Investigation Life Time Model of 22 kV XLPE Cable for Distribution System Applications in Thailand

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Abstract: - Cross-linked polyethylene (XLPE) high voltage cables have been widely used in power transmission and distribution systems. Ageing deterioration of XLPE insulating material can not be avoidable due to its made of polymeric material. This paper mentions to the experimental results on artificial ageing test of 22 kV XLPE cable for distribution system application in Thailand. XLPE insulating material of 22 kV cable was sliced to 60-70 µm in thick and subjected to ac high voltage stress at 23˚C, 60˚C, 75˚C and 90˚C. The specimens were tested under different electrical stress levels varying from 50kV/mm to 130kV/mm. Testing voltage was constantly applied to the specimen until breakdown. Five specimens were tested at each temperature level and each voltage stress level. Breakdown voltage and average time to breakdown were used to evaluate life time of insulating material. Furthermore, the physical model by J. P. Crine for predicts life time of XLPE insulating material was adopted as life time model and was determined in order to compare the experimental results. Acceptable life time results were obtained from Crine's model comparing with the experimental result. In addition, Fourier transform infrared spectroscopy (FTIR) for chemical analysis and scanning electron microscope (SEM) for physical analysis were conducted on tested specimens.

Key-Words: - Artificial accelerated ageing test, XLPE cable, distribution system, insulating material, life time, life time model

1 Introduction

Recently, high voltage (HV) cables are widely used for transmission and distribution networks. Cross-linked polyethylene (XLPE) is widely used for HV cables as an insulating material. XLPE material contains cross-linked bonds in the polymer structure, changing the thermoplastic to an elastomeric. XLPE has good electrical properties and can operation in high temperature. XLPE insulated cables have a rated maximum conductor temperature of 90 °C and an emergency rating up to 140°C, depending on the standard used. XLPE has excellent dielectric properties, making it useful for medium voltage, 10 to 50 kV AC, and high voltage cables, up to 380 kV AC, and several hundred kV DC. Although XLPE having good dielectric properties for high voltage applications, ageing of XLPE material can not avoidable after long time in service under various stress. Furthermore, condition monitoring for XLPE high voltage cable was performed by many researcher in order to monitor the degradation of XLPE insulating material[1,2,3]. In addition, XLPE insulated cable models for high voltage applications have been studied and investigated in order to evaluate a function of service stresses and ageing time. In order to improve dielectric performance of XLPE material, many researcher are studied improved XLPE properties [4], such as increased thermal and mechanical properties [5], detected damage by water treeing in the cables [6], and studied multifactor ageing proposed mathematical models based on experimental conditions of XLPE [7]. Several life models are purposed in order to evaluate a function of service stresses and ageing time, such as the exponential model by Fallou [7], the inverse power law [7], the probabilistic model by Montanari [7],[8], and the physical model by Crine [7], [9].

In Thailand, voltage levels for distribution networks of Provincial Electricity Authority (PEA) are 22 and 33 kV. Overhead line and underground XLPE cables are usually used in PEA distribution networks. However, a function of service stresses and ageing time of underground XLPE cable have been no studied. By this reason, accelerated ageing test have been conducted on 22 kV underground XLPE cable in order to determine a function of service stresses and ageing time. Furthermore, life time model purposed by Crine is adopted as the mathematical model to analyze the experimental results.

2 Insulation Ageing

Generally in services, an insulation system subjected to one or more stress that causes irreversible changes of insulating material properties with time, thus reducing progressively the attitude of insulation in enduring the stress itself. This process is called ageing deterioration and ends when the insulation is no more able to withstand the applied stress. The relevant time is the time-to-failure or time-to-breakdown, alternatively called insulation life time [10]. The main causes of ageing of polymeric cables [5] are:

(1) Thermal degradation.

(2) Partial discharges due to manufacturing imperfections or to mechanical damage.

(3) Water trees, i.e. tree-like micro-cracks that grow from defects when the insulation is subjected to electrical stress and moisture.

(4) Aggression by the environment.

(5) Losses.

3 Ageing Models

Although many models and theories have been proposed for ageing of insulating material but few are reliable, mainly due to they are unable to describe all the interactions among the various parameters. Insulation life time modeling consists of looking for adequate relationships among insulation life time and the magnitude of the stress applied to it. In the case of electrical insulation for polymeric high voltage cable, the stresses most commonly applied in service are electric field due to voltage and temperature due to loss, however, also other stresses, such as mechanical stresses (bending, vibration) and environmental stresses (such as pollution, humidity) can be present.

Physical life model is one of ageing model that model parameters can be estimated only after life tests, often lasting for a very long time. The search for physical models, based on the description of specific degradation mechanisms assumed as predominant within proper ranges of applied stresses. Such models are characterized by physical parameters, that can be determined by measuring directly physical quantities. Some examples of physical models are the following.

3.1 Field Emission Model

This model is based on the physical damage produced by charge injection in the insulating material, thus it holds for high electric field values. The model can be represented by the following equation[11].

$$t_I = \frac{C}{A_I}\left[exp\left(\frac{-B_I\phi^{3/2}}{E}\right) - exp\left(\frac{-B_I\phi^{3/2}}{E_T}\right)\right]^{-1} \quad (1)$$

where

t_I is electrical treeing inception time (however, t_I does not always coincide with life because time to failure is composed by treeing induction and treeing growth time)

C is the critical energy level that charges injected into the insulation must exceed to contribute to tree initiation.

B_I and A_I are material constants.

ϕ is the effective work function of the injecting electrode.

E is apply electrical stress

E_T is threshold electrical stress

3.2 Treeing growth model

This model is used to describe the treeing growth period before permanent failure of insulating material. Many researchers have been purposed mathematical equation for such period. Some examples are the following:

(i) The model purposed by Bahder et al. [12]:

Treeing growth period time can be expressed as in equation (2)

$$t_G = \frac{1}{fb_1\{exp[b_2(E-E_T)]-1\}[exp(b_3E-b_4)]} \quad (2)$$

where

t_G is treeing growth period time

b_1, b_2, b_3, b_4 are constants which depend upon properties of material, temperature and geometry.

f is frequency of applied electrical stress.

