The Electrical Degradation of Fiberglass Poles

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Received on:7/6/2006
Accepted on: 6/3/2008

Abstract

This work involves fiberglass samples used in two kind of aging (45 days aging, 45 days aging with AC of 25 kV). Five sets of fiberglass samples were used in the accelerated aging tests and each set consists of nine fiberglass samples. The tested insulation length of these samples was chosen as 0.3 m. Two metallic bands, upper and bottom, were used as electrodes and tightly wrapped on the samples. The effect of surface condition on the materials electric degradation was studied and the nine samples were divided into' three group. The external surfaces of the first group of tested samples were kept intact, but some scratches were manually placed on the external surfaces of the second group. For the third group, five holes, each with 2.5 cm in diameter, were manually drilled in each sample. The electric experimental using to identify the insulation strength of fiberglass materials were (the lighting impulse test, AC wet flashover tests and, AC dry flashover test).The result show that the CFO voltage and AC flashover under dry condition were higher than under wet condition for all samples. The leakage current has a linear relation ship with applied voltage. The electric degradation is significant when the sample were tested with electric stress.

Key Word: Electric Degradation, Fiberglass pole, Insulation materials

الانحلال الكهربائي لاقطاب الالياف الزجاجية

الخلاصة

يتضمن البحث استخدام نماذج من عوازل الالياف الزجاجية في اختبارات التعتيق المسرع المتضمنن لنوعين من (45 يوم تعتيق ، 45 يوم تعتيق مع فولتية متناوبة من 25 كيلو فولت) استخدمت في هذة الاختبارات خمسة مجاميع من عوازل الالياف الزجاجية وكل مجموعة تتالف من 9 عينات طول كل عينة كان 0.3 متر نوعين من الاشرطة االفلزية استخدمت كاقطاب علوية وسفليه تناول البحث دراسة تاثير الظروف السطحية للنماذج على الانحلال الكهربائي للمواد قسمت العينات التسع الى ثلاث مجاميع حيث احتفظ بالسطح الخارجي للمجموعة الاولى بدون اي تاثير وعملت حزوز على السطح الخارجي للمجموعة الثانية بينما المجموعة الثالثة تحتوي خمسة ثقوب قطر كل ثقب 2.5 سم. الاختبارات الكهربائية المستخدمة لتحديد متانة العوازل هي (اختبارات النبضة الضوئية ، الاختبارات الجافة والرطبة للفولتية المتناوبة لتجاوز الومضة. تشير النتائج الى ان الفولتية الحرجة والتيار الحرج يكون اعلى في الظروف الرطبه ولجميع النماذج والتيار الحرج يتناسب خطيا مع الفولتية المسلطة. الانحلال الكهربائي يظهر بوضوح عندما تكون النماذج تحت ضغط كهربائي.

https://doi.org/10.30684/ etj.26.9.8
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Introduction

The insulation components used in a power distribution system are polymer and porcelain with and without fiberglass pole, which can exhibit different lightening impulse strengths.

In power distribution systems, the fiberglass pole can be used as a second or third insulation component in a combined insulation structure in order to improve the lightening impulse strength[l]

The insulation of all electrical equipment is subjected to continuous electrical stress during its period of service. The continuous electrical stress would decrease the insulation strength of the electrical equipment. At the same time, some other stress factors, such as over voltage, thermal stress, irradiation, cryogenic temperature, and mechanical stress, would also have adverse effect on the material's insulation strength. These electrical and nonelectrical stresses, if combined together, would decrease the material's insulation strength and shorten its insulation life at a faster rate than a single stress. In power systems, the aging of the insulation materials is usually associated with the multi-stress aging process. Among various aging factors, the electrical stress always plays a dominant role during the process of insulation degradation. For other aging factors, when sometimes combined with the electrical stress, their effect on the insulation material might be more obvious. When the material's insulation strength is less than the applied electrical stress, an insulation failure is expected to appear and a fault might also initiate simultaneously in power systems.

Various insulation materials such as polymer, glass, paper, mineral oil, and fiberglass have been used for different insulation structures. Their aging processes have already been proven to be different from each other. The aging process is controlled by two factors: the nature of single or combined external stresses and the inherent resistance of the various insulation materials to applied stresses [2]

In electric power systems, the insulation materials are subjected to all types of stresses when they are in service. The aging mechanisms are various for each class of insulation material because the materials' inherent insulation characteristics are different from each other. Therefore, different materials have different electrical degradation even when they are subjected to the same aging stresses [3]. In order to predict the insulation life, it is significant to know how the stress or stresses degrade the material's insulation strength. The natural aging process of insulation material would take a very long time to complete. Hence, it is unreasonable to conduct natural aging tests in the laboratory [4]. Therefore, different accelerated aging tests have been proposed as alternatives to the natural aging tests. In the accelerated aging test, the insulation material is subjected to a much higher electric stress than normal stress. At the same time, the other non-electrical aging stresses are also applied to the tested insulation material if necessary. As a result, the electrical degradation results of insulation material can be obtained after a much shorter period of time. The results from accelerated aging tests are always used in the aging models to predict the insulation life

Experimental Part

Four types of accelerated aging tests were conducted based on the standards [5, 6, 7].

