PERFORMANCE EVALUATION OF MEDIUM VOLTAGE COMPOSITE INSULATORS IN DESERT AREA OF IRAN

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ABSTRACT

Long-term assessment of composite insulators is more vital to improve the reliability of electric networks. This paper presents the performance evaluation of some medium voltage silicone rubber insulators in desert area of IRAN. The investigation includes a set of destructive and non-destructive tests on specimen insulators, which collected from the field. Using these findings, a useful plan to assess long-term experience of composite insulators is obtained.

INTRODUCTION

Environmental contamination of outdoor insulation has caused many problems such as losses and reduced reliability of electric distribution systems since their inception. To reduce pollution problems of insulators, there are some methods such as cleaning, insulator replacement, silicone greasing, using RTV, using creepage/shed extenders and insulator upgrading [1].

In recent decades, replacement of porcelain or glass insulators with composite insulators is considered as an effective approach to overcome undesirable effects of pollution [2]. However, composite insulators suffer from ageing due to electrical stresses such as corona and dry band activity and environmental stresses such as UV radiation and acid rain, because they may cause surface chemical and structural changes of polymer that may reduce the desired properties of materials such as hydrophobicity [3,4,5]. As experiences with composite insulators are significantly less than porcelain and glass insulators in Iran as well as other countries, therefore providing useful approach to evaluate the performance of composite insulators considering climatic effects and the resulted electrical and mechanical failures, and feasibility study of future operation seems to be essential.

As a result, a performance evaluation approach is provided to assess a few types of 20 kV composite insulators those were replaced to porcelain insulators in distribution network, in a desert region near some brick kilns, in Yazd province (Iran) since year 2000.

In spite of being exposed to industrial pollution of brick kilns and environmental pollution of desert, these insulators operate for 6 years in distribution network without any flashover or failure experience.

In this paper, the performance evaluation plan for composite insulators is presented.

The evaluation approach consists of following tests: visual inspection, hydrophobicity classification, Scanning Electron Microscopy (SEM), measurement of power frequency withstand voltage- dry and wet, studying leakage current, pollution level measurement, measurement of zinc coating thickness on the end fittings, measurement of weathershed hardness, and mechanical test.

SPECIMEN INSULATORS

The specimen insulators consist of four HTV silicone rubber insulators (No.1-4) and two standard cap & pin porcelain insulators (No.5, 6).

Insulators No.2, No.3 and No.4 were taken from distribution network, in a desert region near some brick kilns, in Yazd province (Iran) after 6 years operation. In spite of heavy pollution level due to subjecting to brick kilns, these insulators did not experience any flashover or failure during 6 years operation.

Insulator No.1, which is chosen from stock, has the same Characteristics as insulators No.2, No.3 and No.4.

Table 1 shows some characteristics of insulators No.1, No.2, No.3 and No.4 and Figure 1 shows them.

Figure 1. SIR specimen insulators No.2, No.3 and No.4.

Table 1. Characteristics of SIR specimen insulators.

Max. operation voltage	24 kV
Total creepage distance	638 mm
Arcing distance	268 mm
Specific mechanical load (SML)	70 kN
No. of sheds	4
Sheds diameter	140 mm
Sheds spacing	46 mm

The cap & pin insulator No.5 is chosen from stock and the cap & pin insulator No.6 has been operated at the same condition as insulators No.2, No.3 and No.4. The porcelain insulators have been considered to compare with SIR insulators in some performance evaluation tests.

CLIMATIC CHARACTERISTICS OF YAZD

Yazd province is located the Central Plateau of Iran. The average rainfall is very little; these conditions cause hot and dry weather in the center and temperate weather in around mountainous regions.

Considering geographical position and climatic conditions, this region characterized with low humidity, high degree of evaporation and also daily temperature variation in the summer.

The maximum ambient temperature in the summer reaches to 45°C and the minimum ambient temperature in the winter reaches to -20 °C. Annually average humidity is 25 to 30% and sometimes the wind speed reaches to 90 km/h and cause sand storms in dry and desert areas.

In Yazd province, the ultra violet (UV) radiation intensity is very high, and the light energy in the warmest hours of day exceeds 1000 wats/m^2.

PERFORMANCE EVALUATION PLAN

In order to have a proper performance evaluation plan for composite insulators, a set of destructive and non-destructive tests on specimen insulators has done as listed below.