E is apply electrical stress

E_T is threshold electrical stress

(ii) The model purposed by Dissado et al.[13]:

This model, also purposed treeing growth period time same as the model purposed by Bahder et al., describes by the expression as follow.

$$t_G = \frac{S_C(1/2f)N_C}{\{[exp(L_b\alpha_T(E))]-1\}^{-1}} \quad (3)$$

where t_G is treeing growth period time
d is fractal dimension of tree,
S_C is the number of tree branches at failure,
L_b is tree-branch length,
$\alpha_T(E)$ is first Townsend coefficient
N_C is a material constant;
f is frequency of applied electrical stress

(iii) The model purposed by Montanari [14]:
This model purposed time to failure which initiate by treeing. Tree-growth phenomenology and space charge enter to the treeing path are taking into account. The model can be describe by the expression as follow.

$$t_F = \frac{\left((1/k_1)ln\left[(Q_m/k_2)+1\right]\right)^d}{k_5(E-E_T)^n} \quad (4)$$

where t_F is time to failure
$k_5 = f(k_1, k_2, k_3, k_4)$
k_1, k_2, k_3 and k_4 are coefficients depending on material and tree-growth phenomenology,
Q_m is the maximum amount of space charge entering the channels at depth of penetration x_m;

3.3 Thermodynamic Model
The concept of this ageing model is that thermally-activated degradation reactions cause material ageing. Such reactions carry the moieties that undergo degradation, e.g. polymer chains or monomers from reactant to degraded state, through a free energy barrier. The energy needed to overcome the barrier height, ΔG, is provided by temperature. The applied electric field plays the role of lowering the barrier in different ways, depending on the approach proposed. Some existing of thermodynamic models are as follows.

(i) Crine's model.
This model is purposed by Crine et al. [15]. The concept of the model is that an electric field stress accelerates electrons(e) over the so-called scattering distance (δ) so that they gain a mean energy $e\delta E$ that lowers the barrier. The model can be expressed as:

$$t \propto (h/2kT)exp(\Delta G/kT)csch(e\delta E/kT) \quad (5)$$

where k and h are Boltzmann and Planck constants. Equation (5) provides electrical life lines at a chosen temperature which are straight at high stresses in semilog plot, tending to infinite life when E→0. δ is shown to be a temperature dependent quantity and should be linked to microstructural characteristics of the material (e.g., the dimensions of amorphous regions between crystalline lamellae in Polyethylene) and to the size of submicrocavities that progressively grow in the material due to weak bond-breaking by accelerated electrons [16]. In fact, this involves that the model is not fully explained as a function of temperature and time (submicrocavities increase during ageing time). Hence, it can fit electrothermal life test results, but its estimates cannot be extrapolated at temperatures different from the test ones, as can be done by fully-explicit electrothermal life models. In addition, the model postulates that electrons are enough accelerated to gain the energy needed to break weak bonds: this involves either the presence of sufficiently-large microvoids from the very beginning of ageing process, or of high electric fields, maybe both [17-19].

(ii) Electrokinetic Endurance (EKE) Model
This model have been proposed by Lewis et al. [20]. The model is based on the formation of microvoids by means of chemical bond-breaking processes induced by voltage and temperature. Some of such microvoids can coalesce into larger voids. As soon as sufficiently large voids are formed, from them a crack can start that ultimately breaks insulation. Hence, according to Griffith criterion for crack propagation, the time needed to initiate crack growth, t_C, (which is assumed as predominant during the whole ageing time) is obtained as:

$$t_C = \int_N^{\eta_C} \left\{ \frac{kT}{h} \left[exp\left(\frac{-Ur(E)}{kT}\right)(N-\eta) - exp\left(\frac{-Ub(E)}{kT}\right)\eta \right] \right\}^{-1} d\eta \quad (6)$$

where η is the number of broken bonds, η_C is the critical number of broken bonds, N is the number of breakable bonds, $Ur(E)$ and $Ub(E)$ are the energies needed for bond forming and breaking, respectively.

(iii) Space-charge model
This model have been proposed by Dissado, Mazzanti and Montanari [21]. They assumption is that space-charges injected by electrodes and/or impurities and trapped within the insulation are responsible for electromechanical energy storage that, in turn, lowers the energy barrier, thus favoring degradation. The higher the electrical field stress, the higher the stored charge and energy, hence the

lower the life. After some simplifying hypotheses and proper rearrangements, the model is obtained in the following form:

$$t_C = \frac{kT}{h} exp\left(\frac{\frac{\Delta H}{k} - \frac{C'E^{2b}}{2}}{kT} - \frac{\Delta S}{k}\right)\left[ln\left(\frac{A_{eq}(E)}{A_{eq}(E)-A^*}\right)\right]\left[cosh\left(\frac{\frac{\Delta H}{k} - \frac{C'E^{2b}}{2}}{kT} - \frac{\Delta S}{k}\right)\right]^{-1} \quad (7)$$

where $A_{eq}(E)$ is the equilibrium value of A, the conversion rate of moieties from state 1 to 2. Other quantities introduced in equation (7) are: A^*, the critical limit of A (when exceeded, failure is said to take place); C' and b, material constants;)/2 + (2 1 ΔH= H_a –(H1+H2)/2 and ΔS= Sa – (S1+S2)/2 , enthalpy and entropy contributions of activation free energy per moiety. H and S are enthalpy and entropy per moiety, subscripts 1, a and 2 are relevant to ground, activated and degraded state, respectively. Firstly, the model in equation (7) is used for dc voltage only. However, the model can be extended to ac voltage by splitting activation entropy and enthalpy to a dc part plus an ac contribution [22].

