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(Revision of ANSI/IEEE Std 539-1979)

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

Sponsor
Transmission and Distribution Committee of the IEEE Power Engineering Society

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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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The Institute of Electrical and Electronics Engineers, Inc.
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Secretary, IEEE Standards Board
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
USA

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

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

R. R. Addis
F. C. Buchholz
V. L. Chartier
C. C. Diemond
J. C. Engimann
D. A. Gillies
J. H. Harlow
D. N. Heirman
B. C. Johnson
N. Kolcio
D. G. Kumbera
P. S. Maruvada
T. J. McCarthy
T. J. McDermott
F. D. Myers
J. Panek
T. A. Pinkham
R. M. Showers
J. M. Van Name
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 tires 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:

$$n = 10 \log(P_1 / P_2)\mathrm{dB} \qquad (1)$$

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:

$$n = 20 \log(I_1 / I_2)\mathrm{dB} \qquad (2)$$

$$n = 20 \log (V_1 / V_2)\mathrm{dB} \qquad (3)$$

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.

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:

$$L = k \log_r (q / q_0) \tag{4}$$

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_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

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.

[1]The 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, $x_l, x_2, \ldots X_n$, the distribution function $P(x_1, x_2, \ldots x_n)$ 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 (μV/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 I 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).

4.2 Electric Field Strength

A vector field, often denoted as $\vec{E}$ at a specific point. In a zero magnetic field, it is numerically equal to the force on a motionless unit positive test charge placed at that point. *Syn:* **electric field.**

NOTE — In a zero magnetic field, the force $\vec{F}$ is given by $\vec{F} = q\vec{E}$. The magnitudes of the field components are expressed in volts per meter (V/m) (which dimensionally is the same as Newton/Coulomb).

4.2.1 AC Electric Field Strength

The electric field strength produced by ac power systems as defined by its space components along three orthogonal axes. For steady-state sinusoidal fields, each component can be represented by a complex number or phasor. The magnitudes of the components are expressed by their rms values in volts per meter, and their phases need not be the same.

NOTES:

1 — A phasor is a complex number expressing the magnitude and phase of a time-varying quantity. Unless otherwise specified, it is used only within the context of linear systems driven by steady-state sinusoidal sources. In polar coordinates, it can be written as $Ae^{j\Phi}$ where A is the amplitude or magnitude (usually rms but sometimes indicated as peak value) and Φ is the phase angle. The phase angle should not be confused with the space angle of a vector.

2 — The space components (phasors) are not vectors. The space components have a time-dependent angle while vectors have space angles.

For example, the sinusoidal electric field strength, $\vec{E}$, can be expressed in rectangular coordinates as

$$\vec{E} = \vec{a}_x E_x + \vec{a}_y E_y + \vec{a}_z E_z \tag{5}$$

where, for example, the x component is

$$E_x = \mathrm{Re}(E_{x0} e^{j\phi_x} e^{j\omega t}) = E_{x0} \cos(\phi_x + \omega t)$$

The magnitude, phase, and time-dependent angle are given by E_{x0}, Φ_x, and $(\Phi_x + \omega t)$, respectively. In this representation the space angle of the x component is specified by the unit vector $\vec{a}_x$.

An alternative general representation of a steady-state sinusoidal electric field can be derived algebraically from Eq 5 and is perhaps more useful in characterizing power-line fields because the fields along the direction of the line are small and can usually be neglected. It is a vector rotating in a plane where it describes an ellipse whose major semi-axis represents the magnitude and direction of the maximum value of the electric field, and whose minor semi-axis represents the magnitude and direction of the field a quarter-cycle later. As mentioned above, the electric field in the direction perpendicular to the plane of the ellipse is assumed to be zero. See 4.6.1 and 4.6.2. *Syn:* **ac electric field.**

4.2.1.1 Vertical Component of the Electric Field Strength

The rms value of the component of the electric field strength along the vertical line passing through the point of measurement. This quantity is often used to characterize electric field induction effects in objects close to ground level.

4.2.1.2 Horizontal Component of the Electric Field Strength

The rms value of the component of the electric field strength in a horizontal plane passing through the point of measurement.

4.2.1.3 Longitudinal Electric Field.[2] See 13.7.

[2]Use of this term is deprecated.

4.2.2 DC Electric Field Strength

The time-invariant electric field, produced by dc power systems and space charge, defined by its space components along three orthogonal axes. The magnitudes of the components are expressed in volts per meter. *Syn:* **dc electric field.**

NOTE — The convention in discussion of electric fields near HVDC transmission lines has been to designate the electric field into the ground as positive; i.e., the electric field under a positive conductor is denoted positive.

4.2.2.1 Space-Charge-Free Electric Field

The electric field due to a system of energized electrodes, excluding the effect of space charge present in the interelectrode space.

4.2.2.2 Electric Potential Difference

The line integral of the scalar product of the electric field strength vector and the unit vector along any path from one point to the other, in an electric field resulting from a static distribution of electric charge. *Syn:* **electrostatic potential difference.**

4.3 Magnetic Flux Density

The vector quantity, often denoted as, of zero divergence at all points, which determines the component of the Coulomb-Lorentz force that is proportional to the velocity of a moving charge. *Syn*: **magnetic field**.

NOTES:

1 — In a zero electric field, the force, $\vec{F}$, is given by

$$\vec{F} = q\vec{v} \times \vec{B} \tag{6}$$

where

$\vec{v}$ = The velocity of the electric charge q

The vector properties of the field produced by currents in power lines are the same as those given above for the electric field. The preferred unit for the magnitude of the field components is the tesla (T) (1 T = 10^4 Gauss)

2 — For time-varying (ac) fields, values are expressed as their rms values unless stated otherwise.

4.4 Magnetic Field Strength

A vector quantity, often denoted as $\vec{H}$, related to the magnetic flux density, $\vec{B}$ by:

$$\vec{H} = (\vec{B}/\mu_0) - \vec{M} \tag{7}$$

where

μ_0 = The magnetic permeability of free space
$\vec{M}$ = The magnetization of the magnetic medium

In free space, $\vec{M}$ vanishes and the relationship between $\vec{H}$ and $\vec{B}$ becomes

$$\vec{H} = \vec{B}/\mu_0 \tag{8}$$

The preferred unit for $\vec{H}$ is amperes per meter (A/m).

4.5 Field Uniformity

The extent to which the magnitude and direction of a field are uniform at any instant of time and at all points within a defined region.

4.5.1 Uniform Field

A field whose magnitude and direction are uniform at any instant in time and at all points within a defined region.

4.5.2 Perturbed Field

A field that is changed in magnitude and/or direction by the introduction of an object or by an electric charge in the region.

NOTE — The electric field close to the object is, in general, strongly perturbed by the presence of the object. At power frequencies the magnetic field is not, in general, greatly perturbed by the presence of objects that are free of magnetic materials. Exceptions to this are regions near the surface of thick electric conductors where eddy currents alter time-varying magnetic fields.

4.5.2.1 Weakly Perturbed Field

At a given point, a field whose magnitude does not change by more than 5% or whose direction does not vary by more than 5°, or both, when an object is introduced into the region.

4.5.2.2 Geometric Perturbation of the Electric Field in the Interelectrode Space

A change in the electric field caused by the presence of either a conducting object or one with a dielectric constant different from that of the medium in the interelectrode space. It is assumed that the introduced object does not change the distribution of charges on the energized electrodes.

NOTE — The amount of perturbation depends on the geometry of the object, its location and electric potential, and, when applicable, its electrical parameters (i.e., dielectric constant, conductivity).

4.5.2.3 Space-Charge Perturbation of the Electric Field in the Interelectrode Space

A change in the electric field caused by the presence of space charge in the interelectrode space.

NOTE — The electric field at ground level under dc transmission lines is generally increased due to the presence of monopolar space charge having the same polarity as the nearest conductor. This increase is generally termed “field enhancement.”

4.6 AC Power-Line Fields

Power frequency electric and magnetic fields produced by ac power lines.

4.6.1 Single-Phase AC Fields

Fields whose space components are in phase with each other. These fields will be produced by single-phase power lines. The field at any point can be described in terms of a single direction in space and its time-varying magnitude.

