Influence on measured conductor AC resistance of high voltage cables when the screen is used as return conductor

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ABSTRACT

At Jicable 2011 a measuring system of conductor AC and DC resistance using synchronous sampling was presented. In the method the current circuit is made coaxial to minimize the influence of external magnetic fields and to minimize error due to mutual coupling to the voltage circuit. However, it has been questioned if the current in the screen induces additional power loss in the conductor due to eddy currents which will influence the measured AC resistance. In this paper we use a first order approximation of an iterative method to show that the additional power loss is negligible.

KEYWORDS

High Voltage AC cable, coaxial cable, AC resistance, induced power loss, eddy current, wound wire.

INTRODUCTION

The maximum current limit of High Voltage AC cables depends on the AC resistance of the cable conductor. In the development of, specifically, segmented High Voltage AC cables with large conductor cross-sections, there is a need to measure conductor AC resistances with high accuracy to verify their performance. The CIGRE Working Group B1.03 recommends that the AC resistance of large cable conductors should be measured when cable designs are being type tested [1]. The reason for this recommendation is the calculation complexity of existing theoretical models.

In line with this a measuring system of conductor AC resistance of high voltage AC cables was presented at the Jicable'11 conference [2]. In this method the AC resistance is measured using a low current and the screen of the cable is used as the return conductor to minimize the inductance of the circuit. This will also minimize the mutual coupling between the input current and the output voltage (the voltage drop along the conductor). However, it has been questioned if the current in the screen induces additional power loss in the conductor due to eddy currents which will influence the measured AC resistance. This question is particularly relevant in the common case where the wires of the screen are wound, where the analogy with an ideal coaxial cable with a solid screen is not applicable.

In order to estimate the induced power loss in the conductor due to the magnetic flux density generated by the current in the screen wires we make some geometrical assumptions on the cable and then utilize an iterative method based on Maxwell's equations. The iterative method is well established and is presented e.g. in [3]. A similar method was used by the CIGRE Working Group B1.03 to estimate induced power loss in conductors [1].

THEORY

Geometry

Let us consider a High Voltage AC cable with a wire screen where the conductor is assumed to be solid with a radius r_1 and conductivity σ. A sinusoidal current with frequency f is passed through the conductor and the screen is used as return conductor. The screen is assumed to be made up of n isolated wires with radius r_2 at a distance R from the conductor (i.e. the distance from the centre of the conductor to the centre of the screen wires). The wires are either laid straight or are wound. (Hereafter SG refers to cables with "straight geometry" and WG refers to "wound geometry".) We will consider each of these two cases separately. The wires are assumed to be laid out periodically in the rotational direction of the conductor (the azimuth direction). Thus in a specific transverse cross-section of the cable, each wire, wire number i say, can be characterized by an angle α_i, see Fig. 1. In the WG case we also have a distance L that is the lay length of the screen.

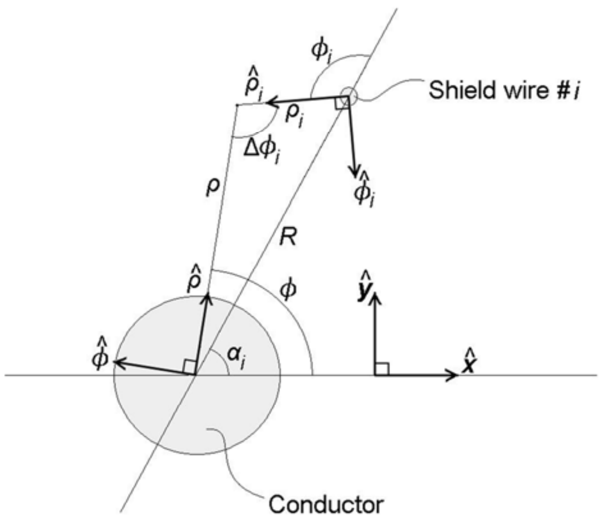

Fig. 1: Schematic figure of a transverse cross-section of the cable with conductor and one screen wire included.

Iterative method

In our case, let the starting point, or zeroth order approximation, of the iterative method be that the current density, $\boldsymbol{J}$, in the conductor is that of an ideal coaxial conductor when a current I of frequency f is passed through it, i.e.

$$\boldsymbol{J}_c^{(0)}(\rho) = k\frac{I}{2\pi r_1}\frac{\mathcal{J}_0(k\rho)}{\mathcal{J}_1(kr_1)}\hat{\boldsymbol{z}}, \tag{1}$$