Statistical Analysis of Partial Discharges

E.Onal, U. Aktepe and Y. Baygar

Abstract— **In this paper, a statistical analysis method is applied to partial discharge (PD) measurements for the quality assessment of electrical insulation in high-voltage equipment. The rod plane electrode system in magnetic field and non-magnetic field is selected as test environment. This data helps to showing scattering and concentration of values. In this study, the partial discharge values of electrode system under magnetic field is higher and more scattering than that of electrode system under non-magnetic field. Moreover, Box and Whisker method used in this study gives a lot of information compared other statistical methods.**

Index Terms—**Partial Discharges, Box-Whisker Plot, Magnetic Field, High Voltage.**

I. Introduction

EFFICIENT generation, transmission and distribution of electricity is one of the important issues of electrical engineering. The stability of the electrical system is related to the state of high voltage components used in system. Problems that may arise in high voltage components can affect the stability of the system and this will lead system not to get desired efficiency. One of the events that can cause problems for the components of system is electrical discharges. The electrical discharges which is the state in which the insulating material becomes electrically conductive are studied in two groups (complete and partial discharges). Partial discharge is electrical discharge which does not fully bridge the insulation. Partial discharge is called as a localized dielectric breakdown. Although partial discharges are usually small in size, they can cause growth problems and can cause the material to deteriorate. Partial discharge is a generic term for discharge events that are not completely realized. The concept of partial discharge includes different groups. These groups can be examined in internal discharges, surface discharges, corona discharges and electrical treeing [1-4]. A lot of study has been done from the past on the subject of partial discharge. Although there are many studies on partial discharge concept, there are few studies on the effect of the magnetic field [5-9]. In this study the effects of the magnetic field on the partial discharge signals are investigated statistically.

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II. Experimental and Statistical Research About Partial Discharge

0.220/100 kV test transformer, coupling capacitance having the value of 1nF, measuring impedance and measuring device are used at experiments. Firstly, the rod-plane electrode system is selected to form and the test setup is established. Electrode gap spacing is selected as 35 mm. By selecting this electrode gap spacing, partial discharge analysis can be performed more safely without breakdown. The rod electrode used in the experiments is 67 mm long, 2 mm thick and chrome plated. In addition, the radius of the tip of the rod electrode is 1 mm. The plane electrode is 10 mm thick, 75 mm in diameter and has a radius of curvature of 3 mm.

Secondly, the high voltage test system to be applied to the selected electrode system is set in two different ways. A high voltage test transformer, a resistor and a capacitive voltage divider are used to apply high alternating voltage to the electrode system. On the plane electrode, plexiglass box with adjustable range is placed. The plexiglass box used for the magnetic field setup is also used in this setup to be identical. Plexiglass box thickness is 3 mm. The distance between the two outer surfaces of the plexiglass to be used in the experiment is selected as 10 mm. The electrical measurement is carried out by means of a partial discharge measuring device (Haefely DDX-9121) and a computer via a coupling capacitor connected in parallel with the high alternating voltage generation test system. Two neodymium cylindrical magnets are added to the system after the partial discharge inception voltage obtained in the absence of the magnetic field. Cylindrical magnets are added to the plexiglass box to create a changing magnetic field. In the analysis part, the data obtained from the tests performed are examined. At this case magnetic field is approximately 100 mT. Firstly, the effects of the magnetic field on the partial discharge inception voltage are investigated. Data obtained in the case of no magnetic field for different vertical and horizontal openings and data obtained in the presence of magnetic field using cylindrical magnets are compared in terms of partial discharge inception voltage in graphs. In this study, the gap of plexiglass box is selected as 10 mm. At here, the first aim is to find the effect of magnetic field on partial discharge and secondly to examine the data statistically as using box and whisker method. When the obtained graphs are examined, it is found that the presence of the magnetic field lowers the value of the partial discharge inception voltage. Since the magnetic flux density is greatest when the distance between the magnets is the smallest, the greatest effect is seen in the horizontal opening of 10 mm. As the distance between the magnets increases, the magnetic flux density decreases, so the effect on the partial discharge starting voltage also decreases. The percentage reduction in the partial discharge inception voltage values is also determined by changing the magnetic flux density values. The largest decrease in the percentage of the partial discharge inception voltage value is found to be the value at which the magnetic flux density is the greatest.

