International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 4, Issue 2, pp: (61-69), Month: April - June 2016, Available at: www.researchpublish.com

Ageing of Dielectric Cables under Multistress

K. Jaghannath

Research Scholar, OPJS University, Rawatsar, Kunjla, INDIA

Abstract: **This paper deals with the various multi stress created on the dielectric electric cables is responsible for the ageing of the dielectric cables and it also explains to improve the break down strength of the dielectric cables by replacing the Polyethylene Power Cable Insulation.**

Keywords: **Dielectric Cables, Electrical, thermal, mechanical, and environmental.**

1. INTRODUCTION

Ageing is an irreversible deleterious change to the service ability of an insulation system the nature of this change may vary. The properties of an insulation system that are influenced by ageing depend on the type of applied stress and the kind of insulation material that is used .Stress that produce aging are called ageing factor The ageing factors can be divided in to four types :

Electrical, thermal, mechanical, and environmental

Electrical stress: The ageing process is caused mostly by an electrical gradient the insulation

Thermal stress: The ageing process is caused by the high temperature environment, resistivity losses or chemical instability of the insulation

Mechanical stress: Ageing is caused by varying mechanical stress, for example, through expansions, vibrations, electric compressive force, etc.

Environmental stress:

Ageing is caused by condition in the environment of the insulation.

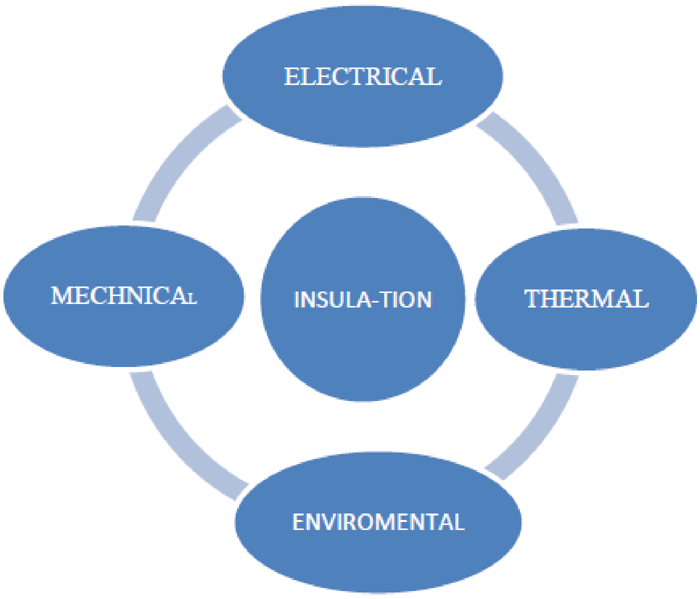


Figure 1 Ageing factors

THERMAL

- Oxidation
- Hydrolysis

ELECTRICAL

- Partial Discharges
- Over voltages
- Tracking

MECHANICAL

- Cracking
- Tension
- Vibrations

ENVIROMENTAL

- Gas, Acids
- Pressure
- Radiation

2. THERMALBREAKDOWN STRESSES IN DIELECTRICS

MATERIAL	**D.C** in *MV/cm*	**A.C** in MV/cm
MUSCOVITE MICA	24	7.18
ROCK SALT	38	1.4
HIGH GRADE PROCELAIN	----	2.8
H.V STEALITE	----	9.8
QUARTZ	1200	----
CAPACITOR	----	3.4-4.4
POLYTHENE	----	3.5
POLYSTRENE	----	5.0

3. THE CONCEPTS OF SYERGY

If an insulation material is subjected to both elevated temperature and an electrical field, then the result may be that failure occurs much sooner than if the two stresses were applies separately .The resulting ageing is not necessarily the algebraic sum of the thermal ageing and the electrical ageing .In most cases new failure mechanisms may created when several stress are present. The synergy effects are due to interactions between different ageing factors .There are two main types of interaction direct interaction and indirect interaction.