4.6.2 Polyphase AC Fields

Fields whose space components may not be in time phase with each other. These fields will be the transversal fields produced by polyphase power lines. The field at any point can be described by the field ellipse; i.e., the magnitude and direction of the major semi-axis and the magnitude and direction of the minor semi-axis. The magnitude of the field strength is the magnitude of the major semi-axis. See 4.2.1.

NOTE — For polyphase power lines, the electric field at a distance of 15 m or more away from the outer phases (conductors) can frequently be considered a single-phase field because the minor axis of the electric-field ellipse is only a fraction (less than 10%) of the major axis when measured at a height of 1 m Similar remarks apply for the magnetic field.

4.6.3 Maximum Value of the Field

At a given point, the rms value of the major semi-axis magnitude of the field ellipse, i.e., the largest value of the field that would be measured at that point.

4.7 Electric Current

The flow of electric charge. The preferred unit is the ampere (A).

4.7.1 Electric Current Density

A vectorpoint function describing the magnitude and direction of charge flow per unit area. The preferred unit is A/m^2.

4.7.2 Ion Current

The flow of electric charge resulting from the motion of ions.

4.7.2.1 Ion Conduction Current

The portion of ion current resulting from ion transport due to the electric field.

4.7.2.2 Ion Convection Current

The portion of ion current resulting from ion transport by fluid dynamic forces, such as wind.

4.8 Space Potential

The electric potential at any point in space relative to some reference potential, usually ground. It is the electric potential difference (see 4.2.2.2) between the reference point and the point in question.

4.9 Voltage Gradient

Synonym for electric field strength. Corona work particularly emphasizes the property that the voltage gradient is equal to and is in the direction of the maximum space rate of change of the voltage at the specified point. The voltage gradient is obtained as a vector field by applying the operator $\tilde{N}$ to the scalar potential function, u. Thus, if $u = f(x, y, z)$,

$$\vec{E} = -\nabla u = -\text{grad } u = -\left(\vec{a}_x\frac{\delta u}{\delta x} + \vec{a}_y\frac{\delta u}{\delta y} + \vec{a}_z\frac{\delta u}{\delta z}\right) \quad (9)$$

Syn: **potential gradient.**

NOTES:

1 — Voltage gradient is synonymous with potential gradient and is often referred to simply as “gradient” or “field strength.”

2 — For alternating voltage, the voltage gradient is expressed as the peak value divided by the square root of two. For sinusoidal voltage, this is the rms value.

4.9.1 Maximum Single-Conductor (or Subconductor) Gradient

The maximum value attained by the gradient $E(\theta)$ as θ varies over the range 0 to 2π, where $E(\theta)$ is the gradient on the surface of the power-line conductor (or subconductor) expressed as a function of angular position (θ). Unless otherwise stated, the gradient is a nominal gradient (see 4.9.7).

4.9.2 Minimum Single-Conductor (or Subconductor) Gradient

The minimum value attained by the gradient $E(\theta)$ as given in 4.9.1 as θ varies over the range 0 to 2π.

4.9.3 Average Single-Conductor (or Subconductor) Gradient

The value E_{av}, obtained from

$$E_{av} = \frac{1}{2\pi}\int_0^{2\pi} E(\theta)\mathrm{d}(\theta) \qquad (10)$$

Approximately, the average single-conductor gradient is given by

$$E_{av} = \frac{\lambda}{2\pi\varepsilon_0 r} \qquad (11)$$

where

λ = Total charge on conductor per unit length
ε_0 = Permittivity of free space
r = Radius of conductor

NOTE — For practical cases, the average conductor gradient is approximately equal to the arithmetic mean of the maximum and minimum conductor gradients.

4.9.4 Average Bundle Gradient

For a bundle of two or more subconductors, the arithmetic mean of the average gradients of the individual subconductors.

4.9.5 Average Maximum Bundle Gradient

For a bundle of two or more subconductors, the arithmetic mean of the maximum gradients of the individual subconductors. For example, for a three-conductor bundle with individual maximum subconductor gradients of 16.5, 16.9, and 17.0 kV/cm, the average maximum bundle gradient would be (1/3) (16.5 + 16.9 + 17.0) = 16.8 kV/cm.

4.9.6 Maximum Bundle Gradient

For a bundle of two or more subconductors, the highest value among the maximum gradients of the individual subconductors. For example, for a three-conductor bundle with individual maximum subconductor gradients of 16.5, 16.9, and 17.0 kV/cm, the maximum bundle gradient would be 17.0 kV/cm.

4.9.7 Nominal Conductor Gradient

The gradient determined for a smooth cylindrical conductor whose diameter is equal to the outside diameter of the actual (stranded) conductor.

4.10 Corona Inception Gradient

The gradient on that part of an electrode surface at which continuous corona (see 7.2.2) first occurs as the applied voltage is gradually increased.

4.10.1 Corona Inception Voltage

The voltage applied to the electrode to produce the corona inception gradient.

4.11 Corona Extinction Gradient

The gradient on that part of an electrode surface at which continuous corona last persists as the applied voltage is gradually decreased.

4.11.1 Corona Extinction Voltage

The voltage applied to the electrode to produce the corona extinction gradient.

4.12 Surface State Coefficient (*m*).

A coefficient ($0 < m < 1$) by which the nominal corona inception gradient must be multiplied to obtain the actual corona inception gradient on overhead power lines.

NOTE — Examples of conditions that affect the surface state are given in 7.2.1.

5. Terms Related to Electric and Magnetic Field Measurement Devices

5.1 General

The following definitions apply to terms that describe the devices commonly used to measure power-frequency electric and magnetic fields in the 0 to 10 kHz range produced by power lines.

5.2 Electric Field Strength Meter

An instrument used to measure electric field strength.

5.2.1 AC Electric Field Strength Meter

A meter designed to measure the power-frequency electric field (see IEEE Std 644-1987 [9]). Two types of electric field strength meters are in common use.

5.2.1.1 Free-Body Meter

A meter that measures the electric field strength at a point above the ground and that is supported in space without conductive contact to earth.

NOTE — Free-body meters are commonly constructed to measure the induced current between two isolated parts of a conductive body. Since the induced current is proportional to the time derivative of the electric field strength, the meter's detector circuit often contains an integrating stage in order to recover the waveform of the electric field. The integrated current waveform also coincides with that of the induced charge. The integrating stage is also desirable, particularly for measurements of electric field with harmonic content, because this stage (i.e., its integrating property) eliminates the excessive weighting of the harmonic components in the induced current signal.

5.2.1.2 Ground Reference Meter

A meter that measures the electric field at or close to the surface of the ground. Frequently implemented by measuring induced current or charge oscillating between an isolated electrode and ground. The isolated electrode is usually a plate located level with or slightly above the ground surface.

NOTE — Ground reference meters measuring the induced current often contain an integrator circuit to compensate for the derivative relationship between the induced current and the electric field.

5.2.2 Optical Field Meter

A meter that measures changes in the transmission of light through a fiber or crystal due to the influence of the electric field (for example, meters based on Pockel's effect). Optical field meters can be used to implement free-body or ground reference measurements. When optical fibers are used, the meter is inherently electrically isolated from ground.

5.2.3 DC Electric Field Strength Meter

A meter designed to measure dc electric field. Two types of dc field strength meters are in common use.

5.2.3.1 Field Mill

A device in which a conductor is alternately exposed to the electric field to be measured and then shielded from it. *Syn:* **generating voltmeter; generating electric field meter.**

NOTE — The resulting current induced in the conductor is a measure of the electric field strength at the conductor surface.

5.2.3.2 Vibrating Probe

A device in which a plate is modulated below an aperture of a face plate in the electric field to be measured. *Syn:* **vibrating plate electric field meter.**

NOTE — The meter responds to the oscillating displacement current from the induced charge on the vibrating plate by generating a negative feedback voltage on the face plate to null the signal from the vibrating plate. The electric field strength is proportional to the feedback voltage.

5.2.3.3 Form Factor

An empirical parameter representing the increased electric field at the surface of a dc field meter that is mounted above the ground plane. The increased field is due to field perturbation by the instrument. In a uniform field, the unperturbed electric field is given by the measured field divided by the form factor for the instrument.

5.3 Wilson Plate

A conducting plate that is grounded through an ammeter; used to collect the ion current that is measured as it flows through the ammeter. The plate is sensitive to both ion current density and changes in the electric field (displacement current). *Syn*: **current plate; ion current plate.**

NOTE — Long integration times are used to minimize the effects of the changes in the electric field (displacement current). If the line voltage and geometry are constant with time, the *average* displacement current is zero.

