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Noise Indicators for Corona Acoustic Signal from Power Lines – Estimation in Intensified Interference Conditions

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In the spectrum of corona acoustic signal two characteristic components can be distinguished: (1) tonal components – higher harmonics of the network frequency and (2) noise component, observed in the frequency band extending above 1 kHz. On the other hand the total intensity of that signal is relatively low – up to 50 dB at 15 m distance from the outmost conductor – and it is strongly dependent on the environmental conditions. Thus the nature of that signal is essentially random. Because of the above-mentioned features, in practice the best evaluation method of the negative environmental impact is a continuous signal monitoring. Unfortunately for such a procedure some problems are encountered with automated extraction of the parameters (indicators) normally used for evaluation of the signal's acoustic annoyance, especially in intensified interference conditions. One of the more efficient methods of filtering out the random interference signals is the statistic spectrum measurement method. In this work a practical realization is described for estimation of corona noise indicators, making use of the statistic spectrum measurement. High efficiency of such an approach has been shown, especially in favorable weather conditions, when the acoustic signal of corona process is relatively low, while the random interference level may be intensified.

Keywords: corona acoustic signal, noise indicators, power lines, intensified interference.

1. Introduction

The allowable environmental noise levels from overhead power lines, specified by the regulation of Poland's Ministry of Environment [4] are mostly located in the 45–50 dB range for the daytime hours and set as 40 dB for the nighttime hours. The regulations concern both the inhabited and recreational areas, located outside the inner city parts. In such places there are often many problems with evaluation of the noise level, resulting from the presence of environmental interference, e.g. barking dogs, singing birds, agricultural activity in the rural regions etc. In such conditions the requirements concerning the signal to background distance are very difficult to fulfill. For the UHV power lines such a situation is often encountered in good weather conditions, when the acoustic signal of the corona process is rather weak, while the environmental interference is often intensified. However one should notice that such problems are sometimes encountered in daytime hours in bad weather conditions, when the corona acoustic signal is relatively high, but still considerable interference is observed from e.g. farming activity. In such a situation the measurement is realized by time-domain elimination of interfering events and by application of statistical methods with respect to short, representative samples of the analyzed signal [8].

Studies of the corona acoustic signal in good weather conditions are still important, in spite of its usually low intensity, because long exposure times are involved, and that contribution can considerably affect the long-term noise levels. The acoustic signal may be also considered in the diagnostic aspect. However in order to make the information about the corona process contained in the signal useful for both diagnostic and environmental purposes it must be filtered out from the environmental interference, which is not correlated with the signal [3].

Extraction of the corona acoustic signal enters a new dimension in the continuous monitoring systems, when there is always a concern, that the long-term noise level value is affected by environmental interference, which is hard to eliminate. The monitoring stations are usually installed in secured places, in which network power supply is available, which, as a consequence, are usually places, where the course of normal life is present, activating many sources of environmental noise. The filtration method usually selected in the monitoring systems is the measurement of statistical levels determined as a function of frequency. Such methods are particularly efficient, when the examined signal exhibits stationary characteristics, while the interference events occur at random in various (random) frequency bands.

2. Research preconditions

In the spectrum of corona acoustic signal two characteristic components can be distinguished: (1) tonal components, with primary harmonic present at doubled network frequency, and (2) noise component, observed at the frequency band above 1 kHz [5]. As has been shown in Fig. 1 in real-world conditions the abovementioned features are not so clearly distinguishable, mainly because of the environmental interference, even in situations, when the acoustic signal is relatively strong. In such cases the noise component is mainly used for evaluation of the A weighted sound level of corona noise, as it exhibits better correlation with the actual A-level value [8]. On one hand the tonal components are definitely less useful for that purpose, even if they can be helpful in the identification of the source, on the other hand their knowledge is required for specification of those components in the meaning of the PN-ISO 1996-2 standard.

For the case of continuous signal monitoring, due to the registration of the non-acoustic parameters, in particular the environmental parameters, there is an additional support for the statistical methods of interference elimination, offered by the correlation analysis. It follows directly from the fact, that the corona process and its accompanying phenomena are strongly correlated with the weather conditions [2]. In the present work the specific environmental conditions, when intense corona process was observed and the environmental interference was almost absent, have been used for verification of correctness of the applied calculation method.

