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APPLICATION OF THE CORONA ACOUSTIC SIGNAL IN THE DIAGNOSIS OF THE POWER LINES TECHNICAL CONDITIONS.

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Abstract

Acoustic signal from corona is usually the first symptom of line damages noticed during routine line inspection service. The goal of the study undertaken by the authors is the utilization of the corona process, because if it is impossible to avoid it one should at least try to take some advantages from that fact. One of possible practical benefits of the corona process is the possibility to evaluate the technical condition of some line elements using the acoustic signal of the corona process. The corona audible signal can be easily recorded and its analysis, making use of the contemporary signal processing techniques and artificial intelligence methods, may be the source of information concerning the line damages, which are very difficult to detect and assess by other methods. The essence of the problem is the fact that useful information about the forms and locations of the UHV line damages is hidden in the structure of the analyzed signal and has to be extracted, in which process the artificial intelligence techniques applied by the authors can be very helpful. As has been shown in previous papers some distinctive features of such phenomena can be extracted in laboratory but in real world conditions, where the line damages are not so frequent and their sources are much less obvious, there may be some problems with collecting a properly representative learning set. An additional obstacle is usually higher and more involved character of background noise in reality. The paper contains some results gathered in real world conditions and their application in the diagnosis of the conductor technical conditions in UHV power lines.

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INTRODUCTION

Audible noise generated by the corona in a working power line emerges when value of the electric field vector E on the surface of a conductor or a line element becomes higher than a critical gradient value E_0. Then microdicharge processes emerge, which are, in addition to the acoustic signal, a source of many other adverse phenomena: RF noise, conductor vibrations, production of ozone and nitrogen oxides.

The critical field value E_0 depends not only on the line's design parameters but also on the atmospheric and environmental conditions, as well as on the technical condition of the transmission line elements. During bad weather conditions (rain, drizzle, mist, wet snow etc.) the intensity of corona effect increases as a results of presence of raindrops on the conductor surfaces and because of the increased air humidity, while in fair weather, when the conductors are dry, the corona effects can be stimulated by contamination’s, adhering insect carcasses as well as scratches and damages of the surfaces of conductors, insulators etc. [1],[4]. Therefore the studies of corona process intensity in fair weather conditions can be very helpful.

The effect of the conductor's surface condition on the corona effect intensity has been analysed (among others) in the works of Project UHV [3]. In the latter study however mainly the effects of the conductor's ageing have been examined.

A new-strung transmission line conductor will usually have many significant irregularities on the surface that lower the roughness and the corona threshold line voltage. Since a transmission line is usually economically designed to be close to the threshold of corona in normal use, a newly-strung conductor have high corona loss, audible noise, and radio noise. The free charge resulting from corona on irregular surfaces causes a local ion bombardment that can blunt the sharp points on an aluminum conductor surface abrasion and hasten the weather removal spider webs, bird droppings, and other fair weather corona sources. From photographs taken of on new and old conductors, it is concluded that the older (aged) conductors are hydrophobic whereas the new are definitely hydrophobic [4].

One of the line damage detection methods used at present is the measurement of RF interference signal, whilst the acoustic signal is usually the first symptom of line damages noticed during routine line inspection service. As the measurement of the RF interference in actual conditions can be rather difficult to realize, the possibility of using also the acoustic signal as a line damage symptom seems very attractive [2]. The primary difficulty in the utilization of acoustic signal is the problem of proper attribution of the signal to its original source. Another problem is the contribution from the environmental background signal, which is usually enhanced in the fair weather conditions.

Preliminary studies carried out during the previous research project [6] have shown, that in some conditions there is a possibility of distinguishing between the sources of increased corona effect by application of artificial intelligent methods. In order to increase the number of correct recognitions, and on the other hand, to promote the applications of the elaborated neural models in real conditions, some additional experimental studies have been carried out in laboratory conditions and real world condition as well.

The results of the laboratory studies have shown that it is possible to choose such a parameterization of that signal, which, by application of artificial intelligence methods, will allow identification with high probability of the origins of increased corona discharge [4],[5].

However in real world conditions the accumulation of data volume sufficient, e.g. for learning an artificial neural network, is extremely difficult, mainly because of a limited number of damage cases, environmental disturbances (more frequent than in the laboratory studies), or problems with physical identification of the damage type when the line voltage is on.

