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IEEE Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines

IEEE Power Engineering Society

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**Transmission and Distribution Committee
of the
IEEE Power Engineering Society**

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Abstract: Definitions and usage of terms used in the measurement and analysis of corona and field effects of overhead power lines are presented in this standard. Correlation between measurements from equipment to standard terms is defined. Weather conditions such as rain, snow, fog, and drizzle are defined and their measurement standards discussed. The intent is to assist in correlating standard terms found in literature and requirements to standard engineering practice.

Keywords: audible noise, corona, electric field, electric field meter, fair weather, field effects, foul weather, freezing rain, magnetic field, perturbed field, radio noise, rain, snow, Trichel streamers, uniform field, wet snow,

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Introduction

This introduction is not part of IEEE Std 539-2005, IEEE Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines.

The purpose of this standard is to achieve uniformity in the use of terms relating to the areas of corona and the electromagnetic environment of power lines. Its scope is to define the most widely used terms specific to or associated with overhead power-line corona and field effects.

The original IEEE Std 539 and its 1979 and 1990 revisions were limited to terms relating to overhead power-line corona and radio noise. Since that time, the areas of interest have broadened to include audible noise, electric and magnetic fields, and space charge. The IEEE Power Engineering Society has recognized this by expanding the scope of the Radio Noise and Corona Subcommittee and renaming it the Corona and Field Effects Subcommittee. Thus, the present revision has accordingly been broadened to include all aspects of power-line corona and electromagnetic fields. This standard marks the departure from the traditional method of specifying levels as they relate to sound pressure levels, exceedence levels, rain levels, etc. This standard adopts the method specified in the National Institute of Standards and Technology, Special Publication 811, Guide for the Use of the International System of Units (SI), 1995 Edition.^a

Development of this revision of the standard was accomplished by the Design and Environmental Considerations Working Group of the Corona and Field Effects Subcommittee under the sponsorship of the Transmission and Distribution Committee of the IEEE Power Engineering Society. The work was carried to completion under the direction of Stephen Sebo and George Gela.

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Contents

1.	Overview.....	1
1.1	Scope.....	1
1.2	Purpose.....	1
2.	Normative references.....	1
3.	Basic definitions	2
4.	Statistical terms.....	5
5.	Weather classifications	7
6.	Terms related to electric and magnetic fields	9
7.	Terms related to electric field strength and magnetic flux density measurement devices.....	15
8.	Terms related to ions.....	17
9.	Terms related to corona and gap discharges	18
10.	Terms related to radio frequency wave propagation	20
11.	Terms related to electromagnetic signals and noise	22
12.	Terms related to electromagnetic signal and noise measurements	24
13.	Terms related to acoustics.....	26
14.	Terms related to audible noise measurements	26
15.	Terms related to coupled voltages and currents.....	29
16.	Terms related to shock and perception effects.....	30
17.	Terms related to shielding from magnetic fields	31
Annex A (informative) Terms relating to the biological effects of electric and magnetic fields in the extreme low frequency range.....		32
Index		36

IEEE Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines

1. Overview

1.1 Scope

The scope of this standard is to define the most widely used terms specific to or associated with overhead power-line corona and field effects.

1.2 Purpose

The purpose of this standard is to achieve uniformity in the use of terms relating to the areas of corona and the electromagnetic environment of power lines.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C63.2-1987, American National Standard for Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz Specifications.¹

ANSI S1.1, American National Standard for Acoustical Terminology.

ANSI S1.4.-1983 (Reaff 2001), American National Standard Specification for Sound Level Meters.

CFR Title 47, Code of Federal Regulations. U.S. Government Printing Office, Washington, D.C. [current edition (annual publication)].²

¹ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

²CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (<http://www.gpoaccess.gov/>).

CISPR 16-2, Specifications for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 2: Methods of Measurement of Disturbance and Immunity.³

CISPR 18-2 (1986), Radio Interference Characteristics of Overhead Power Lines and High-Voltage Equipment—Part 2: Methods of Measurement and Procedure for Determining Limits.

