Sound analysis and PD measurement of HV transmission lines

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Abstract: Due to the high electric fields at the surface of conductors of high voltage transmission lines effects appear, which will be called corona discharges. In the context of a research work at the University of Technology in Graz the electrical and acoustic emissions of dry and moistened high voltage transmission line conductors have been examined and evaluated in an improved way.
Instead of usual acoustic octave and one-third octave analyses the acoustic spectrum of dry and wet conductors have been evaluated with a narrowband analysis method. With this method it can be shown that the in radiated spectrum beside of the broadband noise a whole numbered multiple of the basic frequency of the applied electric field exists.

INTRODUCTION

Today the interest about the arising noise of overhead lines is increasing. The reason for this phenomenon is the rising sensibility of many people living near beside high voltage transmission lines.
The noise of corona discharges of overhead lines is well known and have been discussed in a lot of papers in the sixties and seventies of the last century [1], [2]. Many scientific works have been done about the determination of the noise levels and the frequency spectrum of wet and dry ac transmission lines. With new methods of analog and digital signal processing some of this measurements can be done in a better way and can show new perspectives in the theory of corona discharges.

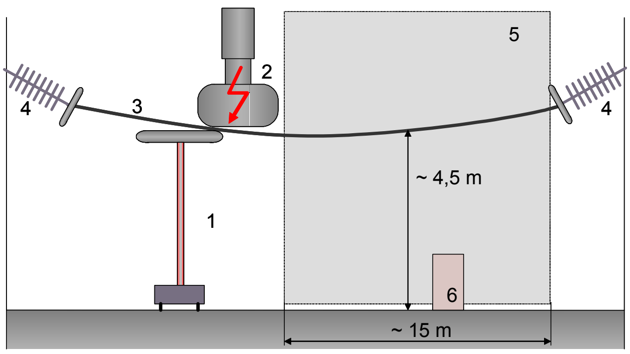

Figure 1: Test setup: 1...voltage divider, 2...high voltage supply, 3...overhead conductor, 4...shielded insulator, 5...measurement area, 6...sensors

TEST SETUP

Figure 1 shows the drawing of the test setup in the high voltage test hall of the University of Technology in Graz. The test hall itself shows a good acoustic performance because the walls of this hall are build in a noise reducing design. The test field is free of influences for the measurement of partial discharges up to a frequency of 1 MHz and shows an attenuation in this frequency domain of 100dB. For the detection of hearable and ultrasonic sound two adequate microphones with a frequency response from 12,5 to 10 kHz and 4 to 80 kHz an appropriate recording equipment were used. For the analysis of the measured signals Fast Fourier Transformation (FFT) and in specially Short Time Fourier Transformation (STFT) was used.

Acoustic signal analysis

In the first time when the noise of overhead lines was evaluated, most measurements where done without any filters and only the sound pressure level was measured. The technique of sound analysis has been developed and so octave band analysis and later third octave band analysis can be done. For further investigations of the acoustic emissions of overhead lines the simple sound analysis with the mentioned analysis methods are not effective enough. It's more suitable to use discrete sound analysis with filters (narrow band) and mathematical methods.
Figure 2 shows a comparison between octave band, third octave band and narrow band sound analysis. In octave band and third octave band analysis sound levels with a frequency near the center frequency of these filters have a higher weight than frequencies away from the center frequency of the octave or third octave filters.

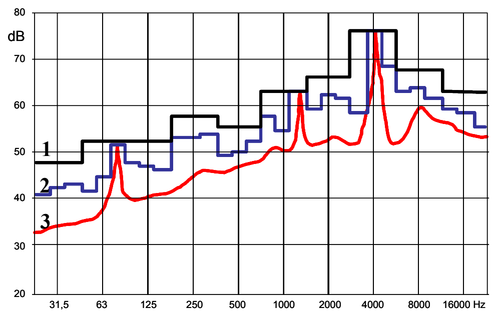

Figure 2: Comparison of octave band (1), third octave b. (2) and narrow band (3) sound analysis [3]

Typical acoustic spectrum of an overhead line

Energized overhead lines with high ac voltages show a typical acoustic appearance. Particularly the sound level with the double frequency of the supply voltage is noticeable. So the acoustic appearance can be described as a “hum” with a broadband noise at the upper frequencies. The “hum” of the overhead lines is changing if the line is getting wet by rain, snowfall or fog.

