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INVESTIGATIONS OF CORONA-INDUCED VIBRATION ON HIGH VOLTAGE CONDUCTORS IN LABORATORY CONDITIONS

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ABSTRACT
In the paper results are presented of studies of conductor vibrations generated by the corona effects in the UHV transmission lines. The experimental studies of the conductor vibrations have been carried out for two layouts − freehanging and tensioned conductors. In the vibrational spectra tonal components of the network frequency (50 Hz) and its second harmonic (100 Hz) have been distinguished. These components have been observed already at relatively low values of the applied voltage, particularly for the freehanging conductors. Weak correlation has been found between the components of the vibrational spectra and the tonal components in the acoustic spectra (100 and 200 Hz) in contrast to their high correlation with the noise components and the RF interference. Certain changes has been found in the spectral structures of vibrations after introducing the tension of the conductors.

1 - INTRODUCTION

Inevitable consequence of the transfer of large amounts of electric energy using UHV transmission lines is the corona effect. The corona process starts when the maximum value of the electric field vector, E on the conductor's surface exceeds the critical value Eo. The process is a source of many adverse effects, in particular energy losses, RF interference, noise, ozone and nitrogen oxides production and the conductor's vibrations [1,2]. The transmission lines are usually constructed in such a way that the maximum value of E varies between 14 and 18 kV/cm, while the critical value Eo in good weather conditions usually varies in the 19-20kV/cm range, but in the extremely unfavourable conditions it falls even below 12 kV/cm [3]. Thus the critical field value depends not only on the line's designing parameters but also on the atmospheric and environmental conditions and the technical condition of the conductor's surface. In bad atmospheric conditions the intensity of the corona effects increases as a result of presence raindrops at the wire's surface and because of the increased air humidity level. Then the intensity of the corona process is determined by the bad atmospheric conditions. In good weather conditions, when the conductors are dry, the main sources of the corona effect are various types of irregularities at the conductor's surface.

Vibrations of the conductors in UHV transmission lines, generated by the corona discharge processes at the surface of the conductors, have been observed and mentioned in several papers [4,5,6]. Such vibration type can result in the metal fatigue, particularly near the clamps and the line poles, what leads to line damages and is an additional source of energy losses. These problems are becoming more and more important with the growing number of transmission lines, and the increasing values of the voltages used. The earlier papers [5,6] have dealt mainly with conductor's vibrations in the presence of hanging water droplets. However the corona effects and thus the conductor's vibrations can be also observed in different conditions. Therefore in the present work a particular attention has been focused on the vibrations generated for dry conductor surfaces. In order to determine the main components of the spectral structures of vibrations their correlations have been evaluated with the emitted noise and RF interference.

The earlier studies [2] have been carried out for freehanging conductors. In the present work the results are also shown for mechanically tensioned conductors, as in real situations. It enabled the observation of certain changes in the vibrations spectral structures and the correlation of their main components with the acoustic components and RF interference.

2 - EXPERIMENTAL STUDIES

The experimental studies have been carried out in laboratory conditions. The conductor bundles of original size 2 $\times$525 mm^2 and 3 $\times$350 mm^2 and 170 mm^2, about 20 m in length, have been supplied with phase voltage from 175(80) kV to 350(220) kV (the latter regards the 170 mm^2 conductors). The measurements of vibrations and acoustic pressure and the RF interference have been carried out in the experimental set-up shown in Fig. 1.