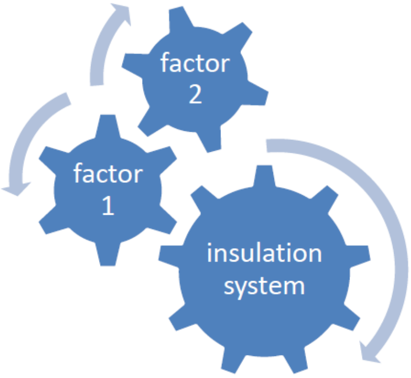


Figure2.The simultaneous presence of factor 1 and the factor 2 gives rise to direct interaction

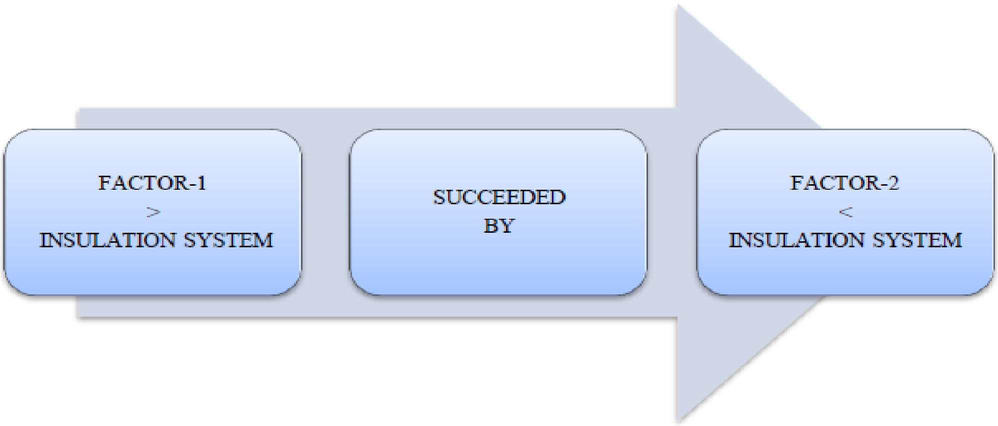


Figure 3 Ageing produced by factor1 influences the ageing caused by factor 2

Direct interaction: "interaction between simultaneous applied factors of influence, which differs from that occurring with sequentially applied factors influence."

Fig.2 shows direct interaction schematically in case of an insulation system exposed to two stress factors that produce direct interaction is oxidation. Both oxygen and elevated temperature are needed at the same time to give synergy effects.

Indirect interaction: "interaction between simultaneous applied factors of influence, which remains essentially unchanged when the factors are applied sequentially

Indirect interaction can only be brought about by ageing factors.

In Fig.3 gives a schematic view of indirect interaction although the simultaneous action of aging factors is, of course, decisive. Mechanical and electrical stress may cause interaction. Voids created by the mechanical stress may give rise to partial discharge. The insulation system may first be exposed to the void producing mechanical stress, and subsequently to an electrical stress, or the two aging factors can be applied simultaneously. In both the cases the result will be additional ageing due to synergy effects, namely partial discharge

4. BREAKDOWN IN SOLID DIELECTRICS

Solid dielectric materials are used in all kinds of electrical circuits and devices to insulate. One current carrying part from another when they operate at different voltages. A good dielectric should have low dielectric loss, high mechanical strength, should be free from gaseous inclusion, and moisture, and be resistant to thermal and chemical deterioration. Solid dielectrics have higher breakdown strength compared to liquids and gases. Studies of the breakdown of solid dielectrics are of extreme importance in insulation studies. When breakdown occurs, solids get permanently damaged while gases fully and liquids partly recover their dielectric strength after the applied electric field Removed. The mechanism of breakdown is a complex phenomenon in the case of solids, and varies depending on the time of application of voltage

Chemical and Electrochemical Deterioration and Breakdown:

In the presence of air and other gases some dielectric materials undergo chemical changes when subjected to continuous stresses. Some of the important chemical reactions that occur are

***Oxidation*:** In the presence of air or oxygen, material such as rubber and polyethylene undergo oxidation giving rise to surface cracks.