The noise indicators, that should be determined from monitored data, are mainly indicators that are useful for elaboration of long-term policy concerning the environmental noise protection, namely L_{DEN} and L_N, and additionally the indicators used for specification and verification of the environment exploitation conditions, with respect to the 24 h period, i.e. $L_{Aeq,\,D}$ and $L_{Aeq,\,N}$. These indicators are defined in the "Environment protection law", and the respective executive regulations to this legal act [6]. The L_{DEN} level is a daytime-evening-nighttime level, while the L_N is a purely nighttime level [1]. The respective levels are determined for all 24 h periods in the whole year. That leads to the necessary averaging of these values over all daytime, evening and nighttime periods in the whole year. The $L_{Aeq,\,D}$ and $L_{Aeq,\,N}$ levels are average levels taken for 16 hours in the daytime period and 8 hours nighttime period, and they are attributed to each individual day. However it has not been specified, which particular day should be taken – there is no algorithm for selection of such a specific day. Therefore in the present work some exemplary data, covering several months, have been used for illustration of the actual value spread in comparison to the all-year L_{DEN} and L_N levels.

3. Experimental research

The measurements have been carried out in the continuous mode in vicinity of a 400 kV double circuit power line with two subconductor bundle 2×525 mm^2. The data have been acquired since November 2007 using the SVAN 210 monitoring station, based on the SVAN 959 analyzer. Such analyzer type, due to replaceable external memory (pendrive), allows gathering large amounts of data and their easy transfer to the base station computer. Thanks to wireless communication mode there is a possibility of remote control and supervision of the station's functioning. The monitoring station is equipped with a pre-polarized

GRAS 40AE microphone, with an all-weather SV200A shield. In addition to the acoustic data recording the accompanying weather data are also acquired, using the WatchDog 2900 weather station. In contrast to many stations available on the market this type of station contains an elaborated, high sensitivity hardware module for measurement of precipitation intensity, with practical resolution of 0.25 mm. In addition to the rain measurement module the station contains modules for measurements of atmospheric pressure, ambient temperature, air humidity, wind speed and direction, and additionally the so called wind gusts. A general view of the noise monitoring station and the accompanying weather station is presented in Fig. 1.

Fig. 1. General view of the acoustic signal continuous monitoring station (SVAN210) and the accompanying WatchDog 2900 weather station.

Working parameters of the monitoring station:

Logger – registration of 1/3 octave audio RMS spectrum, with 10 s time step. An attempt to register the spectra with 1 s time step resulted in generation of huge amounts of data, requiring costly hardware and software for its processing. One 24 h period yielded 86400 spectra datasets (matrix 86400 × 32 in size), what produced 2.5 millions of spectrum datasets monthly.

Main results – spectra registration in 1/3 octave bands from 20 Hz to 20 kHz – registered values of RMS, MAX, MIN and the respective 1%, 5%, 10%, 20%, 30%, 50%, 80%, 90%, 95%, 99% levels, with 15 min time step. The spectrum registration is carried out in time coincidence with the registration of weather data.

For further processing the data are repacked in 24 h cycles (22:00 to 22:00 periods) and monthly cycles. Such a procedure offers an easy way for evaluation of the previously mentioned noise indicators values, in which the averaged (equivalent) levels are estimated from L_{50} statistical levels calculated for the 15 min period data, according to the formula (1):

$$L_D = 10 \log \left(\frac{1}{n} \sum_{i=1}^{n} 10^{0.1 L_{50Di}} \right) \tag{1}$$

where L_D – daytime level, taken for 6:00 to 18:00 period, averaged from the L_{50Di} statistical levels taken for 15 min periods. For the other measuring time periods (evening and nighttime) the respective procedures are the same. Excerpts from the time dependence of selected weather parameters and the continuous monitoring of acoustic signal, measured in November 2007, are presented in Fig. 2.