It is important to note that statistical parameters calculated from various discharge distributions can help to determine the type of discharge source and the development of its activities. Therefore the results may be useful for the improvement of PD recognition fingerprints. Thus, successful PD recognition must be based on reliably performed measurements.

In the high-voltage laboratory, an experiment is conducted under the examination of the effect of magnets on partial discharge. Two separate data sets are obtained in two different experiments. Firstly, when there is no magnetic field, partial discharge signals are produced by increasing the voltage with a variac. The discharge magnitude and voltage values of each passing time of the generated signals are recorded on a computer with a partial discharge measuring device. Secondly, this time the same experiment is carried out with the magnetic field and the data are obtained. The discharge magnitudes (pC) due to the increased voltage for two experiments are shown in Figure 1.

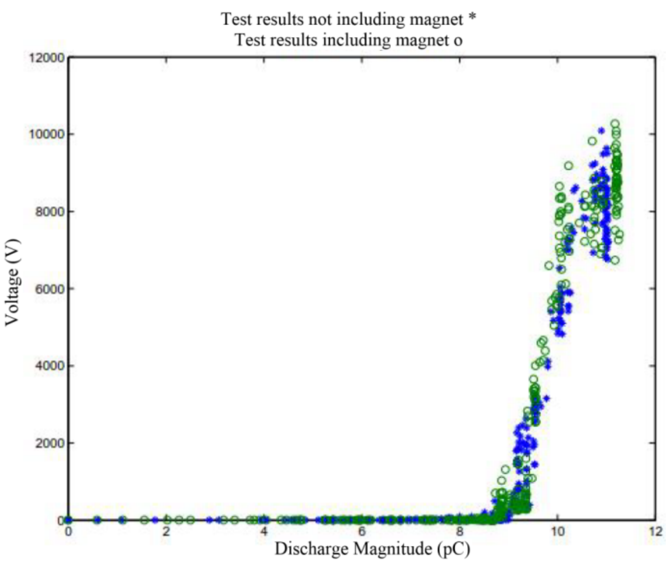

Fig. 1 Voltage-Discharge magnitude graph

Analytical methods used in partial discharge studies are generally Normal distribution, Log-normal distribution, Exponential distribution, Gamma distribution, Rayleigh distribution, Gumbel distribution and Weibull distribution. The data is gathered, organized, computed and interpreted in order to perform a statistical research or survey [10]. There are several ways of representing statistical data which include tabular representation as well as a graphical representation. In statistics, various different graphical methods are explained. For example - line plot, scatter plot, histogram, frequency polygon, ogive etc. There is one more useful graph which is known as a box and whisker plot. The Box and Whisker Method is a graph that shows the graph data according to the central distribution. In statistics, it is assumed that the data points are grouped or clustered around a value called central value. The box and whisker plot contains boxes and tails called whiskers. A box contains the highlight points, or central values i.e. the middle half of the given data points. The whisker reflects the other half of the data points. Box and Whisker Method is shown at Fig. 2 schematically.

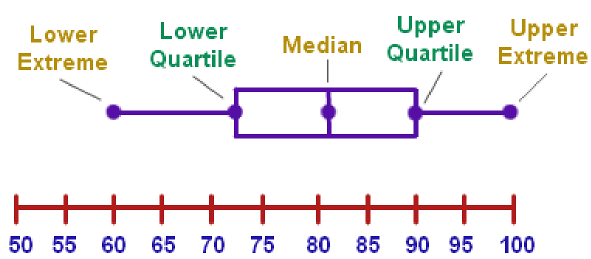

Fig. 2 Box and Whisker Plot

The following studies are conducted in terms of being suitable statistical distribution,

- The applied voltage values are grouped in 0.5 kV intervals.
- Since there is quite a small number of discharges occurring at voltages below 6 kV, these measurements are removed from the dataset.

