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무감독분류 기법에 의한 부분방전 데이터 분석*

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Partial Discharge Data Analysis with Unsupervised Classification

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〈Abstract〉

This study described partial discharge(PD) distribution analysis between the XLPE(Cross-Linked PolyEthylene)and EPDM(Ethylene Propylene Diene Monomer) interface with unsupervised classification. The ϕ-q-n patterns were analyzed using phase resolved partial discharge(PRPD). K-means cluster analysis forms a cluster based on similarities and distances among scattered individuals, and analyzes the characteristics of the formed clusters, dividing the multivariate data into several groups according to the similarity of each characteristic, Is a statistical analysis that makes it easier to navigate. It was confirmed that the phase angle of the cluster with the maximum discharge charge was concentrated around 0 ° and 180 ° at 30 kV after the initial phase distribution localized around 90 ° and 300 ° expanded to the whole phase angle according to the voltage rise. The Euclidean distance between the center of gravity and the discharge charge in the Φ-q cluster increased with increasing applied voltage.

Key Words : Partial Discharge, Unsupervised Classification, PRPD, K-means Clustering

Ⅰ. 서론

Partial discharge occurs when a defect such as a void or foreign matter exists in the insulator. Since the energy amount of the partial discharge pulse is fine, the occurrence of the partial discharge is repetitive every cycle and its position is locally densely packed. It is known as the main cause. Therefore, partial discharge measurement has been attracting attention as an insulation diagnosis technology to prevent accidents. Particularly, in order to analyze the partial discharge phenomenon occurring in the connection part which is a vulnerable part in the cable installation, it is necessary to construct an optimum electrode system and examine the partial discharge characteristic generated in the electrode system.

Partial discharge measurement has become an important study for the diagnosis of the insulation

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condition of high voltage power facilities, while F. H. Kruger presents various detection methods of discharge signals. As a typical method for analyzing partial discharge data, a diagnostic system using an expert system is mainly developed. However, since the developed system is not reliable enough by non-experts, it can only be diagnosed by experts and the reliability of diagnosis results is insufficient. In addition, since the partial discharge inside the insulator due to the complex mechanism has a very irregular tendency and shows characteristics inherent to each measurement environment and measurement apparatus, it is very important to find an appropriate analysis method for diagnosis from the partial discharge.

On the other hand, K-means clustering analysis forms a cluster based on similarities and distances among scattered individuals, and analyzes the characteristics of the formed clusters, dividing the multivariate data into several groups according to the similarity of each characteristic, Is a statistical analysis that makes it easier to navigate. Cluster analysis techniques are widely used in engineering, statistics, pattern recognition, and so on because they have the advantage of being able to obtain meaningful data structures without defining roles for variables and being applicable to almost all types of data. Particularly, the partial discharge characteristic has been reported to be very important because it is accompanied by statistical irregularity with a lot of data. Therefore, in this paper, to develop an data acquisition system for insulator interface, we analyze the population distribution of phase and frequency (Φ-n), phase and discharge charge (Φ-q) with unsupervised classification.

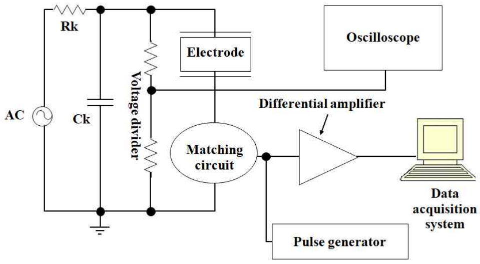
In this paper, we model the interface between the cable insulation material XLPE and EPDM, which is the main part of the fault, and generate the artificial defects. Then, we analyze the cluster distribution of the partial discharge by K-means clustering.

Ⅱ. Data Acquisition

<Fig. 1> shows a block diagram of the measurement system. The AC voltage of 60Hz applied from the power source through the slicer is input to the primary side of the transformer and boosted. The coupling capacitor Ck(500㎊) and an electrode to generate a partial discharge pulse. Since the partial discharge pulse signal generated about 1 ㎲ which can be input to the data acquisition system through the detection impedance. In addition, varistor and Zener diodes are inserted in parallel to detect the impedance when the insulation breakdown occurs. In detecting the partial discharge pulse signal, the frequency component signals of power 60Hz To remove the frequency component of 60Hz. In addition, when using a high-pass filter, an undershoot of a reverse polarity pulse is generated, which is mistakenly recognized as a partial discharge signal, and the data acquisition system may accept it.

