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Corona Identification of Impulse Voltage and Current

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ABSTRACT

The corona effect in the power system has a dominant role in reducing the efficiency of the high-voltage lines. In this study, the current and voltage impulses, which are important in corona determination, have been examined in frequecy spectrogram base from test result. The frequency spectrogram graphs have been obtained from the current-time and voltage-time variation by Matlab program. With these graphs, frequency values have been found to provide an important clarification of the insulation performance of electrical equipment for reliable and accurate diagnosis. These values have been observed according to different conditions like pressure, polarity, and insulation ambient. This spectrogram analysis can be used to find the characteristic frequencies and eliminate the disturbance effect. The time between corona steps decrease when Sulphur hexafluoride (SF_6) gas pressure is increased. The time of second corona is close to leader's discharge time. Corona starts early when SF_6 amount is decreased in gas mixtures. The corona currents are large in the low SF_6 gas mixtures, this situation is related to the high insulation of the SF_6 gas. A feature which is dependent the frequency is not found.

Keywords: Corona, impulse, spectral analysis

Introduction

Impulse voltages are required in high voltage tests for basic investigations of stresses and breakdown in extreme stresses. This is a polar pulse of total short duration with a short rise time and longer fall time [1-3]. According to standards IEC 60060-1 and 60060-2, high voltage impulse tests ranging from several kV to MV are the foreground for electromechanical products to observe and investigate the breakdown mechanism of materials under high voltage and to determine compliance with international standards. Impulse voltages are measured by voltage dividers and peak voltmeters. At the measurement with voltage dividers, voltage dividers must be connected parallel to the unit during test. Since the voltage value is low, small peak impulse voltages can be measured without using a voltage divider. Impulse currents are measured by the magnetic probe, current transformer, and pure resistive shunt methods. Magnetic probe method is accomplished by the integration of the signal from a calibrated pickup loop coupled to the magnetic field of the impulse current. Current transformer method is accomplished by transformation of the current magnitude by means of a calibrated current transformer. Impulse voltage is a voltage that describes the voltage obtained in a building or electric line in the event of a lightning strike when a switch is turned on or off. Impulse voltages rise rapidly from zero to peak without significant vibrations and go back to zero again at a slower pace. Partial discharge (PD) can be produced by many cases. For a discharge to be recognized as a partial discharge, the induced current in the external conductor must be large enough to be perceived and generated with sufficient repetition speed to be perceived as something other than a random sound [4-6]. The detailed nature of the partial discharge waveform depends on the conditions of partial discharge generation, including gas types, gas pressures, charging, space conditions, and so on. In addition, the rise time and the fall time of partial discharge current pulse are influenced directly by electron avalanche and/or streamer/leader discharge extension, and by diffusion and recombination of charge carriers, respectively. In the physical understanding of electrical insulation degradation, analysis of partial

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discharge waveform properties contributes [7-10]. There are many factors that affect corona losses. These factors are electrical factors, field around the conductor, athmospheric factors, heating of conductors according to load current, the beginning of the corona voltage and descructive critical voltage. The conditions of these factors affect corona losses directly or indirectly. Using the Matlab program, corona frequency intervals with corona time known from the current-time graph can be found. In this study, the current-time and voltage-time graphs of the events are examined in the time-frequency domain and the frequency magnitude of the corona is estimated with the help of spectrogram. The frequency component of the partial discharge pulses is an important issue in order to understand the discharge mechanism which must be made clear to reliably and correctly diagnose the insulation performance of the power apparatus [11-14]. About time-frequency imaging, there are a spectrogram represented by Short Time Fourier Transform (STFT) and a scalogram represented by wavelet. First, the time frequency is bounded by the uncertainty principle, because it divides a signal into short segments. The first is that the time resolution and the frequency resolution are uniform as long as they have the same observation time width over the entire frequency range. The second one changes the observation time width according to frequency. In the case of low frequency, the observation time width is extended and the frequency resolution is reduced. Conversely, in the case of high frequency, the time resolution is small and the frequency resolution is large [15]. In this study, short-time Fourier transform and spectrogram method will be tried to obtain results. By definition, the STFT, a complex valued function, conveys both modules and phase information necessary to reconstruct the signal. In practice, an energy density distribution, often referred to as a spectrogram, is preferred. The spectrogram of a signal is defined as the square size of the STFT [16]. In the spectrogram, dark regions correspond to high energy and open regions correspond to low-energy values. To determine the desired value, setting the time and frequency resolution of the spectrogram and the window size have an important role.