The box and whisker plot is a very convenient way of representing groups in a numerical data. These plots help in reflecting the differences between data points which are made without assuming the underlying statistical distribution. Box and whisker plot is very useful in understanding distribution of the data and its quartiles. They summarize data from multiple sources and display the results in a single graph. Box and whisker plots allow for comparison of data from different categories for easier, more effective decision-making [11]. A Box-Whisker chart is drawn for each experiment with the new data set as Figure 3 and Figure 4.

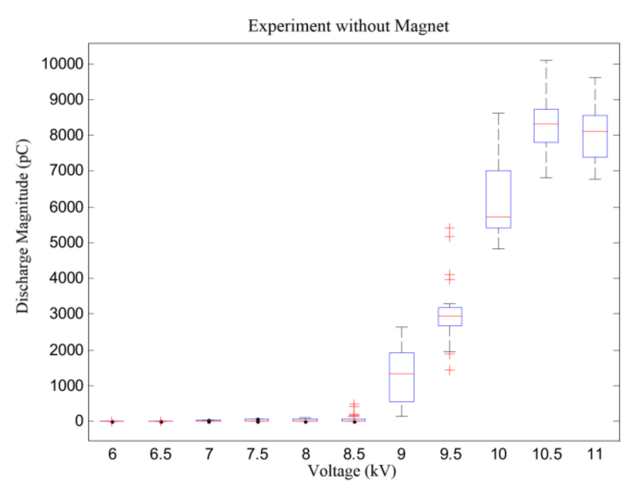

Fig. 3 Box-whisker graph for the experiment without magnet

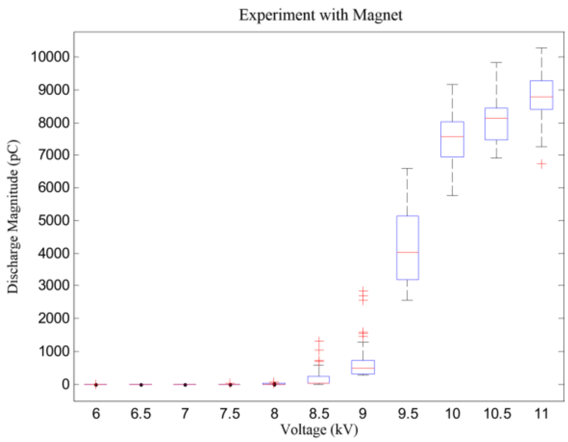

Fig. 4 Box-whisker graph for the experiment with magnet

The results of two experiments are required to be on a common scale for comparison and evaluation. Therefore,

- The experimental voltages and the discharge magnitudes of these voltages, which are rarely seen in discharges (V < 8 kV), have been removed from the data set. To cut the upper limit from a certain point, 11 kV<V voltages and the discharge amplitudes of these voltages are also subtracted from the data set.
- The measurements obtained from the voltage level after the voltage increase is stopped are removed from the data set.

By using the existing data sets, a curve of the third order is formed for the magnetic and non-magnetic states and plotted together with the actual data as in Fig.5 and Fig.6.

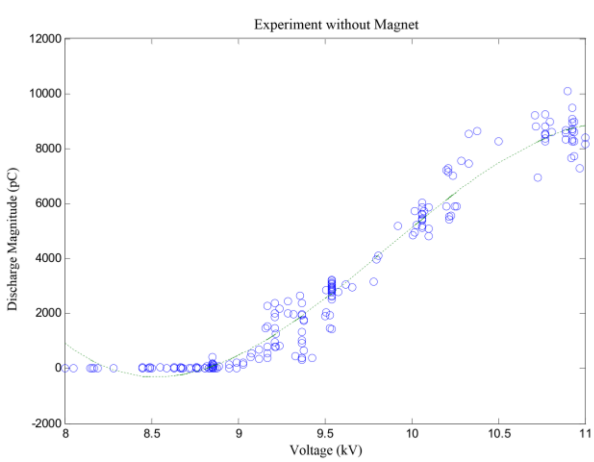

Fig. 5. Curve fitting in the experiment without magnet.

