

INFLUENCE OF THE PROPERTIES OF THE JOINT INSULATION COMPONENTS ON THE SPACE CHARGE AND ELECTRIC FIELD

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Abstract

This paper deals with the influence of the nature and the electrical properties (conductivity and permittivity) of the DC joints insulations components on space charge accumulation and electric field repartition at the XLPE/EPR and XLPE/EPDM joints insulation interfaces.

The results show that the conductivity and permittivity have lower values for XLPE than for EPDM and EPR samples. Also, the charge accumulated at the XLPE/EPDM interface has lower values (with two orders of magnitude) than those on XLPE/EPR samples. Concerning the electric field, its values are more than twice higher on XLPE/EPR samples than on XLPE/EPDM ones.

Finally it is shown that the use for DC joint insulations manufacture of XLPE/EPDM is more benefic, than XLPE/EPR.

Key words: polymers, DC cables joints, electrical properties, space charge, electric field

1. INTRODUCTION

Due to their important advantages (lower costs on long distances etc.), in the last years the weight of direct current (DC) cables in the transmission and distribution of electricity has become increasingly important (Kim 2009). Since the sections of high voltage cables have reduced lengths (1 ... 10 km), for the transmission of energy over long distances several sections are required, connected together with joints. For higher distances, voltages and power, in recent year's great efforts to develop joints with extruded polymeric insulation materials: XLPE, EPDM, EPR, silicone rubber etc. have been made (Fig. 1) (Cold Shrink Joints 2012).

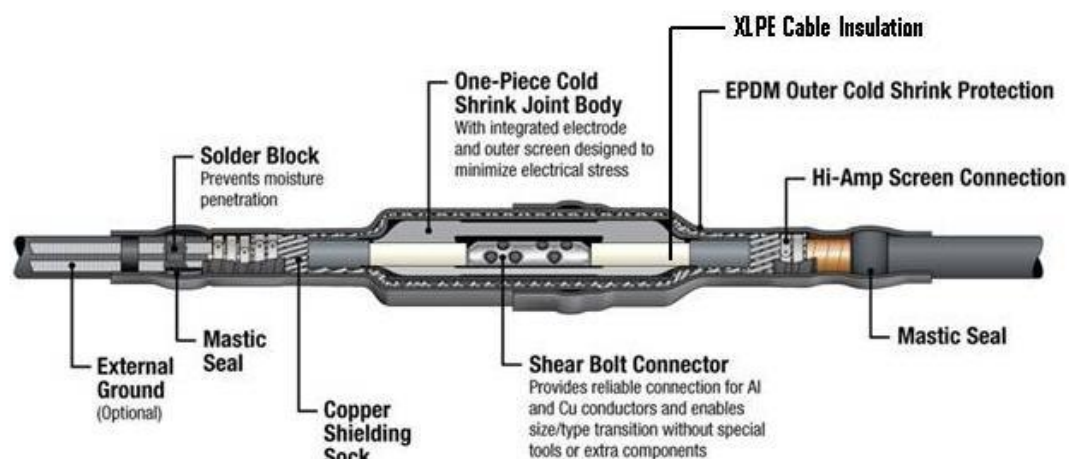


Fig. 1. Cross - section through a joint (Cold Shrink Joints 2012).

Cable joints can be of several types: straight (when connecting two cables with the same rated voltage and the same type of insulation), in Y, and transition joints (when connecting two cables with different rated voltages and insulations).

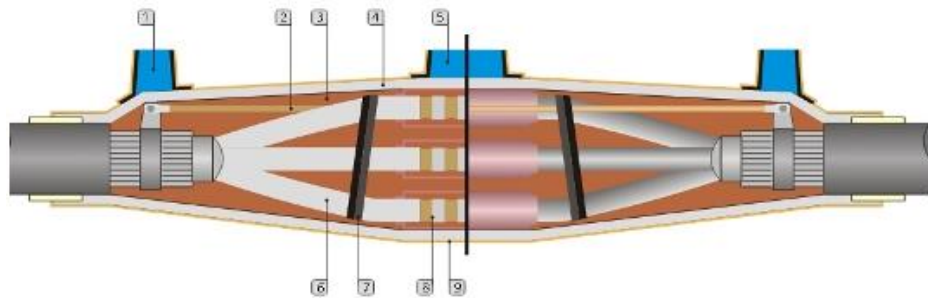


Fig. 2. The structure of a straight type joint: 1 - Riser ; 2 - Earth continuity connection; 3 - C.J compound; 4 – Plastinet; 5 - Pouring gate; 6 - Core Insulation; 7 - PVC (NA) Tape; 8 – Ferrule; 9 - BOPP Tape two layers each half overlapped over plastinet (Straight Joints 3M 2016).

Straight joints (Fig. 2) can be used for indoor, outdoor and underground cable jointing. In the case of resin based cable joints, the based casting resins using polyurethane ensure mechanical protection, electrical insulation and protection against water penetration. A typical Y type branch joint is presented in Figure 3 (Cable Joints 2016). This type of joint is used for low voltage, polymeric, non-shielded cables with 1 to 5 cores. The branch joints can be used, as the straight ones, for indoor, outdoor and underground cable jointing. Transition joints provide a lightweight, compact, and environmentally sealed system for jointing PILC and XLPE power cables.