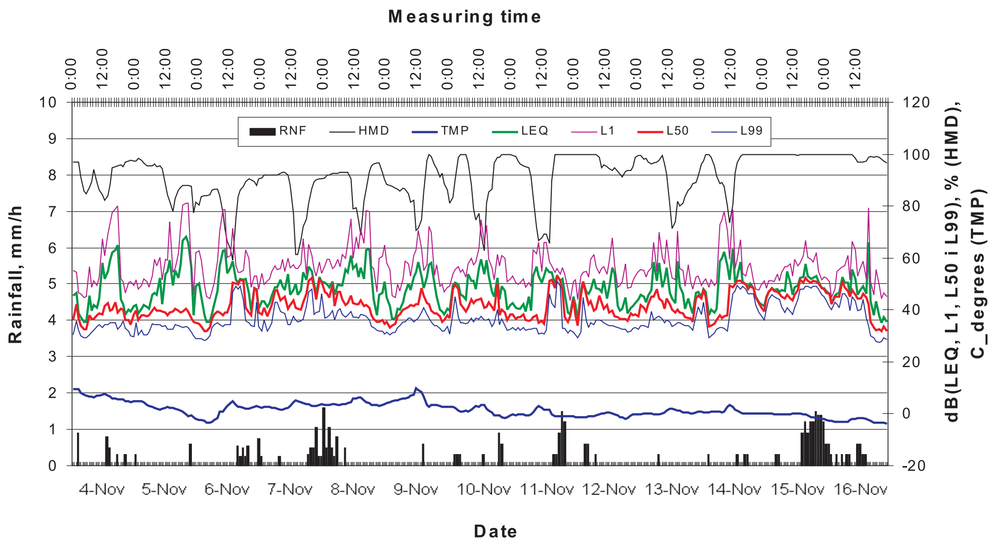

Fig. 2. Time dependencies of selected noise indicators (L_1, L_{50}, L_{99} and L_{EQ}) and environmental parameters (humidity – HMD, rainfall – RNF and temperature – TMP) in vicinity of a 400 kV power line.

As can be easily noticed the L_{EQ} and L_{50} parameters – the basic input data for the calculation of L_{DEN} indicator – become clearly divergent when the signal to noise ratio decreases and are almost coincident for the periods of intense corona process, e.g. in the presence of rain. In consecutive Figs. 3 and 4 various statistic spectra (L_1, L_{50} and L_{99}) and the L_{EQ} spectrum of the corona process has been shown, for the rainy weather periods with very low acoustic background level (no wind) and in relatively windy conditions (4 m/s) respectively. In the presented spectral structures similar tendencies can be noticed as in the respective

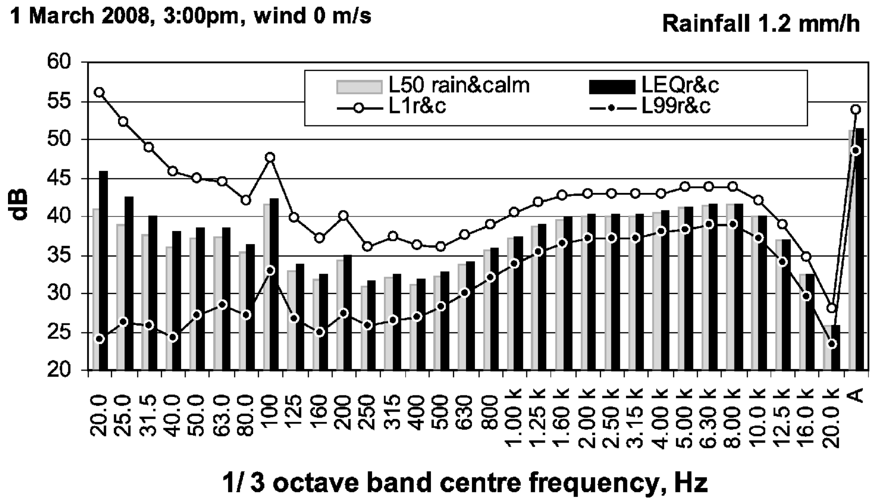

Fig. 3. L_{EQ} spectrum and the statistical spectra (L_1, L_{50} and L_{99}) from the continuous monitoring of the corona acoustic signal in rainy conditions, with low acoustic interference level.

