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Role of Ionic Solutions Affect Water Treeing Propagation in XLPE Insulation for High Voltage Cable

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***Abstract*—**This paper presents the experimental results on role of ionic solutions affect water treeing propagation in cross-linked polyethylene insulation for high voltage cable. To study the water treeing expansion due to the ionic solutions, discs of 4mm thickness and 4cm diameter were taken from 115 kV XLPE insulation cable and were used as test specimen in this study. Ionic solutions composed of $CuSO_4$, $FeSO_4$, Na_2SO_4 and K_2SO_4 were used. Each specimen was immersed in 0.1 mole ionic solutions and was tested for 120 hrs. under a voltage stress at 7 kV AC rms, 1000 Hz. The results show that Na_2SO_4 and $CuSO_4$solutions play an important role in the expansion of water treeing and cause degradation of the cross-linked polyethylene (XLPE) in the presence of the applied electric field.

***Keywords*—**Ionic Solutions, Water Treeing, Water treeing Expansion, Cross-linked Polyethylene (XLPE).

I. Introduction

PRESENTLY, cross-linked polyethylene (XLPE) is were used as insulating material in high voltage cable for electrical transmission and distribution systems due to excellent physical, chemical and dielectric properties.. Although XLPE having good dielectric properties for high voltage applications, ageing of XLPE material cannot avoidable after long time in service under various stress. Many phenomena can induce ageing of XLPE material. Performances of XLPE material have been studied in our previous works [1]-[3]. For XLPE underground cable in wet environmental subjected to electric field, it may contain a large variety of chemical types lead to degradation in the form of ‘‘water treeing’’.

Water treeing was first detected in 1969 by Miyashita [4]. Water trees are electrochemical dendritic patterns which grow in hydrophobic polymers in the presence of ac electric field and water. Water trees consist of “tracks” of oxidized polymer which connect micro-voids. The relevance of themicro-voids is very likely statistical in nature, i.e., the likelihood of survival of a track is increased if it encounters a micro-void from which it can continue to grow [5].

Water treeing is small tree-shaped defects appear inside the insulation and grow in the direction of the electric field. The presence of water trees inside the insulation causes the reduction of the electrical breakdown strength of the insulation and eventually cause insulation breakdown. Water treeing has two types, the bow-tie water tree (btt) that emerge in the cable insulation while the vented water tree (vt) emerge at the cable’s inner and/or outer conducting screens, propagate toward the opposite conductor [6]-[9].

Thiamsri et al. [2] studied effect of applied voltage stress frequency to the occurrence of electrical treeing in 22 kV cross linked polyethylene (XLPE) insulated cable. They found that initial time of visible treeing decreases with increasing in applied voltage frequency. Also, obviously, propagation speed of electrical treeing increases with increasing in applied voltage frequency. Furthermore, two types of electrical treeing, bush-like and branch-like treeing were observed.

Xu et al. [6] found that water treeing region contains a wide range of chemical species, with various forms of carbonyl and metal ions and water being dominant. Water treeing takes place in the direction of the electric field and in a polar amorphous region of the polymer.

Steennis et al. [9] studied the water treeing growth in polyethylene cable insulations. They found that the vented water trees are more dangerous than bow-tie trees as a result of the difference in growth behavior. Vented trees are diffuse structures, growing in many kinds of polymers.

Garton et al. [10] studied the oxidation and water tree formation in XLPE insulation cable. They found that water tree regions of XLPE insulation are prone to additional oxidative deterioration on thermal aging and ionic contaminants probably catalyze this oxidation. The presence of ionic contaminants may influence the treeing process.

Qureshi et al. [11] found that copper sulphate exhibits a much influence on water tree growth in XLPE cables and this effect is increased appreciably under the action of temperature cycling of the ionic solution. Cations play an important dominant role in the initiation and growth of water trees. Different models of water tree based on the ionic nature of chemical species were investigated.

For long term in service, various factors influencing water treeing are electric stress, voltage wave shape and frequency, chemical solutions, presence of oxygen, temperature and mechanical stress. The role of chemical solution to water treeing propagation has been widely studied and investigated [12]-[19].

