ARMOUR LOSS IN THREE-CORE SUBMARINE XLPE CABLES

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ABSTRACT

Measurements have been performed on three-core steel wire armoured cables, to investigate if any discrepancy exist with the standard calculation methods prescribed by IEC60287.

Measurements and calculations of armour loss factor λ_2 described in IEC60287 have been performed on two types of three-core armoured cables. One cable has a single wire armour with steel and plastic wires for reduction of armour loss. The other cable has a double layer armour with opposite laying directions. The measurements verify that the armour loss is not negligible but lower than prescribed by IEC60287 and the standard may therefore need to be revised.

KEYWORDS

EHV, XLPE, submarine cable, type test, routine test

INTRODUCTION

Three types of losses are induced in magnetic wire armouring for ac applications:

1. Resistive losses caused by circulating currents
2. Eddy currents losses induced by magnetic flux
3. Hysteresis losses in magnetic steel wires

Circulating currents are only induced in single core armoured cables with both ends bonded systems. Single core cables with wires of magnetic steel materials are rarely used and the current rating for such cables is limited to around 400 A due to the rapid increase of the power loss at higher currents.

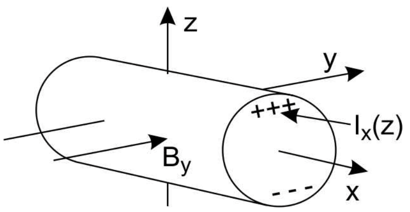

Figure 1

Eddy currents are induced in armour wires by the magnetic flux B generated by conductor currents.

If the flux density B_y in figure 1 is constant inside a wire with diameter d the eddy current loss P_a in the wire is according to equation (1).

$$P_a = \frac{\pi d^4 \sigma \omega^2 B_y^2}{64} \quad W/m \quad (1)$$

The equation shows how the power loss depends on the wire diameter d, wire conductivity σ, flux density B_y and angular frequency ω. The eddy current has its maximum value at the outer and inner part of the wire. The equation gives the maximum power loss in an armoured single-core cable. Practically, the eddy current loss is lower than shown in equation (1), since the skin effect will reduce the power loss inside the wire.

The magnitude of the magnetic flux density depends on the conductor current and the relative permeability μ_r of the magnetic steel material. IEC 60287 recommends μ_r = =400 (IEC 60287 uses the symbol μ_e) for magnetic steel materials. The wires are supposed to have no metallic contact, since the relative permeability will be decrease in the φ-direction through the armouring wires and the wire gaps. The wire gap δ reduces the total permeability, μ_t according to equation (2).

$$\mu_t = \frac{d}{d + \mu_e \delta} \cdot \mu_e \quad pu \quad (2)$$

IEC 60287 recommends μ_t = 10 which determines the wire gap δ to be around 0.4 mm for d=5 mm. The permeability is then reduced about 40 times, compared to having the wires in direct metallic contact with each other. Instead of reducing the permeability of the magnetic steel material itself, the magnetic field intensity H is then reduced indirectly by the existing wire gaps in the cable. For example, a magnetic field intensity H = 4000 A/m originated from a conductor current I = 1500 A, is reduced to about 100 A/m (40 times). It is obvious from B(H) curves for magnetic steel materials that the hysteresis loss is negligible for magnetic field intensities within this range .

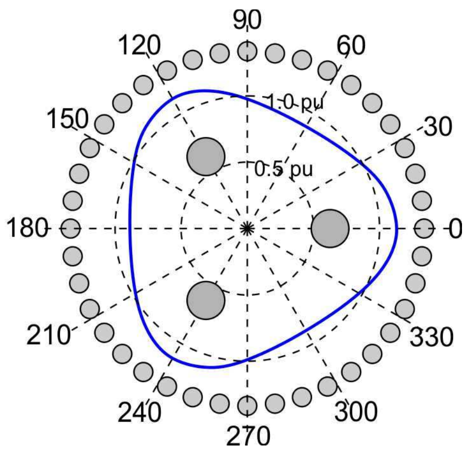

Figure 2