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Effects of dielectric liquids in electrical alternating fields

Muhr M., Pack S., Schwarz R., Koerbler B.
Graz University of Technology
Austria

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 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 a finely way. For this purpose several systems for sound and partial discharges measurement were used in parallel arrangement.

Contrary to dry kept overheadline conductors, the conductors moistened with water showed a changed appearance in acoustic and PD measurement, which suggests mechanical movements of water drops in the changing electrical field producing acoustic sound. This effect is well-known, but until now an exact analysis of the arising acousting emissions was neglected. So, instead of usual acoustic octave and one-third octave analyses the entire spectrum of wet conductors have been evaluated now. 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.

Parallel to the sensitivity examination of the acoustic system for the detection of partial discharges and for the evaluation of the arising corona noises, the partial discharge measuring system have been used for the analysis of the corona discharges, in special at the drying process of moistened lines, too.

General

The power grid connection of the different states in Europe in form of the UCTE-network are historical grown. Before the Liberalization of the electric power market the UCTE-network was responsible for the short time exchange of electric power. Today the UCTE-network is used for exchange of electric power according to the rules of the liberalized market. With that the power flow in some parts of the network rises following the physical laws. To get a better efficiency of the power transmission some of the overhead lines will be operated with higher voltages. Some of these overhead lines were constructed in the early 70´s and designed for voltages of 380 kV. Because the power flow was not so high, some of this lines were operated with 220 kV over a time span of 30 years. Today this power lines will be operated with 400 kV.

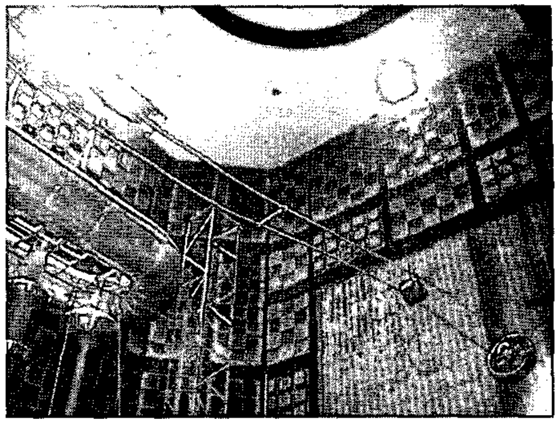

Figure 1: Test arrangement with a double bundle overhead line

The components of this overhead lines were designed for this high voltage level and so no problems were expected on the insulation coordination of the overhead lines. But with the rise of the operating voltage some sections on this lines are getting noisy. At special surrounding conditions with wet and foggy weather people living next to this overhead lines are feeling disturbed.

The level of the arising noise is depending particularly on water droplets which are vibrating in the electric field of the conductor.

To avoid and to find possibilities to decrease this noise emissions investigations on the Institute of High Voltage Engineering and System Management of the University of Technology in Graz were made. One of the investigations was the measurement of the acoustic spectrum of dry and wet overhead lines.

Sources of Acoustic Emissions of Overhead Lines

Beside the noise which will be produced by corona discharges only the wind plays another role for causing sound emissions of high voltage overhead lines. Thereby the sound will be produced oscillations of the conductors which will be initiated by the streaming air. Under normal conditions the sound level of this process is lower than the noise of the corona discharges. The

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sound of the corona discharges are much more critical for people living next to overhead lines. The level of the noise depends on the voltage level and the surface conditions of the conductors of the overhead line as well as the geometric dimensions and the conductor arrangement (Figure 2).

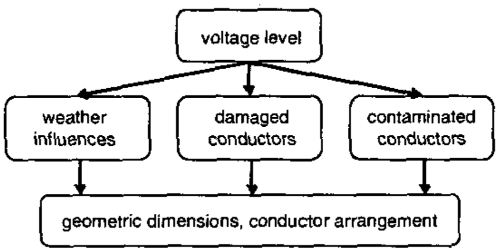

Figure 2: Reasons for corona discharges on transmission lines

Sound Emission by Corona discharges

High electrical fields on peaks are leading to corona discharges which can be detected by visual and acoustic methods. The light and acoustic emissions can be attributed to impulse ionisation processes which will appear in the negative as well as in the positive period of the applied alternating voltage.

The appearance of acoustic emissions will be explained with thermal processes in air released from the ionisation process [6] [7].