In Thailand, voltage levels for distribution networks of Provincial Electricity Authority (PEA) of Thailand are 22 kV, 33 kV and 115 kV. Both overhead line and underground

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XLPE cables are usually used in PEA distribution networks. Underground cables are increasingly used. However, a function of service stresses and aging time of underground XLPE cable have been no studied. By this reason, characteristic, length and wide of water treeing in XLPE insulated disc subjected to electric stress and aqueous ionic solutions were examined in this study.

II. Experimental

A. Specimens

As illustrated in Fig. 1, discs of 4mm thickness and 4cm diameter were taken from 115 kV XLPE insulation cable and were used as test specimen in this study. This type of power cable is used for underground distribution system of Provincial Electricity Authority (PEA) of Thailand. Then, all specimens were drilled down 2 ± 0.3mm to acts as a water needle as shown in Fig. 2. During test period, The XLPE insulation disc was placed in between the ionic solution and a stainless steel plate electrode in a test chamber.

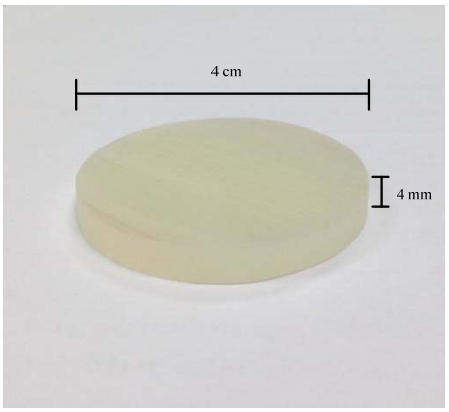


Fig. 1 XLPE insulation discs

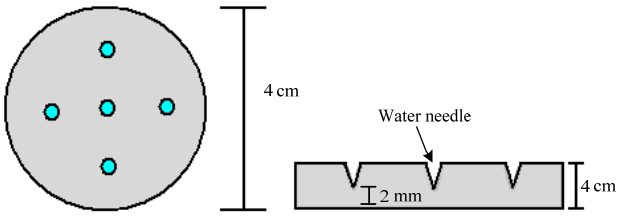


Fig. 2 Water needle

B. Test Method

A test chamber made of acrylic plate having 10cm in length, 10cm in wide and 10cm in height was used in this study as shown in Fig. 3. During test, XLPE insulation disc was placed between an ionic solution and a stainless plate electrode in a test chamber and was subjected to a voltage stress at room temperature (25°C). A voltage of 7 kV_{rms}, 1000 Hz was applied to a stainless needle electrode that was immersed in 0.01 mole ionic solution. The experimental setup is illustrated in Fig. 4. Each specimen was tested for 120 hrs. Ionic solutions composed of $CuSO_4$, $FeSO_4$, Na_2SO_4 and K_2SO_4 were used.