4 Crine's Model Implementation

According to the model purposed by Crine et al. which already addressed in previous section, an application of the model to predict life time of XLPE insulating material for high voltage cable is implemented in this section. However, theoretical explanations are illustrated in [8,9,23,26]. This model is based on two parameters, the activation energy, ΔG, and activation volume, ΔV. The assumption is that an electrical ageing is a thermally activated process with an activation energy $\Delta G=\Delta H-T\Delta S$, where ΔH and ΔS are the activation enthalpy and entropy, respectively. It described the ageing process of electrical insulation (XLPE) by reduces the height of the energy barrier controlling the process. When the time to go over barrier being the inverse of the rate. Time t will reach to aged state is given by

$$t = \left[\frac{h}{2fkT}\right] \cdot exp\left(\frac{\Delta G}{kT}\right) \cdot csc\,h\left(\frac{1}{2} \cdot \frac{\varepsilon_0 \varepsilon' \Delta V F^2}{kT}\right) \quad (8)$$

This equation is well described ageing results of XLPE by the linear relation at high fields. Considering predicts times at zero field in equation (8), t will be equal to infinity since *csch* (0) =∞. Thus, there will be some sort of tail at low field, where t will slowly tend toward ∞. At high field, equation (1) can reduces to

$$t = \left[\frac{h}{2fkT}\right] \cdot exp\left[\frac{\Delta G - \frac{1}{2}\varepsilon_0 \varepsilon' \Delta V F^2}{kT}\right] \quad (9)$$

where

ε_0 = 8.85 × 10^{-12} F/m

ε' = relative permittivity of XLPE = 2.5

h = Planck's constant = 6.626068 × 10^{-34} m^2.kg / s

k = Boltzmann's constant = 1.3806503 × 10^{-23} m^2 kg s^{-2} K^{-1}

F = applied voltage (kV)

T = temperature (K)

f = frequency (Hz)

As illustrated in equation (9), the activation energy, ΔG, and the activation volume, ΔV, are unknown variable. However, ΔG and ΔV can directly obtain from the experimental results in a linear relationship between F^2 and log t. In order to find such linear relationship, logarithm function is applied to the both side of equation (9), as illustrated in equation (10).

$$log(t) = log\left[\frac{h}{2fkT}\right] + log\left[exp\left(\frac{\Delta G - (1/2)\varepsilon_0 \varepsilon' \Delta V F^2}{kT}\right)\right] \quad (10)$$

By arrangement equation (10), equation (11) is obtained.

$$log(t) = log\left[\frac{h}{2fkT}\right] + log\left[exp\left(\frac{\Delta G}{kT}\right)\right] + log\left[exp\left(-\frac{\varepsilon_0 \varepsilon' \Delta V F^2}{2kT} \cdot F^2\right)\right] \quad (11)$$

Finally, equation (12) is obtained.

$$log(t) = \left[log\left(\frac{h}{2fkT}\right) + \left(\frac{\Delta G}{kT}\right)\right] + \left(-\frac{\varepsilon_0 \varepsilon' \Delta V}{2kT} \cdot F^2\right) \quad (12)$$

Empirical form of equation (12) is $y = -ax+b$, where a is slope and b is intercept. Considering the experimental data, ΔG can obtain from slope at the high filed regime and ΔV can obtain from the intercept. Both parameters depend on size of the specimen.

5 Accelerated Ageing

The accelerated ageing is degrading stresses of insulation material, such as electrical stress, thermal stress, mechanical stress, and environmental stress. The accelerated ageing process usually studies multi-stresses [7] (double or triple stresses). The multi-stresses widely used electrical - thermal stress and electrical – mechanical stress.

There are several methods to accelerate the ageing process [7], [24-25]. But the most popular are experimental performed on insulation material at voltages and temperatures higher than normal operating conditions, there are two methods of apply voltage stress. The first method, the voltage is held constant until sample aged and breakdown. In the second method, the voltage stress is increased in steps until sample aged and breakdown. For both, when breakdown occurred are noted experimental data lifetimes for calculation life models. In our experimental, the first method (constant voltage stress) was conducted.

The main goal of ageing models is to establish a relationship for the ageing process and the stresses causing it, and prove them. The models are done through an accelerated process. The most popular are experiments on insulation at voltages much higher than normal operating conditions of cables, at constant frequency. This paper adopted Crine's model for describe and prove the experimental results from accelerated ageing test of XLPE insulating material.

6 Experimental

The specimens for experimental made from unaged 22 kV XLPE distribution power cables having aluminum conductors 17 mm in diameter and XLPE insulation 3 mm thick, as shown in Fig. 1. This type of power cable is used in underground distribution system of Provincial Electricity Authority (PEA) of Thailand. A number XLPE of 1-cm wide ribbons at thickness 60-70µm were cut by a microtome from the insulation around a cables. All specimens were measured precisely before testing so the thickness effect is neglected. The accelerated ageing test chamber consists of a pair of solid stainless cylinders, the lower grounded one is 30 mm in diameter and the upper-high voltage electrode is 10 mm in diameter, which was connected to a 50 Hz testing transformer. Furthermore, heater and temperature sensor are included for heat generation and temperature control. Afterwards placing the specimen between the electrodes, the electrodes were immersed in transformer oil in order to avoid surface flashover in air. Detail of the test chamber is illustrated in Fig. 2. The experimental diagram is shown in Fig. 3 and experimental layout is shown in Fig. 4

The Experimental were conducted at temperatures 23 °C, 60 °C, 75 °C and 90 °C. In addition, the specimens were tested under different electrical stress levels varying from 50 kV/mm to 130kV/mm, as shown in Table 1.