The level of the acoustic sound emissions depends on the prevailing weather. Especial at wet and foggy weather conditions the high voltage transmission lines shows high acoustic emission levels. This phenomena will be accredited to the water drops on the overhead line conductor vibrating in the existing electric field.

Behaviour of Water Droplets in Electrical Fields

Water shows a strong affinity to droplet formation. The reason for this characteristic is founded in the surface energy of water and the resulting surface tension. The geometric form of a water droplet depends on the balance of surface energy and the acting external forces on the droplet. The acting external forces on a water droplet on a conductor of a transmission line are a result of the physical principal of surface wetting, the gravitational force and the forces according to wind and conductor vibrations.

Due to the high electrical constant of $\varepsilon_r = 81$, the water droplets show a strong interaction to the existing electrical fields of the transmission line conductors. This interaction is reasonable for a force that "stretches" the droplet in the direction of the applied electric field [1] [2] [3].

Figure 3 shows the appearance of water droplets formed by precipitation and condensation at an unloaded high voltage transmission line.

Figure 3: Wet conductor surfaces of transmission lines [4] [5]

If wet transmission line conductors will be loaded with high alternating voltages, the water droplets will oscillate in the existing electrical field of the conductors. With this process the water droplets change their geometric form also periodically. Originally smooth and round droplet surfaces are getting spiky according to amplitude and frequency of the electrical field [4].

Caused by the spiky water droplets corona discharges appear, which rise the level of the acoustic emissions.

Measurements on Overhead Lines

Due to the theoretical background of sound emissions measurements of corona discharges the double frequency of the supply voltage will be expected. The sound emission with the double supply voltage frequency will be made responsible for the "hum" of transmission lines.

To verify this theoretical background in the high voltage laboratory of the Institute of High Voltage Engineering and System Management different acoustic measurements were made.

A typical conductor of a transmission line was supplied with different high voltage levels. The frequency as well as the amplitude of the high voltage could be changed in steps from 16 Hz to 300 Hz and from 10 kV up to 1.100 kV.

Beside the measurement of the discrete and third octave band acoustic spectrum in a range of 10 Hz to 12 kHz with microphones and suitable analysis tools the partial discharges of the overhead line was measured too [8]. The partial discharge levels of the test setup and the used power supply devices were smaller than 1 pC.

Dry Overhead Line Conductor

Figure 4 shows the established measured acoustic spectrum of a dry overhead line conductor.

This unexpected discrete acoustic spectrum shows a clear increasing of integer frequency harmonics (100 Hz, 150 Hz,...) of the frequency of the supply voltage. This harmonics are very interesting in the perspective of international researches because until now only third octave band and acoustic sound level measurements were done for the evaluation of overhead lines. Especially a lot of measurements with 100 Hz filters were made until now.

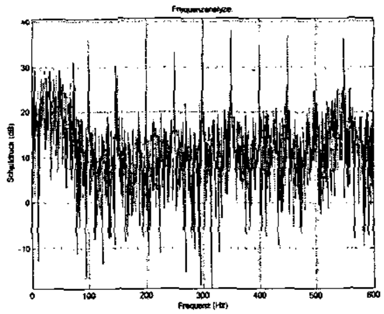

Figure 4: Acoustic spectrum of a dry overhead line conductor at 270 kV and 50 Hz

The measured sixfold harmonic of the supply voltage frequency (300 Hz) shows a higher level than the expected twofold harmonic. If the frequency of the supply voltage was changed, the same results were measured. Figure 5 shows the acoustic spectrum of dry overhead line supplied with an 40 Hz voltage with a level of 260 kV. In Figure 6 the measured acoustic harmonic levels in dependency of the amplitude of supply voltage are shown. It should be noted that a "step function" of higher frequency harmonics appears at higher supply voltages.

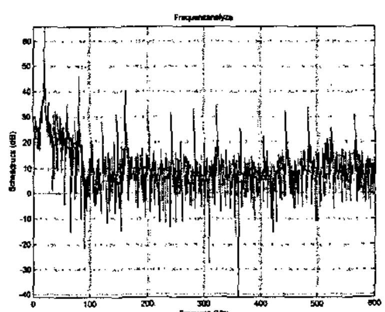

Figure 5: Acoustic spectrum of a dry overhead line conductor at 260 kV and 40 Hz

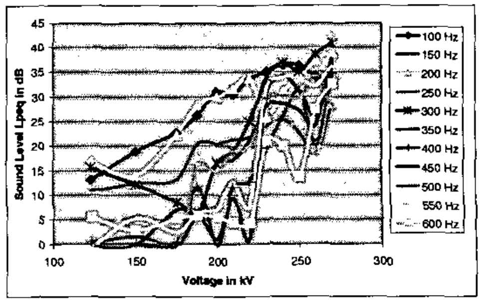

Figure 6: Levels of acoustic harmonics of a dry overhead line conductor at 50 Hz

Figure 7 shows the PD-fingerprint of a dry overhead line conductor supplied with voltage of 270 kV and Frequency of 50 Hz.