***Hydrolysis*:** When moisture or water vapor is present on the surface of a solid

Dielectric, hydrolysis occurs and the material loses their electrical and mechanical properties. Electrical properties of materials such as paper, cotton tape, and other cellulose materials deteriorate very rapidly due to hydrolysis. Plastics like polyethylene undergo changes, and their service life considerably reduces.

Chemical Action: Even in the absence of electric fields, progressive chemical Degradation of insulating materials can occur due to a variety of processes such as Chemical instability at high temperatures, oxidation and cracking in the presence of air And ozone, and hydrolysis due to moisture and heat. Since different insulating materials

Come into contact with each other in any practical reactions occur between these various materials leading to reduction in electrical and mechanical strengths resulting in a failure.

The effects of electrochemical and chemical deterioration could be minimized by Carefully studying and examining the materials. High soda content glass insulation should be avoided in moist and damp conditions, because sodium, being very mobile, leaches to the surface giving rise to the formation of a strong alkali which will cause deterioration.

It was observed that this type of material will lose its mechanical strength within 24 hrs, when it is exposed to atmospheres having 100% relative humidity at 700 C. In paper insulation, even if partial discharges are prevented completely, breakdown can occur due to chemical degradation. The chemical and electrochemical deterioration increases very rapidly with temperature, and hence high temperatures should be avoided.

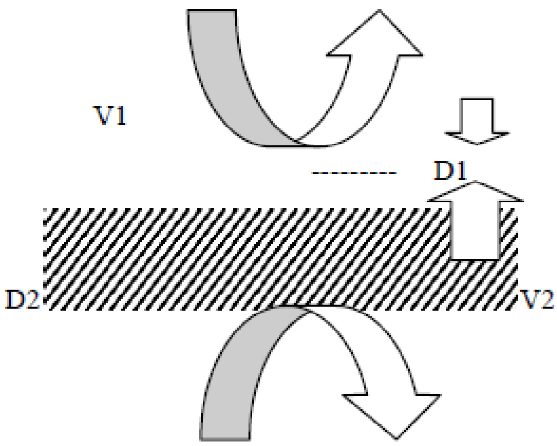
5. BREAKDOWN DUE TO TREEING AND TRACKING

When a solid dielectric subjected to electrical stresses for a long time fails, normally two kinds of visible markings are observed on the dielectric material. The presence of a conducting path across the surface of the insulation. A mechanism whereby leakage current passes through the conducting path finally leading to the formation of a spark. Insulation deterioration occurs as a result of these sparks. The spreading of spark channels during tracking, in the form of the branches of a tree is called treeing. Consider a system of a solid dielectric having a conducting film and two electrodes on its surface. In practice, the conducting film very often is formed due to moisture. On application of voltage, the film starts conducting, resulting in generation of heat, and the surface starts becoming dry. The conducting film becomes separate due to drying, and so sparks are drawn damaging the dielectric surface. With organic insulating materials such as paper and Bakelite, the dielectric carbonizes at the region of sparking, and the carbonized regions act as permanent conducting channels resulting in increased stress over the rest of the region. This is a cumulative process, and insulation failure occurs when carbonized tracks bridge the distance between the electrodes. This phenomenon,

Called tracking is common between layers of Bakelite, paper and similar dielectrics built of laminates. On the other hand treeing occurs due to the erosion of material at the tips of the spark.

Erosion results in the roughening of the surfaces, and hence becomes a source of dirt and Contamination. This causes increased conductivity resulting either in the formation of conducting path bridging the electrodes or in a mechanical failure of the dielectric.

Vented tree **Bow tie tree**



Arrangement for study of treeing phenomena.1 and 2 are electrodes.

When a dielectric material lies between two electrodes as shown in there is Possibility for two different dielectric media, the air and the dielectric, to come series. The voltages across the two media are as shown (V1 across the air gap and V2 across the dielectric). The voltage V1 across the air gap is given as,

V1=V1/d1+ {e1/e2} d2 --------------(1)

Where V is the applied voltage.

