Research on error control of optimal computation combining temperature field with ampacity of cables under complicated conditions

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ABSTRACT

There are many factors affecting the cable ampacity. The error will be large when calculating the ampacity of cables in multi loop cable cluster laying according to the traditional method. For this reason, this research, based on the knowledge of heat transfer, compute the cable temperature field with the numerical method. It uses the finite element method to compute temperature field outside the cables and the cable surface temperature and uses temperature formula to derive the ampacity of cables. Then, it effectively avoid the theoretical model's defect that it cannot compute temperature field outside the cables exactly. This method combines the finite element method with theoretical model and controls the error from an integrated viewpoint. In comparison with the traditional method, it shows that the error is controlled within 3.1%.

KEYWORDS

Cables ampacity; Complicated conditions; Finite element; Theoretical model; Error control

INTRODUCTION

It is an important task for electrical power system to evaluate the maximum current carrying capacity of a cable under any circumstances. This value is helpful for the underground cable network design. But cable ampacity is delayed in operation and maintenance management for cable. There are many approaches trying to analyze the steady-state operating conditions of the cable. The operation state of the cable which is influenced by season, light, laying environment doesn't get good answers in the most cases in practice [1]. Because of the complicated outer environment, the traditional method using heat transfer model cannot calculate the cable ampacity concerning various structural details such as the trench geometry. According to IEC-60287, endurance of an insulation material to high temperatures determines the maximum current-carrying capacity of an underground power cable. Cable ampacity is calculated conventionally using the installation conditions [2, 3, 4].

This paper presents a new approach to thermal field sensitivities and ampacity computations of underground power cables using the finite-element analysis. The new approach tries to build a new model involves the use of coefficients associated with various cable parameters of the environment to calculate the cable ampacity on different occasions. The new model provides an accurate methodology, based on the finite element model, to assess the cable thermal performance subject to external environment. The finite element method is applied to get the thermal field of an underground power cable directly buried in the soil or laying in the cable tunnels. In this paper, it will demonstrate how the developed finite element model works to determine the maximum current carrying capability of cable in different situations and some experimental results are used to verify the presented model.

FINITE ELEMENT HEAT MODEL

TRADITION (IEC) MODEL

The cable ampacity calculation formula is based on the solution of thermal physical temperature of cable steady field differential equation. According to the cable laying environment is different, different load flow calculation formula.

The temperature rise formula:

$$\Delta\theta = (I^2R\ + 0.5W_d)T_1 + [I^2R(1+\lambda_1) + W_d]nT_2 + [I^2R(1+\lambda_1) + W_d]n(T_3 + T_4)$$

The cable ampacity in the air calculation formula:

$$I = \sqrt{\frac{\Delta\theta - W_d\left[0.5T_1 + n(T_2+T_3+T_4)\right] - \delta\cdot De\cdot H\cdot T_4}{RT_1 + nR(1+\lambda_1)T_2 + nR(1+\lambda_1+\lambda_2)(T_3+T_4)}}$$

The cable ampacity directly buried in the soil calculation formula:

$$I = \sqrt{\frac{\Delta\theta - W_d\left[0.5T_1 + n(T_2+T_3+T_4)\right] + (\upsilon-1)\cdot\Delta\theta x}{RT_1 + nR(1+\lambda_1)T_2 + nR(1+\lambda_1+\lambda_2)(T_3+\upsilon\cdot T_4)}}$$

The Cable surface temperature formula:

$$Q_{se} = 90 - W_d(0.5T_1 + T_2 + T_3) - I^2R[T_1 + (1+\lambda_1)(T_2+T_3)]$$

Where

Q_{se} --the Cable surface temperature, ℃；

FINITE ELEMENT HEAT MODEL

The heat transfer model is a classical method to solve thermal issues. However, the standard calculation model is constrained by the complicated outer space. It is presumed that the heat generated by cable losses is discharged into the surrounding environment by conduction through the ground and through the convection at the ground surface. Internal heat is generated by Joule losses in cable conductors and