G.V. Bezprozvannych, M.V. Grynyshyna

Effective parameters of dielectric absorption of polymeric insulation with semiconductor coatings of power high voltage cables

Introduction. The presence of semiconductor shields leads to additional dielectric losses compared to polymer insulation without shields. Losses in cables in the presence of semiconductor coatings depend on the dielectric permittivity and resistivity of the composite polymeric material, which are frequency-dependent characteristics. **Purpose.** *To determine in a wide range of frequencies, taking into account the variance of electrophysical characteristics and thickness of semiconductor shields effective electric capacitance and tangent of dielectric losses angle of high-voltage power cables with polymer insulation.* **Methodology.** *Serial-parallel nonlinear circuit replacement of semiconductor coatings and linear polymer insulation to determine in a wide range of frequency the effective parameters of the dielectric absorption of a three-layer composite system of high-voltage power cables of single core.* **Practical value.** *The obtained relations are the basis for the development of practical recommendations for substantiating the thickness and electrophysical parameters of semiconductor shields to reduce the impact on the effective tangent of the dielectric losses angle of a three-layer composite system of high-voltage power cables. References 23, figures 6.*
Key words: **semiconductor coatings, polymer insulation, high-voltage power cable, nonlinear substitution circuit, complex dielectric permittivity, active conductivity, effective electric capacitance, effective tangent of dielectric losses angle.**

На підставі послідовно-паралельної нелінійної схеми заміщення напівпровідних покриттів та лінійної електричної полімерної ізоляції у широкому діапазоні частоти визначено ефективні параметри діелектричної абсорбції силових високовольтних кабелів одножильного виконання. За результатами моделювання, з урахуванням дисперсії електрофізичних характеристик напівпровідних покриттів, доведено, що ефективна електрична ємність тришарової композитної ізоляційної системи визначається ємністю полімерної ізоляції. Встановлено характер частотних залежностей та максимальні значення ефективного тангенсу кута діелектричних втрат в залежності від співвідношення між питомою електропровідністю на постійному і змінному струмі та товщиною напівпровідних екранів. Отримані співвідношення є підставою для розроблення практичних рекомендацій щодо обґрунтування товщини та електрофізичних параметрів напівпровідних покриттів для зменшення їх впливу на ефективний тангенс кута діелектричних втрат тришарової композитної електроізоляційної системи силових високовольтних кабелів. Бібл. 23, рис. 6.
Ключові слова: **напівпровідні покриття, полімерна ізоляція, силовий високовольтний кабель, нелінійна схема заміщення, комплексна діелектрична проникність, активна питома провідність, ефективна електрична ємність, ефективний тангенс кута діелектричних втрат.**

Introduction. Electricity supply of 15 million units of different consumer groups in Ukraine is provided by medium voltage networks the length of which is over 92 % of networks of all classes [1]. The need to replace about 140 thousand km of electrical networks causes the introduction of high-voltage power cables with polymer insulation based on cross-linked polyethylene, high-performance thermoplastic elastomers [2, 3]. With the introduction of modern high-voltage cable systems, there is, first, the possibility of widespread use of an extensive distributed cable network for data transmission of large volumes [4, 5]. Secondly, the diagnosis of insulation to identify signs of its degradation, which are most pronounced in the high frequency range [6-12].

A design feature of high-voltage power cables with polymer insulation is the presence of semiconductor shields on the conductor core and insulation to equalize the electric field on the core surface and reduce the electric field on the insulation surface [13, 14]. Semiconductor shields are applied simultaneously with the extrusion of polymer insulation. This technology provides high adhesion between the shields and insulation, reduces the likelihood of gas inclusions in the insulation and on the border with semiconductor shields.

Typically, semiconductor layers of composite polymeric material are used by adding carbon black as a filler in the polymer lattice. This material provides a gradual change in the electrical conductivity and dielectric permittivity during the transition of the electric field from the conductor to the electrical insulation [14].

The introduction of acetylene carbon black impurities with a resistivity of particles in the range from 0.0001 to 100 Ω·m leads to a symmetrical radial profile of the electric field in the power cable of coaxial design, which prevents the increase of the local field. The local electric field is the main stimulus for the formation and growth of water treeings, partial discharges and even mechanical ruptures of power cables [15].

The presence of semiconductor shields leads to additional dielectric losses compared to polymer insulation without shields. Losses in cables in the presence of semiconductor coatings depend on the dielectric permittivity and resistivity of the composite polymer material, which are frequency-dependent parameters [16, 17].

