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D.2.14. Etude du champ électrique en zones critiques de câbles haute tension par la méthode des éléments finis tridimensionnels

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D.2.14. Study of electric field in critical zones of HV cables by 3D finite elements methods

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Résumé

Dans ce travail il est presenté un procédé computationnel pour l'évaluation du champ électrostatique en 3D par la méthode d'élements finis. On se sert d'un logiciel disponible comme éditeur graphique et on dévéloppe un software pour faire tout le processus, arrivant finalement à superposer au réseau d'élements finis les courbes equipotentielles et les vectors de champ. Cette méthode est apliqué aux études de champ électrique dans l'isolation d'un câble avec des imperfections et à la détermination des zones de champ maximale dans le cas d'un croisement des câbles. La méthode developpée est générale, aimable et souple, ayant comme uniques limitations la grandeur de la mémoire de l'ordinateur et l'emploi d'éléments à 8 noeuds dans la définition du réseau.

Abstract

A computational procedure to calculate the 3D static electric field by means of finite elements is presented. On the basis of a computational package available as graphic editor the necessary software for the interpretation of data-base generated by the editor, for numerical process and for adding information necessary to superpose equipotential lines and field vectors to finite elements net is developed. This procedure is applied to the evaluation of electric fields in the insulation of a cable with defects and to the determination of high field regions in cables crossing. The computation method is general, friendly and flexible, the only limitation being the computer memory capacity and the use of 8-node elements in the definition of the net

Introduction

Finite elements have proved to be a powerful tool for the numerical resolution of many engineering problems. It is frequently used en 2D problems and recently in 3D problems thanks to computer capability improvements. Applications to Electrical Engineering are reviewed in [1].

In this paper we present a computational procedure to evaluate 3D electrostatic field, using a commercially available 3D graphic editor; the generated data-base is processed numerically by a software developed ad-hoc, applying a finite elements method to calculate the potential and the electrostatic field. This information is transferred to the data-base to plot equipotential lines and field vectors over the finite elements net.

Problem Formulation

The physical problem is the evaluation of an electrostatic field in the 3D space, considering free charges (ρ) materials with different permitivities (ε) and boundary conditions in the frontier (Γ) of three possible kinds: known electrostatic potential, known electrostatic field, mixed. This problem may be formulated by means of Poisson equation:

$$\text{curl } E = 0 \qquad (1)$$

$$\text{div } (\varepsilon \text{ grad}\phi) = -\rho \qquad (2)$$

Where the electrostatic potential ϕ satisfies boundary conditions of Dirichlet type:

$$\phi - g_i = 0 \quad \text{over } \Gamma_i \qquad (3)$$

or boundary conditions of Neumann type:

$$\text{grad } \phi \bullet n - dj = 0 \quad \text{over } \Gamma_j \qquad (4)$$

or mixed, with

$$\Gamma = (\bigcup_i \Gamma_i) \bigcup (\bigcup_j \Gamma_j) \qquad (5)$$

Γ being the border of the studied region Ω.

It is shown [2] that the solution $\phi(r)$ gives a minimum for the field total energy in region Ω. Normally imposed restrictions in high voltage are: Free spatial charge zero in the region Ω and surface charge zero on the boundary Γ. In this case ϕ gives a minimum for the functional:

$$F = \frac{1}{2}\int_{\Omega} (\text{gra } \phi \cdot (\varepsilon \text{ gra } \phi)) d\omega \qquad (6)$$