Test Set-Up

The experiment circuit is shown in Figure 1. In the experiment circuit, Marx Generator, pressure vessel, voltage divider, electrode system and oscilloscope are used. Figure 2 shows the experimental setup at high voltage laboratory. At this test, 1MV Marx impulse generator has been used with compensated voltage dividers 1:3080. HIAS 743 oscilloscope is used in system imaging. This oscilloscope is adjustable according to IEC 61083-1 and IEC 61083-2 standards and has 12-bit real vertical resolution at 120 MS / s. This oscilloscope allows automatic evaluation of all common impulse shapes and parameters and many functionalities like difference, parameter tolerance, STFT, step response, advanced evaluation etc. [9]. The gas insulations are used like 100% Sulphur hexafluoride (SF_6) and 1%SF_6 + 99% Nitrogen (N_2) as an environment. One of the variable parameter is pressure. The pressure is selected as 1 and 2 bar (Table 1).

Table 1. Three different athmosphere conditions

	Athmosphere	Pressure
Case 1	100% SF_6	1 bar
Case 2	1% SF_6- 99% N_2	1 bar
Case 3	100% SF_6	2 bar

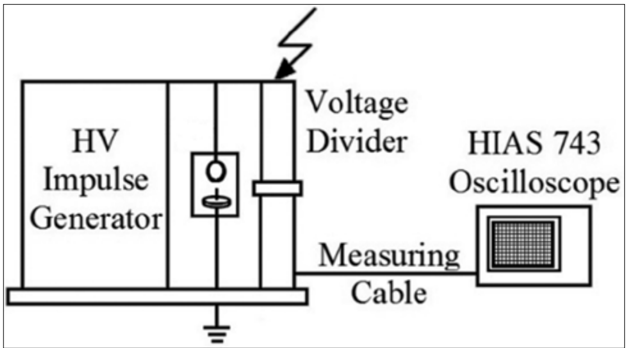

Figure 1 . Experimental set-up

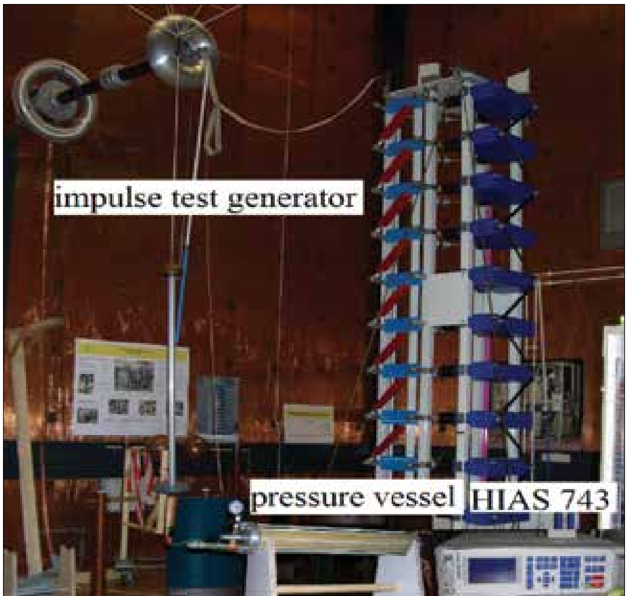

Figure 2 . Test set at high voltage laboratory

In the study, the electrode system is chosen as a spherical electrode of 5 cm diameter and a plane electrode 7.5 cm in length. In addition, the electrode system is completed by adding a 1 cm needle electrode to the plane electrode at shown in Figure 3. This is a non-uniform field representing most systems in practice. SF_6 gas is sensitive to irregularities in the field. In spite of weakness of SF_6, it is widely used today in electric power industry because of its high electrical strength and self recovery ability.