The paper uses the concept of dielectric absorption, which is associated with energy losses in polyethylene insulation, which in turn are determined by the electrical capacitance and the tangent of the angle of dielectric losses. In the general case, the term «dielectric absorption» is explained, for example, in [18, 19] and is used in the study of physical mechanisms of electromagnetic energy absorption, residual charge generation, etc., as well as in the theory of electromagnetic waves [20]. Also, in [19] dielectric absorption and losses are separated.

Analysis of literature sources. Electrophysical characteristics of semiconductor coatings significantly affect the distribution of the electric field and losses in cables at operating frequency of 50 Hz [13]. In [21], the authors obtained an effective tangent of the dielectric losses angle of three-layer composite insulation without taking into account the dependence on the frequency of conductivity and dielectric permittivity and the thickness of semiconductor coatings.

The influence of semiconductor coatings taking into account the polarization losses in the frequency range 200 Hz – 20 kHz is taken into account in [16] on the basis of a parallel substitution circuit in the form of electric capacitance and resistance of each component of the three-layer composite system connected in series.

Using the substitution circuit of polyethylene cross-linked insulation with three relaxation RC-circuits in [22] the emergence of relaxation maxima on the frequency dependence of the dielectric losses angle tangent in polymer insulation with semiconductor shields of medium voltage power cables was proved.

In [17], it was experimentally shown that dielectric losses in semiconductor shields become dominant in high-voltage power cables with polymer insulation at frequency of more than 10 MHz.

The issues of determining the influence of the thickness and electrophysical characteristics of semiconductor coatings on the effective electric capacitance and the tangent of the dielectric losses angle of high-voltage power cables in a wide frequency range remain unresolved and extremely relevant.

The goal of the paper is to determine the effective electric capacitance and tangent of the dielectric losses angle of high-voltage polymer-insulated power cables in a wide frequency range, taking into account the dispersion of electrophysical characteristics and the thickness of semiconductor shields.

Dispersion of electrophysical characteristics of semiconductor coating materials. Polymer non-polar insulation of power cables (cross-linked polyethylene, thermoplastic elastomers) is characterized by high dielectric properties in a wide frequency range. Thus, for cross-linked polyethylene insulation, the specific volume conductivity γ is equal to $(10^{-13} - 10^{-14})$ S/m; dielectric permittivity – at the level of 2.5 (static value) and, practically, weakly dependent on the frequency in the region of weak electric fields, which causes insignificant value of the dielectric losses coefficient $\varepsilon''(\omega)$ and, accordingly, the dielectric losses tangent tgδ of polymer insulation. The dispersion of dielectric permittivity for cross-linked polyethylene is $2.5 - 2.38 = 0.12$ in the frequency spectrum up to 100 MHz [3].

Semiconductor coatings are characterized by high values of specific volume conductivity, dielectric permittivity and dielectric losses coefficient, due to the morphological and structural features of the polymer material.

Conditionally composite polymer material with soot impurities consists of three phases: insulating (Fig. 1, region I), percolation (Fig. 1, region II) and conductive (Fig. 1, region III) [23].

In the low-frequency region, the tunneling effect between soot (carbon) particles is considered to be the main mechanism, which causes a weak dependence of the specific electrical conductivity of the semiconductor on the frequency.
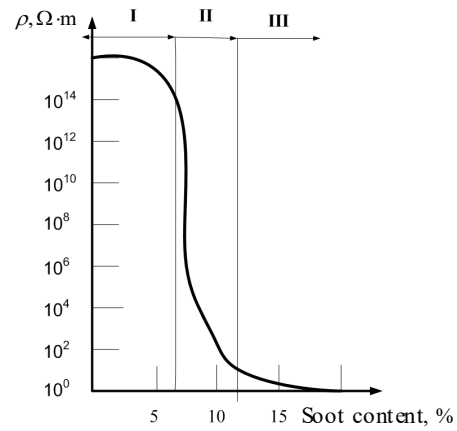

Fig. 1. Influence of soot content on the specific conductivity of semiconductor coating of power cables

In this case, the specific volumetric conductivity γ differs little from the specific volumetric conductivity γ_{dc} at DC. The tangent of the dielectric losses angle tgδ_e due to electrical conductivity decreases inversely proportional to the circular frequency ω and the real part $\varepsilon'(\omega)$ of the complex dielectric permittivity ε^* of the semiconductor coating material (Fig. 2,*a*) [21]

$$\text{tg}\delta_e = \frac{\gamma_{dc}}{\omega \cdot \varepsilon_0 \cdot \varepsilon'(\omega)}, \qquad (1)$$

where $\varepsilon_0 = 8.85 \cdot 10^{-12}$ F/m is the dielectric constant.