5.4 Ion Counter

An instrument that determines monopolar space-charge density by measuring the charge collected from a known volume of air.

5.5 Conductivity Chamber

An instrument that determines the conductivity of the air.

5.6 Faraday Cage

A conducting enclosure that is used to measure the net space charge. *Syn:* **space-charge cage; space-charge density meter.**

5.7 Space-Charge Filter

A device used to measure net space-charge density in which a filter medium is used to remove the charge from an airstream.

5.8 Magnetic Flux Density Meter

A meter designed to measure the magnetic flux density. These meters may use any of several types of flux density sensors or probes.

NOTE — For measurement of the magnetic flux density from ac power systems, the meter shall conform to IEEE Std 644-1987 [9].

5.8.1 Coil Probe

A magnetic flux density sensor comprised of a coil of wire that produces an induced voltage proportional to the time derivative of the magnetic flux density.

NOTES:

1 — To eliminate effects due to electric field induction, it is essential that the coil of wire be shielded.

2 — Since the induced voltage is proportional to the time derivative of the magnetic flux density, the detector circuit of the sensor often contains an integrating stage to recover the waveform of the magnetic field. The integrating stage is also desirable, particularly for measurements of magnetic field strength with harmonic content, since this stage (i.e., its integrating property) eliminates the excessive weighting of the harmonic components in the voltage signal produced by the probe.

3 — This probe can also be used to measure static (dc) magnetic flux density if the probe is rotated at a known rate.

5.8.2 Hall Effect Probe

A magnetic flux density sensor containing an element exhibiting the Hall effect to produce a voltage proportional to the magnetic flux density.

NOTE — Hall effect probes respond to static as well as timevarying magnetic flux density. Due to saturation problems sometimes encountered when attempting to measure small power-frequency flux densities in the presence of the substantial static geomagnetic flux of the earth, Hall effect probes have seldom been used under ac power lines.

5.8.3 Optical Probe

A flux density meter in which the transduction mechanism is optical. A number of physical effects (i.e., magnetostriction, change in birefringence) may be used to affect the light in a “witness crystal” or “sense fiber.”

5.9 Exposure Meter

A device for measuring the amount of a quantity, to which the device has been exposed, over a period of time.

6. Terms Related to Ions

6.1 General

The following definitions apply to terms that deal with the physical description, measurement, generation, and loss of ions.

6.2 Ion

The isolated atom, molecule, molecular cluster, or aerosol that by loss or gain of one or more electrons has acquired a net electric charge.

NOTE — The inclusion of aerosols (particles) under this definition is consistent with historical usage. The use of the terms “small ion” and “charged aerosol” is encouraged.

6.2.1 Monopolar Ion Density

The number of ions of a given polarity per unit volume. The preferred unit is m^{-3}; another commonly used unit is cm^{-3}.

6.2.2 Ionization

The process by which an atom or molecule receives enough energy (by collision with electrons, photons, etc.) to split it into one or more free electrons and a positive ion. Ionization is a special case of charging.

6.2.3 Charging

The process, or the result of any process, by which an atom, molecule, molecular cluster, or aerosol acquires either a positive or a negative charge.

6.3 Ion Charge

The resultant positive or negative charge of an ion, expressed as a multiple of the electron charge.

6.3.1 Field Charging

Charging of aerosols by small ions moving under the influence of an electric field.

6.3.2 Diffusion Charging

Charging of aerosols by small ions in collisions resulting from thermal motion of the small ions.

6.4 Recombination

The process by which positive and negative ions recombine to neutralize each other.

6.4.1 Recombination Rate

The rate at which positive and negative ions recombine in a given gas or liquid. *Syn:* **recombination coefficient.**

6.5 Ion Mobility

The theoretical drift speed of a single, isolated ion in a liquid or gas, per unit electric field strength. The preferred unit is m^2/Vs; another commonly used unit is cm^2/Vs. Ion mobility depends on the ionic species. In air, several ionic species can exist simultaneously.

6.5.1 Mobility Spectrum

The distribution of ions as a function of mobility. Historically, ions have been classified by mobility as small (10^{-5} m^2/Vs to 2×10^{-4} m^2/Vs), medium (10^{-7} m^2/Vs to 10^{-5} m^2/Vs), and large (10^{-9} m^2/Vs to 10^{-7} m^2/Vs).

6.6 Ion Size

Physical dimensions and mass of an ion. Ions are usually classified as small, medium, and large.

NOTE — The radius and mass of an ion depend on the number and type of molecules in the cluster forming the ion. The diameter of an ion comprised of a *single* molecule is about 3×10^{-10} m.

6.6.1 Small Ion

Ion comprised of molecules or molecular clusters bound together by charge. Typical radius is less than 10^{-9} m. Mobility is in the range of 10^{-5} m^2/Vs to 2×10^{-4} m^2/Vs.

NOTE — To avoid confusion with the more general term “ion,” the use of the term “small ion” is encouraged.

6.6.2 Medium Ion

Ion, comprised of several molecules or molecular clusters bound together by charge, that is larger and less mobile than a small ion due to more massive or a greater number of molecular clusters. Typical radius is in the range of 10^{-9} m to 2×10^{-8} m. Mobility is in the range of 10^{-7} m^2/Vs to 10^{-5} m^2/Vs.

6.6.3 Large Ion

Ion comprised of charged particles, liquid or solid, suspended in air. Typical radius is in the range of 2×10^{-8} m to 2×10^{-7} m. Mobility is in the range of 10^{-9} m^2/Vs to 10^{-7} m^2/Vs. *Syn:* **charged aerosol.**

NOTE — Historically, these have been referred to as large or Langevin ions. The use of the term “charged aerosols” in encouraged.

6.7 Net Space Charge

The free, unbalanced charge in a given region, taking no account of the charges of both signs that balance each other. The preferred unit is the coulomb (C).

NOTE — The term “space charge” is often used to refer to net space charge.

6.7.1 Net Space-Charge Density

Net space charge (space charge) per unit volume. The preferred unit is C/m^3. This quantity provides no information about the monopolar space charge density.

6.7.2 Monopolar Space-Charge Density

The space charge density of one polarity. The preferred unit is C/m^3.

6.8 Electric Conductivity

The property of a material or medium permitting flow of electricity through its volume, expressed as the ratio of electric current density to electric field strength in a material or medium. For isotropic homogeneous media, the conductivity is a scalar quantity, with the preferred unit siemens per meter (S/m); 1 S/m = 1 mho/m.

7. Terms Related to Corona and Gap Discharges

7.1 General

Characteristics and effects of corona and gap discharges are defined in this section.

7.2 Corona

A luminous discharge due to ionization of the air surrounding an electrode caused by a voltage gradient exceeding a certain critical value.

NOTE — For the purpose of this standard, electrodes may be conductors, hardware, accessories, or insulators.

7.2.1 Corona, Overhead Power Lines

Corona occurring at the surfaces of power-line conductors and their fittings under the positive or negative polarity of the power-line voltage.

NOTES:

1 — Surface irregularities such as stranding, nicks, scratches, and semiconducting or insulating protrusions are usual corona sites.

2 — Dry or wet airborne particles in the proximity of powerline conductors and their fittings may cause corona discharges.

3 — Weather has a pronounced influence on the occurrence and characteristics of overhead power-line corona.

7.2.2 Continuous Corona

Corona discharge that is either steady or recurring at regular intervals (approximately every cycle of an applied alternating voltage or at least several times per minute for an applied direct voltage).

7.3 Corona Pulse

A voltage or current pulse that occurs at some designated location in a circuit as a result of corona discharge.

7.4 Corona Modes

Modes that can be distinguished. Two principal modes are the glow mode and the streamer mode. Their characteristics and occurrence depend on the polarity of the electrode, the basic ionization characteristics of the ambient air, and the magnitude, as well as the distribution of the electric field. Thus, the geometry of the electrodes, the ambient weather conditions, and the magnitude, as well as the polarity of the applied voltage, are the main factors determining corona modes. Corona modes that are possible during alternating half-cycles of the alternating-voltage waveform are essentially similar to those of corresponding direct-voltage corona modes when effects of space charges left behind from each preceding half-cycle are taken into account. Table 1 lists corona modes according to polarity. The listing is in the order of increasing voltage applied to the electrode. Increasing the applied voltage results in increasing the electric field strength (voltage gradient).