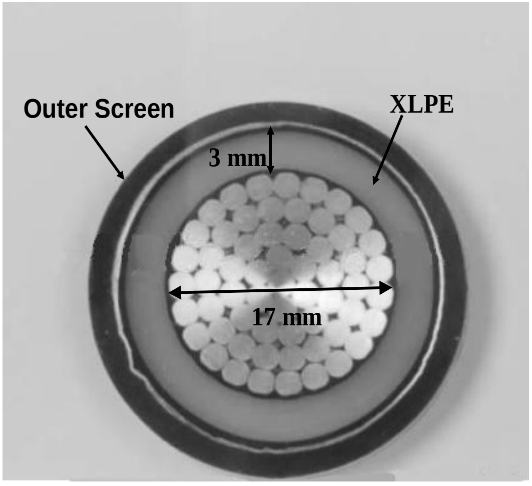

Fig. 1 22kV cables section schematic.

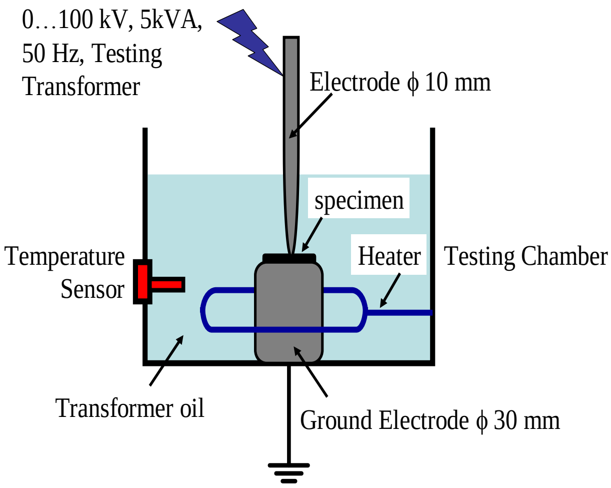

Fig. 2 Accelerated Ageing Test Chamber

As illustrated in Fig. 3, timer unit was used to measure time to breakdown of the specimen. At moment of the electrical and thermal stresses applying to the specimen, timer unit starts record the life time or breakdown time. Once the breakdown occurs, the relay trips automatically and the timer stops. Then, the breakdown time is recorded for analysis. For each breakdown voltage level, five specimens were tested. Once the tests were complete for a data set, the data points were averaged to obtain one data point.

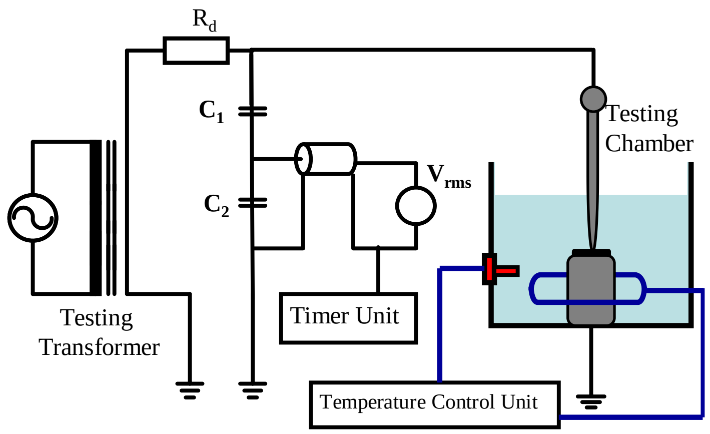

Fig. 3 Experimental Diagram

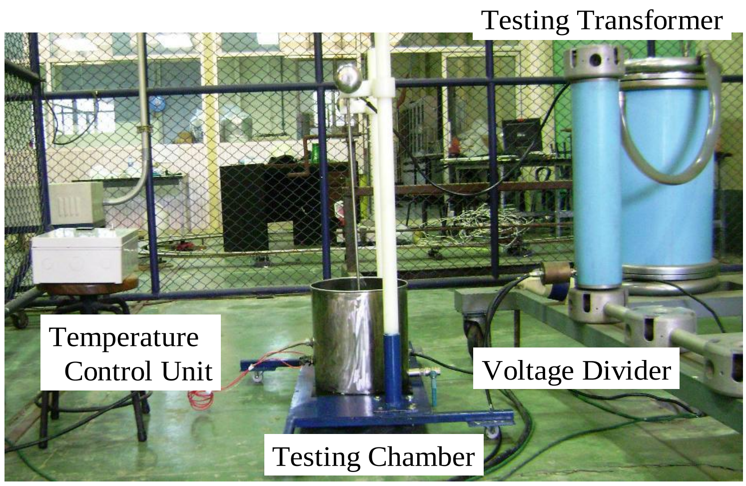

Fig. 4 Experimental Layout

Table 1 Voltage Stress Levels for the Experimental

E (kV/mm)	Tested Voltage Stress Level			
	23 °C	60 °C	75 °C	90 °C
50	X	X	X	O
75	X	X	O	O
90	O	O	O	O
100	O	O	O	X
110	O	O	X	X
120	O	O	X	X
130	O	X	X	X

O : Tested level X : Un - tested level

7 Experimental Results and Discussion

The experimental were carefully conducted in order to obtain the precisely results. Experimental results, time to failure or time to breakdown of the specimen, are illustrated in Table 2.

Table 2 Experimental Results

E (kV/mm)	Average Time to Failure of Tested Specimens (sec)			
	23 °C	60 °C	75 °C	90 °C
50	-	-	-	2,178.3
75	-	-	1373.5	112.3
90	25,200	5973.7	400.8	7
100	3,120	778.2	12	-
110	476	81.8	-	-
120	61.5	7	-	-
130	8	-	-	-

In order to calculation ΔV and ΔG, the experimental results at temperatures 23 °C, 60 °C, 75 °C and 90 °C form accelerated ageing test in Table 2 were plotted in semi-logarithm graph. Then a linear relationship between F^2 and log *t* is obtained by using linear fitting technique, as shown in Fig. 5, Fig. 6 and Fig. 7, respectively.