The total tangent of the dielectric losses angle tgδ_{semi} of the semiconductor coating takes into account the losses on the electrical conductivity tgδ_e and polarization tgδ_{pol} [16, 21]

$$\text{tg}\delta_{semi} = \text{tg}\delta_e + \text{tg}\delta_{pol} = \frac{\gamma_{dc}}{\omega \cdot \varepsilon_0 \cdot \varepsilon'(\omega)} + \frac{\varepsilon''(\omega)}{\varepsilon'(\omega)}, \qquad (2)$$

where $\varepsilon''(\omega)$ is the frequency-dependent imaginary part of the complex dielectric permittivity (Fig. 2,*b*).

Taking into account that the active specific volume conductivity $\gamma_{ac}(\omega)$ at the alternating voltage of the circular frequency ω is determined by the imaginary part $\varepsilon''(\omega)$ of the complex dielectric permittivity (Fig. 2,*c*)

$$\gamma_{ac}(\omega) = \omega \cdot \varepsilon_0 \cdot \varepsilon''(\omega), \qquad (3)$$

the frequency dependence of the tangent of the dielectric losses angle of semiconductor coatings is defined as

$$\text{tg}\delta_{semi}(\omega) = \frac{\gamma_{semi}(\omega)}{\omega \cdot \varepsilon_0 \cdot \varepsilon'(\omega)}, \qquad (4)$$

where $\gamma_{semi}(\omega) = \gamma_{dc} + \gamma_{ac}(\omega)$.

Under the condition $\gamma_{ac}(\omega) >> \gamma_{dc}$, which is valid for modern compositions of semiconductor shields of high-voltage power cables, the tangent of the dielectric losses angle of semiconductor coatings is determined on the basis of [16]

$$tg\delta_{semi}(\omega) = \frac{\gamma_{ac}(\omega)}{\omega \cdot \varepsilon_0 \cdot \varepsilon'(\omega)}. \qquad (5)$$
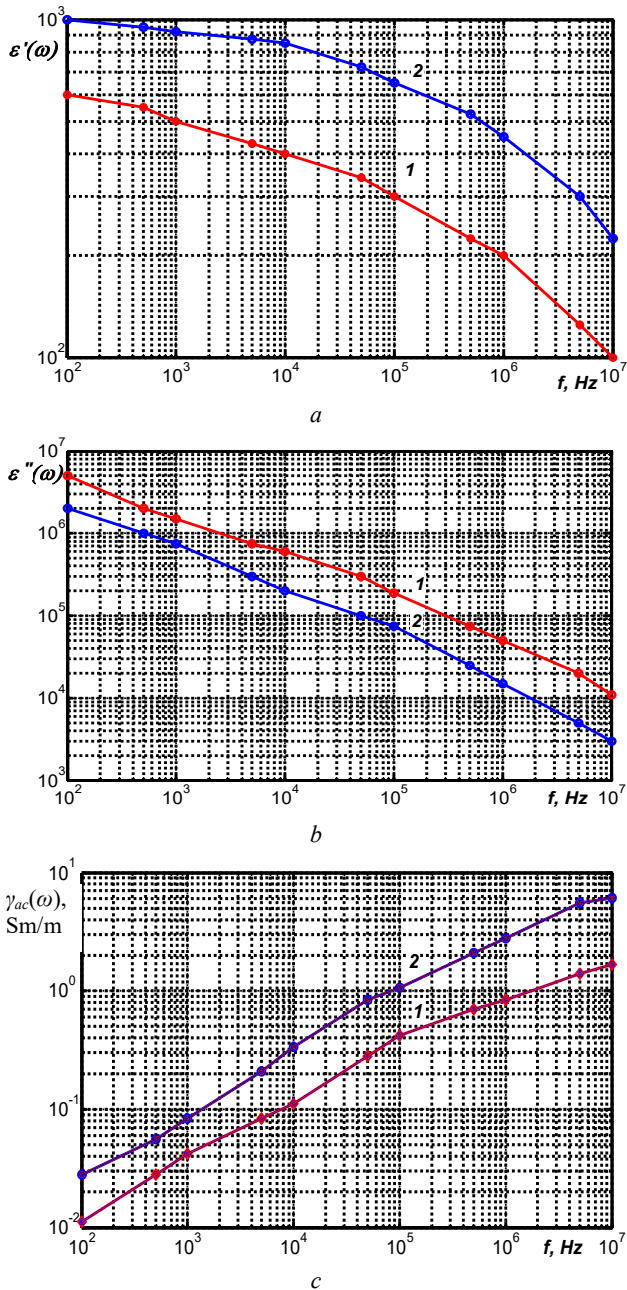
a

