Non-offset design of cables in man-hole considering the thermo-mechanical behaviour of XLPE cables in ducts

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ABSTRACT

The dimensions of the cable off-sets in man-holes should be carefully selected for power cables in duct so that they can absorb thermal expansions and contractions of the cable due to a load change. The dimensions of the off-sets have been calculated so as to suppress the strain on the metal sheath below the allowable values, which are determined by the equations of Bauer, Nease et al. However for large 154 kV or 345 kV class aluminium sheathed cable application of these equations will lose their practicality because of the large man-hole dimensions. Therefore we studied behaviour of cable in duct with non-offsets installation in man-hole whether the non-offset can keep the strain on the aluminium sheath in the ducts below the permissible value and make it possible to obtain smaller manhole than conventional ones.

KEYWORDS

Offset, Non-offset, Manhole, Duct, Cable

INTRODUCTION

When a power cable is subject to a daily load cycle such as occurs on the majority of electric utility lines, it is alternately heated and cooled with the result that internal compressive and tensile stresses are built up by the variable temperature. These stresses are, for the most part, relieved by the longitudinal movement of the cable into the manholes at either end of the individual lengths as the cable in manhole is installed by cable offset design.

Offset design requires larger manhole when aluminium conductor cable is installed, because the cable has higher coefficient of thermal expansion than copper conductor cable.

In this paper, we will explain the thermal-mechanical behaviour of aluminium conductor cable in manhole and duct. It is suggested that non-offset design in manhole is effective for smaller manhole. And there is no problem with the point of reliability.

OFFSET DESIGN OF ALUMINIUM CONDUCTOR CABLE IN MAN-HOLE

When cables are installed using manhole and duct, the offset design is needed. In KEPCO, there are considerations on offset design like below.

- · limiting value of bending radius
- · limiting value of sheath strain

When a straight cable is laid in a duct and subjected to a change of temperature, the movement of the cable is calculated as follows.

$$T_c = \frac{\mu W \ell + 2K}{\alpha E A} \quad [1]$$

$$M = \frac{(\alpha T E A - 2K)^2}{4 \mu W E A} \qquad \text{for } T_c > T \quad [2]$$

$$M = \frac{\ell}{2}\left(\alpha T - \frac{\mu W \ell + 4K}{2EA}\right) \qquad \text{for } T_c \le T \quad [3]$$

For satisfying the limiting value of bending radius, length of cable offset and width of cable offset should be determined by equation (4)

$$R \sin^{-1}\left(\frac{\sqrt{L^2+F^2}}{4R}\right) = \frac{L^2+F^2}{4F}\left(90 - \tan^{-1}\frac{L}{F}\right) + \frac{90}{2\pi} \quad [4]$$

For satisfying the limiting value of sheath strain, length of cable offset and width of cable offset should be also determined by equation (5) for the aluminium conductor cables and equation (6) for the copper conductor cables.

$$\varepsilon = \frac{200 D_s M}{L^2+F^2}\left[\sqrt{6.76\left(1+\frac{L^2}{F^2}\right)+1} - 1\right] \quad [5]$$

$$\varepsilon = \frac{200 D_s M}{L^2+F^2}\left[\sqrt{5.2\left(1+\frac{L^2}{F^2}\right)+1} - 1\right] \quad [6]$$

Where :

A : area of the cross section of conductor [mm2]
W : unit mass of cable [kgf/m]
μ : coefficient of friction
ℓ : length of cable [m]
α : coefficient of thermal expansion of conductor [1/□]
E : Young's modulus of elasticity of the cable [kgf/mm2]
K : restraining force of the cable in the manhole [kgf]
T : conductor temperature change [□]
Tc : temperature change necessary to produce the maximum change of stress in the cable [□]
M : total movement for a length of cable [mm]
R : bending radius of cable [mm]
L : length of cable offset in manhole [mm]
F : width of cable offset in manhole [mm]
ε : sheath strain [%]