IEC 60050-161:1990, International Electrotechnical Vocabulary—Chapter 161: Electromagnetic Compatibility.⁴

IEEE Std 430™-1986, IEEE Standard Procedures for the Measurement of Radio Noise from Overhead Power Lines and Substations.^{5,6}

IEEE Std 644™-1994, IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines.

IEEE Std 656™, IEEE Standard for the Measurement of Audible Noise from Overhead Transmission Lines.

NEMA 107-1987, Methods of Measurement of Radio Influence Voltage (RIV) of High-Voltage Apparatus.⁷

Huschke, R. E., ed., *Glossary of Meteorology*. Boston: American Meteorological Society, 1970.

James, G., and James, R. C., eds., *Mathematics Dictionary*, 4th edition. New York: Van Nostrand Company, 1976.

Kendall, M. G., and Buckland, W. R., eds., *A Dictionary of Statistical Terms*, 4th edition. New York: Longman Group Ltd., 1982.

Reilly, J. P. et al., “Electric and magnetic field coupling from high-voltage ac power transmission lines—classification of short-term effects on people.” *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-97, no. 6, Nov/Dec 1978, pp. 2243–2252.

3. Basic definitions

General terms used throughout this document are defined in this clause.

3.1 wave: A disturbance propagated in a medium.

NOTE—*Disturbance* in this definition is used as a generic term indicating not only mechanical displacement but also voltage, current, electric field strength, temperature, etc. Any physical quantity that has the same relationship to some independent variable (usually time) as a propagated disturbance, (at a particular instance) with respect to space, may be called a wave.⁸

³CISPR documents are available from the International Electrotechnical Commission, 3, rue de Varembe, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁴IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

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⁸Notes in text, tables, and figures are given for information only, and do not contain requirements needed to implement the standard.

3.2 wavelength: The distance between points of the corresponding phase of two consecutive cycles of a sinusoidal wave. The wavelength, λ , is related to the phase velocity, v , and the frequency, f , by $\lambda = v / f$.

3.3 frequency: The number of complete cycles of sinusoidal variation per unit time.

NOTE 1—Typically, for ac power lines, the power frequency is 60 Hz in North America and certain other parts of the world and 50 Hz in Europe and many other areas of the world.

NOTE 2—Electric and magnetic field strength components produced by power lines have frequencies equal to that of power-line voltages and currents.

NOTE 3—The term *power frequency* is often used to avoid specifying whether the power line in question operates at 50 Hz or 60 Hz.

3.4 harmonic content: Distortion of sinusoidal waveform characterized by the magnitude and the order of the Fourier series terms that describe the wave.

NOTE—For power lines, the harmonic content is small and of little concern for the purpose of electric field strength and magnetic flux density measurements except at points near large nonlinear loads (saturated power transformers, rectifiers, aluminum and chlorine plants, etc.), where certain harmonics may reach 10% of the line voltage or current. Laboratory installations may also have voltage or current sources with significant harmonic content.

3.5 signal: The intelligence, message, or effect conveyed over a communication system.

3.5.1 wanted signal: A signal that constitutes the object of the particular measurement or reception.

3.5.2 unwanted signal: A signal that may impair the measurement or reception of a wanted signal.

3.6 noise: An undesired disturbance within the useful frequency band.

3.6.1 electromagnetic noise: A time-varying electromagnetic phenomenon that apparently does not convey information and that may be superimposed on or combined with a wanted signal.

3.6.2 radio noise (RN): Electromagnetic noise having components in the radio frequency range.

3.6.2.1 radiated radio noise: Radio noise that is propagated by radiation from a source into space in the form of electromagnetic waves, e.g., the undesired electromagnetic waves generated by corona sources on a transmission line.

NOTE—Radiated radio noise includes both the radiation and the induction components of the electromagnetic fields generated by the noise source.

3.6.2.2 conducted radio noise: Radio noise that is propagated by conduction from a source through electrical connections.