b

c

Fig. 2. Typical frequency dependencies of electrophysical characteristics of coatings on the core (curve 1) and insulation (curve 2) of high-voltage power cables under the condition of linear volt-ampere characteristics of semiconductor materials

Effective parameters of dielectric absorption of polymer insulation with semiconductor coatings. The serial-parallel substitution circuit of a three-layer composite insulation system taking into account the dispersion of electrophysical characteristics of semiconductor coatings of power high-voltage cables is presented in Fig. 3,*a*.

In Fig. 3,*a* the following marked: C_{ins}, $C_1(\omega)$, $C_2(\omega)$ – capacitances and G_{ins}, $G_1(\omega)$, $G_2(\omega)$ – active conductivities of layers of polymer insulation and semiconductor coatings on the conductive core and insulation according to the parallel substitution circuit, respectively

$$C_1(\omega)=\frac{\varepsilon_1'(\omega)\cdot\varepsilon_0\cdot S_1}{\Delta_1}; \quad C_{ins}=\frac{\varepsilon_{ins}'\cdot\varepsilon_0\cdot S_{ins}}{\Delta_{ins}};$$

$$C_2(\omega)=\frac{\varepsilon_2'(\omega)\cdot\varepsilon_0\cdot S_2}{\Delta_2}; \tag{6}$$

$$G_1(\omega)=\gamma_{semi1}(\omega)\cdot\frac{S_1}{\Delta_1}; \quad G_{ins}=\gamma_{ins}\cdot\frac{S_{ins}}{\Delta_{ins}};$$

$$G_2(\omega)=\gamma_{semi2}(\omega)\cdot\frac{S_2}{\Delta_2}; \tag{7}$$

where ε_{ins}', $\varepsilon_1'(\omega)$, $\varepsilon_2'(\omega)$ are the real parts of the complex dielectric permittivities of insulation, semiconductor coatings on the core and insulation; γ_{ins} is the volumetric specific conductivity of insulation; γ_{semi1}, γ_{semi2} are the total volumetric specific conductivities taking into account the frequency dependence of the active conductivity of semiconductor coatings on the core and insulation; S_{ins}, S_1, S_2 are the cross sections and Δ_{ins}, Δ_1, Δ_2 are the thicknesses of insulation and semiconductor coatings on the core and insulation, respectively.
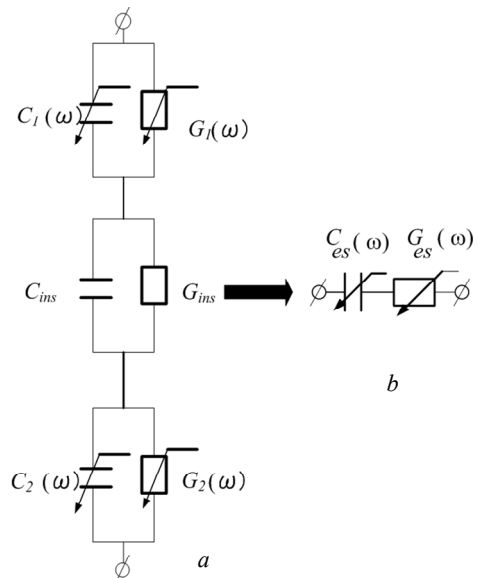

Fig. 3. Serial-parallel (*a*) and equivalent serial (*b*) nonlinear substitution circuit of electrical insulation and semiconductor coatings of high-voltage power cables

The transition from parallel to sequential substitution circuit allows to determine the tangent of the dielectric losses angle, electrical capacitance and active conductivity of each of the components, taking into account (5) – (7):