In the analysis of the experimental results the attention was mainly focused on extraction of distinctive features of the corona audible noise, which are insensitive to the external disturbances encountered in natural environment. The tool used for assistance in the process of selection of distinctive features of the corona effect was the aggregation analysis from the "Statistica" software package

EXPERIMENTAL STUDIES

The noise spectrum registered in the intense corona discharge conditions is dominated by the broadband noise, however tonal components are also observed with frequencies being multiples of the network frequency (hum noise). The broadband component is a result of randomly generated acoustic waves from random sources located along the conductor. The tonal components are generated as a result of coordinated ion movement in the ionized air volume around the conductor and cyclic discharge occurrences in the positive and negative polarity semi-period.

Not all corona modes [4] create random noise and hum in the same proportions. The broad-band random noise is generated primarily by positive-polarity streamers, whereas Trichel pulses may produce intense ionization and consequently a strong 100 Hz hum component. The 100 Hz hum components from each phase of a transmission line are pure tones and cannot be considered uncorrelated. The hum at given location is the result of the addition in magnitude and phase of the direct and ground-reflected pressure waves from each phase.

As it was shown by the studies carried out in laboratory conditions the measurements of the spectral components in the frequency band about 1 kHz are particularly useful, because a high correlation has been found with the interference in the RF and TV bands [2]. On the other hand the high frequency components exhibit low contributions in the environmental noise therefore its possible to achieve high signal to noise ratio.

In the real world studies of the corona audible noise, similarly to the laboratory conditions, the basic information carried by the acoustic signal is contained in the spectral density distribution levels both in the tonal component bands and in the broadband component.

The experimental data has been collected in the neighborhoods of 400 and 220 kV UHV power lines in the area of Poland. The corona noise has been measured in fair weather conditions, when then conductor surfaces were dry, in the locations where increased noise levels have been observed.

Same pictures of power lines, clean, contaminated and damaged conductor and visible corona effect as well, one can see in Fig.1.

Fig.1.Some pictures of UVH power line and conductors – clean, contaminated, damaged and visible corona effect.

In every site a time sample of the acoustic signal has been recorded from a location as near to the conductors as possible - in most cases under the line conductors. The examples of acoustic signal spectra measured in the initial stage of the intense corona process, for various surface conditions and real world conditions have been shown in Fig.2

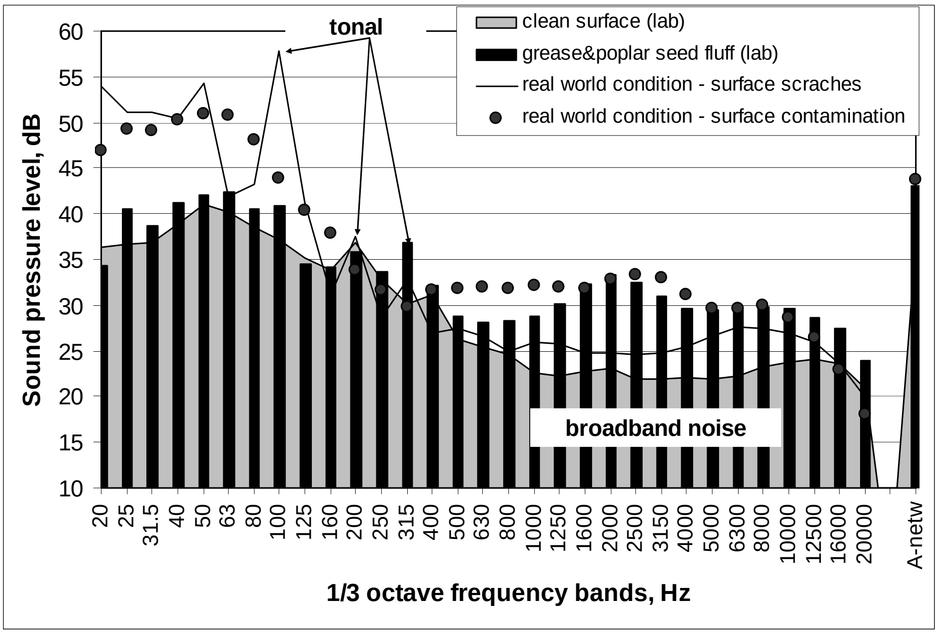

Fig.2.Examples of acoustic spectra measured in the initial phase of corona process for the cases of clean, polluted and damaged conductor surfac

Total of more than 120 cases have been collected, which have been divided into: 1-damages in the support axis (US), 2-insulator damages (UZ), 3-contaminations (Z), 4-unidentified (N). As a result after rejection of the cases with very weak signals (correlated to the background signal) and very high signals (mostly resulting from high air humidity values) 85 cases have been qualified for further analysis.

