Correlation between Insulation Diagnostic Test and AC Breakdown Test for 3.3 kV Class Induction Motor

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The insulation diagnostic test and the AC breakdown test were performed under off-line using the 3.3 kV class induction motor which have been served for 10 years. These tests were conducted in means of nondestructive and destructive test. In this paper, we compared the correlation between the nondestructive and destructive test. Furthermore we setup an experimental condition with moisture and compared the insulation characteristics between moist and dry sample. From the results of the nondestructive and destructive test, it was found that the second AC current, which is the previous step of insulation breakdown, suddenly increased at a point of around 8.5 kV. The insulation breakdown of moist sample occurred at 12-14 kV, which is 4-5 kV lower than dry sample.

Keywords : Deterioration, Insulation diagnostic, Breakdown test, Dry sample, Moist sample

1. INTRODUCTION

An induction motor used in industry is usually exposed to mechanical, thermal, electrical and environmental stress. These stresses affects the stator coils causing the insulation deterioration and increasing the insulation intensity, consequently causes the induction motor's insulation breakdown[2-3,5-7]. Therefore, periodic insulation test is needed to evaluate the insulation conditions in order to prevent a serious emergency situation. Based on the result of the periodic test, the condition based maintenance, such as induction motor overhaul tests, cleaning, impregnation, rewinding etc, can be performed to increase the life of equipment, and achieve the reliability which can save the economic loss.

The standard to decide if the life of electric equipment will be ended or if there is possibility to be ended in the future, is the AC voltage characteristic which shows the insulation breakdown point in normal operating condition. The required voltage strength for electric equipment is 2-3 times the rated voltage. The Japanese Electric Central Institute states that 2E+1 kV is the amount that can cause the partial problems, in cases equipped with the protection devices such as lightning arrester or an over voltage relay[1,12]. International standard IEC216 requires as much as 50 % of the designed amount[4]. Generally, these two standards are equivalent because electric equipment using solid insulators is designed to be 4-5 times the rated voltage strength. In this paper, the over 10 year old high voltage pump induction motor was used, and the off-line insulation characteristic tests and insulation breakdown tests were performed to analyze the correlation between the data from each test.

2. EXPERIMENTAL DETAILS

2.1 Sample making

The sample induction motor has 3 phases and 6 poles, so it has 6 coil groups for each phase. Therefore, 18 samples (coil group 6 ea×3 phase) can be achieved for a motor. The connection parts of the sample upon each coil group were separated. Insulation reinforcement of the coil itself was not applied, because this study is aimed to analyze the insulation characteristics of the 10 year old induction motor.

The coil length was made long enough to prevent flash-over between the end of coil and the iron core. The insulation which is appropriate for 20 kV high voltage, was applied to minimize the leakage current effects between the end of the coil and iron core. Some samples were sprayed to observe the insulation characteristics and breakdown voltage in moist condition as shown in Fig. 1. Tests were performed over 12 hours in moist

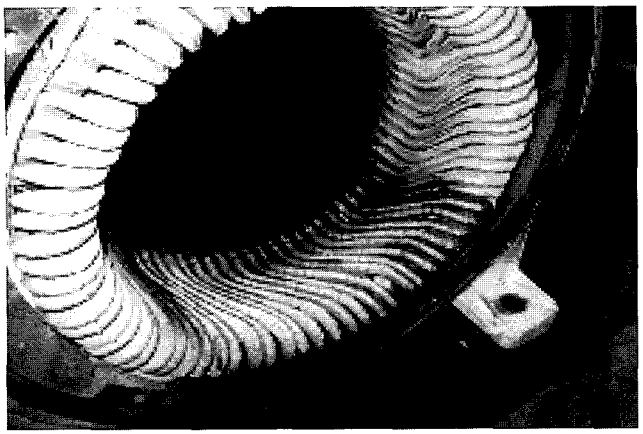

Fig. 1. Setup an experimental condition with moisture.

