Assessment of the Long-Term Levels for Corona Audible Noise in Vicinity of UHV Transmission Lines

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Abstract: - In the paper characteristic features of the corona noise from UHV transmission lines have been distinguished, which can be useful for the noise measurement under high level interference conditions. The utility of statistical methods in elimination of typical environmental interference has been shown, particularly methods based on the measurement of statistical spectra. The effect of inaccurate determination of fair and bad weather conditions periods, and the presence of tonal components in the corona noise spectra on the result of long-term level calculation has been also discussed.

Key-Words: - Corona Phenomena, Audible Noise, UHV Power Lines, Long-term Levels, High Voltage

1 Introduction

The overhead Ultra High Voltage (UHV) transmission lines are sources of adverse environmental effects, what is often the reason of numerous complaints from the local population concerning their presence. In most cases the complaints consider the effects related to the corona process, in particular the radio frequency interference and audible noise. The corona process, and thus also the accompanying processes, essentially depend on the atmospheric conditions, in particular the precipitation occurrence. Therefore UHV lines emit intensified noise during so called bad weather conditions, among which rainfall, wet snowfall, fog and high air humidity are included.

In a properly designed transmission line during fair weather conditions (i.e. when the are dry) the corona process should not take place, because the maximum conductor surface gradient is most often about 15-17 kV/cm, while the critical value (at which the corona process starts) is about 19-20 kV/cm. However during the bad weather conditions the critical value falls down even to 10-12 kV/cm [2], which is much below the maximum value of the "working" electric field. As a result an intensive corona process is started. During fair atmospheric conditions the corona process is observed for significant surface irregularities, caused by contamination's or insect carcasses on the surface, scratches or delaminations etc., and then the noise of the UHV line can be clearly audible [3,7], sometimes even obnoxious. Depending on the environmental conditions the corona noise at the distance of 30 m from the lateral conductor of a 400 kV power line can be predominantly found in the 35-55 dB (A) range.

Audible noise generated by corona may be considered to be composed of two major components: (1) the tonal components (hum noise)- the second and higher harmonics of the AC power frequency - and (2) the broad-band noise component in the band above 500 Hz [1]. The broad-band component that has significant high-frequency content distinguishing it from more common environmental noises. While the noise component is rather stable, the tonal component exhibit considerable fluctuations both in space and time [5], even up to 20 dB. Additionally, not all AC corona modes [1] create random noise and hum in the same proportion. In different weather conditions the relative magnitudes of random noise and hum may be different. For example, in rain, the broad-band component generally dominates, whereas under conditions of conductor icing a high, 100 Hz hum component may be accompanied by a relatively low level of broad-band noise. This is the reason of certain problems with their measurement. On the other hand the tonal components, according to ISO 1996 standard [6], are accounted for in the noise evaluation by introducing a 3 or 5 dB correction to the measured noise level.

Another item is the problem of the environmental disturbances, which are often hard to eliminate using classical methods [3,7].

In the present work the influence of potential errors, related to the above mentioned effects, on the final result of the long-term levels calculations has been analyzed.

Because of seasonal variation of the weather phenomena long-term levels should be taken as a basis for the noise assessment, according to the ISO 1996 standard. Also the Polish Standard PN-N-01339 [5] introduces the long-term values as the basis for the assessment. On the other hand in the American Standard IEEE Std 656 [4] the night-day levels are taken as basis for evaluation. However even if the introduction of both the long-term and night-day levels makes the evaluation more uniform, it does not allow the elimination of errors related to the evaluation of actual periods of bad and fair weather conditions, the effect of environmental interference and the fluctuation of tonal components.

2 Experimental studies

Experimental studies has been used as a basis to distinguish characteristic certain corona noise spectra components, which can be useful in the process of elimination of environmental interference. The studies have been carried out in vicinity of a 400 kV transmission line, in three primary transmission layouts used in Poland: the line with a 2x225 mm^2 conductor bundle (single and double circuit) and the line with 3x350 mm^2 conductor bundle (double circuit). The studies have been carried out in various atmospheric conditions, totally in more than 80 points.