In the study, the results of the experiment are obtained under the following conditions. SF_6 and SF_6 gas mixtures commonly

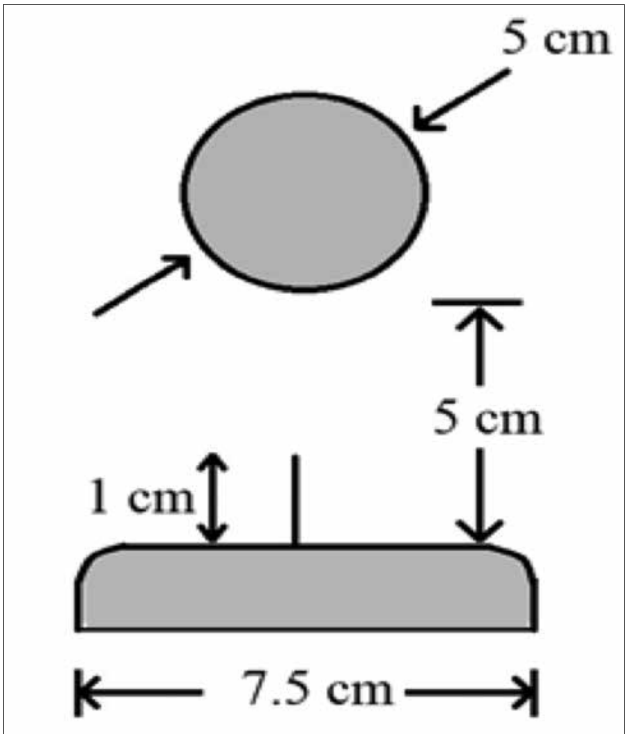

Figure 3. Electrode system

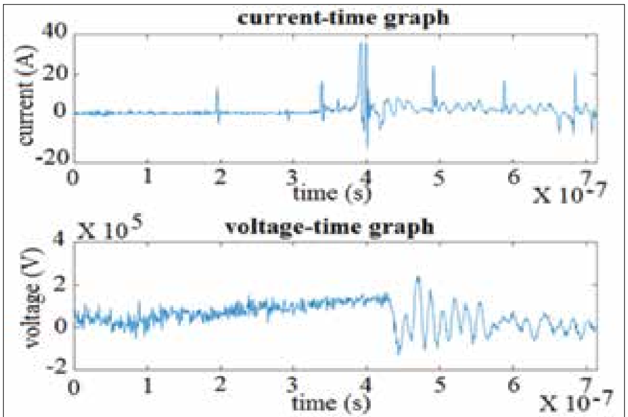

Figure 4. Current-time and voltage-time graphs of second case

used in circuit breaker as insulation ambient. Among the SF_6 gas mixtures investigated so far, SF_6-air, SF_6-CO_2 and SF_6-air appear very promising for technical applications. Although numerical methods are used in SF_6 gas mixtures, the superiority of experimental data is always present.

Spectral Analysis Using the Measurement Data

The experimental data obtained are processed in Matlab program to obtain partial discharge current-time and voltage-time graphs. Initially the peak values of the corona events observed before the breakdown discharge from the current-time graphs are determined. Then, based on the time of these values determined in the current-time graph, the values of the corona voltage are also found. Experimental data are reprocessed in the Matlab program using Spectrogram method to estimate the frequency values at corona moments and are tried to establish connection between these values and experimental data.