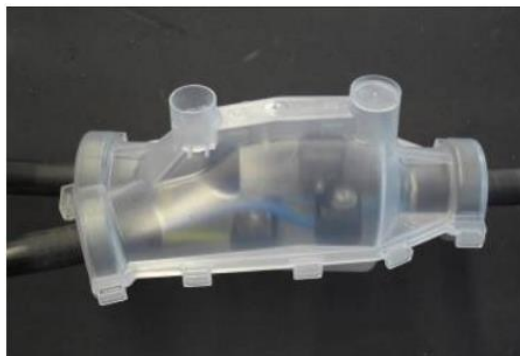


Fig. 3. Joint in Y (Branch Cable Joints 2016).



Fig. 4. Transition joint (Prysmian Group 2016).

Because polymeric materials which are part of a joint have different physical and electrical properties (permittivity, conductivity), during cable operation, at the insulator-insulator interfaces superficial space charge of density ρ_s is separated (Bodega 2005, Bodega 2006, Notingher 2005, Taranu 2015), which leads to the appearance of a supplementary polarization (of heterogeneity) (Notingher 2005). Due to the interfacial polarization phenomena, the insulation behavior of composite systems is greatly different from that of single dielectric components.

Regardless of the manner of manufacture (Stancu 2016) and the type of polymer used for insulation (identical or different from those used for cable insulation), all joint insulations contain space charge. This is produced during manufacturing processes (molecular fracturing, additives etc.), through injection of charge carriers at the interface semiconductor/insulator, due to polymer degradation, partial discharges, etc. (Suh 1994). There are a number of researches on space charge estimation at the interfaces between layers of cross-linked polyethylene (XLPE) and ethylene-propylene-diene-monomer rubber (EPDM) or ethylene-propylene rubber (EPR) (Kwang 2000, Boyer 2011). However, it is to be noted that, in these studies, estimation of the space charge accumulation at the interface is accomplished using an analytical expression that applies only in the case of flat bilayer samples.

On the other hand, as a result of stresses (thermal, electrical) suffered by the joint insulations during operation, new charge carriers appear, which contribute to the increase of space charge density, both inside the homogeneous areas and at the interfaces between them (Taranu 2015). If, in alternating current, the effects of space charge on the degradation and aging of joint insulation can be neglected, in direct current this is no longer possible. In this case, the space charge accumulates continuously, producing a supplementary electric field that exceeds the field corresponding to the voltage at which the cable operates (Stancu 2013). As a result, in some areas of joint insulation (near the interfaces between heterogeneous areas, in cavities etc.) the electric field greatly intensifies, reaching values several times higher than those existing in the absence of charge (Stancu 2013, Taranu 2015).

The electric field was calculated considering different models. Thus, Illias calculated the electric field distribution of electric cable accessories considering defects in the insulation, using on finite element analysis software (Illias 2012). Lachini computed the electric fields distribution of cables affected by humidity (Lachini 2010). Yoshida (Yoshida 1990) used a pressure sensor to determine the stress distribution. It should be noted that all the authors highlight the field intensification in areas with defects, enhancement which is influenced by the properties of the materials from that the insulations are manufactured. The accumulation of space charge is, also, closely linked to the quality of the interface between the two insulating materials. Surface roughness can also be a major factor (Homburg 1994, Smith 1988). Technological parameters (pressure, temperature) applied to obtain the joint insulations (of bilayer type) influence the quality of the interface, which at its turn influence the electrical properties of the insulation (Fig. 5) (Ansorge and Arnold, 2016). Increasing the thickness of the interface leads to a reduced electrical permittivity of the interface (Homburg, 1994).

A lower pressure and temperature make the two polymeric materials not to adhere one to the other, thus appearing gaps, cavities etc. and making imperfect the contact between them. In these gaps and/or cavities partial discharges can occur, which erode the insulation and reduce, over time, the dielectric strength of the insulation. A too high pressure and temperature determine the diffusion of molecules from a material in the other, generating an area (interface) with distinct properties of the constituent materials.

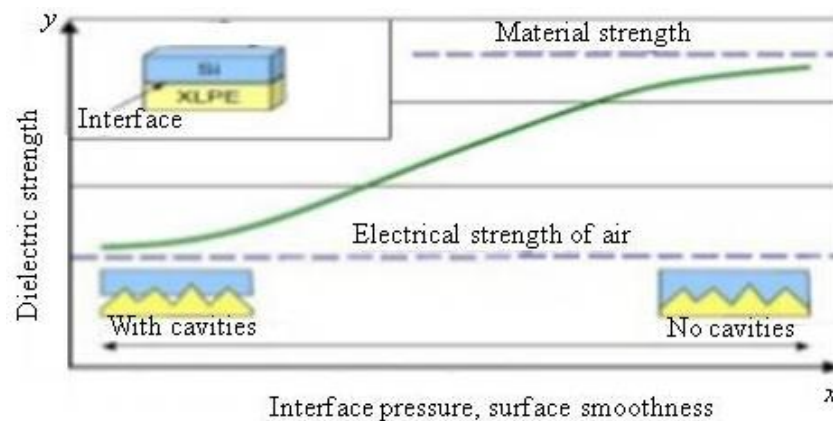


Fig. 5. Influence of the interface quality on the dielectric strength (Ansorge and Arnold 2016)

The internal defects (voids, cavities) of cable joints always accelerate the deterioration of insulation, until finally accidents can arise due to the failure of the joints. Joints are considered the most vulnerable components of a DC line. The statistics made in last year's shows that joints are responsible for 52 % of premature removal from operation of transmission and distribution lines of electricity (Fig. 6) (Gulski 2002). Premature failure of the joint insulation is due to manufacturing defects, reducing the life expectancy of cable joints (Dang 1997).