Since *e1>e2* most of the voltage appears across d1 the air gap. Sparking will occur in the air gap and charge accumulation takes place on the surface of the insulation. Sometimes the spark erodes the surface of the insulation. As time passes, break-down channels spread through the insulation in an irregular "tree' like fashion leading to the formation of conducting channels. This kind of channeling is called treeing. Under a.c. voltage conditions treeing can occur in a few minute or several hours. Hence, care must be taken to see that no series air gaps or other weaker insulation gaps are formed.

Usually, tracking occurs even at very low voltage of the order of about 100 V, whereas

Treeing requires high voltages. For testing of tracking, low and medium voltage tracking Tests are specified. These tests are done at low voltages but for times of about 100 hr or more. The insulation should not fail. Sometimes the tests are done using 5 to 10 kV with shorter durations of 4 to 6 hour. The numerical value that initiates or causes the formation of a track is called "tracking index" and this is used to qualify the surface properties of dielectric materials Treeing can be prevented by having clean, dry, and undamaged surfaces and a clean.

Environment the materials chosen should be resistant to tracking. Sometimes moisture

Repellant greases are used. But this needs frequent cleaning and regressing. Increasing

Creeping distances should prevent tracking, but in practice the presence of moisture films defeat the purpose. Usually, treeing phenomena is observed in capacitors and cables, and extensive work is being done to investigate the real nature and causes of this phenomenon.

6. BREAKDOWN OF COMPOSITE INSULATION

A single material rarely constitutes the insulation in equipment. Two or more insulating. Materials are used either due to design considerations or due to practical difficulties of fabrication. In certain cases the behavior of the insulation system can be predicted by the behavior of the components.

But in most cases, the system as a whole has to be considered. The following considerations determine the performance of the system as a whole:

(i) The stress distribution at different parts of the insulation system is distorted Due to the component dielectric constant and conductivities,

(ii) The breakdown characteristics at the surface are affected by the insulation Boundaries of various components,

(iii) The internal or partial discharge products of one component invariably affect The other components in the system, and

(iv) The chemical ageing products of one component also affect the performance of other components in the system. Another important consideration is the economic life of the system the criterion being the ultimate breakdown of the solid insulation. The end point is normally reached by through puncture, thermal runaway, electrochemical breakdown, or mechanical failure leading to complete electrical breakdown of the system. Hence, tests for assessing the life of insulation (ageing) are very necessary.

7. BREAKDOWN OF SOLID INSULATING MATERIALS

Clearly differentiates between the breakdown and degradation of a solid insulating material. According to him, the breakdown is an event that is sudden and catastrophic and the insulation cannot withstand the service voltage following the breakdown .The degradation, on the other hand takes place over a period. It increases the probability of breakdown and decreases the breakdown voltage; erosion and pit formation are important in the degradation process and are followed by tree formation and/or final dielectric failure. The degradation process after a period of hours to weeks, leads to breakdown. Well-designed

Insulation systems, operated within the scope of design parameters, do not break or degrade. Both these processes are irreversible.

8. DIFFERENCES BETWEEN DEGRADATION AND BREAKDOWN FOR SOLID INSULATING MATERIALS

Features	Breakdown	Degradation
Speed	Fast occurs in << 1s	Hours, years
Evidence	Direct observation normally by eye	Observation would require microscope
Examples	Intrinsic, Thermal, Electromechanical, Partial Discharge in cavities	Electrical Trees, Water trees

9. INSULATING MATERIALS

Polyvinylchloride:

PVC is a relatively inexpensive and easy-to-use material, with the potential to be used in diverse applications. The maximum temperature range is -55°C to 105°C and is flame, moisture, and abrasion resistant. It also holds up against gasoline, ozone, acids, and solvents. It can also be used for medical and food related purposes as it is odorless, tasteless, and non-toxic. PVC can be used in both heavy and thin wall applications. PVC should not be used when flexibility and an extended flex life are required at low temperatures. When used in retractile cord applications, it also shows below average flexibility. PVC displays high attenuation and capacitance loss, meaning that power is lost when used in an electrical system.