The signal has been register using a DAT recorder, and the RTA 840 Norsonic spectrum analyser has been used for the spectral analysis.

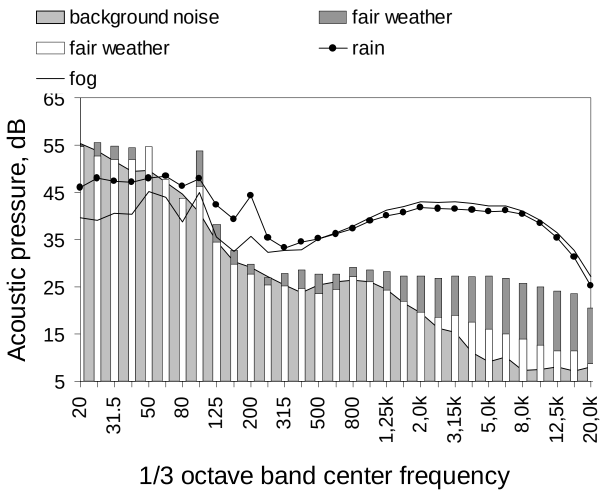

Fig.1.Typical corona-noise spectra in 1/3 octave bands in various weather conditions.

Typical noise spectra in 1/3 octave bands measured in various weather conditions are shown in Fig.1.

In the presented spectrograms both the tonal components and the broad-band noise component can be noticed. The broad-band noise is shown beginning at about 500 Hz and extending up in frequency. T
he roll-off of the broad-band frequency noise above 10 kHz results from the increasing effect of air absorption of said energy with frequency [1]. The 100 Hz hum components from each phase of a power line are pure tones and cannot be considered uncorrelated. The hum at given location is the result of addition in magnitude and phase of direct and ground reflected pressure waves from each phase.

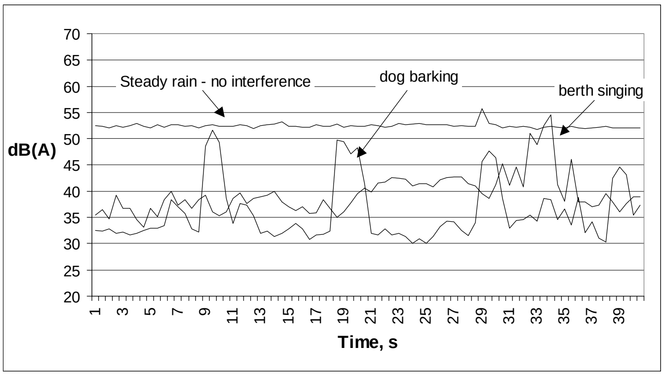

Fig.2. Time dependence of the corona noise A-weighted sound level with visible interference effects.

Examples of time variations of the noise level (A) with clearly noticeable disturbances, measured in various weather conditions, are shown in Fig.2.

3 Analysis of the effect of assumed methodology on the measurement result

Increased interference level conditions. The distinguished characteristic features of the corona noise enable the application of appropriate measurement methodology leading to reduction of measurement errors, resulting from the interference and often rather small distance between the measured signal and the ambient noise. One of such methodologies is the application of statistical levels (percentiles). Exemplary results of application of statistical levels (exceedence levels) for evaluation of the sound level (A) for the corona noise has been shown in Fig.3. The characteristics shown there denote respectively: $L_{Aeq,re}$ - the "reference" level, measured in zero interference conditions, $L_{A\%}$ - the statistical level measured directly on the A filter; $L_{A(s)\%}$ - statistical level determined from the statistical spectra. The percentile values in both cases have given the results closest to the reference level $L_{Aeq,re}$. $L_{Aeq(ave)}$ denotes the noise level measured in the presence of interference.