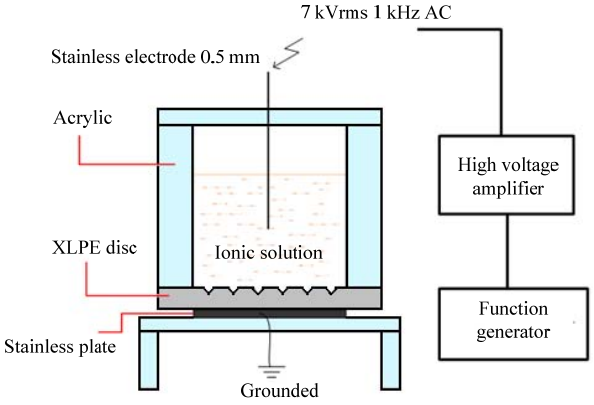


Fig. 3 Schematic diagram of test cell

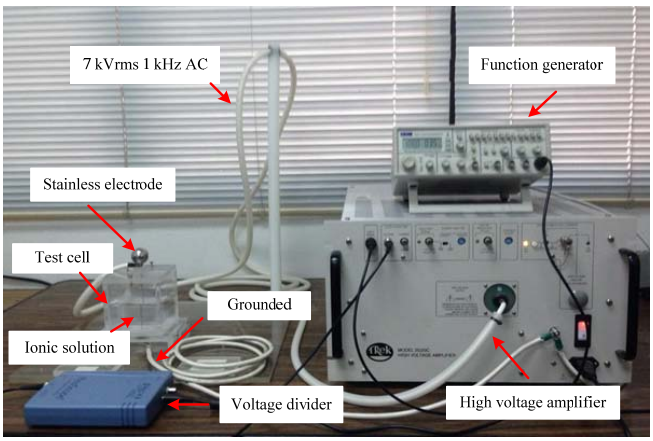


Fig. 4 Experimental setup

III. Results and Discussion

Effect of ionic solutions to the occurrence of water treeing was elucidated. After aging testing period 120hrs, tested specimen on the portions close to the water needle tip were sliced into 0.4mm thickness and were stained by with methylene blue. Then, a microscopic analysis system consisting of transmitted light bright field optical microscope equipped with CCD camera and a computer was used for treeing analysis.

Vented type water treeing (vt) was observed on all tested specimens. The occurrence of water treeing initiated from tip of the water needle and expanded to the plane grounded electrode. Significant difference in water treeing expansion was observed as illustrated in Figs. 5, 6, 7, and 8, respectively. Basically, ionic solution splits up into cationic and anionic species. In this study all solution composed the same anionic specie. Then, cationic species may control the tree initiation and expansions. In case of Na_2SO_4 solution, largest water treeing expansion was measured (average 188µm in length and average 185µm in width). In case of $CuSO_4$ solution, average 156µm in length and average 154µm in width of water treeing expansion were measured. But in case of $FeSO_4$

and K_2SO_4 solutions, no significant differences in water treeing expansion were measured when comparing with those Na_2SO4 and $CuSO_4$ solutions. Smallest water tree expansion was measured on the specimen tested with $FeSO_4$, as illustrated in Table I.

