

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

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Abstract: IEEE Std 539-1990, *IEEE Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines*, defines terms related to the areas of corona and the electromagnetic environment of overhead power lines. Its scope is to define the most widely used terms specific to or associated with overhead power-line corona and fields. This includes terms used in electric and magnetic fields, ions, radio frequency propagation, electromagnetic signals and noise, audible noise, coupled voltages and current, shock and perception, weather and related statistical terms, and measurements and measuring devices.
Keywords: audible noise, corona, electric field, electromagnetic interference, magnetic field, overhead power lines, radio noise

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Secretary, IEEE Standards Board
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Foreword

(This Foreword is not a part of IEEE Std 539-1990, 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 fields.

The original standard 539 and its 1979 revision 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.

Development of this revision of this 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. The members of the Design and Environmental Working Group at the time this standard was completed were:

J. R. Stewart, Chair

R. Aker	V. J. Longo	J. P. Reilly
G. K. Bell	Kate Brown Maracas	S. Rodick
H. Bhai	P. S. Maruvada	W. R. Schlinger
Robert Carberry	T. J. McDermott	S. A. Sebo
J. H. Dunlap	G. B. Niles	J. M. Silva
C. H. Gary	Carlos A. O. Peixoto	Norman E. Spaulding
George Gela	Adalberto Porrino	R. D. Stearns
Wasył Janischewskyj	M. G. Poland	J. M. Van Name
Nester Kolcio	M. A. Reavis	F. W. Warburton

The following persons were on the balloting committee that approved this document for submission to the IEEE Standards Board:

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J. C. Engimann	P. S. Maruvada	R. M. Showers
D. A. Gillies	T. J. McCarthy	J. M. Van Name
J. H. Harlow		S. S. Venkata

The final conditions for approval of this standard were met on November 14, 1990. This standard was conditionally approved by the IEEE Standards Board on September 28, 1990, with the following membership:

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

1. Basic Definitions

1.1 General

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

1.2 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.

1.3 Wavelength

The distance between points of 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 $\lambda = v/f$.

1.4 Frequency

The number of complete cycles of sinusoidal variation per unit time.

NOTES:

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.

- 2 — Electric and magnetic field strength components produced by power lines have frequencies equal to that of power-line voltages and currents.
- 3 — The term “power frequency” is often used to avoid specifying whether the power line in question operates at 50 Hz or 60 Hz.

1.5 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 industrial 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.

1.6 Signal

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

1.6.1 Wanted Signal

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

1.6.2 Unwanted Signal

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

1.7 Noise

An undesired disturbance within the useful frequency band.

1.7.1 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.

1.7.2 Radio Noise (RN)

Electromagnetic noise having components in the radio frequency range.

1.7.2.1 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.

1.7.2.2 Conducted Radio Noise

Radio noise that is propagated by conduction from a source through electrical connections.

1.7.3 Audible Noise (AN)

Any undesired sound.

NOTE — Acoustic noise is synonymous.

1.7.4 Ambient Noise

Ambient noise is the all-encompassing noise associated with a given environment, usually a composite of contributions from many sources near and far.

1.7.5 Background Noise

Background noise is 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.

1.7.6 Random Noise

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

NOTES:

- 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.
- 2 — A random noise whose instantaneous magnitudes occur according to the Gaussian distribution is called “Gaussian random noise.”
- 3 — In power-line noise, “random noise” is a component of the total noise caused by discharges.

1.7.7 Impulse Noise

Noise characterized by transient disturbances separated in time by quiescent intervals.

NOTES:

- 1 — The frequency spectrum of these disturbances is substantially uniform over the useful passband of the transmission system.
- 2 — The same source may produce impulse noise in one system and random noise in a different system.

1.7.8 White Noise

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

1.8 Signal-to-Noise Ratio

The ratio of the value of the signal to that of the noise.

NOTES:

- 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.

- 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.
- 3 — This ratio often may be expressed in decibels (dB).
- 4 — This ratio may be a function of the bandwidth of the transmission or measuring system.

1.9 Frequency Spectrum

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

1.10 Profile

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

1.10.1 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.

1.10.2 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.

1.11 Decibel

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:

$$n = 10 \log(P_1/P_2) \text{ dB} \quad (1)$$

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:

$$n = 20 \log(I_1/I_2) \text{ dB} \quad (2)$$

$$n = 20 \log(V_1/V_2) \text{ dB} \quad (3)$$

where

$$\begin{aligned} I_1/I_2 &= \text{The given current ratio} \\ V_1/V_2 &= \text{The given voltage ratio} \end{aligned}$$

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.

1.12 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, ohms, etc.) or in the units (for example, decibels) expressing the ratio to a reference value.

NOTES:

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

2 — In symbols:

$$L = k \log_r(q/q_0) \quad (4)$$

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_0 = 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

3 — The level as here defined 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.

2. Statistical Terms

2.1 General

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* [14];¹ *Mathematics Dictionary* [13]).

2.2 General Statistical Terms

Terms applied to the procedures of data collection, classification, and presentation.

2.2.1 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.

