LONG TERM RELIABILITY ASSESSMENT METHOD AND AGING CHARACTERISTICS OF POLYMER SURGE ARRESTERS

Juyong Kim Jaebong Lee Chulbae Park Yeunha Jung
Korea Electric Power Research Institute, KEPCO, KOREA
kimjy@kepri.re.kr jbonglee@kepco.co.kr chul93@kepco.co.kr mywendy@kepco.co.kr

ABSTRACT

In this study an accelerated aging test method and equipment which can simulate domestic weather conditions were developed. And long term reliability was assessed using the proposed method for domestic polymer housed distribution surge arresters. This paper presents the results of electrical and chemical analysis of the arresters after 3,000-hour accelerated aging test and 3 years outdoor exposure test. Through the field and laboratory aging test the capability of the proposed reliability assessment method was verified and long term aging characteristics of domestic polymer housed surge arresters was estimated.

INTRODUCTION

Polymer housed surge arresters are light and easy to handle. When a polymer surge arrester explodes, its debris does not scatter. Thus, polymer surge arresters are increasingly used today. Nonetheless, some of the polymer surge arresters applied to distribution lines for the first time in Korea in 1999 broke down due to sealing problem in 2002 hence the interest in predicting the long term aging characteristics of the arresters is increasing.

One of the most effective ways of predicting the aging and lifetime of the polymer surge arrester involves evaluating its operation performance under a simulated environment. For this purpose, the multistress accelerated aging test method is the most appropriate[1-3], simulating long term aging within a short time by repeatedly applying environmental stress[4-6]. Generally used as a method of accelerated aging test of polymer surge arresters, the 5,000-hour test of IEC 60099-4 was originally developed to evaluate the aging characteristics of polymer insulators and it simulates mild climate conditions. This method does not fit the natural environment conditions of Korea. Therefore it does not suitable as a method of predicting the long term aging characteristics of the polymer surge arresters being used in Korea. Moreover, this method cannot be used to evaluate the sealing characteristics of the polymer surge arrester, one of the major causes of its failure. In this paper, an accelerated aging test method suitable for the polymer surge arresters being used in Korea was developed based on the results of analyzing Korean and foreign test methods as well as the specification for testing the accelerated aging of the polymer insulators based on Korea's natural environment conditions. A 3,000-hour accelerated aging test was then performed on full scale arresters. Some specimens were installed at an outdoor exposure test facility for 3 years to evaluate the natural aging characteristics of polymer housed surge arresters.

TEST EQUIPMENT

A. Accelerated aging test equipment

This multistress accelerated aging test equipment is designed to simulate the field environmental conditions that affect to polymer arresters. Its dimension is about 80 m^3 (1,500 mm×1,800 mm×3,000 mm). Fig. 1 shows the structure of this equipment. It can simulate ultra violet radiations from sunshine, temperature, humidity, salt fog, rain and high voltage as aging factors. Stress level of aging factors is as follows.

Table 1. Aging factors and stress level

Factors	Stress Level
Temperature	Summer : 15~80 , Winter: -20~15
Humidity	Summer : 40-95 %, Winter : 30-60 %
UV	Wavelength : 280~315 nm(UV-B lamp)
Salt fog	4,000 µS/cm
Rain	50 µS/cm
Voltage	15.3 kV(MCOV)

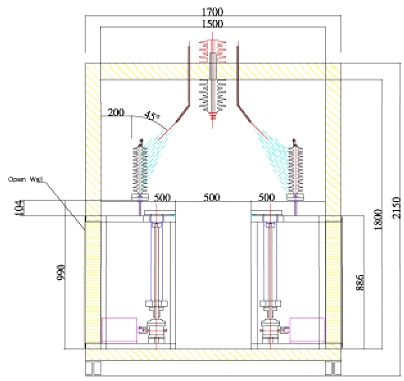


Fig. 1. Schematic diagram of aging test equipment

Sixteen specimens were installed in this chamber and two wire electrodes for measuring leakage current were connected to the lower end of housing and under the disconnector. The wire electrode installed at the lowest shed of housing is to measure surface leakage current and the wire electrode installed under the disconnector is to measure inside leakage current which path through the inside of surge arrester.