Visual Inspection

Visual inspection shows that there is no sign of tracking and erosion, cracks and traces of electrical activities such as corona on the surface of weathersheds of insulators No.2, No.3 and No.4. Also, there is no sign of corrosion on the end-fitting surfaces of the insulators. There are some airborne yellowish pollution layers on the top side and bottom side of all weathersheds, which are continuous and seem to be very heavy (See Figure 1). So, visual inspection shows that there is no sign of damage or ageing process and it is necessary to do some other tests to get more details.

Hydrophobicity Classification (HC)

Hydrophobicity classification of the insulators No.2, No.3 and No.4 was checked based on the method introduced in STRI Guide 92/1 [6].

The test shows that in all 3 insulators, Hydrophobicity Class (HC) of all weathersheds equal 1 (HC1), which is the highest level of HC according to STRI Guide and means all of the tested insulators have maintained their water repellent property completely after 6 years of service.

Electrical Test

Electrical test have been done based on IEC 61109 [7]. The results for dry and wet conditions are presented in Table 2. The results show slightly difference between power frequency withstand voltages of insulator No.1 (from stock) and of insulators No.2 and No.3 and mean that after 6 years of service, insulators have maintained their electrical property.

Table 2. Results of electrical tests of the insulators.

Insulator No.	1	2	3
Dry P.F withstand voltage (kV)	107	101	105
Wet P.F withstand voltage (kV)	76	71	73

Leakage Current (LC) Measurement

LC measurement was carried out under clean fog condition according to IEC 60507 [8]. LC behaviour of insulators has been studied inside a fog chamber [9]. Figure 2, 3 show a view of Niroo Research Institute (N.R.I) fog chamber and LC peaks of insulators respectively.

Figure 2. A view of N.R.I fog chamber

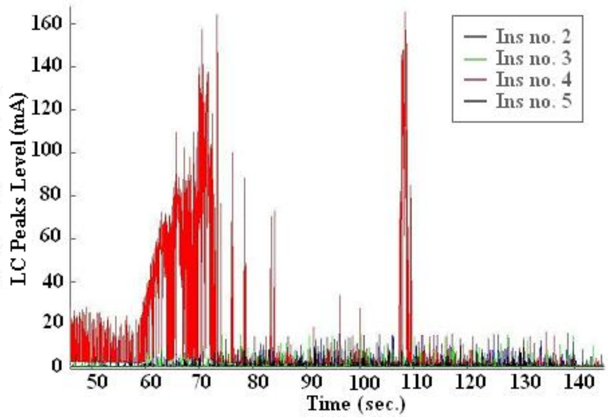

Figure 3. LC peaks levels

According to Figure 3, some issues deserve to be noted:

1. LC peaks level of polluted silicone rubber insulators is so low, which is due to the hydrophobicity of their surfaces even under clean fog condition and presence of contamination.
2. LC peaks level of polluted ceramic insulator is higher than the others, which is due to the presence of contamination, humidity and hydrophilic surface of ceramic. Non-linear behaviour of LC peaks shows formation of dry band activity on hydrophilic surface in the presence of contamination [9].
3. Decreasing of LC peaks level of polluted ceramic insulator between 85 sec. and 105 sec. is due to dry band activity. LC peaks level increased at about 110 sec.

It is obvious that silicone rubber insulators maintained their hydrophobic properties which results in low LC peaks level.

Pollution Measurement

ESDD and NSDD measurements are presented in Table 3. The results show more deposition of pollution on porcelain insulator respect to silicone rubber insulators, which can be due to the difference between material and profile of porcelain and silicone rubber insulators.

Table 3. ESDD and NSDD of insulators.

Insulator no.	ESDD (mg/cm^2)	NSDD (mg/cm^2)
2	0.1502	0.7551
3	0.1361	0.7648
6	0.3579	0.7491

According to IEC 60815 standard, these values indicate a very high-polluted region [10].

Scanning Electron Microscopy (SEM)

To investigate more detail about microscopic structure of silicone rubber of weathersheds, the top side of weathershed No.1 of insulator No.2 was observed in a scanning electron microscope. The sample surface was first coated with a thin gold layer. Figure 4 shows SEM image of weathershed surface of insulator No.2 with magnification equals to 4000 times.

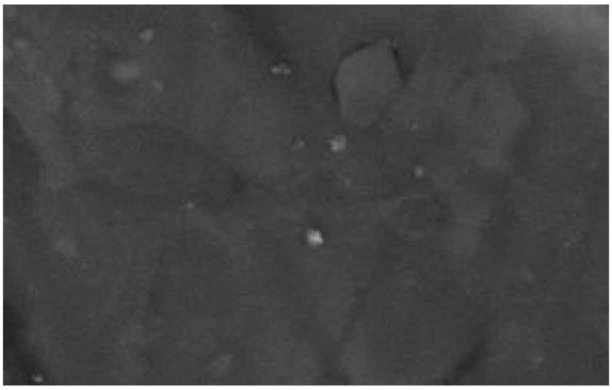

Figure 4. SEM image of surface of insulator No.2.