Semi-Rigid-PVC-(SR-PVC):

This is mainly used as a primary insulation and is very abrasion resistant. (For 30-16 gauge, a 10 mil. wall meets UL style 1061, 80°C, 300 volts.) Semi-Rigid PVC is also heat, water, acid, and alkali resistant, as well as flame retardant.

Plenum Polyvinyl Chloride (Plenum PVC):

Plenum PVC is suitable for use in building spaces behind dropped ceilings or raised floors which are left open to allow for air circulation. Standard PVC is considered a non-plenum insulation option because it does not exhibit the qualities necessary for safe usage in plenum areas. To be plenum-rated the insulation must meet more stringent fire safety regulations.

Polyethylene-(PE):

This compound is used most in coaxial and low capacitance cables because of its exemplary electric qualities. Many times it is used in these applications because it is affordable and can be foamed to reduce the dielectric constant to 1.50, making it an attractive option for cables requiring high-speed transmission. Polyethylene can also be cross-linked to produce high resistance to cracking, cut-through, soldering, and solvents. Polyethylene can be used in temperatures ranging from -65°C to 80°C. All densities of Polyethylene are stiff, hard, and inflexible. The material is also flammable. Additives can be used to make it flame retardant, but this will sacrifice the dielectric constant.

Polypropylene-(PP):

This material is very similar to polyethylene, but has a wider temperature range of -30°C to 80°C. It is used primarily for thin wall primary insulations. Polypropylene can be foamed to improve its electrical properties.

Polyurethane-(PUR):

Polyurethane is known for its extreme toughness, flexibility, and flex life, even in low temperatures. It also has excellent ratings for chemical, water, and abrasion resistance. This material works well in retractile cord applications and can be a good option for salt-spray and low-temperature military purposes. Polyurethane is a flammable material. The flame retardant version sacrifices strength and surface finish. Polyurethane's main disadvantage though, is its poor electrical properties, making it suitable for jackets only.

Chlorinated-Polyethylene-(CPE):
CPE displays very good heat, oil, and weather resistance. Many times CPE serves as a lower cost, more environmentally friendly alternative to CSPE. Its reliable performance when exposed to fire also makes it a favorable alternative to PVC insulation. Chlorinated Polyethylene is commonly found in power and control cables and industrial power plant applications.

Nylon:
Nylon is usually extruded over softer insulation compounds. It serves as a tough jacket, exhibiting strong abrasion, cut-through, and chemical resistance, especially in thin wall applications. It is also extremely flexible. One disadvantage of Nylon is its absorption of moisture which degrades some of its electrical properties.

Thermoplastic-Rubber-(TPR)
In many applications, TPR is used to replace true thermo set rubber. It has improved color ability, higher processing speeds, and a wider usable temperature range. It also displays excellent heat, weather, and age resistance without curing. TPR is not cut-through resistant, but can be used in applications where other properties of rubber are preferred.

Neoprene-(Polychloroprene):
This is a synthetic thermo set rubber that must be vulcanized to obtain its desired qualities. It exhibits supreme abrasion, cut-through, oil, and solvent resistance. Neoprene is also known for its long service life and wide ranges of temperature and usability. It is remarkably flame retardant and self-extinguishing. >Military products often incorporate Neoprene. This material is especially desirable for hand-held corsets.

Styrene-Butadiene-Rubber-(SBR):
this is a thermo set compound with qualities similar to Neoprene. It has a temperature range of -55°C to 90°C. SBR is primarily used in Mil-C-55668 cables.

Silicone:
This material is extremely heat resistant and flame retardant and can be used in temperatures up to 180°C. It is moderately abrasion resistant. Silicone is also extremely flexible. Benefits include a long storage life and good bonding properties necessary in many electrical applications.

Fiberglass:
Fiberglass is the most widely used glass insulation. It can be used continuously in temperatures up to 482°C. This material is moisture and chemical resistant, but only fairly abrasion resistant. Its common applications include heat treating, glass and ceramic kilns, foundries, and extensive applications in aluminum processing.