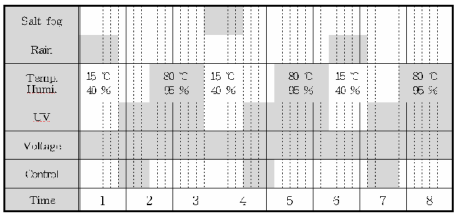


Fig. 2. Summer cycle

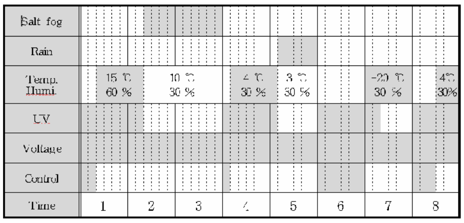


Fig. 3. Winter cycle

B. Outdoor exposure test facility

Outdoor exposure test facility was constructed to get naturally aged arresters. Several kinds of arresters were installed and weather condition and leakage currents were monitored. The purpose of this outdoor exposure test is to compare the characteristics between accelerated aged arresters and naturally aged arresters. Accelerating effect of the proposed aging test will be verified by this test. This outdoor test facility is located at the seaside area in order to apply severe environmental stress to the arresters and the height is about 16 m considering field installation height.

Fig. 4. Outdoor exposure test facility

SPECIMENS

Four kinds specimens were prepared for 3,000-hour accelerated aging test. Group A and B are newly made arresters and group C and D are 2 years natural aged one.

Among these specimens group C has manufacturing defects. Lots of same kind arresters failed in the field due to the moisture ingress to the interface between inner module and housing. Their housing material has also bad performance. These specimens were tested to evaluate the capability of proposed aging test method.

In addition same kind specimens were installed at the outdoor exposure test facility to compare aging characteristics with accelerated aged specimens.

Table 2. Initial condition of specimens

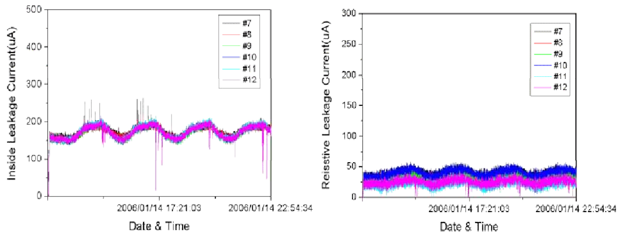
Category	Specimen No.	Manufacturer (field operation)	Referance voltage ($V_{1mA\ dc}$)	Leakage current (at 13.2kV)	
				Total	Resistive
group A	#1 - #6	V Co.(New)	29	140	10
group B	#7 - #12	B Co.(New)	29	140	15
group C	#13 - #14	S Co.(3 years)	29	180	10
group D	#15 - #16	V Co.(3 years)	30	140	14

EXPERIMENTAL RESULTS

A. Leakage current

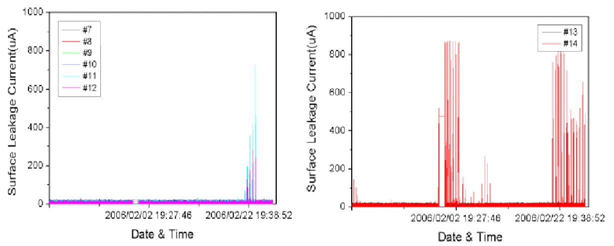
Accelerated aging test was composed of 10 days summer cycle and 11 days winter cycles for 1,000 hours and it was repeated for 3 times. It is the same aging effect as 6 years field operation.

Leakage current of specimens depends on the applied temperature. Inside leakage current was about 180 uA and resistive leakage current was about 50 uA as fig. 5.



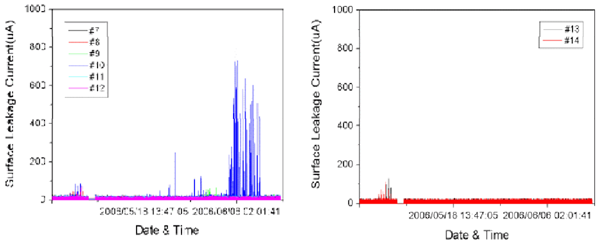
(a) Inside leakage current (b) Resistive leakage current

Fig. 5. Leakage current of group B specimens for 1,000 h.



(a) Group B specimens (b) Group C specimens

Fig. 6. Surface current of group B and C for 1,000 h.