3.6.3 audible noise (AN): Any undesired sound. *Syn:* **acoustic noise.**

3.6.4 ambient noise: The all-encompassing noise associated with a given environment, usually a composite of contributions from many sources near and far.

3.6.5 background noise: The total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal.

NOTE—Ambient noise detected, measured, or recorded with the signal becomes part of the background noise.

3.6.6 random noise: Noise that comprises transient disturbances occurring at random. *Syn:* **fluctuation noise.**

NOTE 1—Random noise is the part of noise that is unpredictable except in a statistical sense. The term is most frequently applied to limiting cases where the number of transient disturbances per unit time is large, so that the spectral characteristics are the same as those of thermal noise. Thermal noise and shot noise are special cases of random noise.

NOTE 2—A random noise whose instantaneous magnitudes occur according to the Gaussian distribution is called *Gaussian random noise*.

NOTE 3—In power-line noise, random noise is a component of the total noise caused by discharges.

3.6.7 impulse noise: Noise characterized by transient disturbances separated in time by quiescent intervals.

NOTE 1—The frequency spectrum of these disturbances is substantially uniform over the useful passband of the transmission system.

NOTE 2—The same source may produce impulse noise in one system and random noise in a different system.

3.6.8 white noise: Noise, either random or impulsive, that has a flat frequency spectrum in the frequency range of interest.

3.7 signal-to-noise ratio (S/N): The ratio of the value of the signal to that of the noise.

NOTE 1—This ratio is usually in terms of measured peak values in the case of impulse noise and in terms of the root-mean-square (rms) values in the case of random noise.

NOTE 2—Where there is a possibility of ambiguity, suitable definitions of the signal and noise should be associated with this term; as, for example, peak signal to peak noise ratio, rms signal to rms noise ratio, peak-to-peak signal to peak-to-peak noise ratio, etc. In measurements of transmission line noise in the AM frequency range, the ratio of average station signal level to quasi-peak line noise level is generally used.

NOTE 3—This ratio often may be expressed in decibels (dB).

NOTE 4—This ratio may be a function of the bandwidth of the transmission or measuring system.

3.8 frequency spectrum: The distribution of the amplitude (and sometimes the phase) of the frequency components of a signal, as a function of frequency.

3.9 profile: A diagram showing the variation of a quantity or parameter with location.

3.9.1 lateral profile: The profile of a parameter, usually near ground level, plotted as a function of the horizontal distance from and at a right angle to the line conductors. For example, a lateral profile of the vertical component of the electric field strength, of the radio noise field strength, etc.

3.9.2 longitudinal profile: The profile of a parameter, usually near ground level, measured at a constant lateral distance from the power line and plotted as a function of distance along the line. For example, a longitudinal profile of the vertical component of the electric field strength, of the radio noise field strength, etc.

3.10 decibel (dB): One-tenth of a bel, the number of decibels denoting the ratio of two amounts of power being ten times the common logarithm of this ratio.

NOTE—The abbreviation dB is commonly used for the term *decibel*. With P_1 and P_2 designating two amounts of power, and n the number of decibels denoting their ratio

$$n = 10 \log (P_1/P_2) \text{ dB}$$

When the conditions are such that ratios of currents or ratios of voltages (or analogous quantities in other disciplines) are the square roots of the corresponding power ratios, the number of decibels by which the corresponding powers differ is expressed by the following equations:

$$n = 20 \log (I_1/I_2) \text{ dB}$$

$$n = 20 \log (V_1/V_2) \text{ dB}$$

where

I_1/I_2 = the given current ratio

V_1/V_2 = the given voltage ratio

By extension, these relations between numbers of decibels and ratios of currents or voltages are sometimes applied where these ratios are not the square roots of the corresponding power ratios; to avoid confusion, such usage should be accompanied by a specific statement of the application in question.

3.11 level: Magnitude, especially when considered in relation to an arbitrary reference value. Level may be stated in the units in which the quantity itself is measured (for example, volts and ohms) or in the units (for example, decibels) expressing the ratio to a reference value.