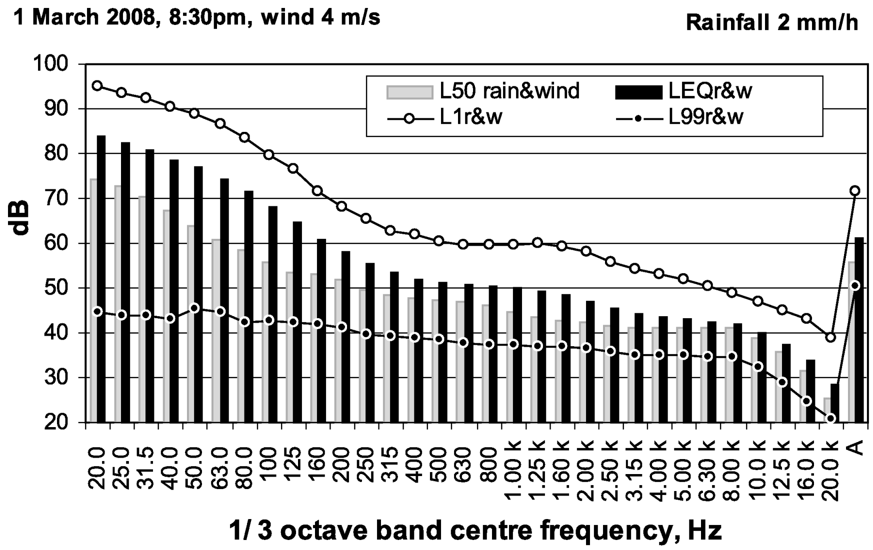

Fig. 4. L_{EQ} spectrum and statistical spectra (L_1, L_{50} and L_{99}) from the corona acoustic signal monitoring in rainy conditions, with intensified acoustic interference level.

time dependencies – in the low acoustic background conditions the L_{EQ} and L_{50} spectra are almost coincident, while for the intensified interference periods (wind, intense rainfall) they become divergent.

This tendency is clearly more pronounced in the low frequency bands.

The L_{50} and L_{EQ} spectra measured in periods with various types of acoustic interference have been presented in Fig. 5. As can be noticed in this figure the interference effects can be observed in different frequency bands and only in the L_{EQ} spectra, while they are hardly noticed in the L_{50} spectra.

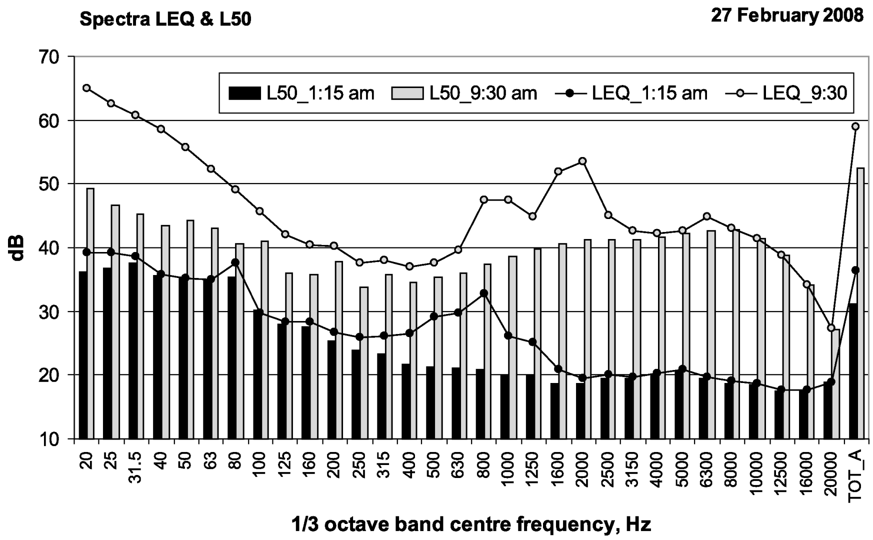

Fig. 5. The L_{50} and L_{EQ} statistical spectra for the monitored acoustic signal with clearly visible interference effects in various frequency bands.

Taking the above into account in order to increase the efficiency of interference signal filtering during the A-level determination, the level value has been calculated from L_{50} spectrum. The shapes of the L_{A50} (determined directly at the A filter) and $L_{A50\,\mathrm{s}}$ (determined from the L_{50} spectrum) have been shown in Fig. 6.

