주상변압기용 절연지의 가속열화 후 전기적 특성

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Electrical Characteristics of Insulating Paper for Pole Transformers after Accelerated Ageing

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Abstract - In this paper, the electrical characteristics of insulating paper, for pole transformers, subjected to accelerated ageing were observed and the results were compared with those of virgin insulating paper.

For the experiment, insulating materials for pole transformers were enclosed together in an oil bath and thermally aged under the real pole transformer operating conditions. After the accelerated ageing of the insulating materials, the dielectrics were measured and compared with the results of the virgin ones.

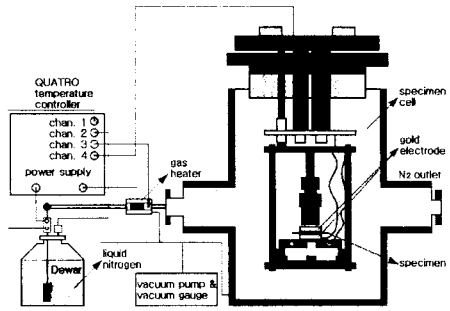
1. Introduction

Kraft paper employed in present as main insulating material for pole transformers and Nomex paper which has recently been adopted only to dry type transformer have their own merits and demerits. The electrical characteristics of the insulating paper are closely related to the manufacturing condition and processes, and needs the analysis and study of the insulating resistance characteristics, dielectric characteristics and breakdown characteristics[1]. Especially, since studies on kraft paper was started prior to those on transformers, lots of works have dealt with them[2] and the works on Nomex paper recently adopted to the transformers has been presented continuously[3]. When the pole transformers encounter a failure, many techniques has been used to analyze the exact cause of the failure. However, since the qualitative and quantitative evaluation of the by-product due to the failure depends on the various mechanisms of the modes and degree of the failure, the accumulation of the data acquired from the failure analysis is hardly valid.

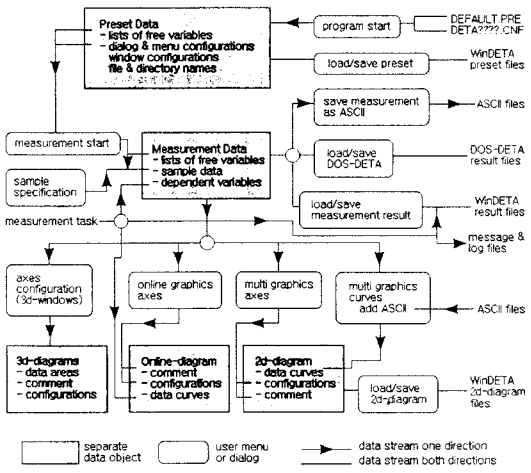
In this paper, the electrical characteristics of 2 kinds of insulating paper employed as solid insulating material in transformers were treated, which can provide the meaningful data in designing and manufacturing the transformers.

2. Experimental setup and procedure

For the experiment, an accelerated ageing chamber was constructed to deteriorate the insulating paper for pole transformers and transformer materials according to the component ratio of real transformers were put together in it, and then temperature inside the chamber was kept to 125℃ for 1 month. The aged insulating paper was selected and its permittivity and tanδ were measured by WinDETA system. The measured data were compared with the virgin insulating paper's values. Fig.1 shows the schematic of the experimental apparatus and data flow in the system.



(a) schematic of the experimental apparatus



(b) data flow

Fig.1 WinDETA system

As shown in Fig.2, the insulating paper specimens impregnated in mineral oil were chosen to measure the dielectric characteristics and dried in a dry cell for 6 hours to remove the oil component. Each specimen treated in the dry cell was installed between golden circular electrodes(20㎜ in diameter) in sample cell.

Temperature and frequency were taken as the experimental variables to the virgin specimen and the deteriorated specimen. Temperature was increased from -50℃ to 250℃ at every thermal step of 2℃. The permittivity and tanδ to each frequency were measured at each temperature with error bound of ±0.5℃ and only their typical values were shown in this paper.

3. Results and discussion

Fig.2 shows the permittivities of the virgin and aged kraft paper.

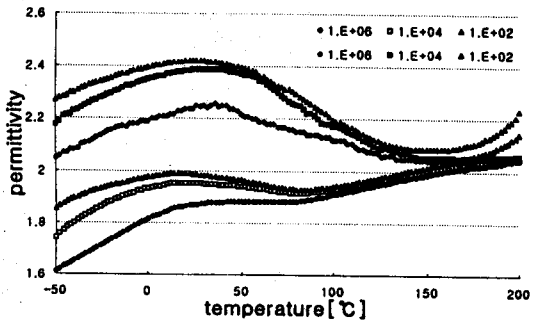


Fig.2 Permittivities before and after ageing of kraft paper(before:hollow, after:filled)

As shown in Fig.2, the permittivity of the aged kraft paper was considerably increased compared with that of the virgin kraft paper, however it was decreased with frequency. In particular, the permittivity of the aged kraft paper was partially decreased in the temperature range of 30℃~150℃, however but for the range, the permittivity of the virgin and aged kraft paper tended to be increased with temperature.