– for semiconductor coating on the core:

$$tg\delta_1(\omega)=\frac{G_1(\omega)}{\omega\cdot C_1(\omega)};$$

$$C_{1s}(\omega)=C_1(\omega)\cdot\left(1+tg\delta_1^2(\omega)\right); \tag{8}$$

$$G_{1s}(\omega)=\frac{\omega\cdot C_{1s}(\omega)}{tg\delta_1(\omega)};$$

– for cable insulation:

$$C_{inss}=C_{ins}\cdot\left(1+tg\delta_{ins}^2\right);$$

$$G_{inss}=\frac{\omega\cdot C_{inss}}{tg\delta_{ins}}; \tag{9}$$

– for semiconductor coating on insulation:

$$\mathrm{tg}\,\delta_2(\omega) = \frac{G_2(\omega)}{\omega \cdot C_2(\omega)};$$

$$C_{2s}(\omega) = C_2(\omega) \cdot \left(1 + \mathrm{tg}\,\delta_2^2(\omega)\right); \qquad (10)$$

$$G_{2s}(\omega) = \frac{\omega \cdot C_{2s}(\omega)}{\mathrm{tg}\,\delta_2(\omega)};$$

and determine the effective electrical parameters (Fig. 3,*b*) of the three-layer composite system under the given frequency electrophysical characteristics and thickness of semiconductor coatings and insulation:

– electrical capacitance $C_{es}(\omega)$:

$$C_{es}(\omega) = \frac{C_{1s} \cdot C_{inss} \cdot C_{2s}}{C_{1s} \cdot C_{inss} + C_{1s} \cdot C_{2s} + C_{inss} \cdot C_{2s}} =$$

$$= \frac{2\,\pi \cdot A_1 \cdot A_{ins} \cdot A_2 \cdot D_1 \cdot D_{ins} \cdot D_2}{\omega^2 \cdot \varepsilon_0 \cdot \left[A_1 \cdot A_{ins} \cdot \varepsilon_2'(\omega) \cdot \Delta_2 \cdot D_1 \cdot D_{ins} + A_1 \cdot A_2 \cdot \varepsilon_{ins}' \cdot \Delta_{ins} \cdot D_1 \cdot D_2 + A_{ins} \cdot A_2 \cdot \varepsilon_1'(\omega) \cdot \Delta_1 \cdot D_{ins} \cdot D_2 \right]}; \qquad (11)$$

and the tangent of the angle of the dielectric losses $\mathrm{tg}\,\delta_{es}(\omega)$

$$\mathrm{tg}\,\delta_{es}(\omega) = \frac{\omega \cdot C_{es}(\omega)}{G_{es}(\omega)} = \frac{\omega \cdot C_{es}(\omega) \cdot \left(G_{1s}(\omega) \cdot G_{inss} + G_{1s}(\omega) \cdot G_{2s}(\omega) + G_{inss} \cdot G_{2s}(\omega) \right)}{G_{1s}(\omega) \cdot G_{inss} \cdot G_{2s}(\omega)} =$$

$$= \frac{\omega \cdot \varepsilon_0 \cdot D_1 \cdot D_{ins} \cdot D_2 \cdot \left[A_1 \cdot A_{ins} \cdot \dfrac{\varepsilon_2''(\omega)}{\gamma_{semi2}(\omega)} \cdot \dfrac{\Delta_2}{D_2} + A_1 \cdot A_2 \cdot \dfrac{\varepsilon_{ins}''}{\gamma_{ins}} \cdot \dfrac{\Delta_{ins}}{D_{ins}} + A_{ins} \cdot A_2 \cdot \dfrac{\varepsilon_1^2(\omega)}{\gamma_{semi1}(\omega)} \cdot \dfrac{\Delta_1}{D_1} \right]}{\omega^2 \cdot \varepsilon_0 \cdot \left[A_1 \cdot A_{ins} \cdot \varepsilon_2'(\omega) \cdot \Delta_2 \cdot D_1 \cdot D_{ins} + A_1 \cdot A_2 \cdot \varepsilon_{ins}' \cdot \Delta_{ins} \cdot D_1 \cdot D_2 + A_{ins} \cdot A_2 \cdot \varepsilon_1'(\omega) \cdot \Delta_1 \cdot D_{ins} \cdot D_2 \right]}, \qquad (12)$$

where

$$A_1 = \left(\omega^2 \cdot \varepsilon_0^2 \cdot \varepsilon_1'(\omega) + \gamma_{semi1}^2(\omega) \right),$$
$$A_{ins} = \left(\omega^2 \cdot \varepsilon_0^2 \cdot \varepsilon_{ins}' + \gamma_{ins}^2 \right),$$
$$A_2 = \left(\omega^2 \cdot \varepsilon_0^2 \cdot \varepsilon_2'(\omega) + \gamma_{semi2}^2(\omega) \right)$$

