a magnetic shielding, several shielding measures can be applied. Examples can be found in [1] [2] [3] [4] [5]. A comprehensive description was published by CIGRE [6]. Depending on the requirements, shielding measures can be realized with limited complexity. At first, the cables itself as well as the phases can be arranged in a favourable way [7]. This is called conductor management and needs no additional equipment. For higher demands, compensation conductor systems ("passive loops" [3] [4]) can be placed above a power cable system.

For highest shielding requirements, ferromagnetic sheathings become essential. Precondition for this shielding measure is, that the sum of all currents, flowing inside the ferromagnetic encapsulation, has to be (almost) zero at all point in time. A shielded three phase system with e.g. zero-system currents has worsened shielding characteristics.

Two different types of ferromagnetic sheathings are analyzed in detail. At first, a shielding by steel pipe is regarded. It is an example for a shielded high power cable system. For smaller transmission tasks, a new cable type was invented with less complexity: a three core cable with an **i**ntegrated **e**lectromagnetic **s**hielding, the **IES**-cable. In 2011, the first IES cable was brought into service. Details are provided in this paper.

SHIELDING BY STEELPIPES

In this paragraph, shielding by steel pipes is analyzed. It is done with respect to the shielding effect as well as to the gain of losses, or the current capacity respectively. To illustrate the challenges the following example is given: A cable system, according to fig. 1 is analyzed. In a steel pipe, there are additional plastic pipes, hold by spacers, to create well defined core spacing. The interstice between plastic- and steel pipe is filled with concrete. The power cables are pulled into the plastic pipes. To show up the limits of this laying technique, a circuit of XLPE insulated 380 kV cables with 3200 mm² copper-conductors is chosen. The cable sheaths are cross-bonded. The external diameter of the steel pipe (steel type St37) is chosen to 1000 mm with a wall thickness of 10 mm. The vertical cover is 1.2 m. To resolve the thermal bottleneck inside the steel pipe, the interstice between plastic- and steel pipe is filled with special, thermally improved concrete [8]. The thermal conductivity is enhanced by a factor of two to four in comparison to standard concrete. The surrounding soil is modelled with properties, according to IEC or VDE standard [9]:

- thermal conductivity of wet soil: λ_w = 1,0 W/(K m)
- thermal conductivity of dry soil: λ_D = 0,4 W/(K m)
- over temperature for drying effects: $\Delta\Theta_g$ = 15 K
- undisturbed soil temperature: Θ_g = 15℃

The relative permeability of ferromagnetic materials depends strongly on the applied magnetic field. The magnetic field, created by the cable system, changes the relative permeability of the shielding material. By this effect, the depth of penetration within the steel pipe and the overall distribution of the magnetic field are changed. Therewith, the conductor losses and eddy current losses in the sheaths are influenced. Additionally, the ferromagnetic material has hysteresis losses. To analyze the effect of ferromagnetic materials, a finite-element software, able to cope with nonlinear material parameters, is applied [10].

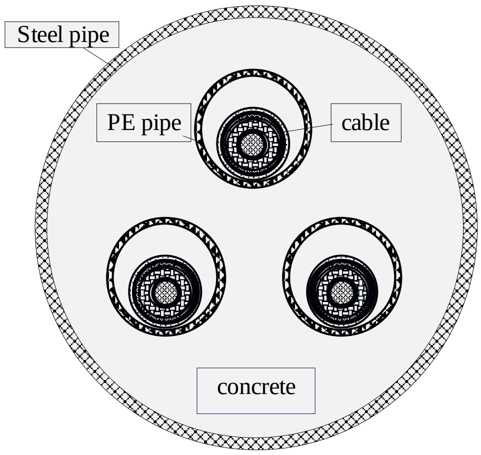

Fig. 1: Single core AC cable system in a steel pipe

At first, the load is kept constant and the core distance is varied. When the PE pipes are placed in a close trefoil formation in the centre of the steel pipe, the minimum core distance is *a* = 200 mm. Fig. 3 sums up the results.