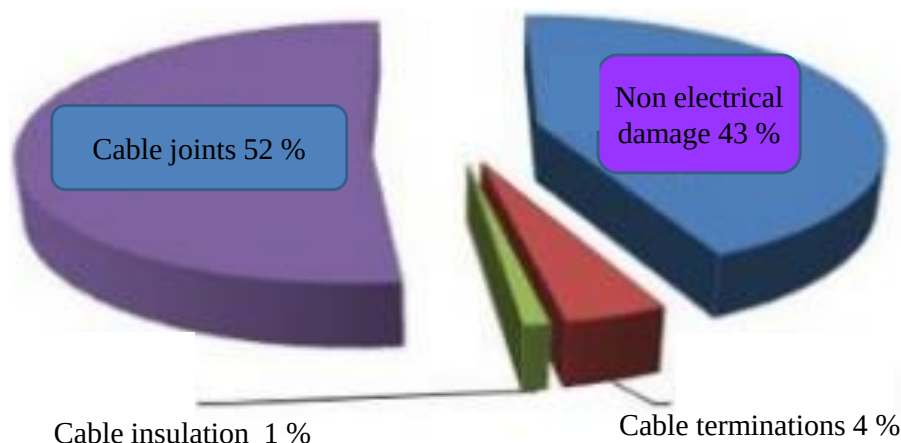


Fig. 6. Statistical distribution of cable failure causes (Gulski 2002).

In a series of previous works (Taranu 2015, Stancu 2015, Stancu 2016), the influence of the properties of the bilayer (XLPE/EPR) insulation components of a joint on the accumulation of space charge at the interface was analyzed, and the electric field distribution was calculated.

In this paper, the results of an experimental study conducted on flat samples of XLPE, EPR and EPDM and sandwiches (bilayers) of XLPE/EPR and XLPE/EPDM are presented. On all samples the electrical conductivity and permittivity were measured, and the charge density at the bilayer interfaces were calculated (Stancu 2016). To calculate the electric field, cylindrical models of joints have been considered, referred as cylindrical samples of XLPE/EPR and XLPE/EPDM. In the end, the results obtained on the two types of cylindrical bilayer samples are analyzed, and conclusions are drawn concerning the practical realization of DC cable joints.

2. MATERIALS FOR JOINT INSULATIONS

To manufacture the joint insulation, multiple polymeric materials are used, such as XLPE, EPR, and EPDM. The most important properties of these materials are presented in Table 1 (Stancu 2016).

Table 1. Properties of polyethylene (XLPE), ethylene-propylene rubber (EPR) and ethylene-propylene-diene-monomer rubber (EPDM) (Stancu 2016)

Material	Property	Unit of measurement	Value
XLPE	Relative permittivity (50 Hz)	-	< 2.3
	Loss factor (50 Hz)	-	< $5 \cdot 10^{-4}$
	DC resistivity	Ωm	> 10^{14}
	Dielectric strength	MV/m	> 22
	Density	kg/m^3	920.5-924,5
EPR	Relative permittivity (50 Hz)	-	3 – 3.8
	Loss factor (50 Hz)	-	0.0034-0.007
	DC resistivity	Ωm	10^{13} - 10^{15}
	Dielectric strength	MV/m	> 20
	Density	kg/m^3	1300 – 1550
EPDM	Relative permittivity (50 Hz)	-	2.8
	Loss factor (50 Hz)	-	0.001
	DC resistivity	Ωm	10^{13} - 10^{15}
	Dielectric strength	MV/m	15
	Density	kg/m^3	1000

3. COMPUTATION MODEL OF CHARGE ACCUMULATED AT INTERFACES

3.1. Case of flat samples

In the case of two bodies that come into contact, and whose surfaces are not ideal (showing some roughness), at the interface between them appear, inevitable, cavities, whose dimensions are about the order of microns (depending on surface roughness and pressure) (Bodega 2003). These cavities can be filled with air - in the case of a pure contact between the bodies - or a lubricant - in the case of an interfacial material (Geene and Ross 2015). Therefore, the physical joint between two insulating layers can be a layer of air or lubricant of a specific thickness. Obviously, the electrical conductivity σ of this layer (or, more simply, interface) depends on the chemical nature (air, etc.) and differs (even by several orders of magnitude) of the electrical conductivity of the layers that separate them (Peppin 1998, Wintle 1999).

Generally, the dielectric properties of this transition area depend on the properties of the dielectric layers that are separated and those of the interfacial layer (air, in the case of a pure contact). Considering A and B the two dielectrics (of conductivities σ_A and σ_B and permittivities ϵ_A and ϵ_B) in contact (Fig. 7 a), "the real interface" between them can be represented by a fictive dielectric C of thickness d_C , conductivity σ_C and permittivity ϵ_C , located between two ideal surfaces AC and CB (Fig. 7 b).

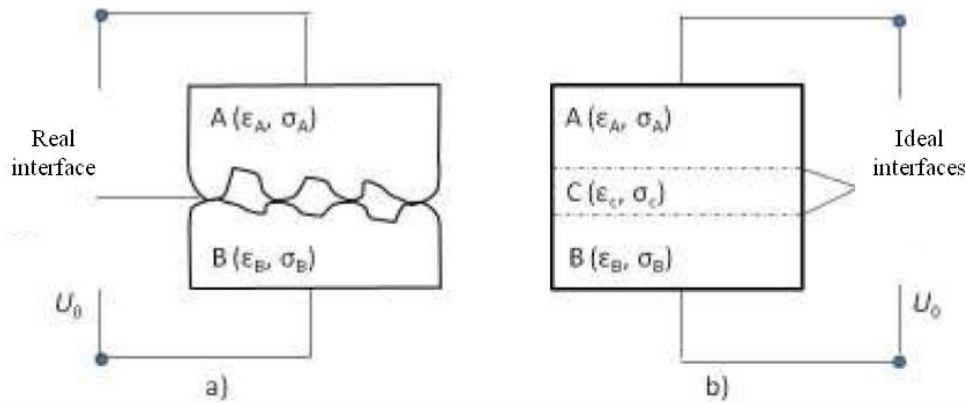


Fig. 7. Interface between dielectrics A and B: a) real; b) modelled by a fictive dielectric C (Stancu 2015).