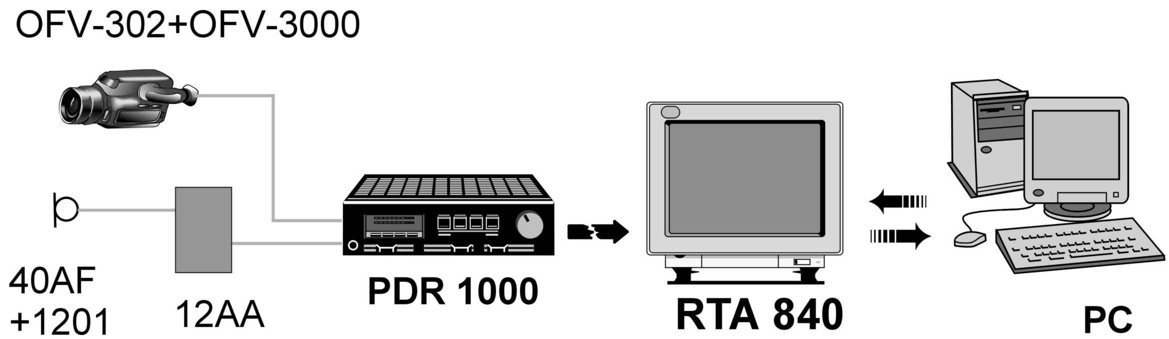

Figure 1: General arrangement of the measurement set-up for registration and analysis of vibration and noise signals; OFD-300 & OFV-3000 $-$ laser vibrometer made by POLYTECH, 40AF+1201 $-$ 1/2" condenser microphone and preamplifier, PDR-1000- DAT recorder, RTA-840 $-$ dual channel Real Time Analyser made by Norsonic.

Both the laser measuring head and the microphone have been placed at about 10 m distance from the conductor bundle. Both measuring lines (for the acoustic and vibrational signals) have been carefully shielded in order to eliminate any influences of the strong electric fields present near the studied group of wires. The RF interference have been measured the monitoring the voltage signal at a 300 Ω resistance, at the 0.5 MHz frequency, using a LMZ5 measuring instrument.

3 - ANALYSIS OF THE EXPERIMENTAL RESULTS

In the spectrum of the vibration velocity two characteristic tonal components can be mainly distinguished: 50 and 100 Hz. The higher harmonics are practically unnoticeable. An example of the narrow band spectrum of the vibration velocity is shown in Fig. 2.

The dependencies of the vibration velocity (in 50 and 100 Hz bands), characteristic components of the acoustic pressure (in the 100, 200 Hz and 8 kHz bands) and the RF interference on the supply voltage are shown in Fig. 3 for the freehanging conductors, and in Fig. 4 for the mechanically tensioned conductors.

For the RF interference the best correlation is observed with the 8 kHz component of the acoustic pressure in both cases, with the 50 Hz vibration component for the freehanging conductors, and with the 100 Hz vibration component for the mechanically tensioned conductors. Certain changes can be also observed in the dependencies of the acoustic and vibrational components $-$ the vibrations of the tensioned conductors exhibited much lower amplitudes for the low values of supply voltage, on the other hand much more levelled dependencies have been observed for the tonal components of the acoustic signal.

The values of the correlation coefficients between the distinguished components and the RF interference are listed in Table 1.