NOTE 1—Examples of the kinds of levels in common use are electric power level, sound pressure level, and voltage level.

NOTE 2—In symbols

$$L = k \log_r (q/q_o)$$

where

L = the level determined by the kind of quantity under consideration

r = the base of the logarithm of the reference ratio

q = the quantity under consideration

q_o = the reference quantity of the same kind

k = a multiplier that depends upon the base of the logarithm and the nature of the reference quantity

NOTE 3—The level as defined here is measured in two common units: decibels when the logarithmic base is 10 or nepers when the logarithmic base is e . The decibel requires that k be 10 for ratios of power or 20 for quantities proportional to the square root of power. The neper is used to represent ratios of voltage, current, sound pressure, and particle velocity. The neper requires that k be 1.

4. Statistical terms

The levels defining corona and field effects on transmission lines are variable in time and cannot, without qualification, be adequately characterized by a single value. Many statistical terms are applied to levels defining corona and field effects. The following definitions apply to more commonly used terms (see also *A Dictionary of Statistical Terms*, 4th edition, and *Mathematics Dictionary*, 4th edition).⁹

4.1 general statistical terms: Terms applied to the procedures of data collection, classification, and presentation.

4.1.1 frequency of occurrence: If a process is repeated n times, during which an event occurs m times, the frequency of occurrence of the event, h , is defined as $h = m/n$. For large values of n , the frequency approaches the asymptotic value, called *probability of occurrence*.

4.1.2 probability of occurrence: The asymptotic value of the frequency of occurrence of the event.

4.1.3 probability density function $[p(x)]$: The derivative of the probability distribution function $P(x)$.

⁹Information on references can be found in Clause 2.

NOTE—An expression giving the probability of a discrete random variable x as a function of x or, for continuous random variables, the probability in an elemental range dx . The total probability is unity or 100%, so that the probability density function represents the proportion of probabilities for particular values of x .

4.1.4 probability distribution function $[P(x)]$: The probability that a parameter is less than or equal to a given value x .

NOTE 1—The distribution function $P(x)$ for a random variable x is the total frequency of occurrence of members with particular random-variable values less than or equal to x . The total frequency of occurrence of all values of x is unity or 100%, so that the distribution function is the proportion of members bearing values less than or equal to x . Similarly, for n , particular values of the random variable, $x_1, x_2, \dots, x_n$, the distribution function $P(x_1, x_2, \dots, x_n)$ is the frequency of values less than or equal to x_1 , for the first values, x_2 for the second, and so on.

NOTE 2—The terms *cumulative probability distribution* and, very often, simply *distribution* are used to denote the probability distribution function.

4.1.5 probability paper: A graph paper with the grid along the ordinate specially ruled so that the distribution function of a specified distribution can be plotted as a straight line against the variable on the abscissa. These specially ruled grids are available for the normal, binomial, Poisson, log-normal, and Weibull distributions, respectively.

4.2 statistical terms related to corona effects: Terms applied to the procedures of data collection, classification, and presentation relating to corona effects.

4.2.1 all weather distribution: A distribution of corona-effect data collected under all weather conditions. Such data are usually obtained from long-term recording stations.

NOTE—Weather conditions are defined in Clause 5.

4.2.2 fair weather distribution: A frequency or probability distribution of corona-effect data collected under fair weather conditions.

4.2.3 foul weather distribution: A frequency or probability distribution of corona-effect data collected under foul weather conditions. Other distributions can also be defined for more specific foul weather conditions such as rain, snow, fog, sleet, frost, etc.

4.2.4 exceedance level: A statistical descriptor that is often used in expressing levels of quantities. For example, in acoustics, the $L_{A,10\%}$ is the A-weighted sound level exceeded for 10% of the time over a specified time period (and for corona noise and a specified weather condition). For the other 90% of the time, the sound level is less than the $L_{A,10\%}$. Similarly, the $L_{A,50\%}$ is the sound level exceeded 50% of the time; the $L_{A,90\%}$ is the sound level exceeded 90% of the time, etc.