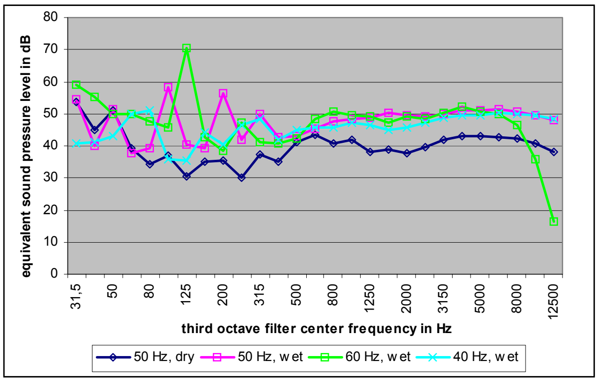

Figure 3: Typical frequency spectrum of a transmission line audible noise wet with 40, 50 and 60 Hz supply voltage [4], [5]

Figure 3 shows typical frequency spectra of an ac overhead transmission line at different operating frequencies about 40, 50 and 60 Hz. With a third octave frequency analysis only the significant levels at near by the centre frequencies of the filters can be detected. Because the multiplicities of 50 Hz supply voltages are nearer at the centre frequencies of the third octave filters this frequencies can be detected better with the third octave analysing method as the 40 and 60 Hz pure tone multiplicities. To track 40 and 60 Hz pure tone multiplicities and higher orders of the 50 Hz pure tone multiplicities discrete analysing methods are better for use. With this methods the difference between wet and dry overhead transmission lines can be shown in an improved way.

Partial discharges at overhead lines

For the analysing of corona noise and partial discharges of overhead transmission lines parallel some acoustic and partial discharge measurements have been done. Thereby a digital PD-measurement system was used. Figure 4 shows an typical PD pattern of single conductor of the test setup (Figure 1).
These partial discharge measurements were used to compare the measured PD patterns with the generated ultrasonic sound signals. The aim is to make some basic investigations for the development of an acoustic PD measurement system.

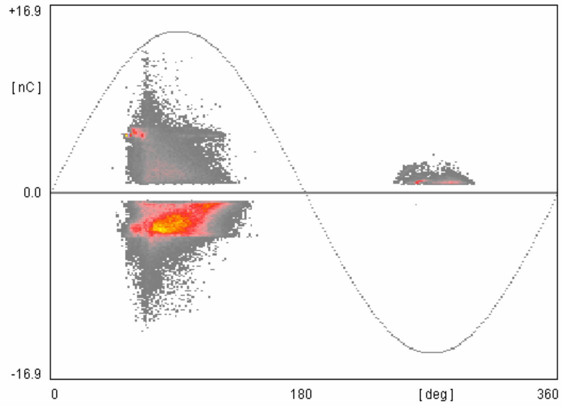

Figure 4: Typical PD pattern of an overhead transmission line at 270 kV

MEASUREMENTS

Combined measurements with the digital conventional partial discharge measurement system and the acoustic sound analysis system have been done at wet and dry overhead transmission line conductors with a cross section of 640 mm².

Acoustic spectrum analysis at overhead lines

Figure 5 shows the third octave frequency spectrum of an wet overhead transmission line at a voltage from 100 kV to 320 kV in 20 kV steps. The frequency of the supply voltage is 50 Hz.

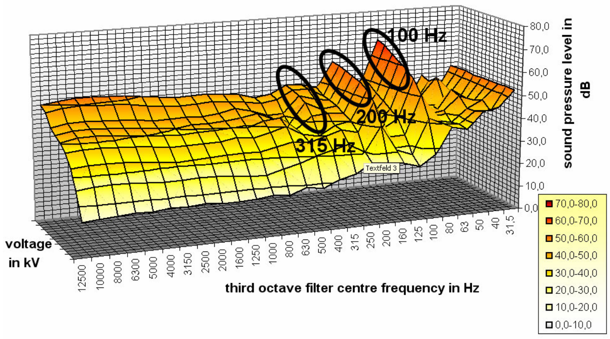

Figure 5: Third octave frequency spectrum of an wet overhead transmission line [5]

Figure 6 shows the discrete frequency spectrum of the same overhead transmission line under similar conditions. It is remarkable that even numbered harmonics show an higher sound pressure level as non even numbered harmonics if the spectrum of the wet overhead transmission line will be compared with the dry one in Figure 7.
At dry overhead transmission lines only the 2nd and 4th harmonic show an higher level than the other harmonics. The reason for this behavior have to be caused by the water droplets at the surface of the conductor.