In order to obtain the phase information of the partial discharge, a zero cross signal of the secondary side of the slidax was input to the data acquisition system.

<Fig. 2> is the data acquisition system. When a partial discharge pulse signal and a zero cross



<Fig. 1> Block Diagram of System

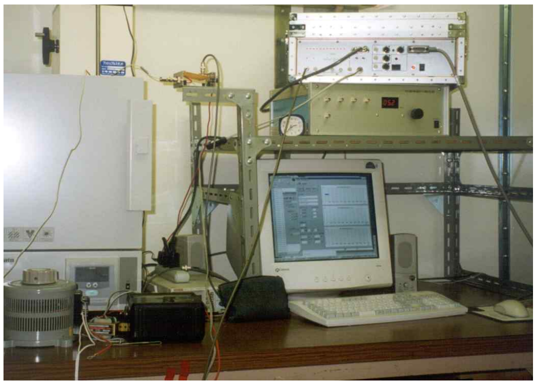
signal that have passed through a differential amplifier are input to the data acquisition system.

In order to remove noise from the outside such as a power source and amplify a weak signal, a 12 bit which is 4096 division(ZCC), an amplitude of PD pulse(AMP), and a phase of PD pulse(PHA) signal, which are three digital signals having a general purpose interface board and stored in the hard disk. The phase angle(ϕ)-discharge charge quantity(q) -Frequency of occurrence(n) pattern and various parameters were calculated using the phase information and the partial discharge charge amount data. Experiments were repeatedly performed by increasing the applied voltage to 10kV and then measuring the discharge pulse for 600 cycles and increasing linearly to 30㎸ in units of 10㎸[2-3].

Ⅲ. PRPD Characteristics

Partial discharge is a time-varying pattern whose discharge amount changes with time. It can be classified into a space pattern with little change with time through a feature extraction and a mapping process.

This feature extraction and mapping process is very important in studying the characteristics of partial discharge distribution according to kinds of defects. In this section, the measured PD pulse data is superimposed on phase with acquired data having only size and time information as shown.

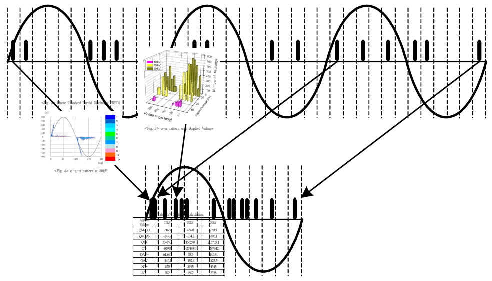


<Fig. 2> Data Acquisition System

The overlapped partial discharge signal is divided into ϕ-q-n, and analyzed using a phase resolved partial discharge(PRPD) analysis in <Fig. 3>.

<Fig. 4> is the ϕ-q-n pattern at 30kV. The ϕ-q-n distribution is generated a discharge at 0 ° to 139 ° phase in the positive polarity region. The average discharge charge was 49pC and the number of occurrences was 4,345. In the negative polarity region, the discharge occurred in the 182 ° to 317 ° phase, the average discharge charge was -123pC, and the number of occurrences are 2,328.

<Fig. 5> is the ϕ-n pattern with Applied Voltage. In the case of 10kV, the maximum number of objects is 67 at the positive polarity region and 94 at 264 ° in the negative polarity region. When 20kV is applied, it contains the largest number of 736



objects at 56 ° in the positive polarity region and the largest number of 407 objects at 247 ° in the negative polarity region. In case of applying 30kV, the maximum number of objects is 673 at 67 ° in the positive polarity region and 538 at 241 ° in the negative polarity region.

The minimum and maximum deviation of the number of discharge occurrences due to the applied voltage rise was slightly reduced from 4.2 to 5.4 in the positive polarity region, but greatly decreased from 18.8 to 5.2 in the negative polarity region.