are the dimensional coefficients (S^2/m^2), which take into account the frequency dependencies of the electrophysical characteristics of semiconductor shields and polymer insulation;

$$D_1 = \left(r_g + \Delta_1 / 2 \right),$$
$$D_{ins} = \left(r_g + \Delta_1 + \Delta_{ins} / 2 \right),$$
$$D_2 = \left(r_g + \Delta_1 + \Delta_{ins} + \Delta_2 / 2 \right)$$

are the geometric factors depending on the radius of the core r_g, the thickness of the semiconductor coating on the core Δ_1, the insulation thickness Δ_{ins} and the thickness of the semiconductor coating on the insulation Δ_2, respectively.

Frequency dependencies of effective parameters of dielectric absorption of three-layer composite system of power cables. Figure 4 shows the model frequency dependencies of the effective capacitance (Fig. 4,*a*) and the effective tangent of the dielectric losses angle (Fig. 4,*b*) determined on the basis of (11), (12) of the single- core power cable with conducting core cross section of 95 mm^2 of voltage of 35 kV. The thickness of the cross-linked polyethylene insulation is 7 mm. The value of the tangent of the dielectric losses angle of polyethylene insulation is $\mathrm{tg}\,\delta_{ins} = 1 \cdot 10^{-4}$ at frequency of 50 Hz and varies inversely proportional to the frequency in accordance with (1): the determinant is the losses on electrical conductivity.

Curves 1, 1′ and 2 correspond to the components of the electrical capacitance: 1 and 1′ – semiconductor shield on the conductive core, the thickness of which is 0.8 and 1.6 mm, respectively; curve 2 – semiconductor shield on

cross-linked polyethylene insulation with thickness of 0.6 mm, curve 3 – actual effective capacitance of the three-layer composite system (Fig. 4,*a*). The volume specific conductivities on the DC of semiconductor coatings on the core and insulation are equal to $\gamma_{dc1} = 10^{-2}$ S/m, $\gamma_{dc2} = 1$ S/m, respectively. For polyethylene insulation – $\gamma_{ins} = 10^{-13}$ S/m. The active specific volume conductivities of semiconductor screens $\gamma_{ac}(\omega)$ at AC voltage were determined on the basis of (3) taking into account the frequency dependence of the components presented in Fig. 2,*c*.

Curve 4 is the value of the insulation capacitance determined by (13) [15]

$$C_{ins} = \frac{2 \cdot \pi \cdot \varepsilon_{ins}' \cdot \varepsilon_0}{\log\left(D_2 / D_1 \right)}, \text{ F/m.} \qquad (13)$$

The simulation results prove that the values of the effective capacitance of the three-layer insulation (curve 3, Fig. 4,*a*), determined on the basis of (11), practically do not differ from the values obtained on the basis of (13) (curve 4, Fig. 4,*a*). The effective capacitance of a cable with semiconductor shields is determined by the dielectric permittivity of the insulation itself and the thickness of the components: the effect of semiconductor shields is insignificant in the high frequency range (see Fig. 4,*a*).

The effective tangent of the dielectric losses angle of a three-layer composition significantly depends on both the electrophysical properties of semiconductor shields materials and their thickness, even with the same electrophysical characteristics (compare curves 1 and 1′, Fig. 4,*b*). Increasing the thickness of the semiconductor shield along the conductive core by 2 times leads to an increase in the effective tangent of the dielectric losses angle by 2 times with the manifestation of the characteristic dipole maximum at frequency of 50 kHz.

Variation of electrophysical properties and thickness of semiconductor shields along the core and cross-linked