Assuming that the surfaces of the flat plates A and B are ideal and that the two plates - of thickness d_A and d_B - represent the dielectric of a capacitor, to which the DC voltage U_0 is applied, at the interface AB - between the plates A and B - a space charge is separated, whose superficial density ρ_{SAB} can be calculated – in the case of a perfect contact between A and B – with the equation (Bodega 2003):

$$\rho_{SAB} = \frac{\sigma_B \varepsilon_A - \sigma_A \varepsilon_B}{d_A \sigma_B + d_B \sigma_A} \cdot U_0 \quad (1)$$

But if the contact between the two materials is not perfect, a layer C of non-zero thickness and properties different than those of materials A and B appears, the space charge density at the AC interface can be determined with the equation (Bodega 2003):

$$\rho_{SAC} = \frac{\varepsilon_A \varepsilon_B}{d_A \varepsilon_B + d_B \varepsilon_A} \cdot U_0 \quad (2)$$

3.2. Case of cylindrical samples

Superficial charge density at instant t from the voltage application ($\rho_s(t)$) was calculated for the cylindrical model of the joint, respectively a cylindrical capacitor with the dielectric consisting of two insulating layers (XLPE/EPR and XLPE/EPDM), using the equation presented in (Stancu 2016):

$$\rho_s(t) = C_1 + C_2 e^{-t/\tau} \quad (3)$$

where

$$\tau = \frac{\varepsilon_1 \ln \frac{r_2}{r_{12}} + \varepsilon_2 \ln \frac{r_{12}}{r_1}}{\sigma_1 \ln \frac{r_2}{r_{12}} + \sigma_2 \ln \frac{r_{12}}{r_1}} \quad (4)$$

$\sigma_{1,2}$ and $\varepsilon_{1,2}$ are the conductivity, respectively the permittivity of the layers 1 and 2, C_1 and C_2 are two parameters whose expressions are presented in (Pepin 1998), r_1 and r_{12} – the radii of inner, respectively outer surfaces of the layer 1 (S_1 and, respectively, S_{12}), and r_2 – the radius of the outer surface of the layer 2 (S_2) of the considered cylindrical model.

4. EXPERIMENTS

4.1. Samples

For manufacture of the samples, the materials have been supplied by the company CABLEL Bucharest, respectively cross-linked polyethylene (for XLPE, average thickness $g = 0.3 \div 0.5$ mm), ethylene-propylene rubber (for EPR, average thickness $g = 0.5$ mm), and ethylene-propylene-diene-monomer rubber (average thickness $g = 0.5$ mm). All types of samples were obtained by molding pellets at different temperatures and pressures. Thus, samples of XLPE were obtained by pressing of pellets at $p = 200$ bar and $T = 190$ °C, for 10 minutes, EPR at $p = 160$ bar and $T = 190$ °C, for 10 minutes, and for EPDM at $p = 160$ bar and $T = 190$ °C, for 10 minutes (Stancu 2015). The bi-layered XLPE/EPR samples were also obtained by moulding at $p = 70$ bar and $T = 145$ °C (for 10 minutes), and those of XLPE/EPDM at $p = 70$ bar and $T = 140$ °C (for 10 minutes) (Stancu 2015).

To analyze the surfaces and the interfaces of the samples, an optical microscope BIOROM T, with a 160-x magnification, was used.

4.2. Surfaces and interfaces analysis

As shown in Figures 8, 9 and 11, samples surfaces are relatively smooth, respectively, at macroscopic levels there are no open pores, craters etc. As a result, the interlayers (of air) will have relatively reduced thicknesses (Fig. 10) (Stancu 2015).

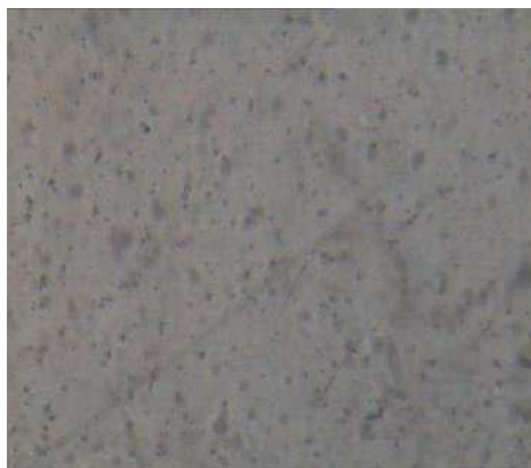


Fig. 8. Surface of a XLPE sample.

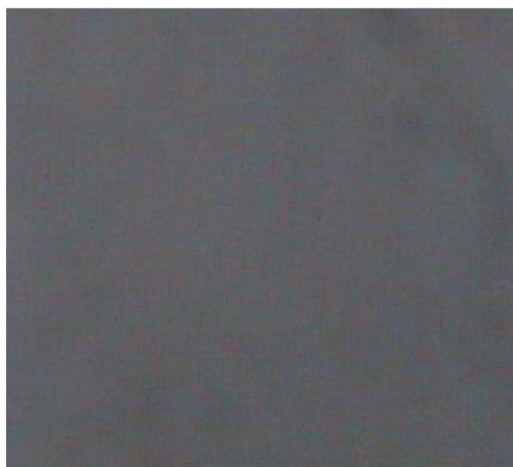


Fig. 9. Surface of an EPR sample.

