Optimal Design of HV Underground XLPE Power Cables

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ABSTRACT

Total cost including cost of power cables row materials, transportation, installation, joints, and running cost of cross-linked polyethene (XLPE) insulation underground power cables project is minimized under the technical constraints of current carrying capacity, short circuit current for conductor, metallic screen, and metallic sheath, lifetime of the insulated cable, and electric stress at the inner and outer diameter of the insulation. Visibility study and comparison between the cost using Copper or Aluminum conductors are applied.

KEYWORDS

Power Cables; UG; XLPE; Optimization, HV, Cost.

INTRODUCTION

The optimal design needs economic, technical and practical aspects to be taken into consideration, for the transmission, and distribution of electrical power. The choice lies between the use of overhead lines or power cables. For economic reasons, overhead lines are used extensively for the transmission and distribution in rural areas where environmental or practical consideration do not dictate otherwise. However, in urban areas, it is more usual to install power cables [1]

The very rapid growth of power cables in residential areas led to the use of polymeric insulted cables because of its lower overall manufacturing and installation costs compared to PILC cables. The Introduction of XLPE and EPR has increased the capability of polymeric insulated cables because of their higher temperature ratings, so now these cables have replaced the familiar PILC cables for most three-phase applications in industrial and commercial areas, XLPE is by far the most popular choice; EPR has a price disadvantage. Thermoplastic HMWPE is no longer used for new installations [2].

HV power cables are used to transfer electrical energy from power sources to various locations to feed the distribution system, which ultimately supplies the loads. All transmission lines in power systems exhibit the electrical properties of resistance, inductance, capacitance, and conductance. The inductance and capacitance are due to the magnetic flux and electrical field around the conductor respectively. The shunt conductance accounts for leakage current pass through insulation, which is negligible, compared to the current flow through a conductor in transmission lines [3].

The series resistance causes a power loss in the conductor; the power transmission capacity of the line is mainly governed by the series inductance. The shunt capacitance causes a charging current to flow in the line and assumes important in power cables transmission lines. The shunt conductance causes dielectric losses in the insulation [4].

The following equation gives the AC resistance per unit length of the conductor at its maximum operating temperature.

$$R_{AC} = R_{DC} \cdot \left(1 + y_s + y_p\right) \quad [1]$$

Where: (R_{DC}) (Ohm/m), is the DC resistance at maximum operating temperature (90ºC), (y_s) and (y_p) are the skin effect, and the proximity effect respectively.

DC resistances of different conductor constructions and cross-sectional areas for Copper and Aluminum are mentioned in IEC 60228.

The self-inductance of power cable considering the mutual inductance (H/m) of adjacent cables in flat formation is given by the following equation [1].

$$L = \left(K + 0.2 \cdot \ln\left(\frac{2.52 \cdot s}{d_c}\right)\right) \cdot 10^{-6} \quad [2]$$

Where: (K) is a constant depends on the conductor formation, (s) is the axial spacing between adjacent cables, and (d_c) is the diameter over the conductor.

The capacitance (F/m) of the insulated power cable is given by the following equation [1].

$$C = \frac{\varepsilon_r}{18 \cdot \ln\left(\frac{d_{in}}{d_c}\right)} \cdot 10^{-9} \quad [3]$$

Where: (ε_r) are the relative permittivity of XLPE, (d_{in}) is the diameter over the insulation.

MATHEMATICAL MODEL

The optimisation problem is defined as the selection of the best element among a set of available alternatives. In the simplest case, an optimisation problem consists of maximising or minimising a real function by systematically choosing input values from within an allowed set and computing the value of the function. More generally, optimisation includes finding "best available" values for an objective function given a defined domain, including a variety of different types of objective functions and different types of domains.

The procedure for solving this very complicated problem is done using Matlab's optimisation, through programs using a nonlinear objective function, and nonlinear