DEGRADATION STUDIES OF POLYMERIC INSULATORS – PRODUCTS PERFORMANCE REQUIREMENTS

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ABSTRACT

Abstract - The aim of this paper is to show studies and results of evaluations of new (t=0) and laboratory aged samples of pin and anchorage polymeric insulators, for 15 kV and 25 kV networks. The polymeric compounds were analyzed by Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA) and Dynamic-Mechanics Analysis (DMA), with objective of verifying changes in properties considering the possibility of degradation. The samples were also analyzed by Fourier Transformed Infrared Spectroscopy (FTIR) and for Scanning Electronic Microscopy (SEM). These analyses had been carried out before and after six months of laboratory aging (weather-ometer, 120 °C temperature, salt spray, water). After these aging, high-voltage electric tests are also carried out: Leakage Current and Impulse Current, to verify the superficial degradation of the polymeric materials used in the housing. In this paper, the aim is to show some performance requirements, obtained in laboratories, and they are suggested for polymeric products specifications.

INTRODUCTION

The polymer stabilization is necessary to that the product or component of electrical network made in polymeric material remains in field with good performance, resistant to the ultraviolet radiation, temperature and other starters of degradation. This study and some others were developed with evaluations in new samples, of new products, with removed products of field with problem and removed samples of field without problem, in the fields of power system utility companies. The new products had been sent to the laboratories, where they had passed for accelerated aging. After this, they had been distributed for the assays and measurements of degradation accompaniment, carried through in the CPqD, UFRGS, UFSC and others universities, and in the high-voltage laboratories in the UNICAMP, CEPEL and the UNIFEI. The programmed withdrawals of products had been carried through. These removed samples of field as good products, had been submitted in these years of natural ageing to the conditions: Caxias do Sul (problem, cold and humid region): subtropical climate, with temperature varying of 35ºC in the summer until 0ºC in the winter (with snow possibility), in the winter with sensation of until -12 ºC negative, with much strong wind. It has pollution in air, and is very high due to concentration of industrial production in the petrochemical, automobile branch and of vegetal oils in rude form (it is in the same scale of pollution that Gravataí). Taquara: climate: favorable, classified as tempered average, with temperature varying of 20ºC in the summer until 4ºC in the winter. It does not have pollution that it can harm the environment, for being a region of farming, according to IBGE. Also, are going to study samples of field, with very hard saline contamination, as Farol de Santa Marta, Santa Catarina. Other developed functional and performance requirements for polymeric products could be used in the improvement and implementation of specifications techniques of products and systems, with optimized performances. Thus, the performance requirements already developed are suggested, previously, also for others products, that can be applicable in the internal specifications of the concessionaire, as well as descript here.

Figure 1 - Insulator from coastal area

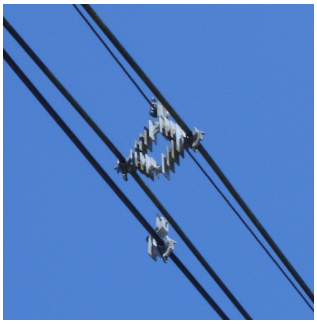

Figura 2 - Problems on HDPE spacer

EXPERIMENTAL

The following accelerated aging and measurements for degradation accompaniment had been carried through.