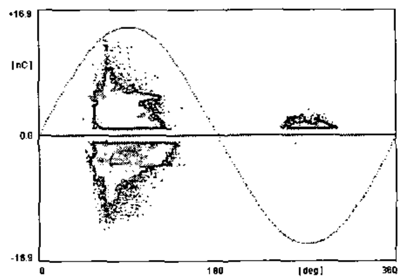

Figure 7: PD-pattern of a dry overhead line conductor (270 kV/50 Hz)

Wet Overhead Line Conductor

Figure 8 shows the measured acoustic spectrum of a wet overhead line conductor. If this measurement will be compare with the dry measurements it can be shown that the sound level of the acoustic emissions is higher.

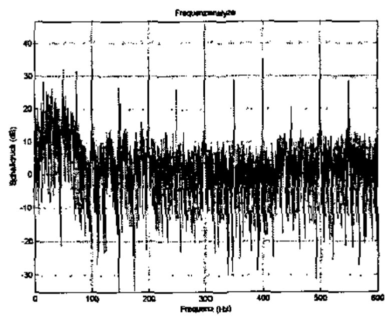

Figure 8: Acoustic spectrum of a wet overhead line conductor at 270 kV and 50 Hz

The unusual of this appearance is the emitted discrete acoustic spectrum. It shows the same integer frequency harmonics of the frequency of the supply voltage as the dry overhead line conductor. But the even number harmonics (2f, 4f, 6f,...) are substantially higher than the even number harmonics of the measured dry conductor. Figure 9 shows the measured acoustic harmonic levels in dependency of the amplitude of supply voltage. It should be noted that the initiation point of the higher harmonics is lower as at the dry conductor. Figure 10 shows the PD-pattern of a wet overhead line conductor.

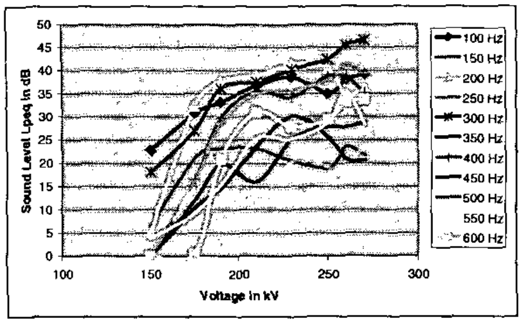

Figure 9: Levels of acoustic harmonics of a wet overhead line conductor at 50 Hz

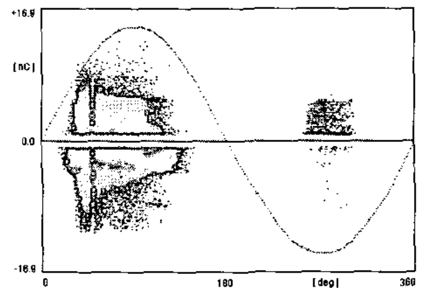

Figure 10: PD-pattern of a wet overhead line conductor (270 kV/50 Hz)

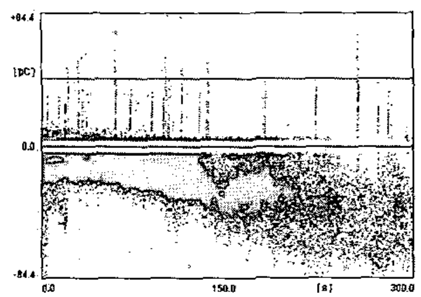

Figure 11: PD-pattern of the drying process of a wet overhead line at 90 kV, 50 Hz, (PD-level vs. time)

Figure 11 shows the drying process of a wet overhead line conductor at a supply voltage with 90 kV.

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Author address:
Michael Muhr,
Stephan Pack,
Robert Schwarz,
Bernhard Koerbler
Institute for High Voltage Engineering and System Management,
University of Technology; Graz,
Inffeldgasse 18, 8010 Graz, Austria, Europe.
Email: surname@hspt.tu-graz,ac.at