Ⅳ. Statistic Calculation and Analysis

Maximum charge(QMAX) - Maximum value of discharge that appear during 1 cycle.

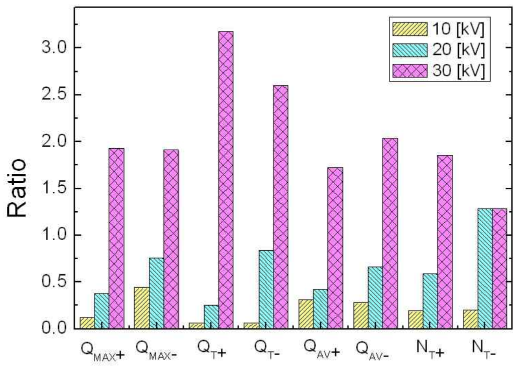
Total charge(QT) - Total value of discharge that appear during 600 cycles

Average charge(QAV) - Q divides whole discharge quantity of partial discharge

Number of discharge(NT) - Total number of discharge that appear during 600 cycles

<Table 1> is the result of statistic calculation with applied voltage.

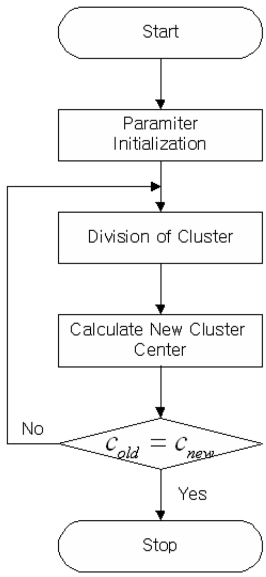
As a result of examining the Ratio value to quantify the variation of various statistical quantities according to the pressure change, the magnitude increases with the increase of the applied voltage as shown in <Fig. 6>. In particular, when the Ratio of the total discharge charge is 10kV, the positive and negative polarities are 0.06 and 0.06, respectively. When the applied voltage is 30kV, the positive and negative polarities are 530% And 470%, respectively. However, when the Ratio value of the total discharge pulse number was 10kV, the positive and negative polarities were 0.19 and 0.20, respectively. However, when the voltage was 30kV, the positive and negative polarities were 1.85 and 1.28, respectively. As compared with the increase 645% in total discharge charge. This means that the amount of discharge per discharge increases with the increase of the voltage. It is considered that the defects of the semiconducting foreign matter are less affected by the charge of the polarity due to application of the high electric field.



<Fig. 6> Statistic Quantities Ratio

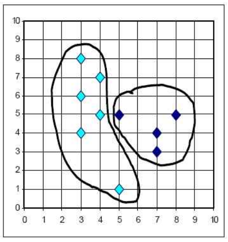
<Fig. 7> is a K-means algorithm flow chart in which the data are assigned to the nearest cluster among the temporary mean vectors of the clusters(C_{old}). After all the data are classified in this way, the cluster is calculated as a new cluster center(C_{new}). This modified cluster center is used as the basis for reclassifying data. The iteration of the algorithm lasts until the cluster center position no longer changes.

The process of the K-means algorithm can be expressed as shown in <Fig. 8>. (a) is the stage 1 process, where the entire data is randomly divided into two clusters. (b) shows the population centered by means of two clusters divided into stage 2 processes. (c) is the stage 3 process, which is the disassembly of the objects divided into the clusters to re-classify them into objects near the center newly obtained in stage 2. (d) shows the process of forming new clusters by classifying each object even in the new cluster center. The stage 4 process repeats the previous steps and finds the most optimal clusters until there is no further change in the clusters.