These accelerated aging tests include:

- 45 days Aging
- 45 Days Aging plus 25 kV AC Voltage

Five sets of fiberglass samples were used in the accelerated aging tests and each set consists of nine fiberglass samples. The tested insulation length of these samples was chosen as OJ m. Two metallic bands, upper and bottom, were used as electrodes and tightly wrapped on the samples. The upper electrode is energized and the bottom electrode was grounded when external electrical stress is considered as an aging stress.

To investigate the effect of samples' surface conditions on the material's electrical degradation, the nine tested samples were divided into three groups. The external surfaces of the first group of tested samples were kept intact Fig 1, but some scratches were manually placed on the external surfaces of the second group Fig 2. For the third group, five holes, each with 2.5 cm in diameter, were manually drilled in each sample Fig 3.

The electrical degradation of insulation material is reflected by the decrease of its insulation strength. Therefore, the electrical degradation of fiberglass material can be obtained by evaluating its insulation strength before and after accelerated aging tests.

According to "IEEE Recommended Practice for Specifying Distribution Composite Insulator" [5], "Standard Specification for Fiberglass-Reinforced Plastic Rod and Tube Used in Live Line" [6] and "IEEE Standard Techniques for High-Voltage Testing" [8], the electrical tests used to evaluate the insulation strength of fiberglass material are:

- The lightning impulse tests
- The AC dry flashover tests
- The AC wet flashover tests

The alternating (AC) leakage current tests were conducted before and after the accelerated aging tests because the surface leakage current is an important indicator of material's insulation strength. The measured electrical parameters included AC leakage current, the AC dry flashover voltage and AC wet flashover voltage, and CFO voltages under dry and wet conditions. To improve the test accuracy, each sample was tested for three times and the average value of the three tests was chosen as the final result.

In the lightning impulse tests, a multi-stage impulse voltage generator was used to generate the 1.2/50 μs standard lightning impulse, and the up and down method was used to evaluate the CFO voltages of the samples[9]. The measurement system is the same as for the CFO voltage tests of fiberglass pole.

The single-phase AC testing transformer was used to perform the AC leakage current tests and AC flashover voltage tests. The digital multi-meters were used to measure the AC voltages and currents for the purpose of a higher accuracy. In the AC leakage current test, the upper electrode was energized and a shunt resistor was connected between the bottom electrode and ground. The measured voltage across the shunt resistor divided by the resistance of the shunt resistor is the leakage current flowing though the fiberglass sample

The AC flashover and lightning impulse tests were conducted under dry and wet conditions. The positive lightning impulse was used to evaluate the CFO voltages.

Result and Discussion

45 Days Aging.

The AC dry and wet flashover voltages, the AC leakage currents, and the CFO voltages were measured before and after the aging test. For each set of samples, the samples with undamaged external surfaces were labeled as NO.1 to No.3, the samples with some scratches on their external surfaces. were labeled as No.4 to No.6, and the samples with holes were labeled as No.7 to No.9.

The CFO voltages of the samples and their AC dry and wet flashover voltages are presented in Table 1 and 2, respectively. Under dry conditions, the AC leakage currents were measured as a function of the applied voltages.

The applied voltage started from 10 kV, then it was increased 10 kV each time until the flashover occurred. The measured leakage currents at 100 kV are presented in Table 3.

The CFO voltages and AC flashover voltages under dry conditions are higher than under wet conditions for all of the tested: samples. The wet AC flashover voltages are only about a half of the dry AC flashover voltages. Among the samples with different external surface conditions, the CFO voltages and AC flashover voltages did not show obvious differences.

After 45 Days of aging in, there was no apparent decrease of the CFO voltages, especially in the dry tests. The AC leakage currents of the samples have higher values after the aging tests. After the clean aging test, the leakage currents of three fiberglass samples are ten or more times higher than before the aging test. The magnitudes of the leakage currents are less than 3 mA . The measured leakage currents of the samples are only slightly higher than before the aging and they are in the range of microamperes.

From the lightning impulse, AC flashover, and leakage current tests, the electrical insulation strength of the tested fiberglass samples did not have a significant decrease after the test. As a result, the test has a negligible effect on the electrical degradation of fiberglass material when selected as an aging stress.