Ethylene-Propylene-Rubber-(EPR):
EPR is known for its excellent thermal characteristics and electrical properties, allowing a smaller cross-sectional area for the same load carrying capacity of other cables. It is commonly used in high-voltage cables. The flexibility of this material also makes it appropriate for temporary installations and applications in the mining industry. These rubbers are also valuable for their heat, oxidation, weathering, water, acid, alcohol, and alkali resistance. EPR can be used in the temperature range of -50°C to 160°C. EPR is not as tear resistant as other insulation options. It is also relatively soft and may require more care during installation to avoid damage.

Rubber:
Rubber insulation generally refers to both natural rubber and SBR compounds, each available in a variety of formulas for use in a wide range of applications. Because formulas vary, so do temperature ranges and some other basic characteristics. While this type of insulation has poor oil, and ozone resistance, it exhibits good low-temperature flexibility, good water and alcohol resistance, good electrical properties, and excellent abrasion resistance.

Chlorosulfonated Polyethylene (CSPE):

CSPE works well as low-voltage insulation. It is known for its ability to perform through a wide temperature range as well as for its resistance to chemicals and UV rays. This insulation material can be found in appliance wire, lead wire, coil leads, transformer leads, and motor lead wire. Chlorosulfonated Polyethylene is sometimes referred to as Hypalon, a registered trademark of Dupont.

Ethylene Propylene Diene Monomer (EPDM):

This synthetic rubber insulation displays outstanding heat, ozone, weather, and abrasion resistance. EPDM also exhibits excellent electrical properties. Further benefits include excellent flexibility at both high and low temperatures, from -55°C to 150°C, as well as good dielectric strength. EPDM replaces silicone rubber in some applications.

PFA:
PFA has temperature ratings ranging from 250°C to 65°C. It also has a very low dissipation factor, making it an electrically efficient option. It does not exhibit thermo set qualities, limiting it to use only in select applications. PFA is also an expensive material, though it can be processed in long lengths.

Polytetrafluoroethylene-(PTFE):
PTFE is a thermoplastic material that can be used across a wide temperature range of -73°C to 204°C. It is extremely flexible, as well as, water, oil, chemical, and heat resistant. The mechanical properties of PTFE are low compared to other plastics.

Fluorinated Ethylene Propylene (FEP):

This material is widely used due to its processing characteristics and wide range of applications. It is also highly flame resistant. Improved data transmission can also be achieved when FEP is foamed. Pricing and processing are also being improved. FEP is commonly used in plenum cable and military applications.

ETFE Tefzel and ECTFE Halar:

These materials are stronger and more flexible than PFA or FEP and can become thermo set through irradiation. Foaming ECTFE and ETFE improves data transmission and reduces weight. ETFE and ECTFE lack many of the electrical advantages of FEP.

Polyvinylidene-Fluoride-(PVDF) :
PVDF is flexible, lightweight, and thermally stable, as well as chemical, heat, weather, abrasion, and fire resistant. It is also a relatively low cost insulation option. This insulation is used in a wide range of industries and applications. It is often found in cables meeting the UL Standard 910 Plenum Cable Flame Test, deeming the cables suitable for use in a building's space for air circulation, typically behind dropped ceilings or raised floors. PVDF is also commonly called Kynar, a registered trademark of Arkema Inc.

Thermoplastic-Elastomers-(TPE):
Thermoplastic Elastomers consist of a mix of polymers, typically a plastic and a rubber, to combine the benefits of each material into one insulating product. TPE can be molded, extruded, and reused, similar to a plastic, while maintaining the flexibility and stretch of rubber. TPE is commonly used in applications where conventional Elastomers are unable to provide the necessary range of physical properties. They are found increasingly in automotive applications and household appliances. Disadvantages of TPE include poor chemical and heat resistance, low thermal stability, and higher cost than other types of insulat

10. CONCULSION

By using Polyethylene plastic with a three dimensional molecular bond that is created within the structure of the plastic. This molecular bond improves a number of properties such as heat deformation, abrasion, chemical and stress crack resistance. The cross linking manufacturing process also produces an increase in low temperature properties, impact and tensile strength, as well as decreasing shrinkage. Cross-linked polyethylene tubes have shape memory characteristics, which only need heat to return it to its original shape

REFERENCES

[1] J. Sletbak, C.w! Reed, and S. Hirabayashi, "Multistress Behaviour of Insulating Materials and Insulating Structures," CIGRE International Conference on Large High Voltage Electric Systems, France, 1984.

