Corona Detection on High-Voltage Switch Gear Based on Acoustic Noise Frequency and Spectrum Analysis

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Abstract—High voltage electrical equipment has the potential to cause corona phenomenon. Corona activity in high-voltage switchgear is the main source of degradation and ultimate failure of insulation. Failure of insulating components on switchgear is a problem many utilities have. Statistics indicating that electrical insulation deterioration causes up to 90% of electrical failures of certain high voltage equipment. In order to avoid electrical failure on high-voltage switchgear, routine corona inspection is needed. One simple method to detect corona activity is by listen its sound. Corona noise can be described as crackling or hissing sounds. Usually high-voltage switchgear is totally enclosed, therefore special equipment is needed to perform corona inspection. Stethoscope attached to switchgear body can be used to help detecting corona sound on enclosed switchgear. This paper describes about corona acoustic frequencies and spectral analysis from the sound produced inside switchgear.

I. INTRODUCTION

Equipment energized with high voltage has the potential to create ionization of the surrounding air or corona discharge. Corona can be defined as a type of localized discharge that results from high, non-uniform electric fields. Corona discharges occur when surface electric field intensity surrounding an energized electrode exceeds a critical value resulting in a localized ionization of the surrounding gas, in most cases air. In high-voltage switchgear, corona is the indication of a voltage problem, and corona indications are present from day one until failure.

Corona activity may occur from sharp edges on energized hardware, broken conductor strands, or defective insulators. When corona occurs it creates ozone, ultraviolet light, nitric acid, electromagnetic emissions and sound. The nitric acid may removes the plating and causes corrosion of the steel parts of the conductors and insulators. The electromagnetic emissions can be heard on an inexpensive AM radio and the corona sound can be heard by human ear.

Corona causes deterioration of the insulator and sometimes causes complete breakdown. Failure of insulating components on switchgear is a problem many utilities have. This can lead to power interruptions and early replacement of parts. Therefore, corona may become the cause of serious economical losses on account of premature repairs and replacement of switchgear components, also reduced safety. These economical losses may be prevented by checking the switchgear in order to detect the presence of corona.

Corona can be detected in a number of methods. The simplest methods are by sight and sound. When observed, corona activity will produces visible light and sometimes seen as a bluish glow around electrodes. But, since corona emits very weak radiation (mostly in the UV band), it is difficult to detect corona by sight. Corona activity can only be perceived with the naked eye in almost absolute darkness. The other method to detect corona is by sounds it’s produced. The audible noise that corona produce can be described as crackling or hissing sounds caused by explosion gas expansions. This noise often can be heard by human ear.

High-voltage switchgear is usually totally enclosed. Access through switchgear components cannot be reach when the gear is energized. For this condition, special equipment is needed to perform corona inspection.

The purpose of this experiment is to analyze corona sounds characteristics and to develop a simple method for detecting corona on high-voltage switchgear. This paper mentioned about corona acoustic frequencies from the sounds produced inside the switchgear.

II. EXPERIMENT AND PROCEDURE

This experiment divided into two parts. The first part is to record corona acoustic noise inside high voltage switchgear using microphone directly. The experimental design is shown in Figure 1. This experiment is aim to record corona acoustic noise directly from high-voltage wire conductor inside switchgear model.
The experiment was conducted in high voltage laboratory and the equipments are transformer, DMI55 & OT75 control unit, insulator, capacitor, grounding switch, wire conductor, switchgear model, microphone and computer. High voltage is generated by transformer and being controlled and measured by DMI55 & OT75 control unit. This high voltage was supplied to switchgear model using wire conductor. The power supply frequency was 50 Hz. The wire conductor inside switchgear model was 25 cm long, and the distance from switchgear body was 12 cm to all direction. The switchgear body was connected to ground and a microphone was set about 10 cm from the top of switchgear model.

Corona occurred on wire conductor inside switchgear model, and then acoustic noise of corona was recorded to computer using microphone. The sampling frequency of the recorded corona acoustic noise was 44.100 Hz.

The second part of the experiment is to record corona acoustic noise using stethoscope attached on switchgear body. This experiment is aim to record corona acoustic noise from outside switchgear model through switchgear body. Procedure of this second experiment is same as the first experiment, only the microphone changed with stethoscope.

III. RESULT AND ANALYSIS

High voltage which supplied to switchgear model is from 1 kV until 34 kV. At 16 kV corona started to occur, and at 34 kV corona sound was heard very loud which can lead to complete failure. Corona acoustic noise was recorded at 16 kV, 20 kV and 34 kV. Microphone and stethoscope noise also recorded right before high voltage was supplied to switchgear model.

All sounds were analyzed using Adobe Audition 1.5 software. With this software, we can get frequency analysis and spectrum analyzer from the sound.

Experiment using microphone

Figure 2. shows spectrum analyzer for microphone noise.

Frequencies which detected from microphone noise are 50 Hz, 100 Hz, 119 Hz and 250 Hz. Fundamental frequency is 50 Hz with sound level equal to -38.7 dBFS. Other frequencies sound levels are less than -65 dBFS.