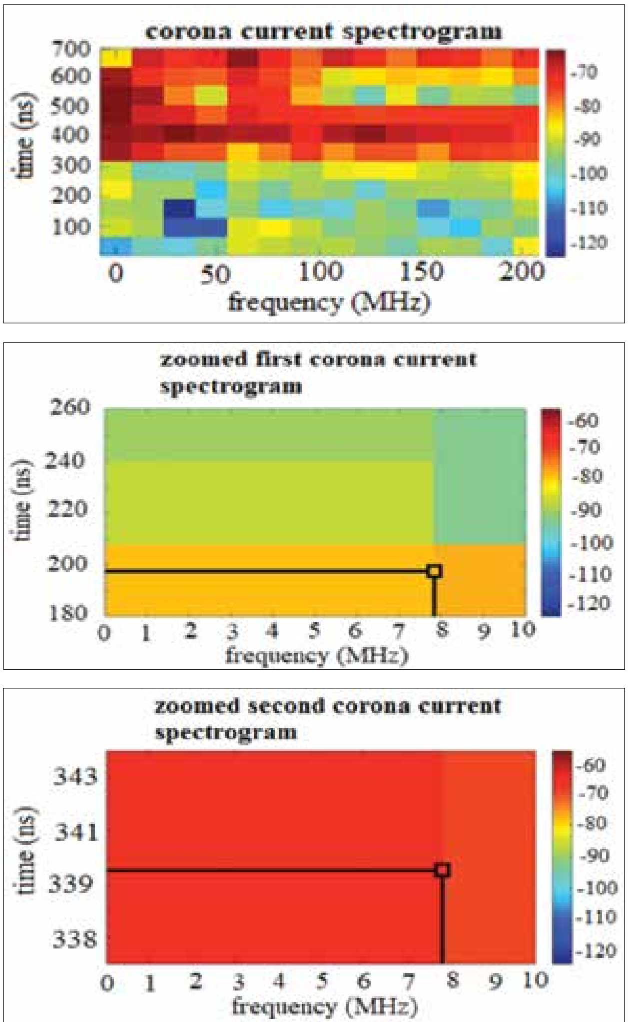

Figure 5. Second case spectogram and zoomed corona points

Case Study 1: 100% SF_6, 1 bar

At first 100% SF_6 and the pressure of 1 bar are selected. These pressures are used because the pressure intervals of the switchgears and circuit breakers used in practice are around 1-2 bar. The current value of the first corona at 4.89×10^{-7} s is determined to be 3.7625 A and the voltage value is found to be 141320,25 V. The first frequency value of this corona is found to be 6,945 MHz. The current value of the second corona at $9,48 \times 10^{-7}$ s is found to be 5,325 A and the voltage value is found to be 200020,25 V. The frequency value of second corona is seen 6,945 MHz.

Case Study 2: 1%SF_6+99%N_2, 1 bar

Due to the fact that SF_6 is electronegative gas, the prominence of SF_6 gas mixtures is gradually increasing. Nowadays, the re-

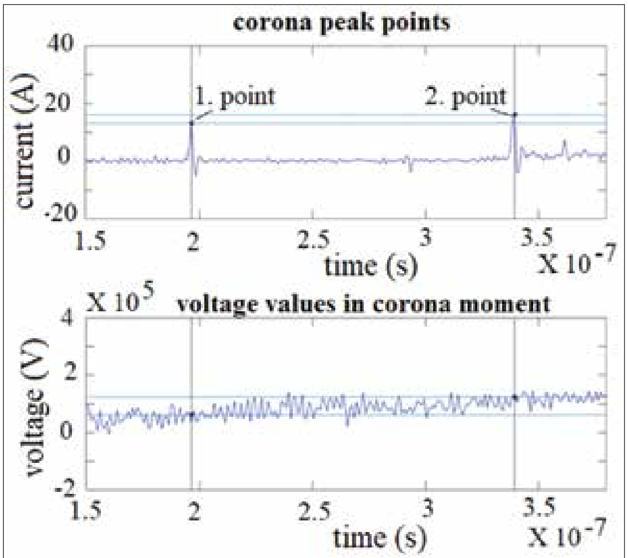

Figure 6. Current-time and voltage-time graphs of third case

Table 2. Parameters of corona moments according to cases

First corona	Case 1	Case 2	Case 3
Time (s)	4.89 E-07	1.96 E-07	7.30 E-07
Current (A)	3.7625	13.02	19.66
Voltage (V)	141320.25	61781.25	270020
Freq. (MHz)	6.945	7.82	23.44
Second corona	**Case 1**	**Case 2**	**Case 3**
Time (s)	9.48 E-07	3.39 E-07	8.25 E-07
Current (A)	5.325	16.01	3.725
Voltage (V)	200020.25	124150.5	262682.5
Freq. (MHz)	6.945	7.82	7.814