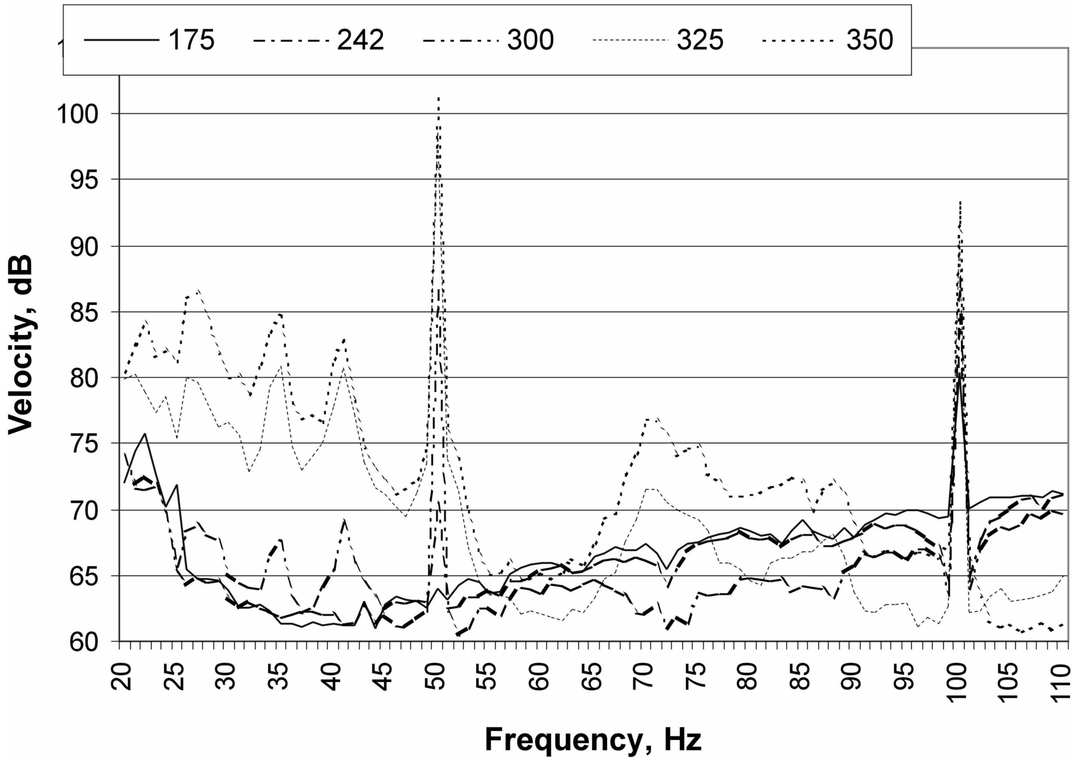

Figure 2: Vibration velocity narrow band spectrum for various supply voltages; the conductor bundle was 2 ×525 mm^2.

Correlation coefficient between RF interference and noise (n) and vibrations (v)					
	50 Hz,v	100 Hz, v	100 Hz,n	200 Hz,n	8 kHz,n
2 ×525 mm^2, freehanging conductors	**0.92**	**0.76**	**0.85**	**0.63**	**0.96**
3 ×350 mm^2, freehanging conductors	**0.94**	**0.87**	**0.87**	**0.75**	**0.97**
170 mm^2, tensioned conductors	**0.89**	**0.95**	**0.88**	**0.86**	**0.99**

Table 1.

The dependencies of the vibrational and acoustic components, best correlated with RF interference, are presented in a graphic form on the plot in Fig. 5. The trend lines have been also marked on the plot. The obtained high values of correlation indicates a possibility of evaluation of conductor's vibration amplitudes using the acoustic signal. Such a possibility would be particularly valuable for the evaluation of the conductor's vibrations in real conditions, when the measurement using the laser vibrometer presents some technical difficulties.

4 - CONCLUSIONS

Characteristic features have been distinguished for the spectral structures of vibration velocity and the well-known noise characteristics have been confirmed as functions of the corona process intensity.

The obtained results have shown high correlation level between RF intensity and the noise component in the 8 kHz band of the acoustic signal and the 50 and 100 Hz components of the vibration velocity for the freehanging and tensioned conductors respectively.

The vibrations of the mechanically tensioned conductors exhibited much lower amplitude for the low values of the supply voltage and much more levelled dependencies of tonal components of the acoustic signal then the freehanging conductors.

Weak correlation has been found for the tonal components of the acoustic signal both with vibrations and RF interference level.

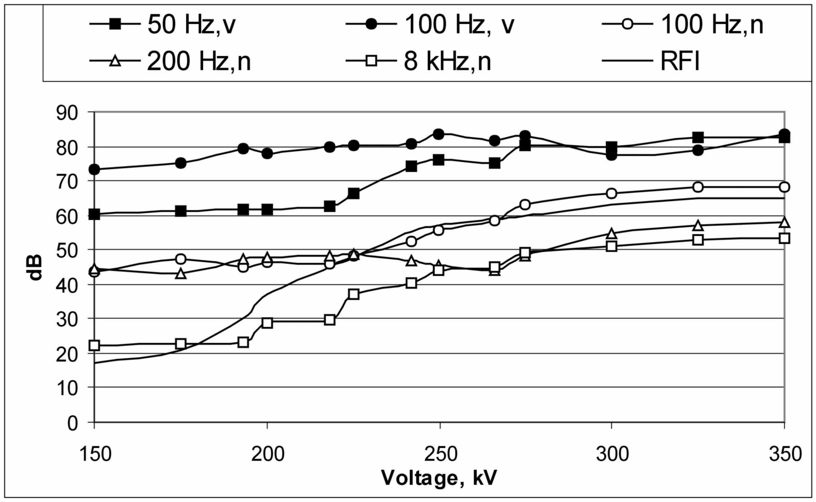

Figure 3: The dependencies of components of the acoustic signals, vibration velocity and RF interference, generated by the corona processes; freehanging conductors were used.