Fig.3 shows the tanδ comparison of aged kraft paper with the virgin kraft paper, measured under same condition.

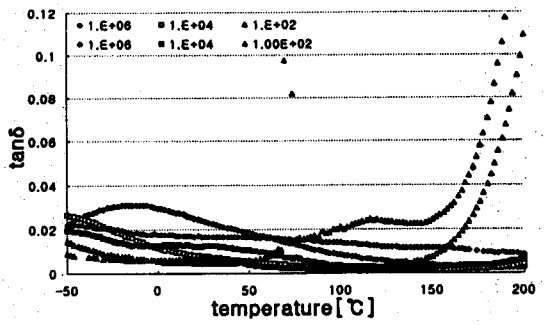


Fig.3 tanδ before and after ageing of kraft paper(before:hollow, after:filled)

As shown in Fig.3, the tanδ of the aged kraft paper was similar to that of the virgin kraft paper in the temperature range below 130℃, however it was rapidly increased at 100Hz over 130℃. And the tanδ of the aged kraft paper showed intermittently very high values over 0.5 and it was considered because the kraft paper was inhomogeneously carbonized all over the surface of the aged kraft paper.

We also measured the permittivity of the virgin and aged Nomex paper under same condition as kraft paper and Fig.4 shows the results.

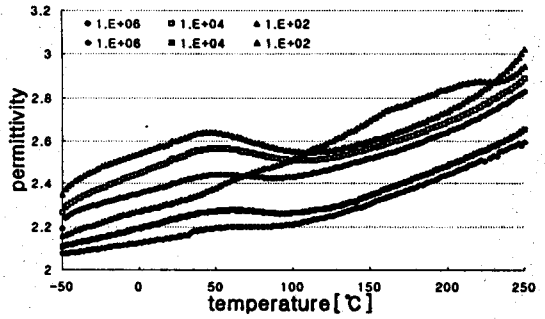


Fig.4 Permittivities before and after ageing of Nomex paper(before:hollow, after:filled)

As shown in Fig.4, the permittivity of the virgin and aged Nomec paper was increased with temperature, but decreased with frequency. And the permittivity of aged Nomex paper generally tended to be somewhat decreased compared with that of the virgin Nomex paper, however in the temperature range of only 110℃~230℃, the permittivity at 100Hz of the aged Nomex paper was higher

than that of the virgin Nomex paper. In particular, the permittivity at low frequency before and after ageing tended to be abruptly increased around 230℃ and it was considered that Nomex paper had been developed as 220℃ class insulating material[4].

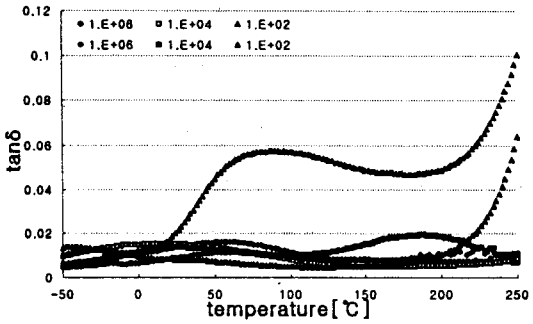


Fig.5 tanδ before and after ageing of Nomex paper(before:hollow, after:filled)

As shown in Fig.5, tanδ of both virgin and aged Nomex paper was below 0.02 at high frequency, however tanδ of the aged Nomex paper was very increased compared with the virgin Nomex paper, at low frequency in the temperature range over 0℃. Particularly, in the temperature range of 60℃~90℃ which can be considered real operating temperature of pole transformers, the tanδ of the aged Nomex paper showed a local peak value and it means the total losses of the transformers may be increased when the Nomex paper is aged. The tanδ of both virgin and aged Nomex paper had much higher values just passing the temperature of 220℃ and it is considered because the withstand temperature of Nomex paper is 220℃.

4. Conclusions

After deteriorating the insulating paper for pole transformers in the accelerated ageing chamber, we measured the dielectric values such as permittivity and tanδ. By comparing and analyzing the values, this paper concludes as follows;

(1) In case of kraft paper, the permittivity after ageing was more increased than that before ageing. In contrast with these results, in case of Nomex paper, the permittivity after ageing was somewhat decreased compared with that of the virgin Nomex paper.

(2) The tanδ of kraft paper after ageing was generally similar to that before ageing, however it was rapidly increased at low frequency in the range of temperature over 220℃. In addition, tanδ of the aged kraft paper intermittently showed irregular values and it is considered because the carbonization due to the ageing on the surface of Nomex paper is not uniformly taken place. The reason why such phenomena did not occur on the surface of Nomex paper was that Nomex paper was originally developed as 220℃ class insulating material and the ageing temperature below the boiling temperature of mineral oil could not affect the ageing of Nomex paper in this experiment. However, the partial discharge in transformers may make very hot spots over 220℃, which makes Nomex paper thermally aged.

[References]

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