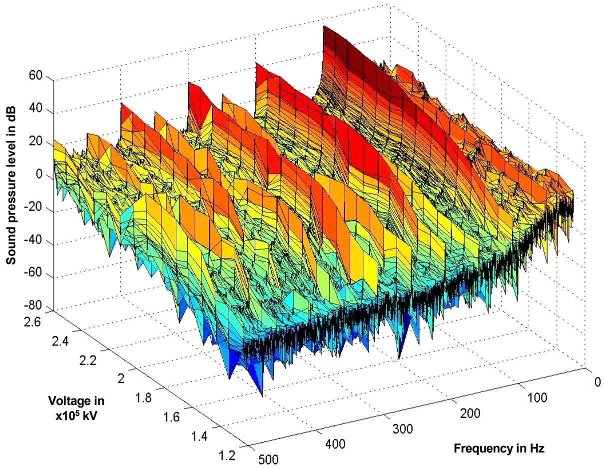

Figure 6: Discrete frequency spectrum of an wet overhead transmission line

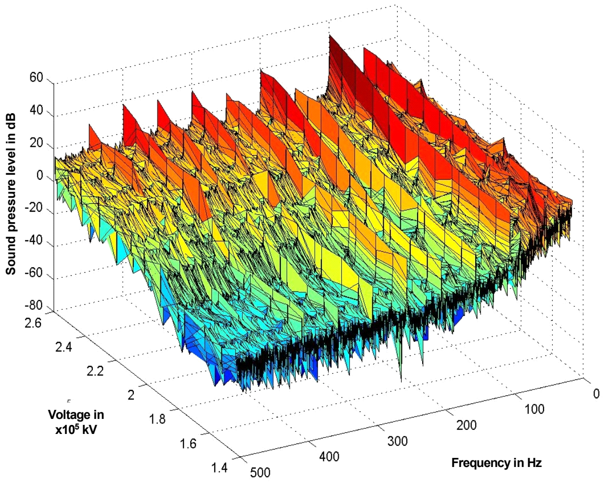

Figure 7: Discrete frequency spectrum of an dry overhead transmission line

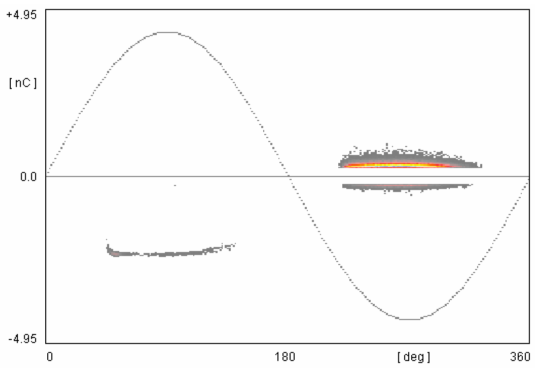

Figure 8: PD pattern of a dry transmission line model at a supply voltage of 45 kV

Acoustic partial discharges measurements

In digital partial measurements systems electric impulses caused by discharges will be counted and arranged in right phase relation to the supply voltage. Different PD sources can be described by typical patterns. In a similar way acoustic signals can also be displayed as a pattern of different frequency spectra. To get such pattern the Short Time Fourier Transformation (STFT) will be used.

Figure 8 shows a typical pattern of a dry transmission line model at a supply voltage of 45 kV. In Figure 9 the acoustic pattern of the same test arrangement as in Figure 8 is diagrammed. The values of the sound level is averaged over several periods of the applying voltage.

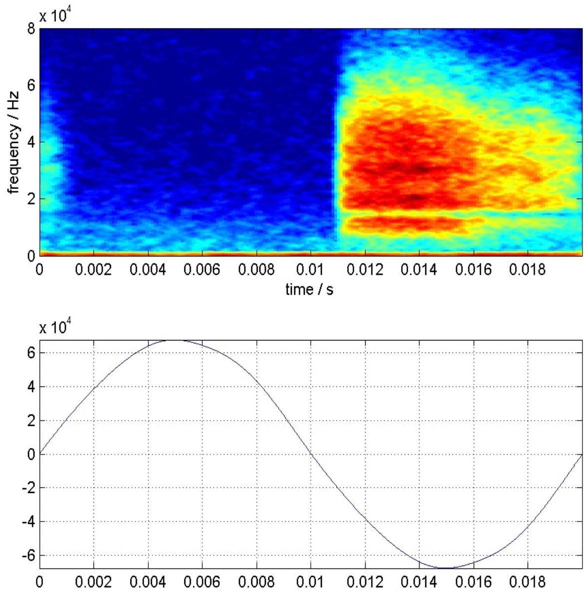

Figure 9: Acoustic pattern of a dry transmission line model at a supply voltage of 45 kV

CONCLUSIONS

Acoustic measurements in power engineering can be used for several reasons whereby basic researches are important for the further development of measurement systems. With the work at the Institute of High Voltage Engineering and System Management of the University of Technology in Graz it can be shown that there is a research potential in acoustic methods for power engineering.

- The using of signal analysis technologies the sound emission of high voltage transmission lines appear in a new light, for instance the higher time harmonics of the supply voltage in the acoustic frequency spectrum.
- Also an question to this higher time harmonics is the connection between their sound pressure levels and presence of water on the conductor.
- Finally the sensitivity and applicability of acoustic partial discharge measurement methods should be acquired for several power equipment.

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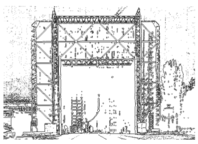

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