2.2.2 Probability of Occurrence

The asymptotic value of the frequency of occurrence of the event.

¹The numbers in brackets correspond to those of the references in Section 15.

2.2.3 Probability Density Function [$p(x)$].

The derivative of the probability distribution function $P(x)$.

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 .

2.2.4 Probability Distribution Function [$P(x)$].

The probability that a parameter is less than or equal to a given value x .

NOTES:

- 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.
- 2 — The terms “cumulative probability distribution” and, very often, simply “distribution” are used to denote the probability distribution function.

2.2.5 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, lognormal, and Weibull distributions, respectively.

2.3 Statistical Terms Related to Corona Effects

Terms applied to the procedures of data collection, classification, and presentation relating to corona effects.

2.3.1 All Weather Distribution

A distribution of corona-effect data collected under all weather conditions. Such data are usually obtained from long-term recording stations. Weather conditions are defined in the next section.

2.3.2 Fair Weather Distribution

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

2.3.3 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.

2.3.4 Exceedance Level

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

2.3.5 Median (L_{50}).

The level exceeded 50% of the time over a specified time period with a specified weather condition.

2.3.6 Arithmetic Mean

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

NOTES:

- 1 — Strictly speaking, arithmetic means of corona-effect data expressed in decibels cannot be taken unless the numbers are converted back to real units such as microvolts per meter ($\mu\text{V/m}$) or micropascals (μPa).
- 2 — An arithmetic mean that is commonly used in audible noise investigations is the energy average of the quantities (see 12.4.1). The units in decibels above 20 μPa are converted to energy units such as microwatts (μW), which are then averaged.

2.3.7 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).

3. Weather Classifications

3.1 General

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 the *Glossary of Meteorology* [12]).

3.2 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.

3.3 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.

3.4 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.

3.5 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

- 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 to 7.6 mm/h, the maximum rate of fall being no more than 0.76 mm in 6. min
- 4) "Heavy," over 7.7 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**.

NOTES:

- 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.
- 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.
- 3 — The only other form of liquid precipitation, drizzle, is to be distinguished from rain in that drizzle drops are generally less than 0.5 mm in diameter, are very much more numerous, and reduce visibility much more than does light rain.

3.6 Snow

Precipitation composed of white or translucent ice crystals, chiefly in complex branched hexagonal form and often agglomerated into snowflakes.

For weather observation purposes, the intensity of snow is characterized as

- 1) "Very light," when scattered flakes do not completely cover or wet an exposed surface, regardless of duration
- 2) "Light," when the visibility is 1.0 km or more
- 3) "Moderate," when the visibility is less than 1.0 km but more than 0.5 km
- 4) "Heavy," when the visibility is less than 0.5 km

The classification of snowfall according to its intensity is identical to that of rain, where the equivalent amount of water accumulated in millimeters per hour is measured. An easier but less accurate approach uses the depth of the accumulated snow.

3.7 Mixed Rain and Snow

Precipitation consisting of a mixture of rain and wet snow. It usually occurs when the temperature of the air layer near the ground is slightly above freezing.

3.8 Wet Snow

Deposited snow that contains a great deal of liquid water. If free water entirely fills the air space in the snow, it is classified as “very wet” snow.

NOTE — This condition causes water drops similar to rain to form on the conductors.

3.9 Hoarfrost

A deposit of interlocking ice crystals (hoar crystals) formed by direct sublimation on objects, usually those of small diameter freely exposed to the air such as tree branches, plant stems and leaf edges, wires, poles, etc.

The deposition of hoarfrost on an object is similar to the process by which dew is formed, except that the temperature of the object must be below freezing. It forms when air with a dew point below freezing is brought to saturation by cooling. *Syn:* **frost; white frost; crystalline frost; hoar.**

3.10 Freezing Rain

Rain that falls in liquid form but freezes on impact to form a coating of glaze upon the ground and on exposed objects.

3.11 Fog

Visible aggregate of minute water droplets suspended in the atmosphere near the earth's surface. According to international definition, fog reduces visibility below 1 km. Fog differs from clouds only in that the base of fog is at the earth's surface while clouds are above its surface. When composed of ice crystals, it is termed ice fog.

Fog is easily distinguished from haze by its appreciable dampness and gray color. Mist may be considered as intermediate between fog and haze. Mist particles are microscopic in size. Mist is less damp than fog and does not restrict visibility to the same extent. There is no distinct division, however, between any of these categories. Near industrial and heavy traffic areas, fog often is mixed with smoke and vehicle exhaust, and this combination is known as smog.

NOTE — Under fog or other dew formation conditions, conductors can become wet or dry depending upon the level of the load current in the conductors. Medium to high load currents produce enough heat through I^2R (resistance) losses to discourage dew formation. Load current also speeds up the drying process after rain, fog, wet snow, etc.

3.12 Freezing Fog

A fog whose droplets freeze upon contact with exposed objects and form a coating of hoarfrost and/or glaze.

4. Terms Related to Electric and Magnetic Fields

4.1 General

The following definitions apply to terms used to describe electric and magnetic fields in the frequency range from 0 kHz to 10 kHz produced by power lines (see notes in 1.4).