Accelerated aging to speed up degradations

a) Aging in the "Weather-ometer", for 6 months, with light bulb of arc xenon of 6500 W, with filters of borosilicate; irradiation of 0.35 W/m^2 in 340 nm; temperature of the black panel during the period of drying of 63°C; cycles of 120 minutes, being 102 minutes of light, followed per 18 minutes of light and "spray" of water, repeated, periodically; without control of relative humidity; the samples pass for posterior determination of electric, physical and chemical properties.
b) Thermal aging, temperature of 120 °C, for 6 months, and posterior determination of electric, physical and chemical properties.
c) Aging in Water, to the ambient temperature, for 6 months (followed of Water Absorption, for Gravimetria), beyond the too much determination of electric, physical and chemical properties;
d) Aging for Electric Tensions (Arc of power, Nominal Tension or Discharge for "flashover" or another electric aggression, more water), and posterior determination of electric, physical and chemical properties; Aging in Salt Spray, 6 months, temperature of 35°C ± 2. The saline salt spray is gotten from a solution of NaCl 5%; posterior determination of electric, physical and chemical properties.
The new samples, t=0, without artificial aging, had passed for evaluations of electric properties (leakage current and others), followed of the too much chemical and physical evaluations (thermal properties, index of fluidity for the thermoplastic one, Microscopy and Spectroscopy by Fourier Transformed Infra-red.

Measurements or Assays for accompaniment of the degradations (Diagnostic Tests)

They are being carried through in the new samples, t=0, and with problems in field, and will also be carried through in the after accelerated aging in laboratories:
a) Electric Properties (leakage current, nominal conductivity, supportability, and others); Supportable Tension in 60 Hz; Internal Evaluations of the baton and the interfaces;
b) Spectroscopy by Fourier Transformed Infra-red. with Reflectance (FTIR/ATR) and for Transmittance;
c) Thermal Properties: Differential Scanning Calorimetry (DSC) (melting temperature (Tm) and temperature of oxidation (Tox)), isothermal DSC for oxidation induction time (OIT), Thermogravimetric analysis (TGA) and Dynamic-mechanics thermal analysis (DMTA);
d) Scanning Electronic Microscopy (SEM);
e) Mechanical Properties: tensile strengths up to 80 and 100% of the maximum supportable resistance to insulators.

PERFORMANCE REQUIREMENTS

FTIR

The effect of a polymer degradation in polymeric products as insulators can take to the functional loss of the products and a stop in the distribution line of electrical energy. Through Fourier Transformed Infra-red Spectroscopy (FTIR), it is possible to determine products of degradation for specific absorptions in certain wavelengths of the infra-red ray. The accompaniment of degradation products is possible, as carbonilas, among others.
Performance Requirement: absence of significant absorptions of carbonilas, in the region of 1600 - 1750 cm^{-1}, for the samples of insulators.

TGA

Through Thermogravimetric Analyses (TGA), it is possible to evaluate the thermal stability of polymers, for variations in loss of mass with heating or through the temperature of beginning of decomposition, for example.
Performance Requirements: 1- for new insulators the kinetic of decomposition in the 350°C region, the maximum temperatures of decomposition and the final residues, for TGA, must be similar, between three new samples, for a verification of material homogeneity, in that concern to additives and loads; 2- for insulators of silicone, the fillers concentration must be (53±1)%; the higher decomposition temperature must be above 530°C; the loss of weight must be of, in the maximum 15%, up to 350 °C, by TGA.

DSC

The thermal analyses technique of Differential Scanning Calorimetry (DSC) is very used for accompaniment of polymeric degradations, through some determinable properties for it as: temperatures of crystallization (Tc), melting temperature (Tm), enthalpies of crystalline melting (ΔH) (that they are related to the crystallization degree, in turn related to the mechanical properties of the end product), glass transition temperature (Tg) (related to the amorphous phase), and temperatures of beginning of decomposition (Tbd or Tid) or temperatures of beginning of oxidation (Tox or OOT); also, under the isothermal form, the times of oxidation induction time can be determined (OIT).
Performance Requirements: 1- the samples of new polymeric insulators bolts must present melting temperature of (130 ± 2)°C (characteristic of HDPE); the temperatures of beginning of decomposition must be superior the 300 °C, for DSC, in nitrogen atmosphere, at 10 degrees/minute; 2- the samples of insulators PEAD bolt must present variations in melting temperatures of 5 C, after 3 months of aging in temperature of 120°, in the maximum; the variations in enthalpies of fusing for HDPE insulators bolt (crystallinity degree), after aging, must be inferior 15%; 3- the samples of insulators type

bolt, of HDPE, and of anchorage type, of silicone, must present, in isothermal DSC, in 200°C, an oxidative induction time (OIT) bigger than 60 minutes; 4- the samples of new silicone products must present temperatures of oxidation or beginning decomposition minimum of 220°C (OOT), for DSC, in oxygen atmosphere, 10 °/minute.