In order to visualize the interface between XLPE and EPR, respectively XLPE and EPDM, from bilayer samples of XLPE/EPR and XLPE/EPDM, slices of 1 mm were taken and then viewed at an optical microscope. In Figures 10 and 12, the shapes of the interfaces between XLPE/EPR and XLPE/EPDM are presented. It was found that the interfaces are relatively smooth, and that the two materials XLPE and EPR, respectively XLPE and EPDM adhere well to each other.

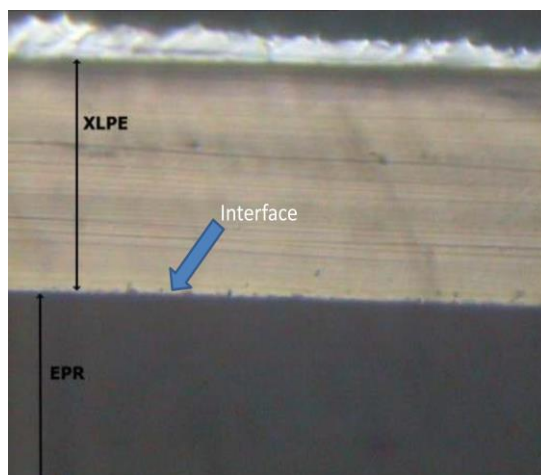


Fig. 10. Interface between XLPE and EPR.

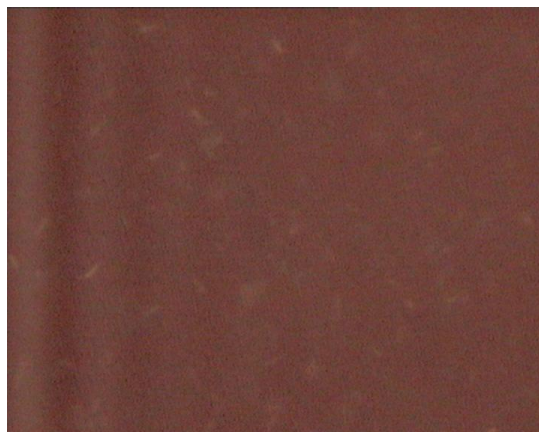


Fig. 11. Surface of an EPDM sample.

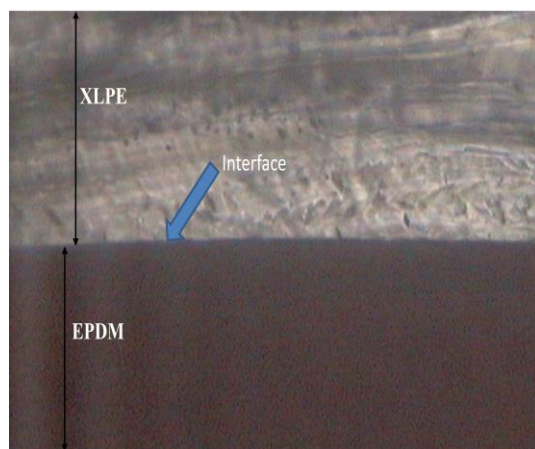


Fig. 12. Interface between XLPE and EPDM.

4.3. Electrical conductivity

DC conductivity (σ_{DC}) was calculated using the absorption/resorption currents measured on each type of flat samples. In order to measure the absorption/resorption currents an electrometer Keithley 6517 was used, at an applied voltage $U_0 = 500$ V for $\tau = 500$ s (Stancu 2015). The measurements were performed on disc samples with a diameter of 90 mm, at room temperature ($T = 30$ °C). Before the measurements, the samples were depolarized for 2 hours. The absorption/resorption currents were measured on 3 samples of each type, an arithmetic average was computed, and the conductivity σ_{DC} values were calculated (Stancu 2015) with the equation:

$$\sigma_{DC}(t) = \frac{i_a(t) - i_r(t + \tau)}{U_0} \frac{g}{S} \quad (5)$$

with $i_a(t)$ the average absorption current determined at time t after applying the voltage, $i_r(t + \tau)$ – average resorption current determined at time $t + \tau$ after applying the voltage, U_0 – applied voltage, g – thickness of the sample and S – area of the measuring electrode surface (Stancu 2015).

4.3.1. Absorption/resorption currents

Figures 13 ... 16 present the time variations of absorption and resorption currents measured at 500 V, for 600 s. It was found that, for all samples, both the absorption, and the resorption currents reduce their intensity in time. This is due to the reduction (up to cancellation) of the polarization and space charge components of the currents (Notingher 2005). After 1-2 hours, the absorption currents are reduced to the values of the conduction currents, and the resorption currents are canceled. It was found out that the absorption/resorption currents are higher for EPR and EPDM than for XLPE samples (Figs. 13 and 14). Also, the absorption/resorption currents are higher in the case of XLPE/EPR than in the case of XLPE/EPDM (Figs. 15 and 16).