Table 1— Corona Modes

Positive (Anode) Corona		Negative (Cathode) Corona	
Mode	**Characteristic**	**Mode**	**Characteristic**
Burst corona, onset streamer*	Moderate amplitude, moderate repetition rate	Trichel streamer (pulse)	Small amplitude, high repetition rate
Glow†	Essentially pulseless	Glow‡	Essentially pulseless
Prebreakdown streamer	High amplitude, low repetition rate	Prebreakdown streamer**	Moderate amplitude, moderate repetition rate

*With alternating voltage, positive onset streamers often become suppressed by space charge created during the negative half-cycles.
†With alternating voltage, when onset streamers are suppressed the positive glow will be the first corona mode as the applied voltage is raised.
‡With alternating voltage, negative glow may be difficult to observe because of the predominance of Trichel streamers.
**With alternating voltage, breakdown usually occurs during the positive half-cycle before the development of any negative prebreakdown streamers.

7.4.1 Glow Mode

A stable, essentially steady discharge of constant luminosity occurring at either positive or negative electrodes.

7.4.1.1 Burst Corona

Corona mode that may be considered as the initial stage of positive glow. It occurs at a positive electrode with electric field strengths at and slightly above the corona inception voltage gradient. Burst corona appears as a bluish film of velvetlike glow adhering closely to the electrode surface. The current pulses of burst corona are of low amplitude and may last for periods of milliseconds. (See NOTE in 7.4.2.1.)

7.4.1.2 Positive Glow

A bright blue discharge appearing as a luminous sheet adhering closely and uniformly to the electrode. Positive glow appears at electric field strengths above those required for burst corona (7.4.1.1) and onset streamers (7.4.2.1). The corona current of positive glow is essentially pulseless.

7.4.1.3 Negative Glow

Corona mode that occurs at electric field strengths above those required for Trichel streamers (7.4.2.2). Negative glow is confined to a small portion of the electrode and appears as a small, stationary, luminous bluish fan. The corona current of negative glow is essentially pulseless.

7.4.2 Streamer Mode

A repetitive corona discharge characterized by luminous filaments extending into the low electric field strength region near either a positive or a negative electrode, but not completely bridging the gap.

7.4.2.1 Positive Onset Streamers

Streamers occurring at electric field strengths at and slightly above the corona inception voltage gradient. These appear as bright blue "brushes" increasing in length to several inches as the voltage gradient is increased. The associated current pulses are of appreciable magnitude, short duration (in the range of hundreds of nanoseconds), and low repetition rate (less than 1 kHz).

NOTE — Occurrence of burst corona and positive onset streamers requires the same range of electric field strength.

7.4.2.2 Trichel Streamers

Streamers occurring at a negative electrode with electric field strengths at and above the corona inception voltage gradient. A Trichel streamer appears as a small, constantly moving purple fan. The current pulse is of small amplitude, short duration (in the range of a hundred nanoseconds), and high repetition rate (in the range of tens of kilohertz or more).

7.4.2.3 Positive Prebreakdown Streamers

Streamers occurring at electric field strengths above those required for onset streamers and positive glow. The discharge appears as a light blue filament with branching extending far into the gap. The associated current pulses have high magnitude, short duration (in the range of hundreds of nanoseconds), and low repetition rate (in the range of a few kilohertz).

NOTE — When appearing as multiple discharges, these streamers are usually referred to as a *plume*. When the plume occurs between an electrode and airborne particle (snow, rain, aerosols, etc.) coming into near proximity or impacting on the electrode, it is referred to as an *impingement plume*. When the plume occurs due to the disintegration of water drops resting on the electrode surface, it is referred to as a *spray plume*.

7.4.2.4 Negative Prebreakdown Streamers

Streamers occurring at electric field strengths close to breakdown. The discharge appears as a bright filament with very little branching and extends far into the gap. The associated current pulse has high magnitude, long duration, and low repetition rate.

7.5 Corona Loss

Power lost due to corona process. On overhead power lines, this loss is expressed in watts per meter (W/m) or kilowatts per kilometer (kW/km).

7.6 Ozone

A colorless gas, O_3, with a penetrating odor; an allotropic form of oxygen.

NOTE — Corona and other electrical discharges dissociate the oxygen molecule, which can cause the following reactions:

$$O_2 \rightarrow O + O$$

$$O + O_2 \rightarrow O_3$$

7.7 Arc

1) A discharge of electricity through a gas, normally characterized by a voltage drop in the immediate vicinity of the cathode approximately equal to the ionization potential of the gas.
2) A continuous luminous discharge of electricity across an insulating medium, usually accompanied by the partial volatilization of the electrodes.

7.8 Spark

A sudden and irreversible transition from a stable corona discharge to a stable arc discharge. It is a luminous electrical discharge of short duration between two electrodes in an insulating medium. It is generally brighter and carries more current than corona, and its color is mainly determined by the type of insulating medium. It generates radio noise of wider frequency spectrum (extending into hundreds of megahertz) and wider magnitude range than corona. A spark is not classified as corona.

7.8.1 Microspark

A spark breakdown occurring in the miniature air gap formed by two conducting or insulating surfaces. (This is sometimes called a gap discharge.)

8. Terms Related to Radio Frequency (RF) Wave Propagation

8.1 General

Terms relating to the propagation of RF waves along power-line conductors are defined in this section. It is assumed that the propagation can be described as one or more transmission line modes. This is valid for frequencies such that all conductor spacings are only a small fraction of a wavelength.

8.2 Reflected Wave

When a wave in one medium is incident upon a discontinuity or a different medium, the reflected wave includes the wave component traveling in a different direction to the incident wave in the first medium, as well as the incident wave. If the wave is in a unidimensional medium, i.e., a transmission line, then the reflected wave travels in the opposite direction to the incident wave.

8.2.1 Reflection Coefficient

At a given frequency, at a given point, and for a given mode of propagation, the ratio of some quantity associated with the reflected wave to the corresponding quantity in the incident wave.

8.3 Standing Wave

A wave in which, for any component of the field, the ratio of its instantaneous value at one point to that at any other point does not vary with time.

NOTES:

1 — A standing wave is most frequently produced by reflection. The sum of the incident and reflected waves, if they are periodic, will produce a standing wave.

2 — Commonly, a standing wave is a periodic wave in which the amplitude of the displacement in the medium is a periodic function of the distance in the direction of any line of propagation of the waves.

8.3.1 Standing-Wave Ratio

The ratio of the amplitude of a standing wave at an antinode to the amplitude at a node. The standing-wave ratio in a uniform transmission line is

$$\frac{1 + \rho}{1 - \rho} \tag{12}$$

where

ρ = The reflection coefficient

8.4 Propagation Constant

The complex quantity of a traveling plane wave at a given frequency whose real part is the attenuation constant in nepers per unit length and whose imaginary part is the phase constant in radians per unit length.

8.5 Characteristic Impedance

The ratio of the complex voltage of a propagation mode (see 8.6) to the complex current of the same propagation mode in the same transverse plane with the sign so chosen that the real part is positive.

NOTE — The characteristic impedance of a line with losses neglected is known as the surge impedance.

8.5.1 Wave Impedance

The complex factor relating the transverse component of the magnetic field to the transverse component of the electric field at every point in any specified plane, for a given mode.

8.6 Propagation Mode

A concept for treating propagation of electromagnetic noise (see Section 9) along a set of overhead power-line conductors. Modal waves form a complete set of noninteracting components into which the propagated wave may be separated.

NOTES:

1 — For a three-phase horizontal single-circuit transmission line with one conductor per phase and without ground wires, the following modes are defined:

2 — Mode 1—The transmission path is between the center phase and the outside phases. It has the lowest attenuation and the lowest surge impedance.

3 — Mode 2—The transmission path is between outside phases. It has an intermediate attenuation and an intermediate surge impedance.

4 — Mode 3—The transmission path is along all three phases and returning through ground. It has the highest attenuation and the highest surge impedance.

8.7 Longitudinal Attenuation

The decrease in electromagnetic noise field strength (see Section 9) caused by dissipation of energy as a result of propagation along an overhead power line and through the earth.

NOTES:

1 — In North American practice, units are decibels per mile (dB/mile) or decibels per km (dB/km).