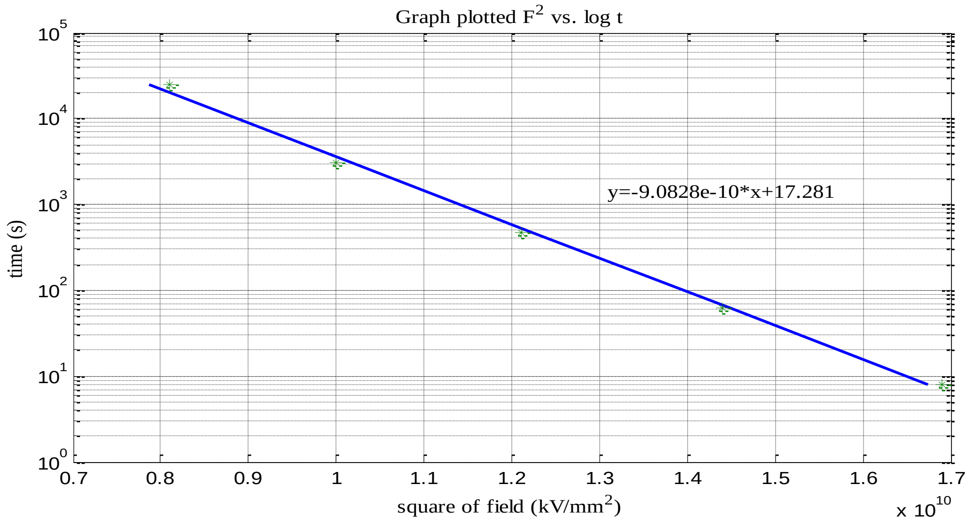

Fig. 5 A Linear Relationship Between F^2 and log *t* at 23 ℃

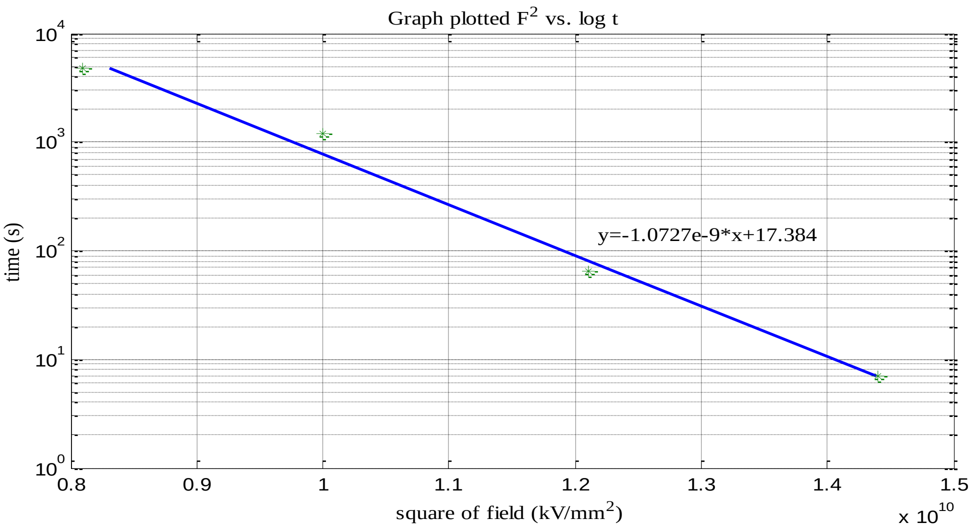

Fig. 6 A Linear Relationship Between F^2 and log *t* at 60 ℃

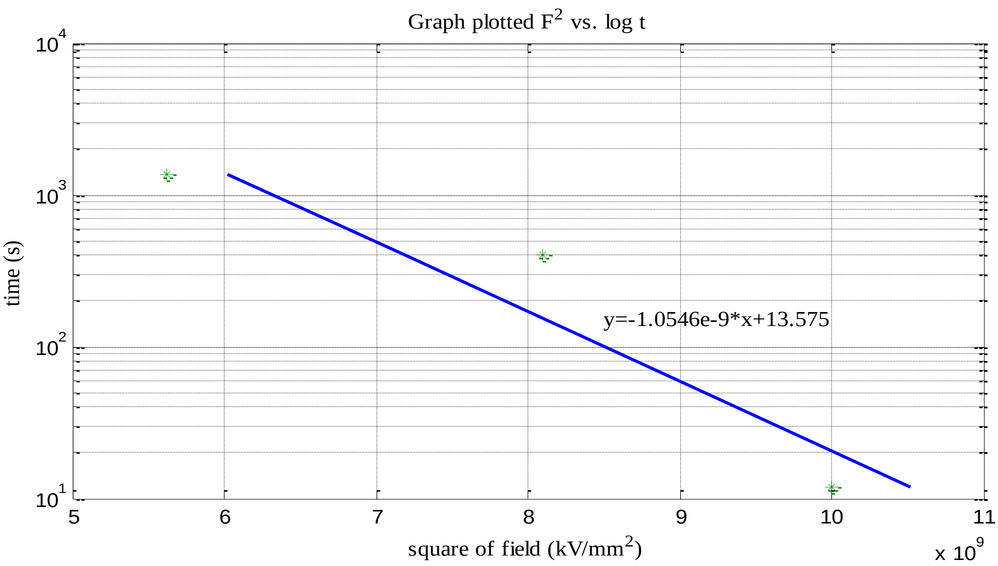

Fig. 7 A Linear Relationship Between F^2 and log *t* at 75 ℃

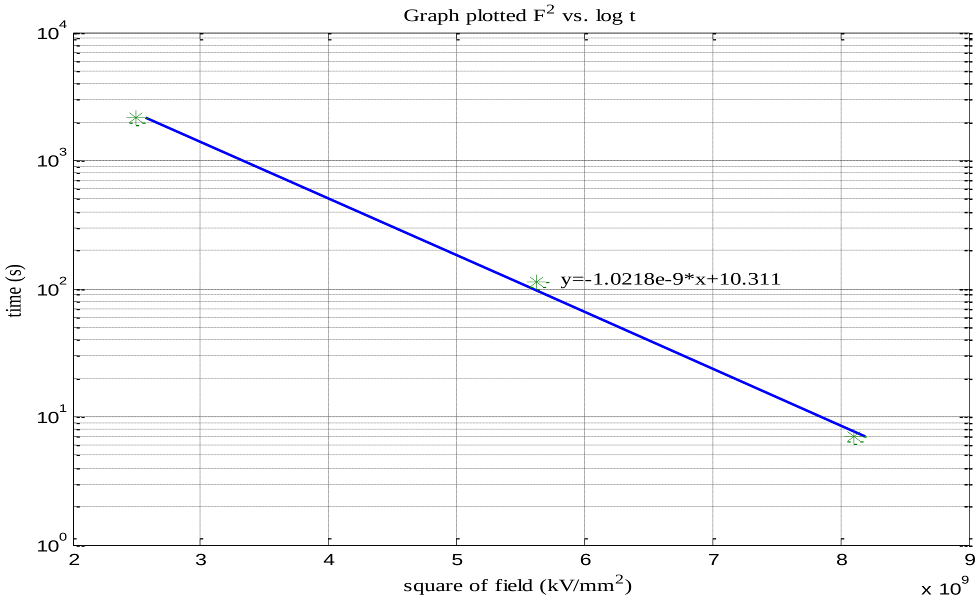

Fig. 8 A Linear Relationship Between F^2 and log *t* at 90 °C

By using a linear fitting technique, the linear relationship between square of electric field stress, F^2, and log *t* can be determined in term of y= -ax +b, while y = log *t*, x = F^2, a = slope and b= intercept, respectively. Parameters from a linear fitting technique, as illustrated in Table 3, were used to determined ΔV and ΔG. According to equation (12), ΔV and ΔG can be determined by the following expression.

$$\frac{\varepsilon_0 \varepsilon' \Delta V}{kT} = a \qquad (13)$$

$$\Delta V = \frac{akT}{\varepsilon_0 \varepsilon'} \qquad (14)$$

$$\log\left(\frac{h}{2fkT}\right) + \frac{\Delta G}{kT} = b \qquad (15)$$

$$\Delta G = kT\left(b - \log\left(\frac{h}{2fkT}\right)\right) \qquad (16)$$