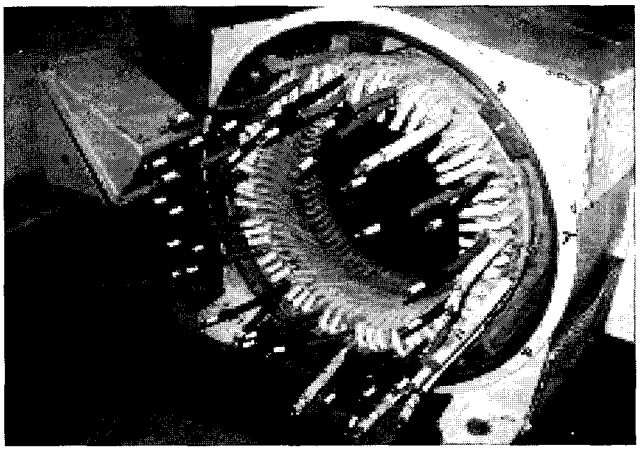

Fig. 2. The end features of the sample coils.

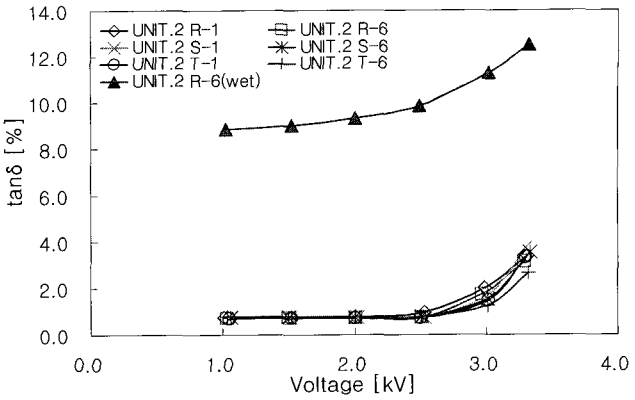

Fig. 3. The tan δ test for dry and moist samples.

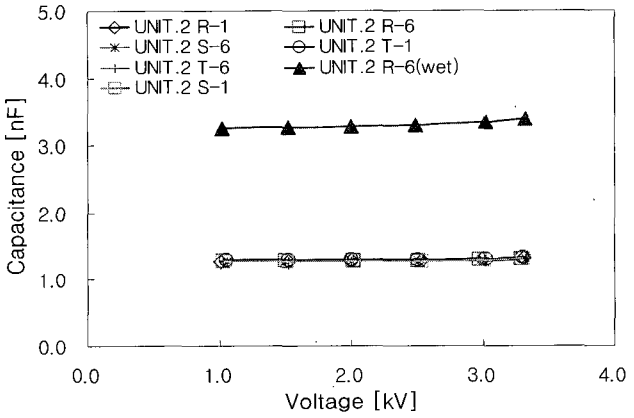

Fig. 4. The capacity test for dry and moist samples.

condition. The rest of coils except for the sample, were insulated with lead lines for ground connection, to prevent an induction discharge of adjacent coils during the test. Figure 2 shows the end features of the sample coils.

2.2 Test methods

At first, nondestructive test was performed for each sample, and then the data were collected from the step-by-step test using the 60 kV AC withstanding tester. The AC and DC voltage were impressed on each to test nondestructive characteristics of the sample. International standard such as ANSI/IEEE 434 and ASTM D149-97a, was used to obtain the variable test results. The initial test voltage was 7 kV. The voltage was raised quickly to the initial voltage, and then raised to the breakdown voltage with the 1 kV raising and holding method.

3. RESULTS AND DISCUSSION

3.1 Nondestructive test

The nondestructive insulation characteristic test was performed on the stator coil of the 2 inductor motors. The DC and AC voltage was impressed between the solid and ground, and the insulation resistance and polarization index were measured with the digital insulation tester. The dielectric loss test was performed to measure the dielectric loss with schering bridge, and partial discharge test was performed with 10 nF coupling capacitor and PD Detector. Insulation characteristic test was performed to find out the deterioration characteristic differences by voltage increase. The insulation characteristic test was performed on the highest voltage parts R-1, S-1, T-1 and the lowest voltage parts R-6, S-6, T-6. Consequently, there were no differences found. In the case of the 3.3 kV inductions motor, the voltage between the solid and ground in operating condition was 1.9 kV which can affect the main coil insulator. Therefore,