2 — For multiconductor systems, such as those normally found in electric power systems, it is convenient to describe wave propagation as made up of a set of noninteracting modes, each with its own attenuation constant (see 8.6).

3 — In the context of this standard, the electromagnetic noise energy is the result of corona and gap discharges.

9. Terms Related to Electromagnetic Signals and Noise

9.1 General

Terms related to Electromagnetic Signals and noise are defined in this section. See also IEC 50 (161): 1990 [7].

9.2 Electromagnetic Signal

The intelligence, message, or effect to be conveyed over a communication system or broadcasting system via electromagnetic waves.

9.2.1 Radio Signal

A carrier in the RF range that is modulated by an electromagnetic signal.

9.3 Carrier

A continuous electromagnetic wave having a repeating variation in time and at least one characteristic that may be varied from a known reference value by modulation.

NOTE — Examples of carriers are a sine wave and a recurring series of pulses.

9.4 Modulation

The process by which some characteristic of a carrier is varied in accordance with a modulating signal.

9.4.1 Amplitude Modulation (AM)

Modulation in which the amplitude of a carrier is caused to depart from its reference value by an amount proportional to the instantaneous value of the modulating signal.

9.4.2 Phase Modulation

Modulation in which the angle of a carrier is caused to depart from its reference value by an amount proportional to the instantaneous value of the modulating signal.

9.4.3 Frequency Modulation (FM)

Modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the carrier frequency by an amount proportional to the instantaneous value of the modulating signal.

NOTE — Combinations of phase and frequency modulation are commonly referred to as frequency modulation.

9.5 Demodulation

The process by which the signal is recovered from a modulated carrier.

9.6 Intermediate Frequency (IF)

The frequency resulting from a frequency conversion that is amplified locally in the receiver before demodulation.

9.7 Frequency Band

A continuous range of frequencies extending between two limiting frequencies.

NOTES:

1 — Some bands of frequencies that are defined by agreement are called *channels*. A band used in a particular communication link is also called a *channel*.

2 — Some commonly known frequency bands are defined below. For a complete list of assigned and available frequencies and frequency bands, refer to the current edition of CFR Publication 47 [4].

9.7.1 Amateur Band

Frequency bands assigned for the transmission of signals by amateur radio operators.

NOTE — The amateur bands may differ from country to country. The bands presently in use in the United States under 300 MHz are 1.8–2.0 MHz, 3.5–4.0 MHz, 7.0–7.3 MHz, 10.1–10.15 MHz, 14.00–14.35 MHz, 21.00–21.45 MHz, 24.89–24.99 MHz, 28.0–29.7 MHz, 50–54 MHz; 144–148 MHz, and 220–225 MHz.

9.7.2 Citizens Bands

Frequency bands allocated for short-distance personal or business radio communication, radio signaling, and control of remote devices by radio. *Syn*: **personal radio services bands.**

NOTE — The frequency bands may differ from country to country. The bands presently in use in the United States are 26.965–27.405 MHz; 72–76 MHz and 462.550–467.425 MHz.

9.7.3 AM Radio Broadcast Band

A band of frequencies assigned for amplitude-modulated broadcasting to the general public.

NOTE — In the United States and Canada, the frequency band is 535-1605 kHz. This is one of the International Telecommunications Union (ITU) frequency allocations, on a worldwide basis, for broadcasting.

9.7.4 FM Radio Broadcast Band

A band of frequencies assigned for frequency-modulated broadcasting to the general public.

NOTE — In the United States and Canada, the frequency band is 88–108 MHz.

9.7.5 TV Broadcast Band

Any one of the frequency bands assigned for the transmission of audio and video signals for television (TV) broadcasting to the general public.

NOTE — In the United States and Canada, the frequency bands are 54–72 MHz; 76–88 MHz; 174–216 MHz, and 400-890 MHz.

9.7.6 Power-Line Carrier

The use of RF energy, generally below 600 kHz, to transmit information, using power lines to guide the information transmission.

9.8 Electromagnetic Disturbance

Any electromagnetic phenomenon that may degrade the performance of a device, a piece of equipment, or a system.

NOTES:

1 — An electromagnetic disturbance may be electromagnetic noise, an unwanted signal, or a change in the propagation medium itself.

2 — The term “system” is used hero in its generic sense, which may include inert and living matter.

9.9 Electromagnetic Interference

Degradation of the performance of a device, a piece of equipment, or a system caused by an electromagnetic disturbance.

NOTE — The English words “interference” and “disturbance” are often used indiscriminately.

9.9.1 Radio Interference (RI)

Degradation of the reception of a wanted signal caused by RF disturbance. *Syn*: **radio frequency interference (RFI)**.

NOTES:

1 — RF disturbance is an electromagnetic disturbance having components in the RF range.

2 — The English words “interference” and “disturbance” are often used indiscriminately. The expression “radio frequency interference” is also commonly applied to an RF disturbance or an unwanted signal.

9.9.2 Television Interference (TVI)

A radio interference occurring in the frequency range of television signals.

9.9.3 Conducted Interference

Interference resulting from conducted radio noise or unwanted radio signals entering a transducer (receiver) via the electrical connections.

9.10 Radio Influence Voltage (RIV)

The radio frequency voltage appearing on conductors of electrical equipment or circuits, as measured using a radio noise meter as a two-terminal voltmeter in accordance with specified methods (generally termed conducted measurements); see NEMA 107-1987 [11]; CISPR Publication 16 (1987) [5]; CISPR Publication 18-2 (1986) [6].

NOTE — The term “influence” was coined to avoid the general admission that power systems would generate and conduct “interference.” The term “influence,” is used only in North America; the term “interference” is preferred elsewhere.

9.11 Radio Noise Field Strength

A measure of the field strength of the radiated radio noise at a given location.

NOTES:

1 — In practice, the quantity measured is not the electromagnetic field strength of the interfering waves but some quantity that is proportional to, or bears a known relation to, the electromagnetic field strength.

2 — The radio noise field strength is measured in average, rms, quasi-peak, or peak values, according to which detector function of the radio noise meter is used.

3 — The radio noise field strength is expressed either in μV/m, or in dB above 1 μV/m, per unit bandwidth, or in a specified bandwidth.

10. Terms Related to Electromagnetic Signal and Noise Measurements

10.1 General

Terms related to the measurements of electromagnetic signals and noise are defined in this section.

10.2 Antenna

A device used to radiate or receive electromagnetic waves.

10.2.1 Vertical Antenna

An antenna consisting of a vertically arranged conductor. *Syn*: **monopole antenna; rod antenna; whip antenna.**

10.2.1.1 Shunt-Fed Vertical Antenna

A vertical antenna connected to ground at the base and excited (or connected to a receiver) at a point suitably positioned above the grounding point.

10.2.1.2 Series-Fed Vertical Antenna

A vertical antenna insulated from ground and energized (or connected to a receiver) at the antenna base.

NOTES:

1 — A rod antenna responds to the electric field component of the electromagnetic wave.

2 — A rod antenna is omnidirectional in the horizontal plane.

3 — The connection of a rod antenna to a receiver may be via a coupler to which the rod is permanently attached.

10.2.2 Loop Antenna

An antenna consisting of one or more turns of a conductor. If the circulatory current is essentially uniform, the antenna will have a radiation pattern approximating that of an elementary magnetic dipole.

NOTE — The loop antenna responds to the magnetic field component of the electromagnetic wave, in the direction of the loop axis.

10.2.3 Dipole Antenna

Any one of a class of antennas having a radiation pattern approximating that of an elementary electric dipole.

NOTE — Common usage considers the dipole antenna to be a metal radiating or receiving structure that supports a line current distribution similar to that of a thin straight wire, a half-wavelength long, so that the current has a node at each end of the antenna.

10.2.4 Biconical Antenna

An antenna consisting of two conical conductors that have a common axis and vertex and are excited or connected to the receiver at the vertex. When the vertex angle of one of the cones is 180°, the antenna is called a discone.

10.2.5 Log-Periodic Antenna

Any one of a class of antennas having a structural geometry such that its electrical characteristics repeat periodically as the logarithm of frequency.

10.3 Detector

A device that performs detection (extraction of signal or noise from a modulated input) and weighting (extraction of a particular characteristic of the signal or noise).