The obtained results, ΔV and ΔG, are illustrated in Table 4. Temperature dependent of obtained results can be observed. Finally, Crine's models from the experimental results are obtained according to equation (9). By the obtaining Crine's model, life time of XLPE insulating material can be calculated. The calculation results are shown in Table 4. The calculation results, time to failure, from Crine's model agree with the experimental results.

In order to confirm the precisely of Crine's model, life times from the experimental and from Crine's model are plotted together in semi-logarithm graph, as shown in Fig. 9, Fig. 10, Fig. 11 and Fig. 12, respectively.

Table 3 Parameters from a linear fitting technique

Parameters	Experimental Results (sec)			
	23 ◦C	60 ◦C	75 ◦C	90 ◦C
a	9.0828×10^{-10}	1.027×10^{-9}	1.0546×10^{-9}	1.218×10^{-9}
b	17.281	17.384	13.575	10.311

Table 4 Parameters of Crine's Model

Parameters	Experimental Results (sec)			
	23 ◦C	60 ◦C	75 ◦C	90 ◦C
Δ V[m3]	3.26×10^{-25}	4.46×10^{-25}	4.58×10^{-25}	4.63×10^{-25}
Δ G [J]	2.09×10^{-19}	2.37×10^{-19}	2.30×10^{-19}	2.23×10^{-19}

Table 5 Life Time Result from Crine's Model

E kV/mm	Crine's Model Results (Sec)			
	23 ˚C	60 ˚C	75 ˚C	90 ˚C
	-	-	-	2,336.7
75	-	-	2085.7	95.9
90	18,944	4780	153.4	7.6
100	3,533	1200	20.7	-
110	552	65.5	-	-
120	72	7	-	-
130	8	-	-	-

