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D.2.8. Capacité de transport des câbles aéro-souterrains

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Résumé:

Dans ce papier, les équations de conservation d'énergie, développées par Anders (1995), sont utilisées pour définir un modèle mathématique pour l'évaluation de l'intensité admissible du courant dans les câbles sur poteau installés sous une gaine de protection. Une comparaison est faite entre la modèle proposé et celui de Hartlein et Black qui est le seul autre modèle publié dans la littérature traitant du même sujet. Un example numérique et une comparaison avec les résultats expérimentaux sont présentés.

D.2.8. Rating of cables on riser poles

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Abstract

In this paper, energy balance equations developed in Anders (1995) are used to define the mathematical model for rating of cables on riser poles installed under a protective guard. The method proposed in this paper is compared with the model of Hartlein & Black which is the only other model dealing with this subject described in the literature. A numerical example and a comparison with the test results are presented.

INTRODUCTION

Power delivery systems frequently consist of a combination of overhead lines and underground cables. In most cases, the underground cable system is connected to the overhead line through a short section of cable located in a protective riser. Figure 1 shows a cross-section of a submarine cable installed on a riser pole with a protective guard. The protective guard is often simply referred to as a riser. The current carrying capacity of the composite system is limited by that segment of the system that operates at the maximum temperature. Very often, the riser-pole portion of the cable system will be the limiting segment.

Considering the importance of accurately rating power cable systems consisting of cables on riser poles, Hartlein and Black (1983) introduced a mathematical model to represent such systems. The model is based on a modified thermal circuit consisting of thermal resistances separated by local system temperatures. The analysis results in a number of algebraic equations that are simultaneously solved for the system temperatures for a given cable ampacity. The theoretical developments were substantiated by experimental evidence for cables in protective risers located indoors without solar radiation and wind.

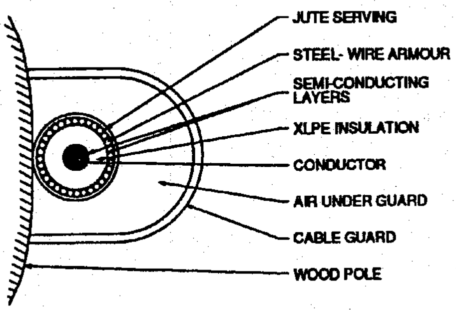

FIGURE 1 CROSS-SECTION OF A SUBMARINE CABLE ON RISER POLE (CRESS & MOTLIS, 1991)

The pioneering work by Hartlein and Black suffered from gaps in knowledge (no formulae were given for computation of heat transfer coefficients under certain conditions) and, in several cases, required assumptions which were incompatible with typical cable-riser geometry. Much new experimental work has been reported during the 12-year period since the publication of their paper. This paper updates the work of Hartlein and Black (1983) by redefining the mathematical model and supplementing information lacking in their work. Careful comparison of both models is also offered. The new model has been tested against Hartlein's and Black's experimental data, as well as the data for outdoor tests reported by Cress and Motlis (1991) and the results are summarized in Section 4. The new model is implemented in the CEA's Cable Ampacity Program (CAP), (Anders et al., 1990)

THERMAL MODEL

The assumption used in developing the mathematical model for the cable-riser system is that the cable and the riser are concentric bodies with their length much greater than their diameters. Equations given in Appendix A (Anders, 1995) can be used to determine the required temperatures. The parameters required in these equations are described in the following sections.

Radiation shape factor

The radiation shape factor is obtained considering two long concentric cylinders. In the case of a single cable in the riser, we have:

$$F_{s,w} = \left(1 + \sigma_s / \varepsilon_s + A_s \sigma_w / A_w \varepsilon_w\right)^{-1} \tag{1}$$

where

σ_s = the reflectivity of the cable outside surface;
ε_s = the emissivity of the cable outside surface;
σ_w = the reflectivity of the wall inner surface;
ε_w = the emissivity of the wall inner surface;

$A_s = \pi D_e$, $A_w = \pi D_d$, $A_o = \pi D_o$. D_e, D_d and D_o, (m) are the cable outside diameter and the riser inside and outside diameters, respectively. The maximum area exposed to solar radiation is LD_o. When several cables are present, the mutual radian area between them must be subtracted from the area radiating to the riser inner surface. The most common installations have either one or three cables inside the guard. The effective radiating area to the guard walls three cables in touching trefoil formation is equal to (Weedy, 1988):

$$A_{sr} = 3\pi D_e - 3 \cdot 0.618 D_e \tag{2}$$

In this case, the radiation shape factor has the form:

$$F_{s,w} = \left(1 + \sigma_s / \varepsilon_s + \zeta A_s \sigma_w / A_w \varepsilon_w\right)^{-1} \tag{3}$$

where

$$\zeta = \frac{3}{1 - \dfrac{6\pi A_s}{A_{IC}} \dfrac{\varepsilon_s \sigma_{IC}}{\varepsilon_{IC}}}$$

Also, $T_4'' = \dfrac{\rho_C}{2\pi} \ln \dfrac{D_o}{D_d}$.

Convection coefficients

The cable and the riser form a vertical annulus. If the temperature of the cable or riser is different from the air temperature, the natural convection occurs in the annulus gap. This natural convection makes the heat transfer processes in cable-riser systems very complicated.

Convection coefficients required in equations (A1) are summarized in Tables 1 to 3 at the end of the paper. The basis for the selection of these coefficients is briefly described below.

Riser outside surface.

The convection heat transfer on the outside surface of the riser includes natural and forced convection. Normally, the forced convection is much stronger than free convection. In the case of natural convection, the vertical