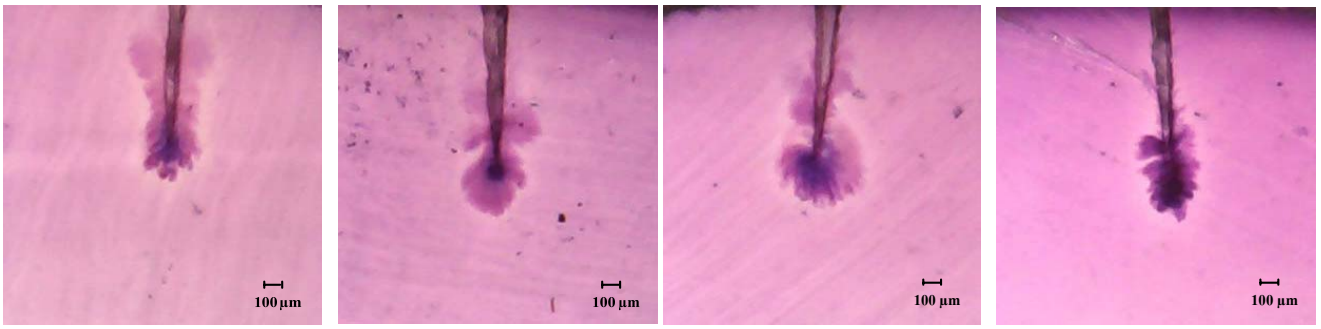


Fig. 5 Water treeing occurrence from Na_2SO_4 solution

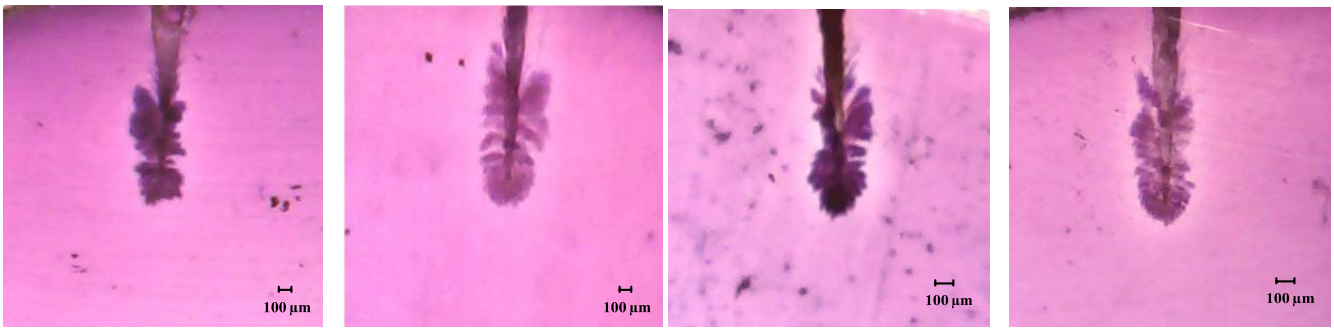


Fig. 6 Water treeing occurrence from $CuSO_4$ solution

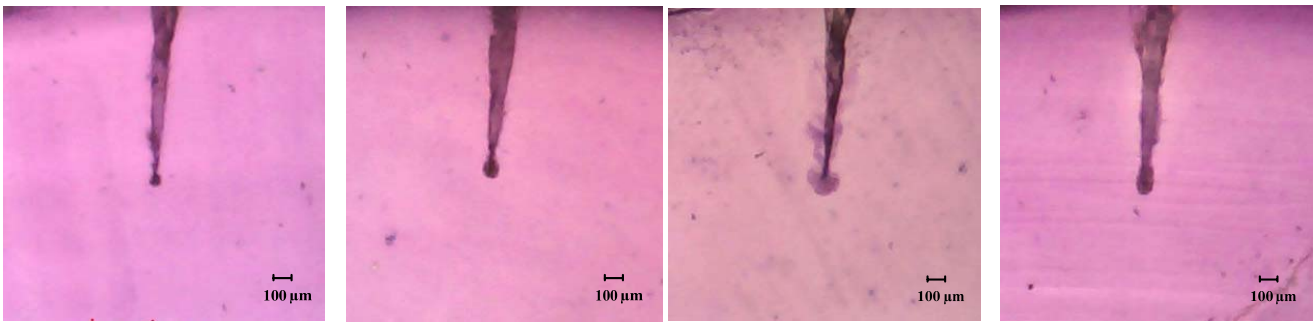


Fig. 7 Water treeing occurrence from $FeSO_4$ solution

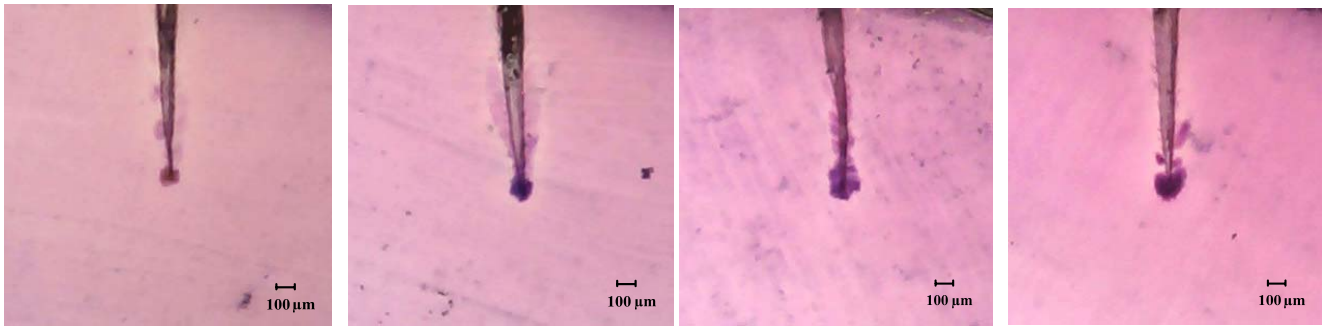


Fig. 8 Water treeing occurrence from K_2SO_4 solution

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TABLE I
WATER TREEING IN XLPE INSULATED DISCS

Ionic solution	Water treeing (μm)	
	Average length	Average wide
$NaSO_4$	188	185
$CuSO_4$	156	154
KSO_4	76	74
$FeSO_4$	60	54

IV. CONCLUSION

The role of ionic solution to water treeing expansion was studied. Na_2SO_4 and $CuSO_4$ solutions exhibit a much stronger propensity toward water treeing expansion and it gets enhanced appreciably. Vented trees with different initiation mechanisms were measured. From this study, cations play a dominant role in the expansion of water treeing.

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