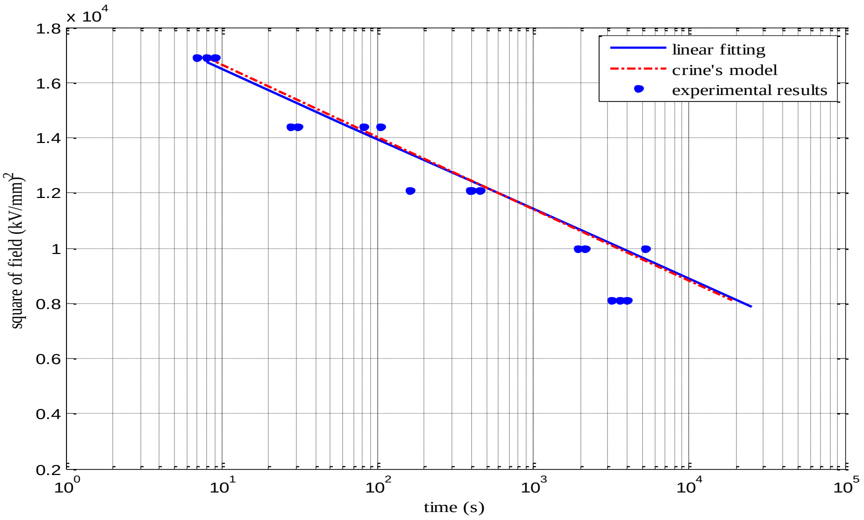

Fig. 9 Comparison Life Time from Experimental and Crine's Model at 23 ˚C

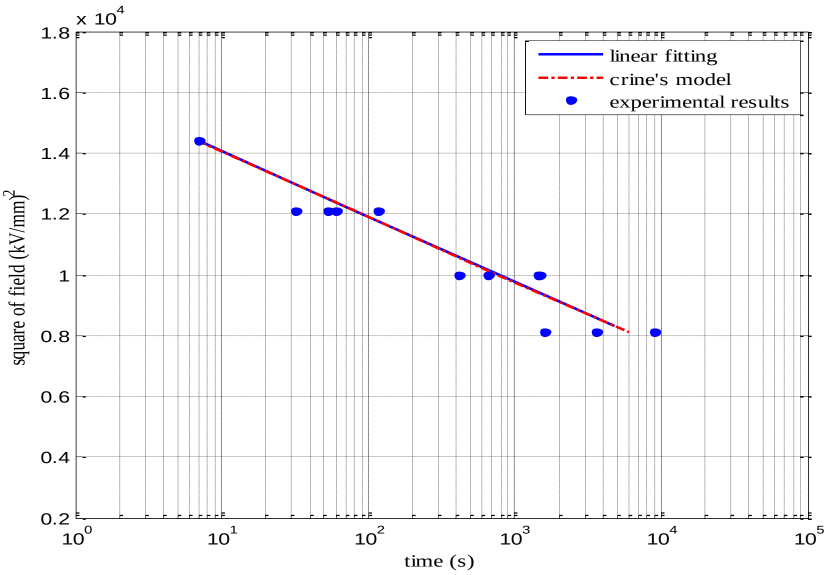

Fig. 10 Comparison Life Time from Experimental and Crine's Model at 60 ˚C

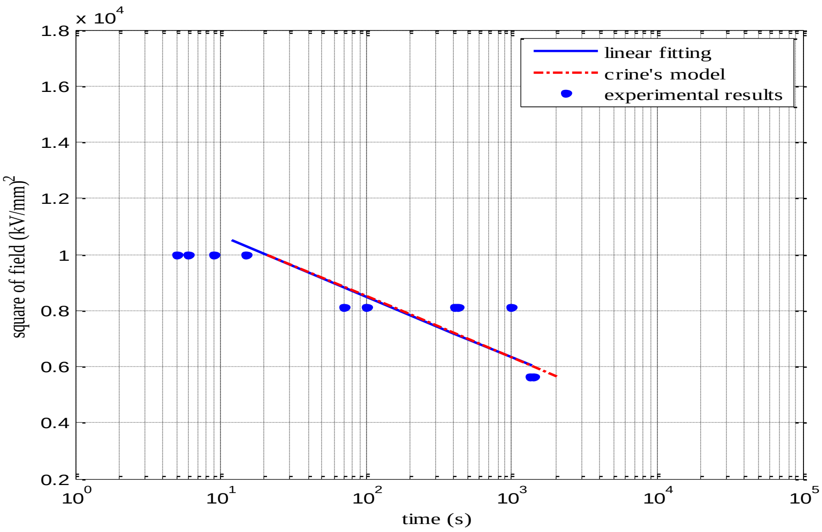

Fig. 11 Comparison Life Time from Experimental and Crine's Model at 75 ℃

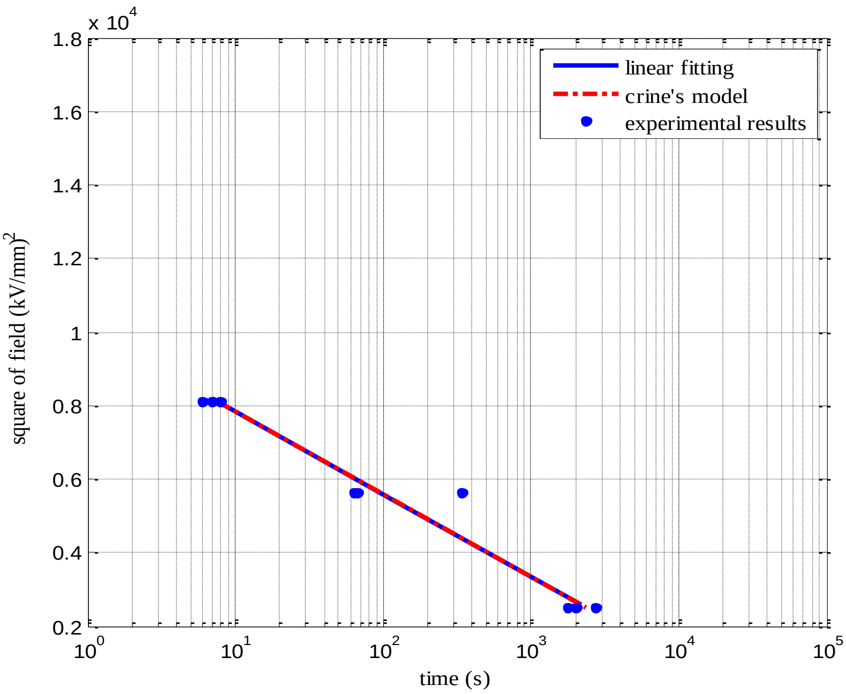

Fig. 12 Comparison Life Time from Experimental and Crine's Model at 90 ℃

In order to compare the effect of temperature, experimental results and time to failure from Crine's model for each temperature level were plotted together in semi-log scale

In order to observe physical damage, tested specimen surface observation by using the scanning electron microscope, SEM, was performed. Example of SEM observation results are shown in Fig. 11 and Fig. 12. Carbon from carbonization was observed at the damaged point.

