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A CUSTOMIZED PULLING-CABLE SOFTWARE

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ABSTRACT

Hydro-Quebec's underground distribution network mainly consists of electric cables installed by pulling through the ducts. In order to improve the estimates of the pulling forces, our company has developed a new customized software. The model upon which this software is based on takes into account several effects related to the bending stiffness of the real cable. Such effects were so far neglected by the available classic Rifenburg-Smith models. The accuracy of the new software has been validated with actual data recorded during cable pulling installations performed at a test site and in Hydro-Québec's underground network.

KEYWORDS

Distribution cables, Pulling forces, Pulling software, Modeling and Characterization, Optimization.

INTRODUCTION

Two mechanical limits must be avoided during the cable pulling operation: the maximum tensile force applied to the cable and the maximum sidewall pressure at bends. Exceeding these limits may lead to damages to the electric insulation, with harmful consequences on reliability and the service life of the weakened cable.

The most practical manner to insure that the allowed maximum tensile force and sidewall pressure are not exceeded is to evaluate by calculation the maximum pulling forces at the design stage of the electric cable route. Therefore, the need arises for a cable pulling software capable of providing reliable results.

All commercial software currently available is based on a classic Rifenburg-Smith model which represents the electrical cable as a rope without any bending stiffness. However, in the case of cable routes with important direction changes, significant bending effects occur at the bends due to the mechanical stiffness of the electrical cable. The numerous measurements performed by Hydro-Quebec have shown that the classic model could grossly underestimate the real pulling forces for some of the more convoluted routes.

In order to improve the estimates of the cable pulling forces, our company has developed in the early 90's a software that considers the various bending effects occurring when a cable is pulled through bends. However, with the new requirements established by designers for our underground network and the fast-paced evolution of PC operation systems, this software has nowadays become obsolete. Therefore, a new customized software has been recently developed, and is described in this paper.

ANALITICAL PULLING MODELS

Two analytical cable pulling models were used when developing the new software: the classic Rifenburg-Smith model [1, 2] has been completed by our bending model [3].

All commercial software so far available was developed exclusively around the Rifenburg-Smith model, which assumes that the cable behaves as a rope without any bending stiffness. Such an simplified approach implies that the pulling force is solely dependent on three factors: i) the longitudinal friction between the cable and the conduit due to the weight of the cable itself, ii) the longitudinal friction resulting from the lateral pressure induced at bends between the inner surface of the cable and the conduit sidewall and iii) the variations in the potential energy of the cable in the case of a route with sloping and/or leveling changes.

Our complementary bending model takes into account the effects of cable stiffness when passing through a bend. As the stiffness of the cable is no longer null as in the case of the Rifenburg-Smith model, additional effects contributing to an overall increase of the required pulling force must be considered: i) additional contact and fiction forces at the cable-conduit interface, ii) internal losses of mechanical energy due to the bending hysteresis effect, including the effect resulting from the relaxation of the bending moments.

The corresponding analytical formulations were presented in previous papers and reports [3, 4, 5]. The electrical cables used for power distribution, especially the medium-voltage three-phase one, represent a complex component, from the point of view of their mechanical behavior. Their bending stiffness is characterized by a strong non linear variation with respect to the cable curvature. Our bending models approximate this non linear moment-curvature relationship by a simplified bi linear variation, defined by only two values for the bending stiffness modulus.

As an example, the influence of the pulling tension and bending stiffness *EI* on the additional axial force at the bend is shown in Fig. 1 for a bend characterized by a radius R=1.5 m. The additional relative axial force at this bend, defined by the relationship of the tensions with and without the bending stiffness, increases with the stiffness of the cable but decreases significantly for higher tension in the bend area. This means that the effects related to cable stiffness will be more important in the first part of the cable