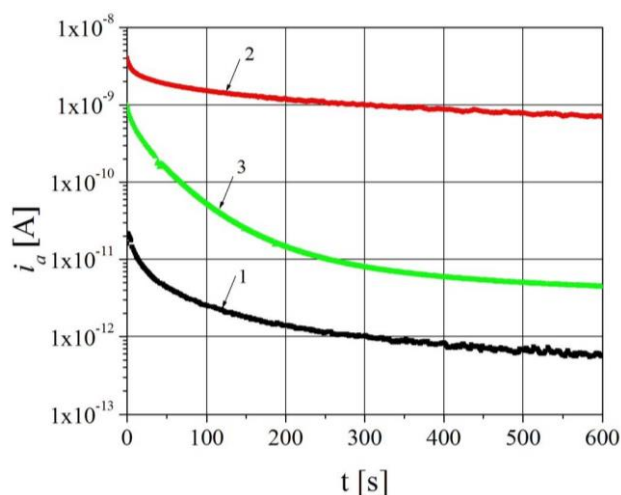


Fig. 13. Variation of absorption currents (i_a) with time for XLPE (1), EPR (2) and XLPE/EPR (3) samples ($U_0 = 500$ V, $T = 30$ °C).

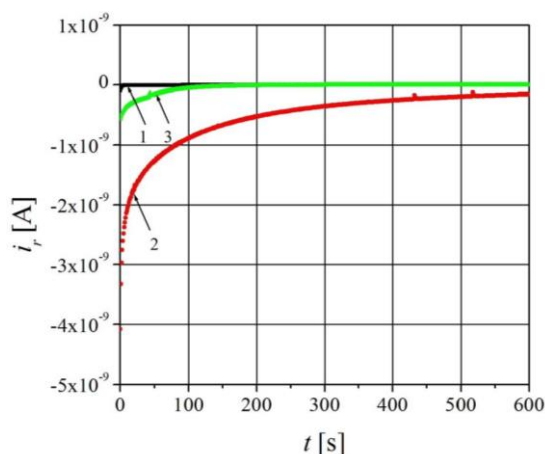


Fig. 14. Variation of resorption currents (i_r) with time for XLPE (1), EPR (2) and XLPE/EPR (3) samples ($U_0 = 500$ V, $T = 30$ °C).

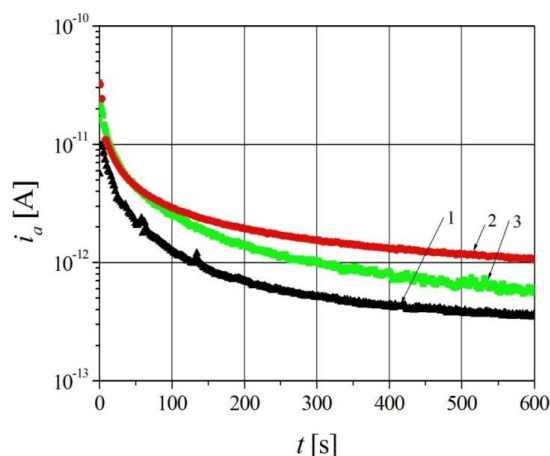


Fig. 15. Variation of absorption currents (i_a) with time for XLPE (1), EPDM (2) and XLPE/EPDM (3) samples ($U_0 = 500$ V, $T = 30$ °C).

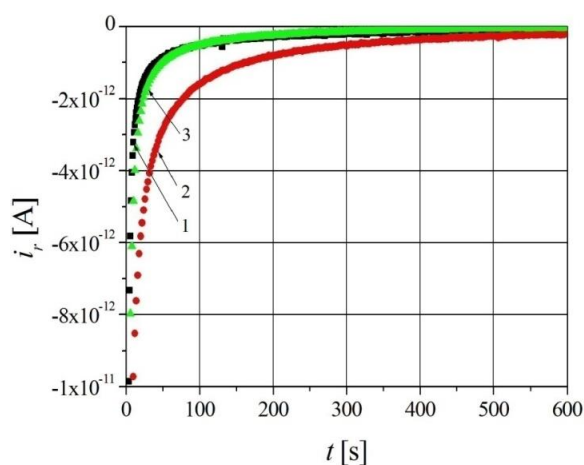


Fig. 16. Variation of resorption currents (i_r) with time for XLPE (1), EPDM (2) and XLPE/EPDM (3) samples ($U_0 = 500$ V, $T = 30$ °C).

4.3.2. Electrical conductivity

Figures 17 and 18 present the time variations of the DC conductivity (σ_{DC}) for XLPE, EPR, EPDM, XLPE/EPR and XLPE/EPDM samples.

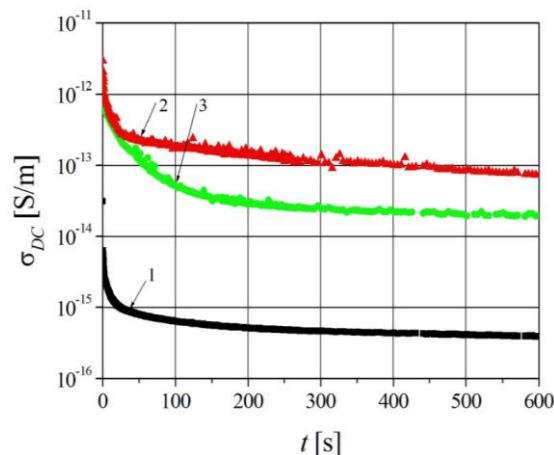


Fig. 17. Time variations of the electrical conductivity for XLPE (1), EPR (2) and XLPE/EPR (3) samples ($U_0 = 500$ V, $T = 30$ °C).

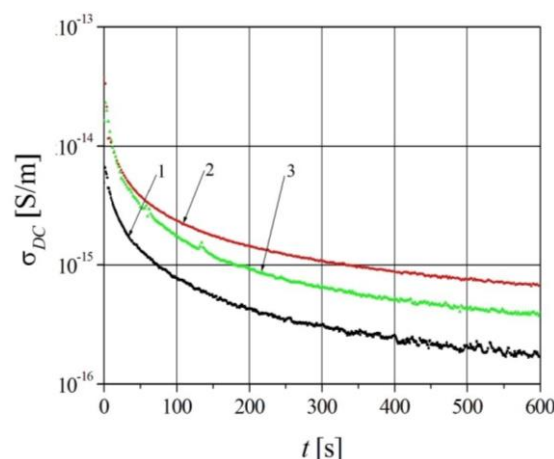


Fig. 18. Time variations of the electrical conductivity for XLPE (1), EPDM (2) and XLPE/EPDM (3) samples ($U_0 = 500$ V, $T = 30$ °C).