SEM image shows that the weathershed surface of insulator No.2 is not cracked and the surface of this sample was uniformly smooth and lacked detail. In addition, there is no evidence of material degradation or ATH exposure or reduction of polymer concentration. So, the insulator No.2 maintains its polymeric structure without any degradation.

Zinc Coating Thickness Measurement

The measurement of zinc coating thickness on the end fittings of insulators was carried out according to IEC 60383-1 [11]. The averages of measured thickness are shown in Table 5. Moreover, all of the measured minimum thicknesses of insulators were more than 70micrometers.

The results show that after 6 years of service, there is no decline of zinc coating thickness on the end fitting of insulators and the zinc coating thickness is acceptable.

Table 5. The average of measured thickness of zinc coating

Insulator No.	2		3	
Position	Ball	Socket	Ball	Socket
thickness (micrometer)	104	101	115	91

Measurement of Weathershed Hardness

Measurement of weathershed hardness was carried out according to ASTM D2240 [12]. The average of weathershed harness is listed in Table 6.

The results show that the amounts of average hardness of insulators from network are slightly more than of insulator chosen from stock and these little changes are not significant. Maybe additional crosslinking of siloxanse molecules of silicone rubber backbone structure is the reason for little increasing in hardness of weathersheds.

Table 6. The average of weathershed hardness

Insulator No.	1	2	3
Shore A hardness	72.3	75	75

Mechanical Test

Mechanical test consists of verification of tightness of the interface between end fittings and insulator housing and of the SML, which was carried out according to IEC 61109 amend.1subclause 7.4 [7].

The insulator No.2 was subjected to crack indication by dry penetration, in accordance with ISO 3452 [13], on the housing in the zone embracing the complete length of the interface between end fittings and insulator housing and including the end of the metal part. After 5 min., the insulator was be subjected to a tensile load, which was rapidly but smoothly increased from zero to 70% of SML (equals to 49 kN) and then maintained at this value for 1 min., applied between the metal fittings. The housing, metal fitting and core didn’t cut. 20 min. after start time of the test, the dry penetrant was removed from the surface and the surface was dried, and a developer was applied. There was no evidence of cracks in the interface.

This part of test shows that the tightness of joint of insulator No.2 has not been affected by stresses after 6 years of service and the result of this test was satisfactory.

Then, the insulator No.3 was subjected to a tensile load applied between the couplings. The tensile load was increased rapidly by smoothly from zero to approximately 75% of SML (equals to 52 kN) and then was gradually increased to SML (equals to 70 kN) in one min. No failure was occurred. Then tensile load was increased until the failing load, which was recorder equals to 95 kN. The curve of failing load test is shown in Figure 5.

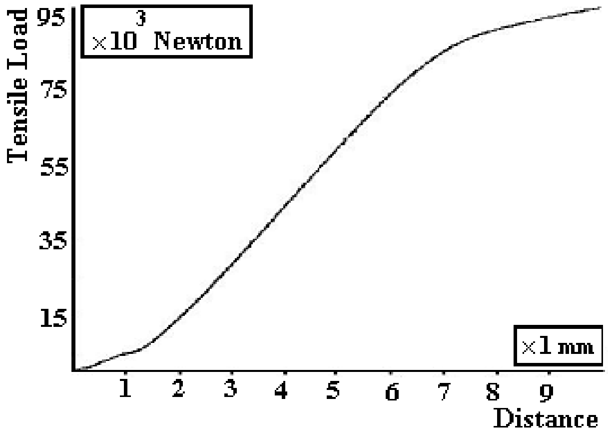

Figure 5. The result of failing load test

CONCLUSION

1. The results show that the specimen insulators are not affected by electrical and environmental stresses and high-level pollution of the region after 6 years of service. Because the specimen insulators maintain their properties. There is no evidence of hydrophobicity loss, reduction of electrical and mechanical properties and ageing of silicone rubber.
2. All tests, which were carried out on the insulators, indicated that the specimen insulators are still in good condition and confirmed the insulators performance for future operation.
3. The performance evaluation plan seems to be useful for the other regions to evaluate the performance of composite insulators.

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