The spectrum analyzer for corona acoustic noise which recorded using microphone at 16 kV, 20 kV and 34 kV are shown in Figure 3.

The characteristics of corona acoustic noise are:
1. At 16 kV, frequencies which detected are 50 Hz, 119 Hz and 250 Hz. Fundamental frequencies are 50 Hz and 250 Hz with sound level -30.7 dBFS for 50 Hz and -60.1 dBFS for 250 Hz.

2. At 20 kV, frequencies which detected are 50 Hz, 100 Hz, 119 Hz, 150 Hz, 250 Hz and 450 Hz. Fundamental frequencies are 50 Hz and 250 Hz with sound level -29.4 dBFS for 50 Hz and -59.5 dBFS for 250 Hz.

3. At 34 kV, frequencies which detected are 0-49 Hz, 50 Hz, 51-99 Hz, 100 Hz, 119 Hz, 150 Hz, 200 Hz, 250 Hz, 300 Hz, 350 Hz, 400 Hz, 450 Hz, 500 Hz, 550 Hz, 600 Hz, 700 Hz, and 3.7 kHz-8.3 kHz. Fundamental frequencies are 50 Hz, 100 Hz, 150 Hz, 200 Hz, 250 Hz, 300 Hz, 350 Hz, 400 Hz, 450 Hz, and 500 Hz.

Table 1 shows summary for the fundamental frequencies and sound level from the experiment using microphone.

<table>
<thead>
<tr>
<th>Fundamental Frequency (Hz)</th>
<th>Noise dBFS</th>
<th>16 kV dBFS</th>
<th>20 kV dBFS</th>
<th>34 kV dBFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>-38.7</td>
<td>-30.7</td>
<td>-29.4</td>
<td>-21</td>
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<tr>
<td>100</td>
<td></td>
<td>-44.2</td>
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<td></td>
</tr>
<tr>
<td>150</td>
<td>-36.2</td>
<td></td>
<td>-51.2</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>-59.6</td>
<td>-59.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>-60.1</td>
<td>-59.5</td>
<td>-59.6</td>
<td></td>
</tr>
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<td>300</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>400</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>450</td>
<td>-52.7</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>-60.9</td>
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</tbody>
</table>

Corona occurrence can be judged by comparing corona acoustic sound to microphone noise. Microphone noise only produces fundamental frequency at 50 Hz with -38.7 dBFS sound level. On the other side, corona acoustic sound produces fundamental frequencies not only at 50 Hz but also in multiples of 50 Hz. The sound level also increase when corona occur.

**Experiment using stethoscope**

Figure 4 shows spectrum analyzer for stethoscope noise.

Frequencies which detected from stethoscope noise are 50 Hz, 119 Hz, 150 Hz, 250 Hz and 350 Hz. Fundamental frequency is 50 Hz with sound level equal to -32 dBFS.

The spectrum analyzer for corona acoustic noise which recorded using stethoscope at 16 kV, 20 kV and 34 kV are shown in Figure 5.

Figure 5. Spectrum analyzer for corona acoustic noise which recorded using stethoscope at 16 kV, 20 kV and 34 kV.

(a) 16 kV

(b) 20 kV

(c) 34 kV
250 Hz, 300 Hz, 450 Hz, 550 Hz, 600 Hz, 700 Hz, 950 Hz, 1000 Hz, and 1 kHz-1.6 kHz. Fundamental frequencies are 50 Hz, 100 Hz, 150 Hz, 200 Hz, 250 Hz, and 300 Hz.

Table 2 shows summary for the fundamental frequencies and sound level from the experiment using stethoscope.

<table>
<thead>
<tr>
<th>Fundamental Frequency (Hz)</th>
<th>Noise</th>
<th>16 kV</th>
<th>20 kV</th>
<th>34 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
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<td>-31.2</td>
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<td>100</td>
<td>-55.7</td>
<td>-55.7</td>
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<tr>
<td>150</td>
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<tr>
<td>200</td>
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<tr>
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<td>-59.5</td>
<td>-56.2</td>
<td>-52.2</td>
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<tr>
<td>300</td>
<td>-52</td>
<td>-52</td>
<td>-52</td>
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</tr>
</tbody>
</table>

Similar with microphone experiment, corona acoustic sound produces fundamental frequencies not only at 50 Hz but also in multiples of 50 Hz. The sound level also increase when corona occur.

IV. CONCLUSION

1. Corona may become the cause of serious economical losses.
2. In order to prevent losses, switchgear inspection is needed.
3. Corona acoustic sound produces fundamental frequencies in multiples of 50 Hz (power system frequency).
4. At higher voltage, corona acoustic sound produces more fundamental frequencies and higher sound level.
5. In enclosed switchgear, stethoscope can be used to detect corona activity inside.

REFERENCE

[1] Ninedorf, D., What is Your IQ? (Insulation Quality), Montello, WI 53949.