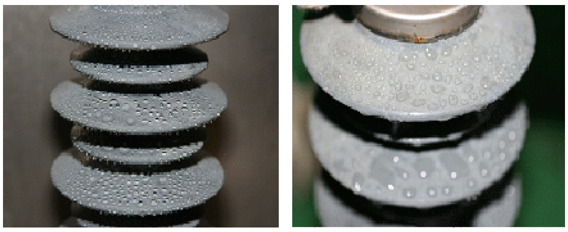
(a) group B specimens (b) group C specimens

Fig. 7. Surface current of B and C for 2,000-3,000 h.

Fig 7 shows surface leakage current for 3,000 hours. For the first 1,000 hours newly made specimens group A and B showed very low current but field aged specimens C and D showed very high surface leakage current at the rainfall period of the winter cycle. Actually surface leakage current is very high in the field for winter season. Therefore we believe that this proposed aging cycle should reflect field condition.

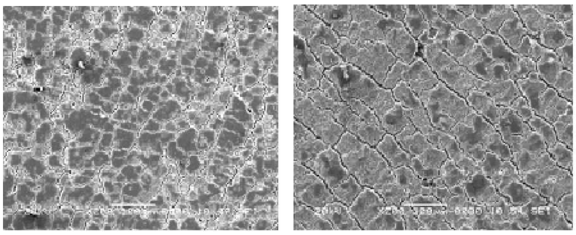
At the end of accelerated aging test surface leakage current of group C and D was disappeared and that of group A and B was increased very high. It is due to the surface pollution characteristics of the housing.

B. Hydrophobicity and surface microstructure



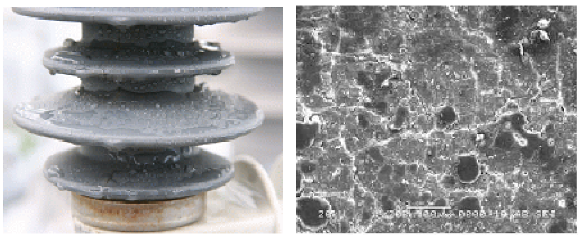
(a) Initial (b) after 3,000 h aging

Fig. 8. Hydrophobicity of group B(specimen #9)



(a) Initial (b) after 3,000 h aging

Fig. 9. Surface microsturucure of group B(specimen #14)



(a) Hydrophobicity (b) surface microstructure

Fig. 10. Outdoor installed arrester for 3 years

Hydrophobicity of group A and B was decreased after 3,000-hour accelerated aging test and microcracks of the surface of group C and D specimens were magnified as fig. 9. The surface of outdoor installed arresters was highly degraded after 3 years aging. It means that the surface condition depends on the pollution. Accelerated aging test only can simulate salt fog for a pollution but field installed arresters can be affected by so many kinds pollutants.

C. FTIR analysis

In order to assess surface condition of housing material, small part of hosing was extracted from specimens after every 1,000 hours accelerated aging test. Outdoor installed samples were also extracted to compare aging status with accelerated aged samples. Among the results of FTIR we compared 2,916 cm^{-1} and 1,014 cm^{-1} peaks of natural and accelerated aged samples. Fig 11 shows the FTIR peaks of group A(specimen #1). In this comparison we supposed 3,000-hour aging to 6 years field operation because 3,000-hour accelerated aging test have 6 times summer and winter.

Fig. 12 shows the variation of Al_2O_3 filler(a) and CH_2 asymmetric stretch(b). It shows that accelerated aging test can reflect field condition and CH_2 bonding will be decreased by the aging. Al_2O_3 also will be exhausted from surface by the aging time.

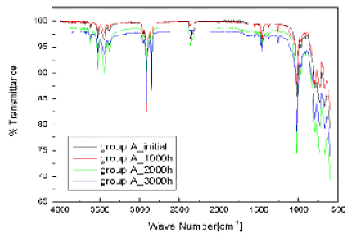
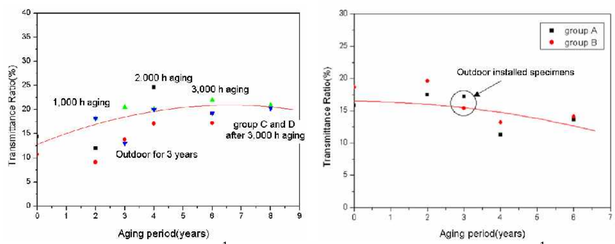


Fig. 11. FTIR peaks of group A (specimen #1)



(a) 1,014 cm^{-1} (b) 2,916 cm^{-1}

Fig. 12. Transmittance ratio of FTIR peaks

D. Dielectric loss analysis

To compare dielectric loss of housing material flat samples with 0.2-0.4 mm thickness which were produced by microtome were prepared from housing. Its dielectric characteristics were measured by dielectric thermal analyzer according to temperature and frequency.

