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Water treeings in polyethylene insulation of power cables

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Résumé :
A partir de la représentation du tenseur de tension de Maxwell, on examine le mécanisme le mécanisme de la formation d'arborescences électrochimiques dans un câble d'énergie à isolant polyéthylène. On établit que les arborescences sous tension alternative se développent plus rapidement (environ 100 fois) que sous tension continue. Afin d'apprécier la résistance des mélanges polymériques aux arborescences , on propose deux paramètres – le temps nécessaire à l'apparition des arborescences et leur vitesse de développement. On présente une méthode d'essai permettant de réduire considérablement le temps d'appréciation de la résistance aux arborescences de mélanges polymériques.

Abstract
According to representation of Maxwell tensor of tension is offered the mecanism of water treeings (WT) forming in the power cables with polyethylene insulation. It is found that under the AC the WT are expanding much more faster (about 100 times) then under DC. In order to estimate the stability of polymer compositions against the WT are suggested two parameters – the time before the appearance of initial observable WT and the speed of growth of the WT. The quick test is offered, it is sharply to reduce time of researches according to stability of polymeric compositions to WT.

Polyethylene (PE) insulation (I) has a number of essential advantages in comparison with other types of isolation on electrical, physical-mechanical and processing behavior, in this connection PEI has found wide application for power cables (PC). However under operating conditions under operation of an electric field and the humidity in PEI arise water treeings (WT) [1,2], which considerably reduce life expectancy PC. Diagnostics WT is difficult and is labour-consuming, they are difficult for detecting in a substantial external environment in PEI, though treeings can exist in tentative sort in great manies on length PC, not reducing noticeably electrical properties of a cable before particular time.

The analysis of behaviour of molecules of water in PEI in an electric field has shown [3], that the homogeneous field practically does not render influence on sorption of water. However PEI in the power cable works in a nonuniform electric field, which can render noticeable influence on sorption of a moisture.

At manufacture PEI of a cable the method of extrude in isolation arises shallow gaseous inclusions (cavity), which approximately can be presented as orbs or cylinders. If the inclusion is inside of isolation and is filled by water owing to humidifying, it is possible to spot values of local strengths of a field and value of specific pressure, which arise on a demarcation between polymer and water. For an estimate of the indicated parameters we shall take the following design sizes for the power cable with isolation from cross-link of polyethylene (CPE): for cables on 110 kV we shall accept $d_2/d1 \cong 1{,}9$; for cables on 220 kV – $d_2/d_1 \cong 2{,}9$ (where d_1 and d_2 - diameters on the screen conductor and on a surface of isolation). Local strength of fields on a demarcation line by polyethylene and water were inside inclusion, we shall define on known of physics of dielectrics to the formulas: for spherical inclusion - in water $E_{1cp}=3E_w \cdot \varepsilon_2/(2\varepsilon_1+\varepsilon_2)$, in cross-link polyethylene $E_{2cp}=3E_w\varepsilon_1/(2\varepsilon_2+\varepsilon_1)$, where E_w - working field strength; for cylindrical inclusion - in water $E_{1cyl}=2E_w \cdot \varepsilon_2/(\varepsilon_1+\varepsilon_2)$, in cross-link polyethylene $E_{2cyl}=2E_w \cdot \varepsilon_1/(\varepsilon_1+\varepsilon_2)$. The specific pressure (P_{sp}) defined(determined), considering a cable as cylindrical capacity: $P_{sp}=F/S=D \cdot E \cdot R_2 \cdot [\ln (R_2/R_1)]^2/2$, where F- force; S-square; a E-electric field strength; D-offset of an electric field; R_1 and R_2 - radiuses on a surface conductor and electrical isolation in PC accordingly. At calculations it was accepted: E_w=10 MV/m; relative permittivity (ε) - for distilled water $\varepsilon_1 \cong 81$, for cross-link polyethylene $\varepsilon_2 \cong 2{,}3$. The design values are reduced in the table 1.

The table 1

Local field strength E_i (MV/m) and specific pressure P_{sp} (Pa) on a demarcation water - CPE

Inclusions as sphere			
E_{1sp}	E_{2sp}	P_{cp1sp}	P_{cp2sp}
0,42	14,8	70	2370
Inclusions as cylinders			
E_{1cyl}	E_{2cyl}	P_{cp1cyl}	P_{cp2cyl}
0,55	19,4	120	4100