The obtained results indicate, that the values of L_{A50} and $L_{A50\,\mathrm{s}}$ levels coincide with the major part of the considered time period. Therefore it can be concluded that the two indicators are estimates of comparable effectiveness. However in some time periods the difference is clearly noticeable – the $L_{A50\,\mathrm{s}}$ values are lower than the respective L_{A50} values. That might indicate the better effectiveness of the $L_{A50\,\mathrm{s}}$ estimate in automatic filtration of the environmental interference effects.

Further increase of the interference filtration effectiveness might be achieved by choosing other (higher) percentile values, particularly in daytime measurements, when the interference intensity is usually much higher and more diverse. Such a decision should be however preceded by a preliminary analysis of the nature of the interference signals. The goal of the present work was merely the indication of a general interference filtration method in the continuous acoustic signal monitoring systems.

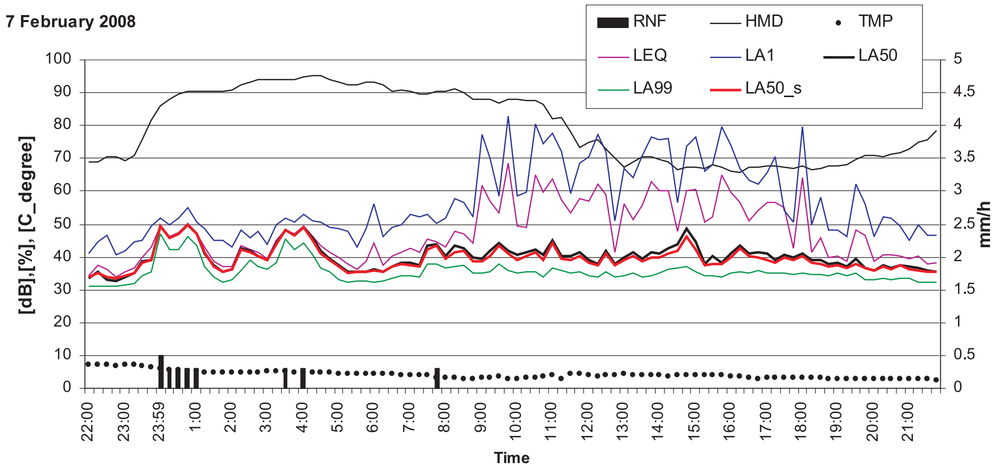

Fig. 6. Time dependencies of selected noise indicators (L_1, L_{50}, L_{99} and L_{EQ}), the $L_{A50\,\mathrm{s}}$ indicator and ambient weather parameters (humidity – HMD, rainfall – RNF and temperature – TMP) in the vicinity of a 400 kV power line.

A separate problem during the estimation of corona noise indicators is the estimation of $L_{Aeq,\,D}$ and $L_{Aeq,\,N}$ values, attributed to individual 24 h periods. Although the all-year data, including all the typical weather conditions, are not available yet, still the data collected in several months provide an illustration of possible ambiguities in the corona noise evaluation, shown for randomly selected weather conditions. As can be seen from the data listed in Table 1, the standard uncertainty is mostly contained in the 2–3 dB range, what means that the extended uncertainty, for the assumed confidence level of 95% (and normal distribution), will take values between 4 and 6 dB.

4. Conclusions

In the paper partial results have been presented from a continuous monitoring of the corona acoustic signal, accompanied by application of an effective automatic method of interference signal filtration, by registration of statistical spectra.

It has been shown that application of the L_{A50} level as the estimator of equivalent level in most cases leads to satisfactory results, however in intensified random interference conditions better results can be achieved by estimation of the equivalent level using the $L_{A50\,\mathrm{s}}$ estimator, which is determined from the L_{50} statistical spectrum.

In the daytime period, when the interference levels are usually higher than during the nighttime period, the effectiveness of the proposed approach can be improved by increasing the percentile value from L_{50} even to L_{90}.

The determination of $L_{Aeq,D}$ or $L_{Aeq,N}$ indicators in a randomly selected day can be affected by a considerable error. The error value may differ from the year average value even by 6 to 9 dB.

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