The concept of exceedance levels can also be used as a statistical term for other corona effects such as radio noise, corona loss, and dc fields and ions. Any exceedance level can be easily obtained from distributions that have been plotted on probability paper. *Syn:* **L-level**.

NOTE—When using this format for specifying levels for quantities such as rain, the form would be $L_{\text{rain},10\%}$, which would indicate the level of rain that would be exceeded 10% of the time over a specified time period.

4.2.5 median ($L_{50\%}$): The level exceeded 50% of the time over a specified time period with a specified weather condition.

4.2.6 arithmetic mean: The numerical result obtained by dividing the sum of two or more quantities by the number of quantities. *Syn:* **average**.

NOTE 1—Strictly speaking, arithmetic means of corona-effect data expressed in decibels cannot be taken unless the sound pressure values are converted back to field quantity values, expressed in units such as microvolts per meter ($\mu\text{V}/\text{m}$) or micropascals (μPa).

NOTE 2—An arithmetic mean that is commonly used in audible noise investigations is the energy average of the quantities [see **14.3.1 energy-equivalent sound level ($L_{A,eq}$)**]. The units in decibels above 20 μPa are converted to energy units such as microwatts (μW), which are then averaged.

4.2.7 geometric mean: The numerical result obtained by taking the n th root of the product of n quantities, n being equal to or greater than two.

NOTE—In radio noise measurements, geometric means have been used to determine the long-line frequency spectrum from the short-line frequency spectrum by taking the geometric mean of the maximum and minimum values in microvolts per meter across the spectrum (or the arithmetic mean of values in decibels).

5. Weather classifications

Corona phenomena are drastically affected by the weather. Foul weather conditions have the greatest effect on corona generation, and it is important to have a common understanding of the weather terms that are used (see *Glossary of Meteorology*).

5.1 precipitation intensity: The rate of precipitation, usually expressed in millimeters per hour (mm/h). Since precipitation intensity in general is not constant, an average over some time period shorter than 1 h is most useful, unless instantaneous intensity is measured. *Syn:* **intensity of precipitation.**

NOTE—Rain gauge measurements can provide an indication of intensity except for light rain, where the quantization error is large.

5.2 fair weather: The weather condition when the precipitation intensity is zero and the transmission line conductors are dry.

NOTE—This should not be confused with the general connotation of fair weather as descriptive of pleasant weather conditions. Common usage is subject to misinterpretation, for it is a purely subjective description. Technically, when this term is used in weather forecasts, it is meant to imply no precipitation, less than 40% sky cover of low clouds, and no other extreme conditions of cloudiness, visibility, or wind.

5.3 foul weather: The weather condition when there is precipitation or that can cause the transmission line conductors to be wet. Fog is not a form of precipitation, but it causes conductors to be wet. Dry snow is a form of precipitation, but it may not cause the conductors to be wet.

5.4 rain: Precipitation in the form of liquid water drops with diameters greater than 0.5 mm or, if widely scattered, smaller diameters.

For observation purposes, the intensity of rainfall at any given time and place may be classified as follows:

- 1) *Very light*—scattered drops that do not completely wet an exposed surface regardless of duration
- 2) *Light*—the rate of fall being no more than 2.5 mm/h
- 3) *Moderate*—from 2.6 mm/h to 7.6 mm/h, the maximum rate of fall being no more than 0.76 mm in 6 min
- 4) *Heavy*—over 7.6 mm/h

When rain gauge measurements are not readily available to determine the rain intensity, estimates may be made according to a descriptive system set forth in observation manuals. *Syn:* **drizzle.**

NOTE 1—For corona studies, probability distributions for rain are produced from data obtained during “measurable rain,” i.e., rain intensities that can be measured with standard rain counters such as tipping buckets or instantaneous rate meters.

NOTE 2—For ac lines, heavy rain levels are often considered representative of maximum or $L_{5\%}$ levels. Heavy rain data are often generated by artificial tests on conductors strung in high-voltage test setups.