NOTE — In a radio noise receiver, the voltage applied to the detector depends upon the nature of the noise and the bandwidth of the filters used in the intermediate frequency stages. To furnish calibrations that are independent of the bandwidth and can be made with readily available equipment, an unmodulated carrier is used. With such input, all detectors (peak, quasi-peak, average, or rms) will indicate the same value of radio noise.

10.3.1 Average Detector

A detector, the output voltage of which is the average value of the magnitude of the envelope of an applied signal or noise.

NOTES:

1 — This detector function is often identified on radio noise meters as *field intensity* (FI). (Field intensity is deprecated; *field strength* should be used.)

2 — FI (field strength) setting on some radio noise meters produces a reading proportional to the average value of the logarithmic detector output on the meter scale.

3 — Radio noise meters of modern design do not have the detector function identified as “FI” or “Field Intensity.” Also, modern radio noise meters have true average detector functions, but a few still have average logarithm (sometimes called “carrier”) detector functions.

10.3.2 Peak Detector

A detector, the output voltage of which is the true peak value of an applied signal or noise.

10.3.3 Quasi-Peak (QP) Detector

A detector having specified electrical time constants that, when regularly repeated pulses of constant amplitude are applied to it, delivers an output voltage that is a fraction of the peak value of the pulses, the fraction increasing toward unity as the pulse repetition rate is increased.

NOTES:

1 — The fundamental characteristics of the quasi-peak detector are given in ANSI C63.2-1987 [1]. These characteristics, with the exception of the optional 600 ms discharging time constant, are the same as those specified by the International Special Committee on Radio Interference {CISPR Publication 16 (1987) [5]}.

2 — QP setting on some older radio noise meters produces a reading proportional to the average value of the quasipeak output of the logarithmic detector on the meter scale.

10.3.4 Root-Mean-Square (RMS) Detector

A detector, the output voltage of which is the rms value of an applied signal or noise.

NOTE — The instrument manufacturer must specify a “crest factor” to go along with the rms detector function. Typical crest factors on rms detectors are 20 dB to 26 dB, some are as high as 36 dB, and in rare cases an instrument may have a crest factor as high as 40 dB.

10.4 Bandwidth

The range of frequencies within which performance, with respect to some characteristic, falls within specified limits.

10.4.1 Impulse Bandwidth

The peak value of the response envelope divided by the spectrum amplitude of an applied impulse.

10.4.2 Random Noise Bandwidth

The width in hertz of a rectangle having the same area and maximum amplitude as the square of the amplifier frequency response to a sinusoidal input. *Syn:* **fluctuation noise bandwidth.**

11. Terms Related to Acoustics

11.1 General

Terms from acoustics relevant to the study of audible noise from power lines are defined in this section (see ANSI S1.1-1960 (Reaff. 1976) [2]).

11.2 Audio Frequency

An audio frequency is any frequency corresponding to a normally audible sound wave. This usually covers the range from 20 Hz to 20 kHz.

11.3 Octave

The interval between two sounds having a fundamental frequency ratio of two.

11.4 Pure Tone

A sound wave, the instantaneous sound pressure of which is a simple sinusoidal function of time.

11.5 Hum

A component of transmission-line audible noise consisting of pure tones of the power frequency and its harmonics.

NOTE — For ac transmission lines, this is caused by ion motion in the air surrounding the conductors.

12. Terms Related to Audible Noise (AN) Measurements

12.1 General

Terms related to the generation, measurement, and evaluation of audible noise from power lines are defined in this section (see also ANSI S1.4-1983 [3] and IEEE Std 656-1985 [10].)

12.2 Insertion Loss

The difference, in decibels, between the sound pressure level of a component (e.g., windscreen) measured before the insertion of the component and the sound pressure level measured after the insertion of the component (provided that the source of the noise remains unchanged).

12.3 Sound Pressure Level

Twenty times the logarithm to the base 10 of the ratio of the pressure of a sound to the reference pressure, expressed in decibels. The reference pressure shall be explicitly stated.

NOTES:

1 — The following reference pressures are in common use:

1) 20 micropascals (μPa)
2) 0.1 pascal (Pa)

Reference pressure (1) is in general use for measurements concerned with hearing and with sound in air and liquids, while reference pressure (2) has gained widespread acceptance for calibration of transducers and various kinds of sound measurements in liquids.

2 — Unless otherwise explicitly stated, it is to be understood that the sound pressure is the effective (rms) sound pressure.

3 — It is to be noted that in many sound fields the sound pressure ratios are not the square roots of the corresponding power ratios.

12.4 Sound Level

A weighted sound pressure level, obtained by the use of metering characteristics and the weightings A, B, C, or D specified in ANSI S1.4-1983 [3]. The weightings employed must always be stated. The reference pressure is always 20 μPa.

NOTES:

1 — The meter reading (in decibels) corresponds to a value of the sound pressure integrated over the audible frequency range with a specified frequency weighting and integration time.

2 — A suitable method of stating the weighting is, for example, "The A-weighted sound level was 43 dB," or "The sound level was 490 dB (A)."

3 — Weightings are based on psychoacoustically determined time or frequency responses in objective measuring equipment. This is done to obtain data that better

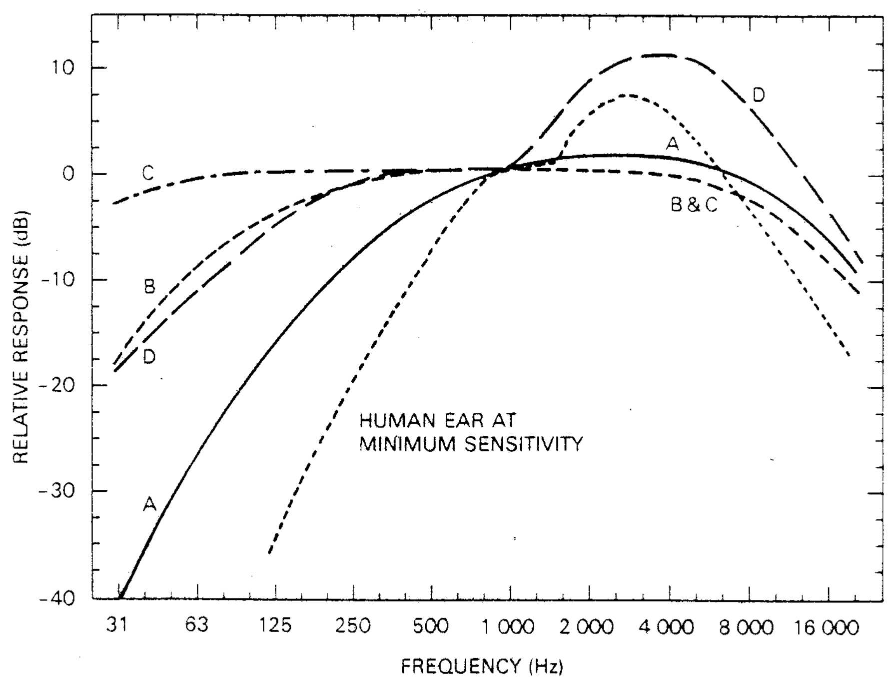

Figure 1— Weighting Characteristics for Sound-Level Meters

Reprinted with permission from the EPRI "Red Book," Transmission Line Reference Book–345 kV and Above (2d ed., revised, EL 2500), Figure 6.2.3.

predict the subjective listener reaction than would wide band measurements with a meter having either an instantaneous time response or a slow average or rms response. Standard weighting characteristics indicating relative response as a function of frequency are designated A, B, C, and D and are shown in Fig 1.

12.4.1 Energy-Equivalent Sound Level, (L_{eq}).

The average of the sound energy level (usually A-weighted) of a varying sound over a specified period of time.

NOTES:

1 — The simplest and most popular method for rating intermittent or fluctuating noise intrusions is to rely upon some measure of the average sound-level magnitude over time. The most common such average is the equivalent sound level, L_{eq}, expressed in decibels.

2 — The term “equivalent” signifies that a steady sound having the same level as the L_{eq} would have the same sound energy as the fluctuating sound. The term “energy” is used because the sound amplitude is averaged on an rms-pressure-squared basis, and the square of the pressure is proportional to energy. For example, two sounds, one of which contains 24 times as much energy as the other but lasts for 1 h instead of 24 h, would have the same energy-equivalent sound level.