The curve fitting the two experiments is shown in Figure 7 on the same graph. It is seen that the discharge amplitudes in the case where the magnet is used are larger than the non-magnet state.

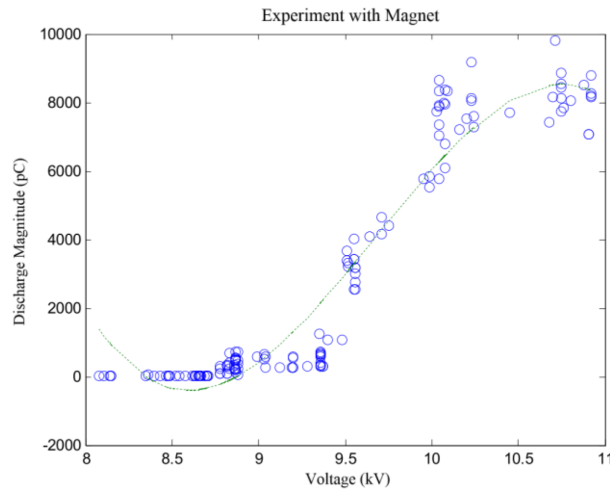

Fig. 6. Curve fitting in the experiment with magnet

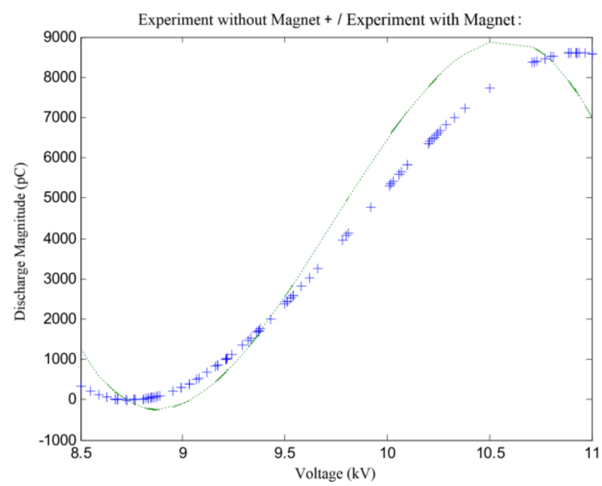

Fig.7. Curve comparison

III. CONCLUSIONS

Box plot is a graphical display that simultaneously describes several important features of a data set, such as center, spread, departure from symmetry, and identification of observations that lie unusually far from the bulk of the data. It not only consists of a rectangular box representing the inter-quartile range of the data as well as indicating the lowest and highest observations. There is a line drawn across the box at the median of the data set and whiskers that extended from each end of a box. The lower whisker is a line from the first quartile to the smallest data point within 1.5 inter-quartile ranges from the first quartile. The upper whisker is a line from the third quartile to the largest data pint within 1.5 inter-quartile ranges from the third quartile. Box plots are particularly useful in graphical comparisons among data sets, because they have high visual impact and are easy to understand. For example, figures 3 and 4 show, in each category, comparative box plots for three distribution variables. There, the statistical analysis of breakdown processes focuses basically on the estimation of the breakdown voltage. It is observed, that the breakdown-measurements have basically different dispersion than measurements in magnetic field. In non-magnetic field we see normal like distributions with relatively low scatter, in magnetic field, the distribution is different and the scatter clearly increased. Taking into account, that the PD is a breakdown-like process, it seems likely, that the measured PD parameters have different dispersion and distribution as well. So, from the results can be derived, that the distributions of the measured PD parameters in the two setups differ significantly from each other. Therefore, box plots give a graphical summary of three distribution variables used in this investigation, which help to have a close look over the data range of selected distribution variables thus identify the accepted range as well as the extreme value.

As seen figure 5 and figure 6, scattering and amplitudes of partial discharges increased. Corona inception voltage for this two cases is approximately 9.5 kV. The effect of magnetic field on corona inception voltage could not be observed. For example, at 10.5 kV, the partial discharge with magnetics field is about % 15 higher than that of without magnetic field. This study can be expanded by adding new statistical techniques.

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BIOGRAPHIES

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