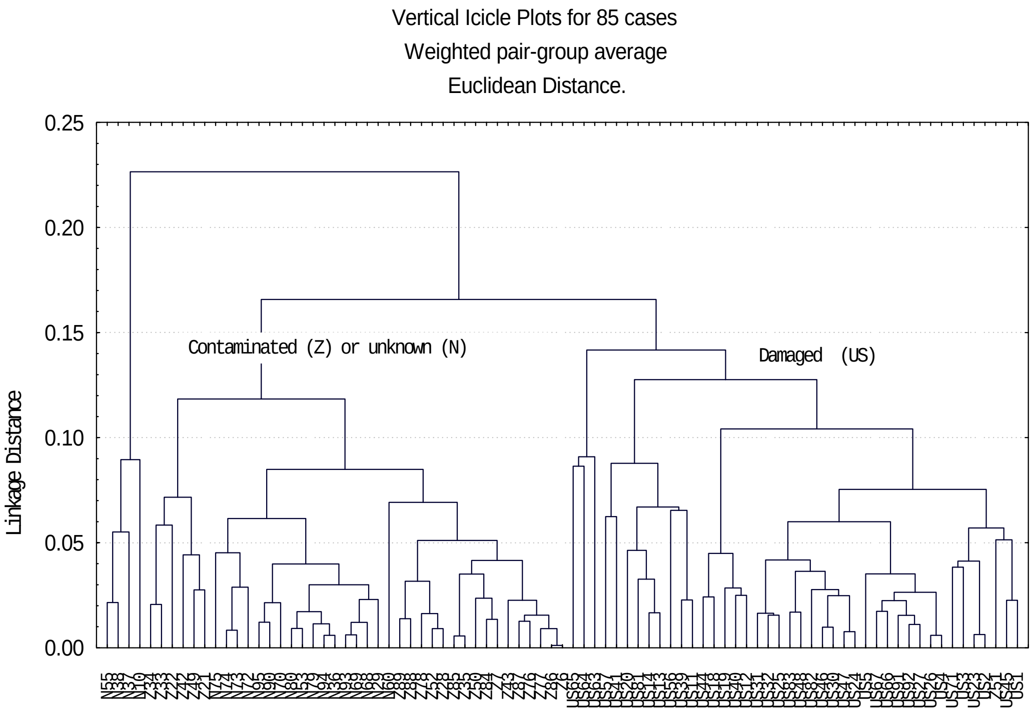

Fig.3. The final shape of agglomeration of the data set.

VECTOR OF DISTINCTIVE FEATURES FOR CORONA NOISE

In parametrization of the corona audible noise special attention has been paid to the quality of the feature vector selection in the real world conditions. In construction of the feature vector the selected features of the static spectrum X1 and dynamic spectrum X2 have been used, defined as follows:

$<f1, f2, \ldots, f5>=X1$, where: fi – averaged values in the i-th frequency band: 100, 200 Hz in 1/3 octave bands and1-2.5, 3.15 – 6.3, 8-12.5 kHz, dB

$<M0, M1, M2>=X2$, where: M0, M1 i M2 – moments of respective components in the spectrum frequency bands [5]:

The obtained 15 element feature vector, which is considerably too large as for the measured number of cases, has been subject to the cluster analysis procedure in order to extract the features useful in the construction of a neural model, and on the other hand to reject the identical or unwanted data.

In the first stage agglomeration has been carried out with respect to the signal features. After several stages elimination of these features the final feature vector contained six features, for which the case agglomeration test has been carried out, with application of various connection methods and distance measures. Finally the weighted average connections have been used, with Lance-Williams formula and

Euclidean metric. The agglomeration of cases with respect to the above mentioned measures has been shown in Fig.3. As can be noticed in the picture considerably good separation has been obtained between the damage cases and the rest - contaminations and unidentified cases. Among the contamination and remaining cases there are also groups of aggregated features, so they probably may represent similar types of line defects, which cannot be identified at the moment.

CONCLUSIONS

The obtained results show the difficulties encountered during the data gathering in reality. As a consequence of insufficient knowledge about specific cases of line contaminations and damages, and on the other hand similar nature of the occurring contaminations and damages, the obtained sets of data are inhomogeneous according to laboratory data.

The applied cluster analysis turned out to be particularly useful in elimination of identical and unwanted cases in the set of distinctive features. The features representing the signal's time dependence exhibit poor discriminative properties. There is also a good aspect of that fact, because the acquisition of these features is time consuming and technically more demanding.

The presented results indicate a possibility of construction of a diagnostic system for the UHV line damages, with application of the corona audible noise as a supporting method to the systems based on the RF interference signal measurement, particularly in the aspect of discrimination between the contaminations and damages of the conductor surface. However for the construction of the neural model of the studied phenomenon further enlargement of the data base is necessary, so that the data represent a wider spectrum of real line damage cases.

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