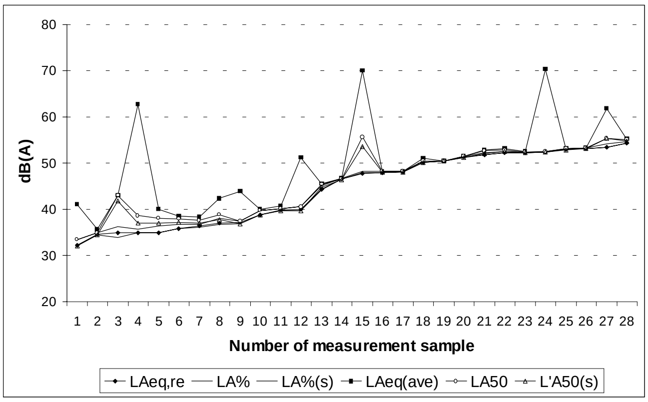

Fig.3. Exemplary results of application of statistical levels for evaluation of the A-weighted sound level for the corona noise

As can be seen in Fig.3 all characteristics have given rather similar results in the low interference level conditions and for high intervals from the acoustic background, i.e. in the analyzed cases of higher levels of the measured noise. The divergences between the particular characteristics become clearly noticeable when the interference is observed, and when distance from the acoustic background becomes lower, what can be also treated as a relative increase of the interference, however taking a very specific form. In most cases the L_{50} gives the best results, however it can be noticed that for the high interference cases better conformance with the "reference" levels is observed for levels with higher percentiles, namely L_{65} and L_{70} for the analyzed case (see Fig.4).

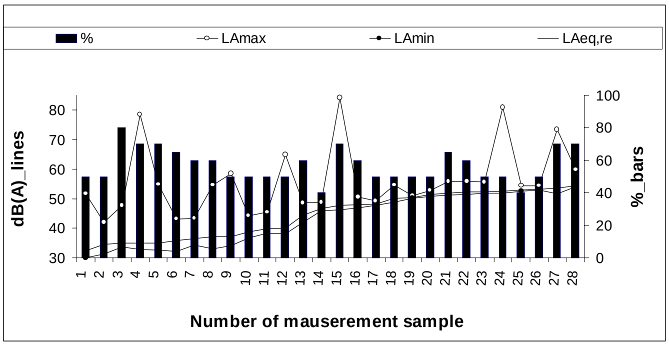

Fig.4.Diagrams of L_{Amax}, L_{Amin}, L_{Aeq} levels and the percentile value of the best conformance with the „reference" level, $L_{Aeq,re}$

Thus it can be concluded that in the presence of increased interference level the statistical levels L_{65} and L_{70} should be used. The choice of the best statistical level may depend on the type of the interference, in particular on the steady or transient nature of the interference.

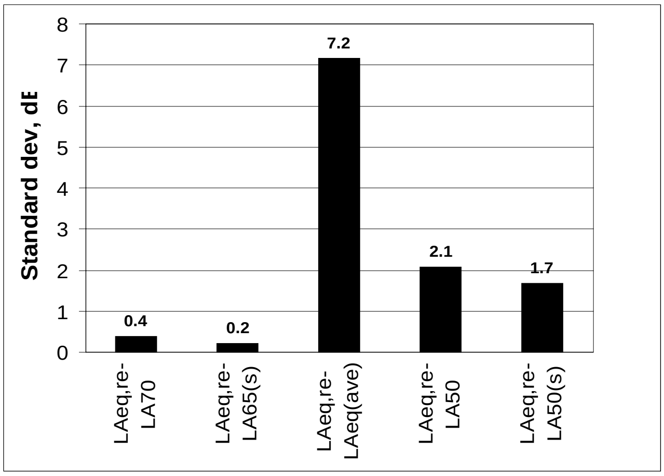

Fig.5. Dispersion of calculating results of differences between „reference" level and particular characteristics.