3 — Mathematically, the equivalent sound level is defined as

$$L_{eq} = 10 \log\left[\frac{1}{(t_2 - t_1)}\int_{t_1}^{t_2}\frac{p^2(t)}{p_{ref}^2}dt\right] \quad (13)$$

where

$p(t)$ = The time-varying A-weighted sound level, in μPa
P_{ref} = The reference pressure, 20 μPa
$(t_2 - t_1)$ = The time period of interest

If the cumulative probability distribution of a noise is known, then L_{eq} can be estimated by

$$L_{eq} = 10 \log\left[\frac{1}{100}\sum_{0}^{n}(P_x - P_{x-1})\text{antilog}\,\frac{L_x}{10}\right] \quad (14)$$

where

P_x, P_{x-1} = Selected adjacent steps along the probability scale, expressed in percent (%)
L_x = The highest noise level in each step
x = The step number
n = The total number of steps

12.4.2 Day-Night Sound Level, (L_{dn})

The L_{dn} rating is the average A-weighted sound level in decibels integrated over a 24 h period. A 10 dB(A) penalty is applied to all sound occurring between 10 P.M. and 7 A.M.

NOTES:

1 — L_{dn} is intended to improve upon the L_{eq} rating by adding a correction for nighttime noise intrusions, because people are more sensitive to such intrusions.

2 — The L_{dn} can be derived from daytime and nighttime L_{eq} values as follows:

$$L_{dn} = 10 \log\left(\frac{1}{24}\right)\left[15\ \text{antilog}\frac{L_d}{10} + 9\ \text{antilog}\ \frac{L_n + 10}{10}\right] \quad (15)$$

where

L_d = The L_{eq} for the 15 daytime hours
L_n = The Leq for the 9 nighttime hours

3 — The purpose of L_{dn} is to provide a single-number measure of time-varying noise for a specific time period (24 h).

12.5 Band Pressure Level

For a specified frequency band, the sound pressure level for the sound contained within the restricted band. The reference pressure must be specified.

NOTE — The band may be specified by its lower and upper cutoff frequencies or by its geometric center frequency and bandwidth. The width of the band may be indicated by a modifying prefix, e.g., octave band (sound pressure) level, half-octave band level, third-octave band level, 50 Hz band level.

12.5.1 Octave Band Pressure Level

The integrated sound pressure level of all components in a frequency band corresponding to a specified octave.

NOTE — The location of an octave band pressure level on a frequency scale, f_o, is usually specified as the geometric mean of the upper and lower frequencies of the octave. The lower frequency of the octave band is $f_o/\sqrt{2}$ and the upper frequency is $(\sqrt{2})\, f_o$. A third-octave hand extends from a lower frequency $f_o/\sqrt[6]{2}$ to an upper frequency of $(\sqrt[6]{2}) f_o$.

12.6 Microphone

An electroacoustic transducer that responds to sound waves and delivers essentially equivalent electric waves.

12.6.1 Free-Field Microphone

A microphone that has been designed to have a flat frequency response to sound waves arriving with perpendicular incidence (i.e., straight at the microphone).

12.6.2 Random-Incidence Microphone

A microphone that has been designed to have a flat frequency response in a diffuse sound field where sound waves are arriving equally from all directions.

12.6.3 Pressure-Gradient Microphone

A microphone in which the electric output substantially corresponds to a component of the gradient (space derivative) of the sound pressure.

NOTE — Pressure-gradient microphones may be of any order, for example, zero, first, second, etc. Thus, a pressure sure microphone is a gradient microphone of zero order. The rms response to plane waves is proportional to $\cos^n\theta$, where θ is the angle of incidence and n is the order of the gradient. Because of the finite dimensions of all gradient microphones, however, the response characteristic and the directional characteristic, respectively, are only approximations of the derivative of the sound pressure and of the directional formula noted.

12.6.4 Pressure Microphone

A microphone in which the electric output substantially corresponds to the instantaneous sound pressure of the impressed sound waves.

NOTE — A pressure microphone is a gradient microphone of zero order and is nondirectional when its dimensions are small compared to a wavelength.

13. Terms Related to Coupled Voltages and Currents

13.1 General

The following definitions apply to terms used to describe the coupling of voltage or current to objects in the vicinity of electric power lines due to the effects of electric, magnetic, or electromagnetic fields.

13.2 Induction

The process of generating time-varying voltages and/or currents in conductive objects or electric circuits by the influence of the time-varying electric, magnetic, or electromagnetic fields. *Syn* : **ac coupling**.

13.2.1 Electric Field Induction

The induction process that results from time-varying quasi-static electric fields. *Syn*: **capacitive coupling**.

NOTES:

1 — The term "electric field induction" is preferred over "electric induction" because the latter may be taken to mean electric flux density.

2 — Electric field induction was formerly called electrostatic induction. This usage is deprecated because electrostatic fields are time invariant.

13.2.2 Magnetic Field Induction

The induction process that results from time-varying quasi-static magnetic fields. *Syn*: **inductive coupling**.

NOTES:

1 — Magnetic field induction was formerly called electromagnetic induction. This usage is now deprecated because electromagnetic induction refers to combined electric and magnetic field effects (see 13.2.3).

2 — The term "magnetic field induction" is preferred over "magnetic induction" because the latter may be taken to mean magnetic flux density.

13.2.3 Electromagnetic Field Induction

The induction process that results from time-varying electromagnetic fields. *Syn*: **electromagnetic coupling**.

13.3 Conductive Coupling

The process of generating voltages and/or currents in conductive objects and electric circuits, otherwise unenergized, due to deposition of charge. *Syn*: **dc coupling**.

13.4 Open-Circuit Voltage

A voltage on a conductive object or in an electric circuit as a result of induction or deposition of charge.
Syn: **object-to-ground voltage**.

13.4.1 Open-Circuit Induced Voltage

The rms power-frequency voltage on an ungrounded conductive object relative to ground or the voltage across the terminals of an open circuit loop, as a result of induction. *Syn*: **object-to-ground induced voltage**.

13.4.2 Open-Circuit DC Voltage

The dc voltage on an ungrounded conductive object relative to ground, as a result of deposition of charge. *Syn*: **object-to-ground dc voltage**.

13.5 Short-Circuit Current

The current between a conductive object and ground through a zero impedance connection or in a closed circuit, as a result of induction or deposition of charge. *Syn*: **object-to-ground current**.

13.5.1 Short-Circuit Induced Current

The rms power frequency current between a conductive object and ground through a zero impedance or in a closed circuit, as a result of induction. *Syn*: **object-to-ground induced current**.

13.5.2 Short-Circuit DC Current

The dc current between a conductive object and ground through a zero impedance,as a result of deposition of charge. *Syn*: **object-to-ground dc current**.

13.6 Steady-State Induced Current

The rms power-frequency current in any circuit, as a result of induction.

13.7 Longitudinal Electromotive Force (LEF)

Voltage per unit length of a circuit, induced by the magnetic field, when the circuit is in the vicinity of a power line. *Syn*: **longitudinal electric field**.[3]

13.8 Transient Discharge

An electric discharge of momentary nature, resulting from a sudden change in the electric-circuit voltage or current. The discharge may be energized via electric, magnetic, or electromagnetic field induction. *Syn:* **spark discharge**.

NOTE — In many cases, the sudden change in the electric circuit is the result of an insulation breakdown of a small gap, such as between an energized object and a person attempting to grasp it. When the open-circuit voltage is high, the transient discharge may be initiated by a spark. For low open-circuit voltage, physical contact may produce the transient discharge without any associated spark.

13.8.1 Peak Discharge Current

The peak current occurring during a transient discharge.

NOTE — Due to the very short discharge time, substantial peak currents (up to a few amperes) can be encountered in typical induction circumstances.

[3]Use of this term is deprecated.

13.8.2 Discharge Energy

The energy transferred during a transient discharge.

13.8.3 Charge Transfer

The process of charge movement, especially that occurring during a transient discharge.

14. Terms Related to Shock and Perception Effects

14.1 General

The following definitions apply to terms used to describe electric shock and perception effects in people that could occur due to contact with circuits energized by electric and/or magnetic field induction from power lines. Primary electric shock effects due to large currents are outside the scope of this document and are not discussed. See reference [15] for additional information.

14.2 Electric Shock

Stimulation of the nerves and possible convulsive contraction of the muscle caused by the passage of an electric current through the human or the animal body.