It was found that both in the case of the XLPE/EPR and XLPE/EPDM samples, the electrical conductivity is higher than that of XLPE, and respectively lower than that of EPR and EPDM. On the other hand, the values of the conductivity for the bilayer samples of XLPE/EPR are higher than those obtained for XLPE/EPDM. As in the case of absorption/resorption currents, for all samples, the conductivity values reduce in time, due to the decrease of the polarization and space charge densities.

DC conductivity values determined in this section (Table 4) were used to calculate the space charge density separated at the interfaces XLPE/EPR and XLPE/EPDM. At its turn, the space charge density was used to calculate the electric field.

4.3.3. Electrical permittivity

The measurement of electrical permittivity was carried out on samples taken from flat plates of XLPE, EPR, EPDM, XLPE/EPR and XLPE/EPDM. The samples (flat discs) had the diameter of 45 mm. Before measurements, the samples were depolarized for 2 hours.

The values of real (ϵ_r') and imaginary (ϵ_r'') parts of the complex relative permittivity were measured, for frequencies between 1 mHz and 1 MHz. Table 4 shows the values of ϵ_r' (noted, simply, ϵ_r) at 50 Hz for the XLPE, EPR and EPDM samples. It was found that the values of the DC conductivity at 600 s are higher for EPR than for EPDM, and the values of the relative permittivity at 50 Hz are higher for EPR and lower for EPDM.

4.4. Space charge density

Considering that the steady state is reached after $t = 600$ s, the values of space charge density ρ_s accumulated at the interfaces of the XLPE/EPR and XLPE/EPDM cylindrical samples were calculated with the equation (3), using the $\sigma_{1,2}$ conductivities values for 600 s, and the permittivities values $\epsilon_{1,2} = \epsilon_0 \epsilon_{r1,2}$, with $\epsilon_{r1,2}$ measured at 50 Hz (Table 2). It can be seen that the space charge density is higher in XLPE/EPR ($\rho_{sXLPE/EPR}$) than in XLPE/EPDM ($\rho_{sXLPE/EDM}$) (Table 3). This is due to higher values of the relaxation time $\tau = \epsilon/\sigma$ for the XLPE/EPDM than for XLPE/EPR.

Table 2. Values of the electrical conductivity σ and permittivity ϵ_r

Sample	$\sigma(600 \text{ s}) \text{ (S/m)}$	$\epsilon_r(50 \text{ Hz}) (-)$
XLPE	$3.0 \cdot 10^{-16}$	2.20
EPR	$9.0 \cdot 10^{-14}$	2.80

Table 3. Values of the relaxation time τ and space charge density ρ_s

Sample	$\tau \text{ (s)}$	$\rho_s \text{ (C/m}^2\text{)}$
XLPE/EPR	$0.86 \cdot 10^{14}$	$8.65 \cdot 10^{-4}$
XLPE/EPDM	$0.33 \cdot 10^{16}$	$1.31 \cdot 10^{-6}$

4.5. Electric field

For the computation of the electric field, cylindrical models of joints were considered, made of two polymeric layers of different properties, respectively the cylindrical layers of XLPE/EPR and XLPE/EPDM (Fig. 19). The computational domain $D = D_1 \cup D_2$ (Fig. 19) consists of sub domain D_1 (corresponding to layer 1, of thickness g_1 , relative permittivity ϵ_{r1} and electrical conductivity σ_1) – delimited by the surfaces S_1 (of radius r_1) and S_{12} (of radius $r_{12} = r_1 + g_1$) and D_2 (corresponding to layer 2, of thickness g_2 , relative permittivity ϵ_{r2} and electrical conductivity σ_2) – delimited by the surfaces S_{12} and S_2 (of radius $r_2 = r_1 + g_1 + g_2$) (Table 4). The surface S_1 is at the potential $V_1 = 10$ kV, and the surface S_2 is at $V_2 = 0$.

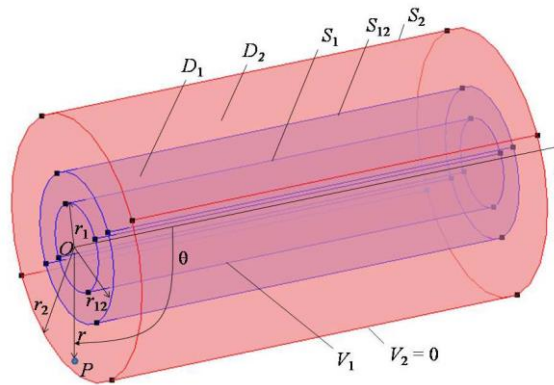


Fig. 19. Computation domain related to cylindrical samples.