The results of comparison of the "reference" levels $L_{Aeq,re}$ and the values of the rest of the characteristics are shown in Fig.5 as a plot of standard deviations of differences between "reference" level and particular characteristics. The obtained results prove that the lowest dispersion of the results is observed for the "optimally" chosen statistical level A, determined from the statistical spectrum - the standard deviation almost two times lower than for the statistical level measured directly on the A filter. Much worse results have been obtained when measuring the L_{50} levels, and slightly lower value of the standard deviation has been obtained for levels determined from the spectrum.

Long-term predictions. The values of long-term levels can be determined according to the formula below (1):

$$L_{\mathrm{Aeq,LT}} = 10\lg\left(t_f\, 10^{0,1L_{(\mathrm{Aeq})\mathrm{dp}}} + t_b 10^{0,1L_{(\mathrm{Aeq})\mathrm{zp}}}\right) \qquad (1)$$

where:

- $L_{(Aeq)f}$ - the averaged noise level in good weather conditions, dB
- $L_{(Aeq)b}$ - the averaged noise level in bad weather conditions, dB
- tf,tb - average percentage values of periods of fair and bad weather respectively

Taking into account that in practice in most countries it is assumed that the bad weather conditions occur during 5-10% of the year, the error that can be made in practice by assuming inaccurate period of these conditions is found to be in the 1-3 % range. In Poland the average year periods of fair and bad weather conditions are assumed to be 90 % and 10 % respectively.

Table 1. Examples of long-term levels ($L_{Aeq,LT}$ and $L_{Ar,LT}$) computations

Examles of long-term levels computation using formula 1.						
No	Measurement levels, dB					
	fair weather			bad weather		
	Equivalent level	tone adjustment	ambient noise	Equivalent level	tone adjustment	ambient noise
	L_{Aeq}	K_1	L_{Aam}	L_{Aeq}	K_1	L_{Aam}
no tone adjustement:						
1	39	0	31	51	3	32
2	35.5	0	29			
3	37	0	30			
4	**36.5**			**53.9**		
Long-term average sound level $L_{Aeq,LT}$						44.6
with tone adjustement:						
5	39	0	31	51	0	32
6	35.5	0	29			
7	37	0	30			
8	**36.5**			**50.9**		
Long-term average rating level $L_{Ar,LT}$						**42.2**

Another error that can be committed results from the absence of estimate for the actual period when the tonal components have been observed in a sense of ISO 1996 standard [8] and they should be taken into account by estimation of the appropriate rating level. The differences in calculations of the long-term audible noise level taking into account $L_{Ar,LT}$ and without correcting for the tonal components $L_{Aeq,LT}$ are listed in Table 1.

It can be easily noticed that in practice the difference between those levels will be always contained within 1.5-2.5 dB.

4 Summary and conclusions

As a result of the analysis carried out the following conclusions can be formulated:

1. It is possible to apply the statistical levels for elimination of environmental interference in the measurement of corona noise, and the best results are obtained for statistical levels L_{50}, determined from the statistical spectrum. For the increased interference level the higher percentiles should be used, even L_{70}. For the latter case much worse results have been obtained when the statistical level has been measured directly on the A filter.
2. A considerable contribution to the long-term noise level comes from the noise emitted during good weather conditions, which is usually caused by improper technical condition and contamination's of the conductor's surface.
3. The error resulting from incorrect evaluation of periods of bad atmospheric conditions increases with height of the difference between the noise levels in fair and bad weather conditions. Most frequently the error is contained in 1-3 dB range.
4. Correcting the calculations for the presence of tonal components leads to the increase of the long-term level, in most cases by 1.5 - 2.5 dB. The lower values refer to the cases when the tonal component are absent during fair weather conditions
5. The evaluation of the UHV line noise based on the long-term levels is more adequate than the evaluation using the equivalent level. It contains contributions from the line noise in both fair and bad weather as well as the tonal components, while the evaluation using the equivalent level in practice takes into account only the bad weather conditions. As can be seen from the results an UHV line can be a bothersome noise source even in fair weather conditions.

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