DMA

Through analysis thermal-dynamic-mechanics (DMTA) or analysis dynamic-mechanics (DMA), it is possible to determine the of Vicat softening point and the modules of loss and storage of polymers. The values of the (ε"), in special, and also, the temperature, in the maximum of loss module, maximums of tan delta, are usual to determined the glass transition temperature of polymer.

Performance Requirements: 1- the samples of new silicone products must present point of Vicat softening(ºC), by DMA, of (- 25 ± 3) ºC; 2- bigger variations that 30% in the Tg, by tan delta and ε", do not must to occur for the silicone products, after 3 months of aging, at 120°C.

MEV

Photomicrographies were gotten for scanning electron microscopy (SEM) of samples. They show the morphologic structures of polymers of the products, related to the final mechanical properties of the products. The appearance of crazies and cracking, signals of degradation, also can be followed by microscopy. Comparing the silicone samples with and without aging in water and in saline mist, it can be thought about reduction of the concentration of the filler, trihydrated alumina, in the surface, in function of the ageings, corroborating with found for Inone et al, after saline salt spray(2). It can be said that occurred erosion in the microscopical level. The aged sample presents holes or emptinesses in the breaking surface; already this was not observed in the micrographs of the breaking of samples in time zero (that is, in the samples without aging, it does not have formation of holes). The holes seem to be caused by the mineral load particle extraction (alumina).

Performance Requirement: It must have homogeneous distribution of the filler in the polymeric matrix, by microscopy.

Electric assays

In the insulators, the assays of disruptive tension and supportable tension with leakage chain measurement had been carried through and the variations in leakage current, mainly, were intended to evaluate the some types of aging in laboratory and field.

Insulators

It can be concluded that the percentile variations, for insulators type anchorage, in the leakage current under mist (or sprayed) e, mainly, under rain, gotten for the results of the samples before and after aging of six months in water well are raised, what also it occurs in lesser intensity for the ones in aging in saline mist. Already for the insulators type bolt, practically, variations do not run. Another fact to be observed is that the values found for current dry, initial leakage and the final one (after all the too much determination, expecting it drying of samples under assay, and happening again it determination in the following day) for the two types of insulators, also shows distinct behaviors, that is, for the insulator type anchorage it has more than 60% of variation enters chains of initial and final escape (values of leakage current dry before and after the disruptive tension); already for the insulators type bolt, it does not have variation. The aging and stress provoked by the electric assays had compromised the performance of the insulators of anchorage and its electric qualities, what bolt did not occur for the ones of the type. For the aged insulators type anchorage in field, per 3 years in Caxias do Sul, it was possible to observe high values of leakage current under rain, (6000% variations), what case of aged or disruptive, bigger that 1000μA. For new samples was not found for none another one; that is, the field of Caxias do Sul was more aggressive, in that concern to this property, of what any of the 6 months of accelerated aging, water, weather-ometer, temperature of 120 °C and saline salt spray.

Performance Requirements: 1- the leakage current in for new silicone insulators, type anchorage, in "the sprayed" condition, in 8/13,8kV$_{rms}$, must be lesser than 20μA. The variations in leakage current, in "the sprayed condition", after 3 months of aging the 120°C, can be of, in maximum, 40%, for insulators type anchorage;
2- the leakage current in 8/13,8 kVrms, in "the sprayed" condition, must be lesser that 120μA, for new insulators of PEAD, type bolt. The variations in leakage current, in "the sprayed" condition of, after 3 months of aging the 120°C, can be of, in the maximum, 25%, for these insulators type bolt.