Table 4. The characteristics of subdomains $D_{1,2}$ for XLPE/EPR and XLPE/EPDM

Dimension	D_1	D_2
Internal radius r_1 (mm)	11.0	11.3
External radius r_2 (mm)	11.3	11.8
Thickness (mm)	0.3	0.5

Figure 20 presents the variations of the electric field E with the radial coordinate r in a cylindrical sample XLPE/EPR, in the absence and in the presence of surface space charge ρ_s , immediately after applying the voltage U , considering the steady state regime of the electric field. It was found that the presence of space charge causes a significant increase of E in the XLPE layer compared to that of EPR. Also, the presence of charge of density $\rho_s = 8.65 \cdot 10^{-4} \text{ C/m}^2$ causes an increase of the field in the XLPE layer with 115 % over the values obtained in the absence of charge. On the other hand, the value of E of about 30 MV/m - resulted in the case of the presence of superficial charge $\rho_s = 8.65 \cdot 10^{-4} \text{ C/m}^2$ - approaches the value of XLPE's dielectric strength, for which the insulation breaks down (Notingher 2005).

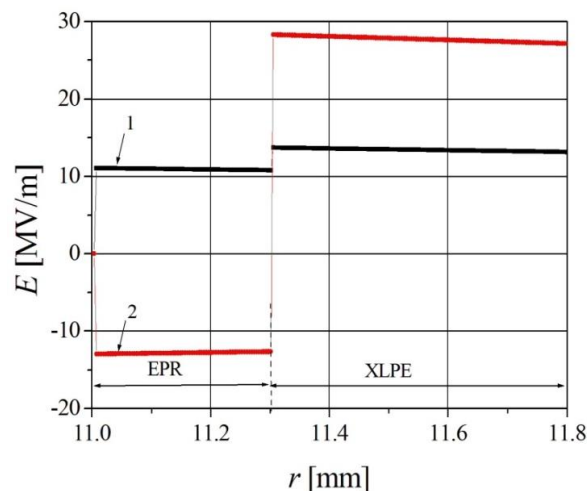


Fig. 20. Variation of the electric field in the steady state regime ($t = 600 \text{ s}$) with the coordinate r , in the absence of charge (1) and in the presence of charge of density ρ_s (2) ($\rho_s = 8.65 \cdot 10^{-4} \text{ C/m}^2$, $U = 10 \text{ kV}$), for XLPE/EPR samples.

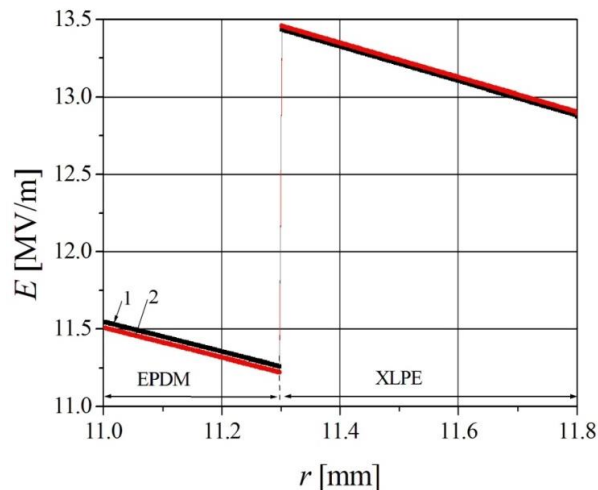


Fig. 21. Variation of the electric field in the steady state regime ($t = 600$ s) with the coordinate r , in the absence of charge (1) and in the presence of charge of density ρ_s (2) ($\rho_s = 1.31 \cdot 10^{-6} \text{ C/m}^2$, $U = 10$ kV), for XLPE/EPDM samples.

Figure 21 presents the variations of the electric field E with the radial coordinate r in a cylindrical sample XLPE/EPDM, in the absence and in the presence of surface space charge ρ_s , immediately after applying the voltage U , considering the steady state regime of the electric field. It was found that the presence of space charge of density $\rho_s = 1.31 \cdot 10^{-6} \text{ C/m}^2$ causes an insignificant increase of E in the XLPE layer compared to that of the EPDM layer, due to the reduced value of the charge density. The presence of charge of density $\rho_s = 1.31 \cdot 10^{-6} \text{ C/m}^2$ causes an increase of the field in the XLPE layer with 1 % over the values obtained in the absence of charge.

Comparing the results shown in Figures 20 and 21, it can be seen that in the bilayer insulation of XLPE/EPDM density charge at the interface accumulates with two orders of magnitude lower than in XLPE/EPR. Consequently, the maximum values of the electric field are also lower in XLPE/EPDM than in XLPE/EPR. As a result, the probability of premature breakdown of the XLPE/EPDM insulation type will be lower than in the case of XLPE/EPR. On the other hand, the variations with coordinate of the electric field in EPR/XLPE bilayer insulations are lower in the XLPE, respectively EPR regions than in the XLPE and EPDM regions from the case of XLPE/EPDM bilayer insulations (Figs. 20 and 21). Therefore, the use of EPDM for the second layer of the insulation of a joint is more benefic for safety operation of the power transmission line.

5. CONCLUSIONS

The influence of the properties of the component layers of the DC joints (XLPE, EPR and EPDM) on the accumulation of charge at its interfaces, and the values of the electric field was studied.

The DC conductivity values are higher for EPR, respectively XLPE/EPR, followed by EPDM and XLPE/EPDM.

The AC electric permittivity has higher values for EPR than for EPDM.

Based on the DC conductivity and AC permittivity values, the space charge density accumulated at the interfaces XLPE/EPR and XLPE/EPDM was calculated. The values of the charge density are, in general, reduced, but higher for XLPE/EPR (with two orders of magnitude) than for XLPE/EPDM.

Due to the separation of space charge at the interfaces of bilayer samples, the electric field decreases in EPR and in EPDM, and increases in XLPE. The maximum values of the electric field are up to 3 times higher in the cylindrical samples of XLPE/EPR than of XLPE/EPDM. Therefore, EPDM is more recommended to be used as an insulation joint than EPR.

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