polyethylene insulation of 35 kV power cable leads to different nature of frequency dependencies of the effective tangent of the dielectric losses angle (curves 1–5, Fig. 5,*a*). The effective tangent of the dielectric losses angle of the three-layer composite system is (1–7) times higher than the dielectric losses tangent of the actual polymer insulation tgδ_{ins} for frequency of 50 Hz (compare curves 1–5, Fig. 5,*b*) in a wide frequency range due to the active specific conductivity of semiconductor coatings (see Fig. 2,*c*).
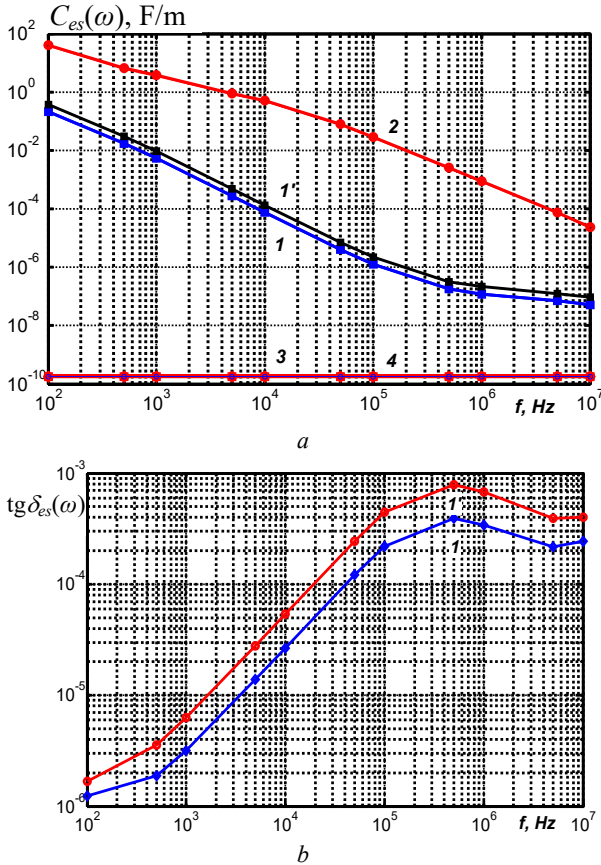

Fig. 4. Frequency dependencies of equivalent parameters dielectric absorption of high-voltage power cable taking into account the dispersion of electrophysical characteristics of semiconductor shields

In Fig. 5*a*,*b* curves 1–5 correspond to the model dependencies, curve 6 (Fig. 5,*a*) – to the experimental one for a sample of power single-core cable with polyethylene insulation (insulation thickness 7 mm) at voltage of 35 kV, which has long been unprotected from moisture – natural humidity (there are no water-blocking tapes in the cable construction). Dielectric parameters are measured by a digital meter of the capacitance and the tangent of the dielectric losses angle RLC Meter DE-5000 in the frequency range 100 Hz – 100 kHz.

Curve 1 – the thickness of semiconductor shields on the conductor and insulation is 1.2 and 0.6 mm, curve 2 – $\Delta_1 = 0.6$ mm and $\Delta_2 = 1.2$ mm with specific conductivity at DC $\gamma_{dc1} = 10^{-4}$ S/m, $\gamma_{dc2} = 10^{-2}$ S/m, respectively; curves 3, 4 – $\Delta_1 = 0.6$ mm and $\Delta_2 = 1.2$ mm with $\gamma_{dc1} = 10^{-4}$ S/m, $\gamma_{dc2} = 10^{-4}$ S/m (curve 3) and $\gamma_{dc1} = 10^{-2}$ S/m, $\gamma_{dc2} = 10^{-4}$ S/m (curve 4); curve 5 – $\Delta_1 = 1.2$ mm and $\Delta_2 = 0.6$ mm with $\gamma_{dc1} = 10^{-2}$ S/m, $\gamma_{dc2} = 1$ S/m.
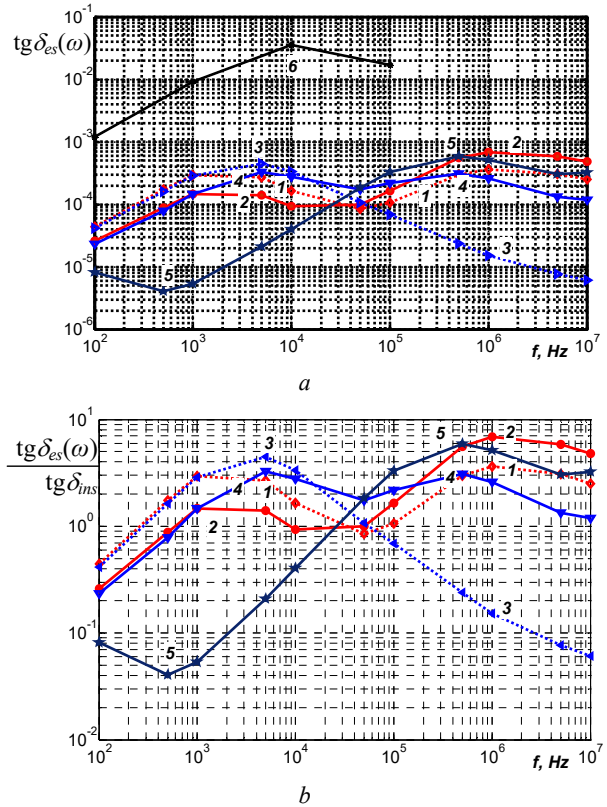