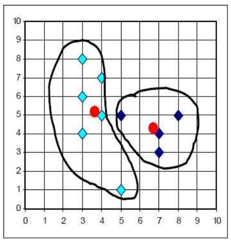


<Fig. 7> Flow chart of K-means Clustering

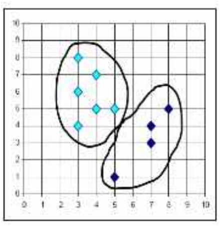
<Fig. 9> shows the cluster center distribution of ϕ-q function. The maximum number of objects is 141 at 23pC in the positive polarity region and 94 at the -454pC in the negative polarity region when 10kV is applied. 20kV contains the largest number of 736 objects at 21pC in the positive polarity region and 407 at the -33pC in the negative polarity region. In the positive polarity region with 30kV, it contains the largest number of 763 objects at 20pC, and the negative polarity region contains the largest number of 538 objects at −39pC. As the applied voltage increased, the difference between the minimum and maximum values of discharge was increased from 146pC to 475pC in the positive polarity region and from 69pC to 179pC in the negative polarity region.



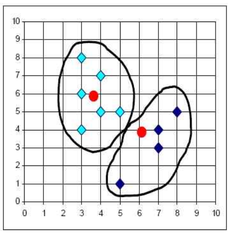
(a) stage 1



(b) stage 2



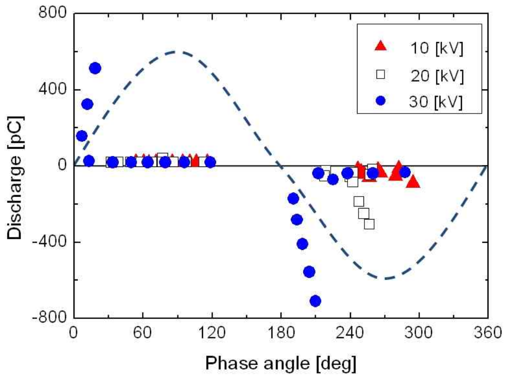
(c) stage 3



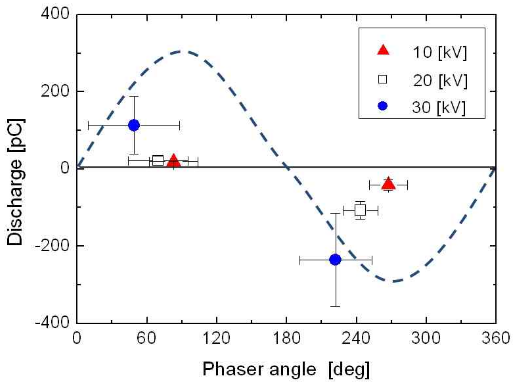
(d) stage 4

<Fig. 8> Stage of K-means Clustering

<Fig. 10> shows the standard deviation of the mean center angle, phase angle, and partial discharge charge from the central distribution of ϕ



<Fig. 9> Result of K-means Clustering



<Fig. 10> Mean Value and Standard Deviation

-q function clusters. When 10kV is applied, the center of the positive polarity region is 66pC at phase 86 ° and the center of negative polarity is -144pC at phase 267 °. When 20kV was applied, the center of the positive polarity region was 95pC at phase 56 ° and the center of negative polarity was -180pC at phase 241 °. It is confirmed that the center of the positive polarity region is 110pC at the phase 51 ° when 30kV is applied, and the center of the negative polarity region is -228pC at the phase 223 °. The phase angle standard deviation of the positive polarity region increased from 18.6 to 39.1

with the applied voltage increased from 10.2 to 29.2, and the partial discharge charge standard deviation of the negative polarity region increased from 39.8 to 49.9, The partial discharge charge standard deviation of the region increased from 33.3 to 41.6.

Ⅴ. Conclusion

As a result of cluster analysis of the partial discharge distribution of interface defects of XLPE and EPDM using data acquisition system, the phase angle of clusters with the largest partial discharge occurrence number in the Φ-n cluster and the largest discharge charge in the Φ-q cluster As the voltage increased, it shifted to about 0 ° in the positive polarity and to about 180 ° in the negative polarity region.

When the partial discharge data obtained by the data acquisition system is clustered, the phase angle with the largest partial discharge charge amount and the highest number of partial discharge occurrences are 78 ° and 67 ° in the positive polarity region at 10 kV, respectively, 265 ° and 264 °, respectively. As the applied voltage increased, it was confirmed that the difference was 20 ° and 67 °, 214 ° and 241 °.

The Euclidean distance between the center of gravity and the discharge charge in the Φ-q cluster increased with increasing applied voltage.

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