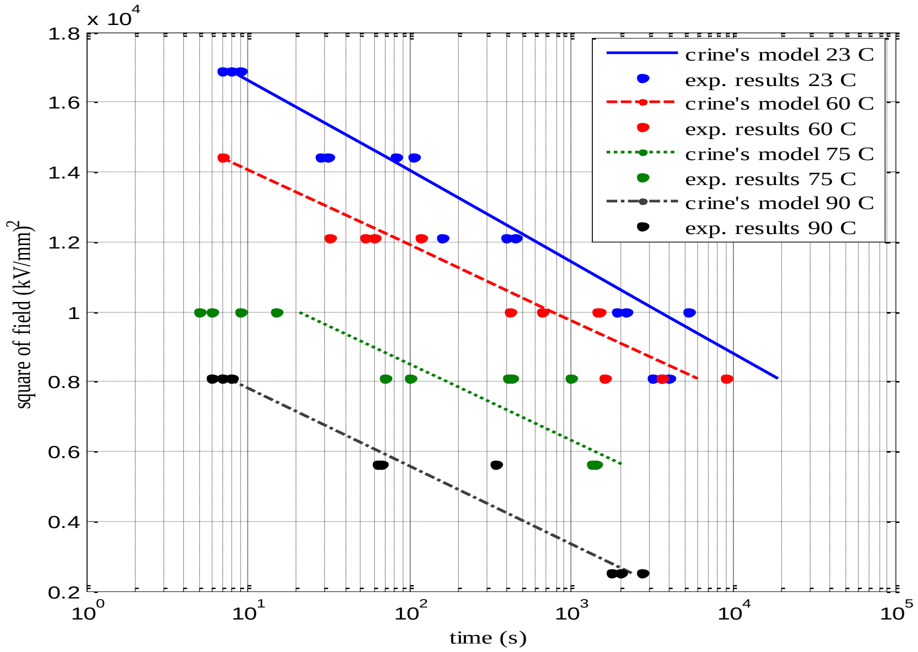

Fig. 13 Comparison time to failure from experimental results and Crine's model

Fig. 14 Surface Damaged due to Electric stress 90 kV/mm at 23 ͦC

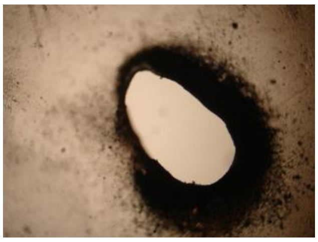

Fig. 15 Surface Damaged due to Electric stress 90kV/mm at 60 ͦC

Fig. 16 Surface Damaged due to Electric stress 90kV/mm at 75 ͦC

Fig. 17 Surface Damaged due to Electric stress 90kV/mm at 90 ͦC

Chemical analysis was performed by the Fourier transform infrared spectroscopy (FTIR) for un-aged and aged specimens. Furthermore, SEM observation results agree with chemical analysis results. For XLPE insulating material, C=C peaks at 1610 cm^{-1} appeared for aged specimen [27]. As illustrated in Fig. 18 for unaged specimen and Fig. 19 for aged specimen at 23 ͦC , C=C peaks at 1610 cm^{-1} is only observed on FTIR result of aged specimen comparing with unaged specimen. Appearing of C=C peaks at 1610 cm^{-1} confirmed carbonization process due to ageing process.

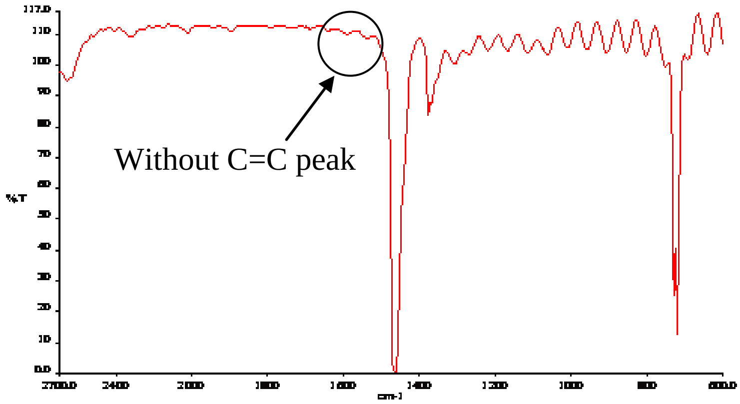

Fig. 13 Chemical Analysis by FTIR for Unaged Specimen

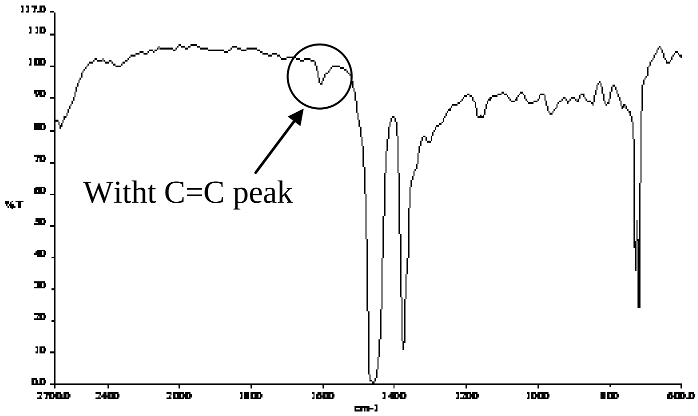

Fig. 14 Chemical Analysis by FTIR for Aged Specimen

After well conducting the experimental and carefully analysis the experimental results, very acceptable results in life time from Crine's model were obtained when comparing with the experimental data. However, accuracy of the experimental results depends on the precisely thickness of specimen, voltage stress stabilization and accuracy of temperature control unit.

7 CONCLUSION

Accelerated ageing test of XLPE insulating material from 22kV high voltage cable was conducted. Three temperature levels, 23°C, 60°C and 75°C, and electrical stress between 75 -140 kV/mm are testing conditions. Electrical stress and time to breakdown were used to evaluate life time of insulating material. Crine's model parameters, ΔV and ΔG values, were obtained from a linear relationship between F^2 and log t. Life time can be reasonable well predicted by Crine's model for given electrical stress and temperature. Acceptable lift time results can be obtained when using Crine's model for calculation. Furthermore, lift time result from Crine's model agree with the experimental data. Physical observation by using SEM and chemical analysis by using FTIR supported the experimental results, as well.

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