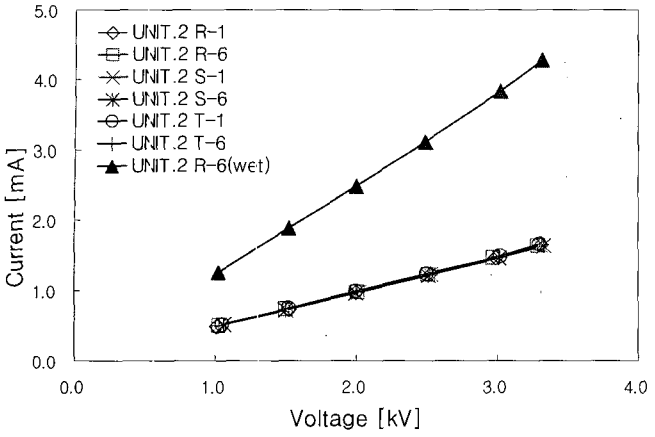

Fig. 5. The AC current characteristics for dry and moist samples of unit A.

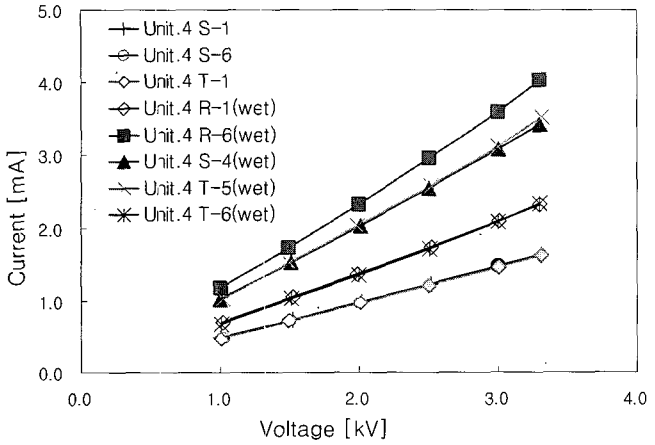

Fig. 6. The AC current characteristics for dry and moist samples of unit B.

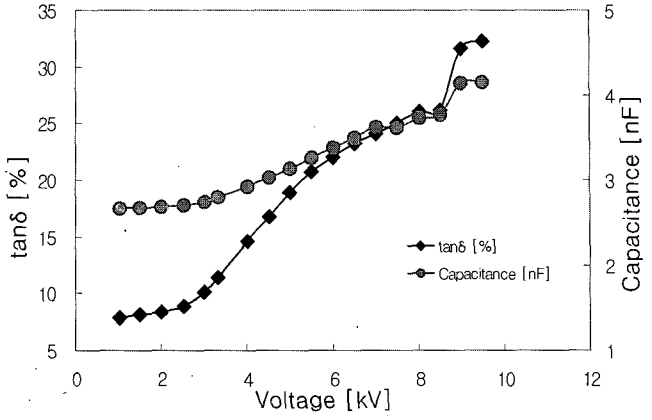

Fig. 7. The tan δ characteristics at breakdown voltage.

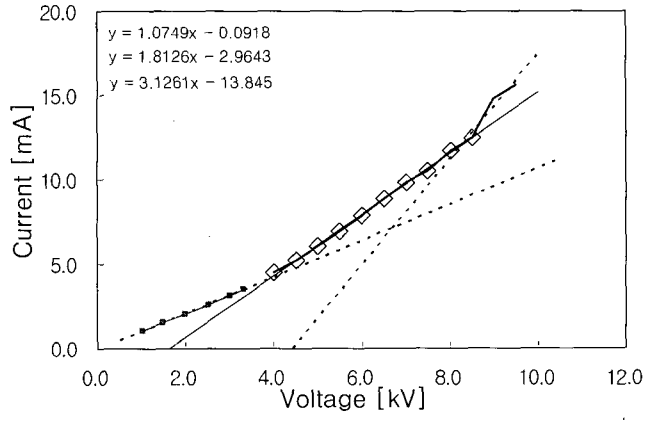

Fig. 8. The AC current characteristics at breakdown voltage.

the insulation deterioration of the 10 year old induction motor under the rated voltages of 3.3 kV was not serious.