Tension Mechanical Assays

The tension mechanical assay in the insulators was carried through up to 80% of the SMR (supportable maximum resistance), after that, up to 100% of the SMR, in new insulators and after the aging. The displacement was through load control: of 1000 N/s until 4.000N; later N/s started to dislocate 666 until 50.000N. All the assayed insulators had not presented visual alterations up to 100% of the SMR.

Performance Requirement: the insulators type anchorage must support tension mechanical assay (displacement through the load control: of 1000 N/s until 4.000N and after 660 N/s until 50.000N), without had presented visual alterations, up to 100% of the SMR (supportable maximum resistance).

Other developed requirements

Some other Performance Requirements to be suggested for specifications of insulators follow:

Performance Requirement: general for polymeric products: the polymeric products must contain thermo-oxidative and photo-oxidative stabilization system.

Results of assays meet presented in articles previously published [6].

For Insulators of Silicone:

1- The maximum variations allowed for the surface property, rugosity, after 3 months at 120°C, or water, or ultraviolet, or saline salt spray, of the insulators of silicone or blankets of silicone (prepared in the same way that the insulators) can be of, in the maximum, 65%[4].

2- The permissible variations in hardness Shore A, after aging of 3 months 120°C, are of, in the maximum, 10%, in the insulators of silicone and polymeric blankets of silicone[4].

3- Variations in tensile strength up to 20% and of percentile maximum deformation up to 40%, with speed of assay of 50mm/min can be acceptable, after 3 months of aging at 120°C or water or ultraviolet to blankets, prepared in the same way that the insulators[4].

For Spacers, Insulators and polymeric knotting accessories, in HDPE (high density polyethylene):

1- Temperature of beginning of oxidation (Tox) or temperature of degradation, by dynamic DSC, for the new products, at least 275°C[5] ;

2- Oxidation induction time (OIT) greater that 100 minutes for the thermoplastic products, without accelerated aging, by DSC, at 200° C[5] ;

3- Maximum Variations in the melt flow index of 20% °C, after 2 days of thermal aging at 120°C[5] ;

4- Variations of 20% in the maximum force of the tension mechanic assay, after 3 months at 120°C, or after 3 months of aging in ultraviolet[5] ;

5- Filler concentration uniforms, in 4 determination, in random points of the product[5] ;

6- Variations of, in the maximum, -20% in the electric properties of disruptive tension under rain and of, in the maximum, +20% in the leakage current in spray mist condition, between new insulators and spacers and after 3 months of accelerated aging at 120°C, or aging in ultraviolet or in water[5] .

For the cables with recovering in of polyethylene (PE):

1- The temperature of beginning of oxidation (Tox) bigger than 265°C can be required[5] ;

2- For the PE, after 14 days of aging 70°C, an oxidative induction time (OIT)at 200°C, greater than 20 minutes (requisite removed of internal specifications (Telebrás) for metallic wire and cable with recovering in PE) [5] .

For knotting rubbers:

1- For new rubbers of knotting, temperature of beginning of oxidation (Tox) bigger than 230°C can be required[5];

2- Maximum variations of 20% in the properties gotten for DMA (Tg, by E‘ at 30°C, and tan Delta at 30°C)[5]

CONCLUSIONS AND CONSIDERATIONS

The proposals of performance requirements, presented in this work, could be inserted in the practical interns of products of power companies, for support to the specification of purchases. Thus, the polymeric products will have greater durability in field; they will be functionally more trustworthy, through the stabilization required in the formularizations of the polymeric masses, that is, the supplier will have that to use a specific stabilization system thermo and photo-oxidative for the application of the final product. This system of used stabilization, together with the adequate conditions of processing, will lead to the lesser degradation of these products in service in the different fields of the power utility companies.

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