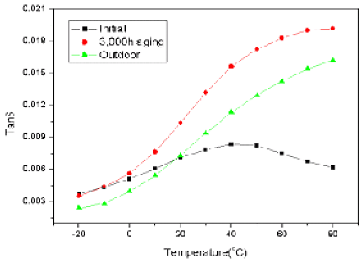
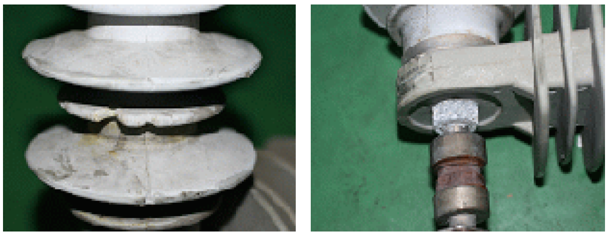


Fig. 13. Variation of dielectric loss at 1MHz

Fig 13 shows dielectric loss of housing material of initial, accelerated aged and outdoor installed arresters. Dielectric loss did not increased by temperature rising at initial condition but that of aged sample was sharply increased by temperature rising. In addition dielectric loss of 3,000-hour aged sample was higher than that of 3 years outdoor installed sample.

E. <u>Deformation and damage</u>



(a) Erosion (b) Corrosion

Fig. 14. Damage after 3,000-hour aging test

Due to the accelerated aging test some of specimens were damaged. Especially housings of group C specimens were eroded by the high leakage current. Fig 14 shows the erosion of housing(a) and corrosion of metal part of specimens(b). Through the specification tests we verified electrical performance of the specimens after accelerated aging test. All of the specimens had no electrical deterioration. It means that proposed aging test could not induce abnormal aging. In addition it can discriminate manufacturing defects. But most of disconnectors did not explode by test current 20 A due to the moisture intrusion. At last we carried out sealing performance test according to IEEE C62.11. Resistive leakage current and RIV voltage were dramatically increased after sealing integrity test. It shows that the proposed aging test can apply mechanical stress to the arresters and induce moisture ingress to the inside of arresters.

CONCLUSION

In this paper, an accelerated aging test method suitable for the polymer surge arresters being used in Korea was developed based on the results of analyzing Korean and foreign test methods as well as the specification for testing the accelerated aging of the polymer insulators developed based on Korea's natural environment conditions. A 3,000-hour accelerated aging test was then performed on full scale arresters.

The results of analyzing the housing material of specimens that aged naturally at the outdoor test site and those that underwent the 3,000-hour accelerated aging test revealed that the 3,000-hour accelerated aging was roughly equivalent to 6 years of operation of the polymer surge arresters in the field. When the electrical performance of the specimens at the end of the accelerated aging test was evaluated, the tracking performance of the insulation hangers and sealing performance of disconnectors of some specimens were found to have deteriorated. Moreover, an additional sealing test revealed a deterioration of the accelerated aged specimens in the sealing performance compared to their early state. This suggests that a polymer surge arresters may break down as a result of moisture penetration in case of long term operation.

The accelerated aging test method used in this paper was confirmed to be capable of simulating the aging of polymer surge arresters in the field thus enabling the prediction of their long term aging characteristics.

REFERENCES

[1] Raji Sundararajan, "Multistress Accelerated Aging of Polymer Housed Surge Arresters under Simulated Coastal Florida Conditions", Vol. 13, No. 1, pp. 211-226, Feb. 2006

[2] IEC standard 60099-4, "Metal-oxide surge arresters without gaps for a.c. systems, 2004

[3] IEC Standard 61109, "Composite insulators for a.c overhead lines with a nominal voltage greater than 1000V-definition, test methods and acceptance criteria", 1992

[4] Jeffrey J. Kester, "Multistress aging tests of polymer housed surge arresters", IEEE Trans. on Power Delivery, Vol. 13, No. 2, pp. 446-451, Apr. 1998,

[5] T. G. Gustansson, "Aging of Silicone Rubber under AC or DC Voltages in a Coastal Environment", IEEE Trans on DEI., Vol. 8, pp. 1029-1039, 2001

[6] Raji Sundararajan, "In-Service Aging and Degradation of 345kV EPDM Transmission Line Insulators in a Coastal Environment", IEEE Trans. on DEI., Vol. 11, pp. 348-361, 2004