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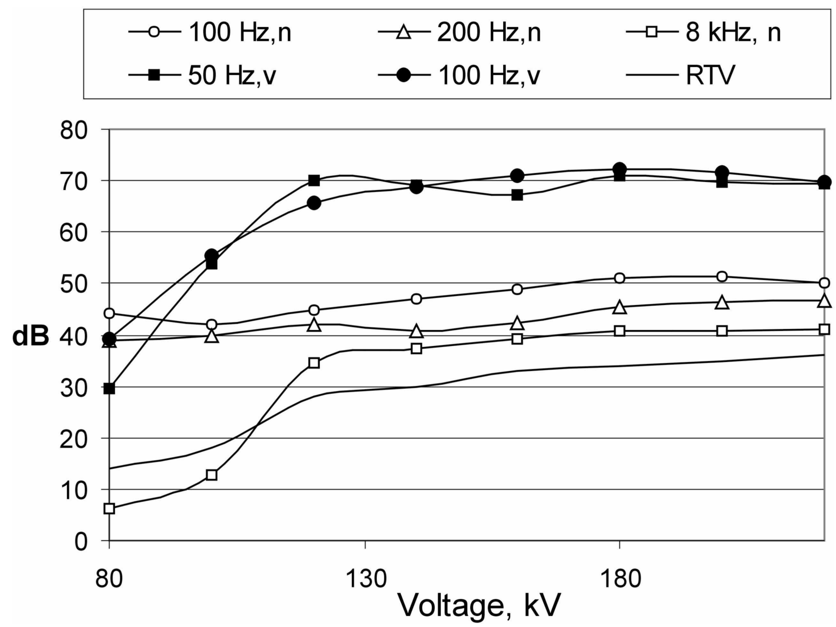

Figure 4: The dependencies of components of the acoustic signals, vibration velocity and RF interference, generated by the corona processes; mechanically tensioned conductors were used.

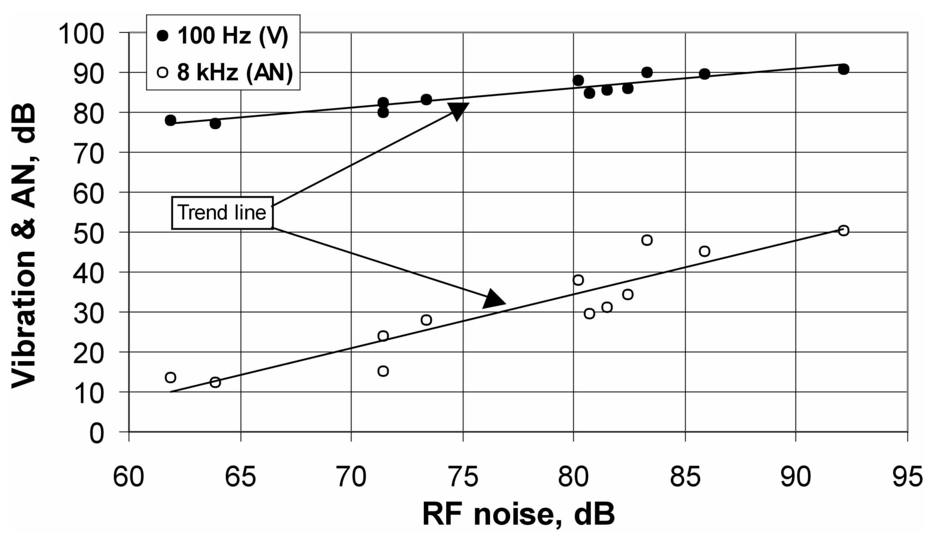

Figure 5: The dependencies of the 8 kHz component of the acoustic signal and 100 Hz component of the vibration velocity as a function of the RF interference level.