[2] N. Parkman, "Some Factors Affecting the Performance and Ageing of Insulation in Electrical Equipment," NORD-IS 1986.

[3] T. Tanaka, "Internal Partial Discharge and Material Degradation," *IEEE Fansactions on Electrical Insulation*, Vol. EI-21, No. 6, pp. 899-905, December 1986.

[4] W,K. Park, D. Konig, and H.-J. Klos, "Some Fundamentals on Multifactor Surface Aging Mechanisms of Different Epoxy Resin Systems," CEIDI: Virginia Beach, USA pp. 286-289, October 1995.

[5] T Hibma and H.R. Zeller, "Space Charges and Dielectric Ageing," IEEE International Conference on Properties and Applications of Dielectric Materials, 1985.

[6] A. Hadid and C. Laurent, ''An Experimental Technique to Study Space Charge Injection in Polymeric Materials under AC Voltage," *IEEE Pansactions on Electricullnsulation,* Vol. 27, No. 6, pp. 1095-1100, December 1992.

[7] I? Paloniemi, "Theory of Equalization of Thermal Ageing Processes of Electrical Insulating Materials in Thermal Endurance Tests 1-111," *IEEE Pansactions on Electrical Insulation,* EI-16, pp. 1-30, February 1981.

[8] *IEEE Guide for Designing Multistress Ageing Ests of Electrical Insulation in a Radiation Environment,* IEEE Std 775-1993. Virginia Beach, USA, pp. 205-210, October 1995.

[9] A.C. Gjzrde, "Multi Factor Ageing of Polymer Insulation. Survey of Literature," TR 3480, ISBN 82-594-0005-7, 1989 (in Norwegian).

[10] A.C. Gjzrde, "Multi Factor Ageing of Epoxy--the Combined Effect of Temperature and Partial Discharges," Ph.D. thesis, Norwegian Institute of Technology, 1994.

[11] Survey,"lEEE Transactions *on* Electricallnsulation, Vol. 24, No. 3, pp. 741-764, 1989.

[12] G.C. Montanari, "Electrical Life Threshold Models for Solid Insulating Materials Subjected to Electrical and Multiple Stresses," IEEE Tansactions *on* Electricallnsulation, Vol. 27, No. *5,* pp. 974-985, 1992.

[13] IEC Report, Publication 505, Guide for Evaluation and Identification of Insulation *Systems of* Electrical Equipment, 19 75.

[14] G.C. Stone and R.G. Heeswijk, "Parameter Estimation for the Weibull Distribution,"lEEE Transactions *on* Electricallnsulation, Vol. EI-12, No. 4, pp.

[15] G.C. Montanari andM. Cacciari, 'A Probabilistic Insulation Life Model for Combined Thermal-Electrical Stresses," IEEE Transactions *on* Electrical Insulation, Vol. EI-20, No. 3, pp. 519-522, June 1985.

[16] S.M. Gubanski, "Analysis of Life Time Estimation Methods Based on Data for Electro-Thermally Aged PET Films," IEEE Symposium on Electrical Insulation, Canada, June 1990.

[17] G.C. Stone, "The Statistics of Ageing Models and Practical Reality," IEEE *Transaction son Electrical Insulation, Vol*2.8 ,No5,pp. 716-728, October 1993.

[18] E.L. Brancato, *'R* Pathway to Multifactor Ageing," IEEE Transactions *on* Electrical Insulation, Vol. 28, No. *5,* pp. 820-825, October 1993.

[19] J.R. Laghari, "Complex Electrical Thermal and Radiation Ageing of Dielectric Films," IEEE Transactions *on* Electrical Insulation, Vol. 28, No. 5, pp. 777-788, October 1993.