striction of use of SF_6 has brought about the use of SF_6 at low ratio. The most common of these mixtures is a mixture of SF_6 and N_2. Surveys show that the breakdown strength of SF_6 gas mixtures with few amount of SF_6 is higher than single gases. In this study, the corona discharges is examined rather than the breakdown stresses. As seen in Figure 4, the current value of the first corona at $1{,}96\text{x}10^{-7}$ s is determined to be 13,02 A and the voltage value is found to be 61781,25 V. The first frequency value of this corona is found to be 7,82 MHz. The current value of the second corona at $3{,}39\text{x}10^{-7}$ s is found to be 16,01 A and the voltage value is 124150,5V. The first frequency of this corona is seen 7,82 MHz. Environmental conditions in the second case (1% SF_6-99% N_2) play a decisive role. The second case, according to all the other cases, has the earliest first and second corona times and the largest first and second corona current values. The corona frequencies observed in the first and second case are the same.

In terms of being an example, case 2 analysis is given in detail in this study. The spectrogram analysis of the current of case 2 is shown in Figure 5.

Case Study 3:100%SF_6, 2 bar

The third case is related to 100% SF_6 and the pressure of 2 bar. The current value of the first corona at $7.30\text{x}10^{-7}$ s is determined to be 19,66 A and the voltage value is found as 270020 V. The first frequency value of this corona is 23.44 MHz. The current value of the second corona at $8.25\text{x}10^{-7}$ s is found as 3.725 A and the voltage value is found as 262682.5 V. The frequency of second corona is 7.814 MHz. The pressure parameter analysis can be performed by comparing the first and third cases. It is obvious that as the pressure rises, the corona voltage increases and the corona time also increases. Current-time and voltage-time graph of the case 3 is shown in Figure 6. The longest formation time of the first corona is seen in the third case. Also the biggest corona voltages are seen in this case. In this case, the first corona frequency is higher than the other cases and the second corona frequency is close to the other cases. According to the second case where both the environment and the pressure are different, in the third case, the current value formed by the first corona is larger and the current value formed by the second corona is larger in the second case. The largest first corona current value is seen in the third case, while the second largest corona current value is seen in the second case.

The results obtained from spectrogram analysis are suitable for the breakdown mechanism of the SF_6 gas mixture. The breakdown voltage is increased by the pressure. As pressure increases, the duration of breakdown also increases. The main focus here is on the corona frequencies. The frequencies of the corona can give us an idea of the cause and character of the corona. The values determined in the direction of all these graphs are given in the Table 2 below. At this study first and second corona inception values are obtained. From this data, standad deviation, mean value and 50% breakdown value can be computed. Moreover the electrical field near the sphere electrode (high voltage electrode) can be calculated via the Comsol Software Program. This proposal for detection of the corona impulse provides better results in removal of wideband noise, yielding a significant reduction of background noise for impulse measurement and breakdown analysis. The wavelet based decomposition analysis is a superior method for extracting noise. This method gives charge, phase, frequency and time information of corona signals.

Conclusion

In this study, current, voltage impulses, corona phenomena are investigated in spectrogram base. With the data obtained from the test results, current-voltage / time and spectrogram graphs are obtained with Matlab program. With these graphs, frequency values which have an important place in order to clarify the insulation performance of the electrical materials for the reliable and correct diagnosis are estimated. It has been observed that these values react differently depending on different pressures, environments, conditions, and the values of current, voltage, time and frequency are differentiated. As a result, the corona spectrograms are used to find the source of noise and to suppress this noise. By examining the frequency spectrograms, the source of noise can be determined from the noise frequencies. The low frequencies of 500 kHz belong to the test circuit. It is known that the signals up to 10 MHz are due to electromagnetic disturbance and the frequencies above 10 MHz are from electronic digitizers [14-16]. It is necessary to examine the lower frequency bands to analyze the signals of the test circuit. Corona values tell us about streamer propagation. As pressure increases, streamer changes to leader propagation. This case refers to decreased corona data. Therefore, in future research, corona data can be examined in detail for atmospheric pressures. More experiments are needed for definite results. The fact that SF_6 is an electronegative gas and the creation of global warming indicates that future work will be based on SF_6 gas mixtures. For this analysis, the knowledge of resolution is also important. In the direction of this study, frequency identification in corona events can be made much simpler, faster and more innovative with the development of technological possibilities in the future.

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