Some samples were wetted for 12 hours to compare insulation characteristics between dry and moist samples. In the dielectric loss test, the dry sample showed satisfied condition within a standard of 3.5 % as shown in Fig. 3. On the other hand, the moist sample showed 10 % over the standard rate. Moreover, the moist sample showed high electric capacity values compared to the dry sample. This means that the dielectric loss as shown in Fig. 4 and the electric capacity test responses well in moist condition because of the electrical characteristic changes due to the water properties of high dipole moment and high relative dielectric constant.

As shown in Fig. 5 and Fig. 6, moist samples in the AC current test are showing the high AC current and steep inclination according to the moisture amount, compared to the dry one. This can be explained by the reason of the increased leakage current and dielectric loss effects due to moisture. In partial discharge tests, the partial discharge of the moist samples starts to occur at lower voltages compared to the dry samples.

3.2 Destructive test

The insulation breakdown occurred at 10 kV during the dielectric characteristic test and AC current test on the T-5 moist sample of No 4 inductor. Dielectric characteristic test results showed that the first sudden increase point of AC current occurred at around 3 kV and the second sudden increase point of AC current and dielectric loss occurred at around 8.5 kV as shown in Fig. 7 and Fig. 8.

The sudden increase point in AC current occurs from the stage before the insulation breakdown. Consequently, it can be confirmed that the second sudden increase point has a very close correlation with the breakdown voltage.

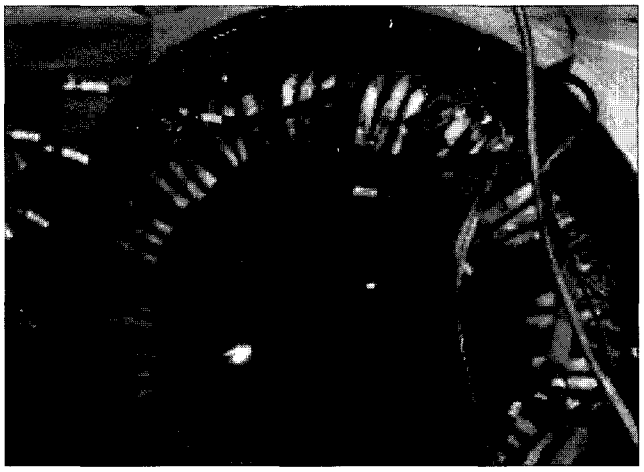

Fig. 9. Arc occurrences between the insulator and iron core on the end of windings before the sample's insulation breakdown.

The partial discharge increases steeply over 2.6 kV, it is equal to the steep increase of AC current and dielectric loss. Therefore, it means that the partial discharge characteristic has a very close correlation with the partial discharge loss caused by the numerous air voids in the insulator.

The AC breakdown of the samples occurred around at 17-19 kV, which is 2.2-2.5 times the required dielectric strength (2E+1 kV, 7.6 kV) in operating condition, and 5-6 times the rated voltage 3.3 kV. The designed dielectric strength of the induction motor coil is generally 4-5 times the rated voltage, so this sample can be assumed to be safe from the insulation deterioration.

Moist samples were somewhat different in accordance with the moisture amount. The insulation breakdown of moist samples occurred at 12-14 kV which is 4-5 kV lower than dry sample. This means that moisture significantly affects the deterioration of insulation strength and insulation breakdown. The breakdown characteristic test, which was aimed to check the long operating time effects, was performed with the AC current just like the nondestructive tests on the high voltage point and central point of the coil sample. Consequently, the breakdown characteristic of the AC voltage showed no differences from the results of the nondestructive test. All samples showed that the isolation breakdown occurred at the end of the coil. Figure 9 shows an arc occurrence between the insulator and iron core on the end of coil right before the sample's insulation breakdown. These test results show that the end of the coil is the weakest part for the insulation breakdown.

4. CONCLUSION

Results of the nondestructive tests and the insulation breakdown tests are as follows.

The second AC current sudden increase point, which occurs right before the insulation breakdown, is around at 8.5 kV on nondestructive and destructive both. It means that the insulation diagnosis test and the AC breakdown test have a very close correlation. The insulation breakdown of moist samples occurs at 12-14 kV which is 4-5 kV lower than dry, even though there are some differences according to the moisture amount. It means that the moisture affects strongly to the insulation breakdown and insulator deterioration. The partial discharge of the moist samples occurred at lower voltages than dry one.

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