Furthermore, the sample's external surface condition is not an important factor on influencing the electrical degradation in the test. After the aging test, the information on the electrical degradation of fiberglass samples is obtained by measuring their electrical parameters. It is noticed that the leakage current of the sample is a more sensitive indicator of electrical degradation than other electrical parameters, especially when the electrical degradation is not very obvious. In general, after the aging test, if the measured leakage current increases to a high magnitude, it can be concluded that obvious electrical degradation of the fiberglass material has occurred. The electrical degradation of insulation material could be estimated by analyzing such electrical parameters as leakage current, AC flashover voltage and CFO voltage

45 Days Aging Plus 25 kV AC Voltage

One set of green fiberglass samples was aged in for 45 Days. At the same time, the AC voltage with a magnitude of 25 kV was applied to nine samples. The same electrical tests were performed for the samples. The CFO voltages, the AC flashover voltages, and leakage currents at 100 k V are presented in Table 4 to Table 6 respectively.

The CFO voltages and AC flashover voltages decreased by a large amount after the aging test. Also, after the aging test, the increase of leakage currents after the plus AC voltage test is obvious. The electrical degradation of fiberglass samples is shown by the measured electrical parameters before and after the aging test. However, the samples with different external surface conditions still have similar insulation strengths after the aging test.

After exposed to test and 25 kV/m electrical stresses for 45 Days, the electrical test results, especially the CFO voltages, are less than those from the test. Hence, the external electrical stress has a significant impact on the electrical degradation of fiberglass material.

If the duration of plus electrical stress test was extended to a longer time and/or a higher external electrical stress was applied to the tested fiberglass samples, there would be more severe electrical degradation. In some laboratory research, the duration of aging tests were extended, such as 3 months, in order to study insulation materials' abilities to resist electrical degradation and analyze their performances [10].

Conclusion

Before the accelerated aging tests, the CFO voltages of the fiberglass samples are about 210 kV under dry conditions and 170 kV under wet conditions. The AC flashover voltages are 120 kV under dry conditions and 70 kV under wet conditions. The leakage currents at 100 kV AC voltage are less than 300 μA for all the samples, and they have a linear relationship with the applied voltages.

After the Accelerated Aging Tests, the electrical degradation caused by the test is very insignificant. When the test was performed with the specific electrical stress, the electrical degradation was still not very obvious. However, the electrical degradation of the fiberglass samples happened very quickly when they are tested with electrical stress. The combined effect of 25 KV voltage and electrical stress on fiberglass material is the most important reason for electrical degradation.

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Table 1 The CFO Voltages samples before and after 45 days Aging

CFO / Sample	Dry condition		Wet Condition	
	Before (kV)	After (kV)	Before (kV)	After (kV)
No.1	207	195	182	183
No.2	207	198	177	145
No.3	207	192	177	176
No.4	205	189	172	164
No.5	206	198	174	168
No.6	N/A	N/A	N/A	N/A
No.7	207	195	176	172
No.8	207	196	173	163
No.9	204	193	175	155

Table 2 The AC Dry and Wet Flashover-Voltages of samples before and after 45 days Aging.

AC / Sample	Dry condition		Wet Condition	
	Before (kV)	After (kV)	Before (kV)	After (kV)
No.1	119	126	74	57
No.2	125	124	71	57
No.3	123	122	72	52
No.4	126	124	72	52
No.5	124	124	72	52
No.6	N/A	N/A	N/A	N/A
No.7	125	129	70	55
No.8	124	127	68	56
No.9	123	124	65	50

Table 3 The AC Leakage Currents of brown and green samples at 100 kV before and after 45 days Aging

AC Current / Sample	Dry condition	Wet Condition
	Before (μ A)	After (μ A)
No.1	229	242
No.2	233	259
No.3	220	310
No.4	217	282
No.5	227	281
No.6	206	240
No.7	200	252
No.8	218	279
No.9	221	302

Table 4 The CFO Voltages of green samples before and after 45 days Aging plus 25 kV AC Voltage.

CFO / Sample	Dry condition		Wet Condition	
	Before (kV)	After (kV)	Before (kV)	After (kV)
No.1	222	206	202	181
No.2	216	206	194	184
No.3	222	209	195	183
No.4	217	205	196	175
No.5	213	204	195	175
No.6	217	205	197	174
No.7	217	200	180	168
No.8	213	198	196	169
No.9	213	196	200	169

Table 5 The AC Dry and Wet Flashover Voltages of green samples before and after 45 days Aging plus 25 kV AC Voltage.

AC / Sample	Dry condition		Wet Condition	
	Before (kV)	After (kV)	Before (kV)	After (kV)
No.1	119	113	61	58
No.2	120	117	62	58
No.3	131	117	62	58
No.4	116	114	61	54
No.5	116	115	60	54
No.6	116	114	60	54
No.7	116	111	59	51
No.8	116	116	59	51
No.9	117	115	59	49

Table 6 The AC Leakage Currents of green samples at 100 kV before and after 45 days Aging plus 25 kV AC Voltage.

AC Current / Sample	Dry condition	Wet Condition
	Before (μ A)	After (μ A)
No.1	163	171
No.2	131	137
No.3	160	176
No.4	176	180
No.5	165	227
No.6	165	176
No.7	161	175
No.8	162	165
No.9	149	192