Fig. 5. Frequency dependencies of the tangent of the dielectric losses angle at different electrical properties and thickness semiconductor shield of the power cable for voltage of 35 kV

Thus, provided:
1) $\Delta_1 > \Delta_2$ and $\gamma_{ac1} > \gamma_{dc1}$, $\gamma_{ac2} \approx \gamma_{dc2}$ (curve 1) there are two characteristic maxima of the effective tangent of the dielectric losses angle near the frequency of 1 kHz and 1 MHz with values of tgδ_{es} 3–3.3 times higher than tgδ_{ins};
2) $\Delta_1 < \Delta_2$ and $\gamma_{ac1} > \gamma_{dc1}$, $\gamma_{ac2} > \gamma_{dc2}$ (curve 3) there is one maximum of tgδ_{es} at frequency of 5 kHz with a value exceeding 4.5 times;
3) $\Delta_1 > \Delta_2$ and $\gamma_{ac1} \approx \gamma_{dc1}$, $\gamma_{ac2} \approx \gamma_{dc2}$ (curve 5) there is one maximum of tgδ_{es} near the frequency of 50 MHz with values of tgδ_{es} 6 times higher than tgδ_{ins}.
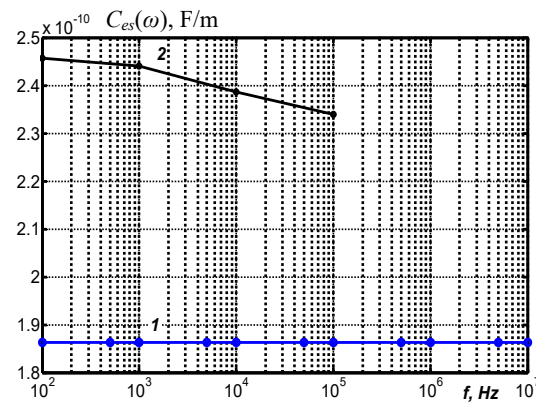

Fig. 6. Model (curve 1) and experimental (curve 2) dependencies of equivalent capacitance of single-core cable for voltage of 35 kV

The nature of the change in the frequency model dependence of the effective tangent of the dielectric losses

angle for curve 3 is more consistent with the experimental curve 6 of the sample of power cable with moistened polyethylene insulation. Confirmation of humidity and diffusion of acetylene carbon black (carbon) according to the theory of percolation is the manifestation of the frequency dependence of the capacitance of the sample of 35 kV power cable with insulation thickness of 7 mm (Fig. 6, curve 2).

Conclusions.

For the first time in a wide frequency range the influence of electrophysical characteristics, taking into account the dispersion of complex dielectric permittivity and active specific conductivity, as well as the thickness of semiconductor shields on the effective dielectric absorption parameters of three-layer composite electrical insulation system of high voltage cables has been determined.

The effective electrical capacitance of a three-layer composite system is determined by the electrical capacitance of the polymer insulation and depends on the dielectric permittivity and insulation thickness, which is confirmed by experimental data.

The considered algorithm for determining the effective tangent of the dielectric losses angle in a wide frequency range is the basis for creating a methodology for substantiating the electrophysical characteristics and thickness of semiconductor shields to reduce their impact on effective dielectric absorption parameters of high-voltage polymer-insulated power cables.

Conflict of interest. The authors declare no conflict of interest.

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G.V. Bezprozvannych[1], *Doctor of Technical Science, Professor,*
M.V. Grynyshyna[2], *Postgraduate Student, Tech. Director,*
[1] National Technical University «Kharkiv Polytechnic Institute»,
2, Kyrpychova Str., Kharkiv, 61002, Ukraine,
e-mail: bezprozvannych@kpi.kharkov.ua (Corresponding author)
[2] TOV «Interkabel Kiev»,
5, Dachnaya Str., p. Kapitanovka,
Kiev-Svyatoshinsky district, Kiev region, 08112, Ukraine,
e-mail: m.grynyshyna@interkabel.ua