14.2.1 Primary Electric Shock

An electric shock sufficiently severe to cause direct physiological harm.

14.2.2 Secondary Electric Shock

An electric shock not sufficiently severe to cause direct physiological harm. Nevertheless, such a shock could result in injury from involuntary muscular response.

14.3 Safe Let-Go Level

The current level passing through a hand grip contact for which 99.5% of the subject population would retain sufficient muscular control to voluntarily release the subject grip and break contact.

NOTE — The safe let-go level is a function of the frequency and voltage and varies considerably for various contact areas and pressures. Individual responses vary greatly from the mean level, and different levels are obtained for men, women, and children.

14.4 Threshold of Perception

The level of stimulation at which 50% of the population is just able to consciously detect the presence of the stimulus.

14.4.1 Steady-State Current Perception Threshold

The current at which stimulation is perceptible for 50% of the subject population.

NOTE — The threshold is a function of the frequency and voltage and varies considerably for various contact areas and pressures. Individual responses vary greatly from the mean threshold, and different levels are obtained for men, women, and children.

14.4.2 Transient Discharge Perception Threshold

The level of transient discharge that is perceptible for 50% of the subject population.

NOTE — The threshold varies considerably for various contact areas and transient discharge characteristics. Individual responses vary greatly from the mean thresholds, and different levels are obtained for men, women, and children.

14.5 Annoyance Shock

An electric shock from a steady-state or a discharge current for which a person would consider the sensation to be a mild irritant if it were to occur repeatedly.

14.6 Startle Shock

An electric shock from a steady-state or a discharge current that, if it occurred unexpectedly, would produce an unintentional muscular reflex.

14.7 Aversive Shock

An electric shock from a steady-state or a discharge current that after one exposure would motivate people to avoid situations that they felt would lead to similar experiences.

15. References

This standard shall be used in conjunction with the following publications.When the standards listed on the next page are superseded by an approved revision, the revision shall apply.

[1] ANSI C63.2-1987, American National Standard for Specifications for Electromagnetic Noise and Field Strength Instrumentation, 10 kHz to 40 GHz.[4]

[2] ANSI S1.1-1960 (Reaff. 1976), American National Standard for Acoustical Terminology.

[3] ANSI S1.4 .-1983, American National Standard Specification for Sound-Level Meters.

[4] CFR Publication 47, Code of Federal Regulations. U.S. Government Printing Office, Washington, D.C. {current edition (annual publication)}.[5]

[5] CISPR Publication 16 (1987), CISPR Specifications for Radio Interference Measuring Apparatus and Measurement Methods.[6]

[6] CISPR Publication 18-2 (1986), Radio Interference Characteristics of Overhead Power Lines and High-Voltage Equipment, Part 2.: Methods of Measurement and Procedures for Determining Limits.

[7] IEC 50 (161): 1990, International Electrotechnical Vocabulary—Chapter 161: Electromagnetic Compatibility.[7]

[8] IEEE Std 430-1986, IEEE Standard Procedures for the Measurement of Radio Noise from Overhead Power Lines and Substations (ANSI).[8]

[4]ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA.
[5]CFR publications are available from the Superintendent of Documents, US Government Printing Office, P.O. Box 37082, Washington, D.C. 20013-7082, USA.
[6]CISPR documents are available from the International Electrotechnical Commission, Case Postale 131, 3 rue de Varembé, CH 1211, Genève 20, Switzerland/Suisse. CISPR documents are also available in the United States from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA.
[7]IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembé, CH 1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA.
[8]IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[9] IEEE Std 644-1987, IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines (ANSI).

[10] IEEE Std 656-1985, IEEE Standard for the Measurement of Audible Noise from Overhead Transmission Lines (ANSI).

[11] NEMA 107-1987, Methods of Measurement of Radio Influence Voltage (RIV) of High Voltage Apparatus.[9]

[12] Huschke, R.E., ed. *Glossary of Meteorology*. Boston: American Meteorological Society, 1959.

[13] James, G. and James, R.C., eds. *Mathematics Dictionary*. 4th ed. New York: Van Nostrand Company, Inc., 1976.

[14] Kendall, M.G. and Burckland, W.R., eds. *A Dictionary of Statistical Terms*. 4th ed. New York: Longman Group Ltd., 1982.

[15] Reilly, J. Patrick and Delaplace, Louis R., eds. "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.

[9]NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, D.C. 20037, USA.

Annex A Terms Relating to the Biological Effects of Electric and Magnetic Fields in the Extreme Low Frequency (ELF) Range (Informative)

(This Appendix is not a part of IEEE Std 539-1990, IEEE Standard Definitions of Terms Relating to Corona and Field Effects of Overhead Power Lines, but is included for information only.)

A.1 General

The following definitions apply to some terms used to describe biological effects of electric and magnetic fields produced by power-supply systems.

A.2 Extreme Low Frequency Range

Frequency range from 3 Hz to 3 kHz.

A.3 Environment

The combined external factors that affect the health, growth, reproduction, and survival of an organism.

A.4 Ecology

The interrelation between organisms and their environment or the division of biology concerned with the study of such relationships.

A.5 Exposure

An expression of the quantity of some material, agent, etc., that is incident on an organism.

A.5.1 Dose

The amount of a chemical or other agent delivered to an organism; usually normalized to the mass of an organism.

A.5.2 Dose-Response Relationship

The relationship between dose and magnitude (or frequency) of response.

A.5.3 Dosimetry

1) The determination of dose or dose rate arising from an experimental or environmental exposure.
2) The comparison of dose or dose rate in one experiment (or situation) with that in another.

A.5.4 Chronic Exposure

Exposure over a relatively long time.

A.5.5 Acute Exposure

Exposure to a large dose during a relatively short time.

A.5.6 Treatment

The systematic application of some agent (e.g., chemical, electric field) to a sample of organisms in an experimental setting for the purpose of determining the biological effect(s) of the agent.

A.5.7 Peripheral Stimulation

Action by a chemical or physical agent at or near the surface of an organism.

A.5.8 Phosphene

Visual sensations due to nonoptical stimulation of the visual system.

A.6 Effect

A change in an organism or in a specific biological parameter as a result of application of some treatment (e.g., chemical). Also, a difference in some parameter between a control and treatment group that is biologically and/or statistically significant.

A.6.1 Congenital Effect

Existing at or from birth.

A.6.2 Environmental Impact

A change in existing conditions due to a natural or artificial cause, whether beneficial or adverse, that affects an organism and its surroundings.

A.6.3 Stress

The nonspecific response of an organism to any demand upon it, whether pleasant or unpleasant, that results in certain biochemical changes. In popular usage, the harmful connotation is often assumed, i.e., excessive stress or distress.

A.6.4 Biological Variability

A range in the degree of response to internal and external stimuli that organisms normally exhibit because of genetic makeup and environmental conditioning. This biological or normal variability must be considered when determining the effect of any one specific factor, e.g., an electric field.

A.6.5 Cardiovascular Effect

Effect pertaining to the system comprised of the heart and the blood vessels.

A.6.6 Excitability

The sensitivity of an excitable membrane to a stimulus.

A.6.6.1 Excitable Membrane

The membrane of nerve or muscle cells having an electrochemical property that results in sudden, major changes in ionic permeability when excited by an appropriate stimulus.

A.6.7 Genetic Effect

An alteration in DNA material within the cell. If germ cells (sperm, egg) are involved, mutations in offspring can result. If somatic (all other) cells are involved, effects such as premature aging or cancer can result.

A.6.8 Immunological Effect

Effect pertaining to the immune system.

A.6.9 Neuromuscular Effect

Effect pertaining to the nervous system associated with muscle function.

A.6.10 Neurosensory Effect

Effect pertaining to the nervous system associated with sensory function.

A.6.11 Syndrome

A particular group of symptoms that occur together and that define a particular disease or abnormality.

A.6.12 Zeitgebers

Biological triggers that respond to external stimuli and that influence the circadian rhythm (see A.7.7.1).

A.6.13 Action Potential

The electrical response of an excitable membrane that leads to the propagation of a nerve impulse; a nerve impulse.

A.6.14 Evoked Potential

The electrical response of a neuron or neurons elicited by electrical or natural (i.e., auditory, visual, etc.) stimulus. To be contrasted with spontaneous activity, such as that recorded by the EEG.

A.6.15 Resting Potential

The normal potential difference between the inside and the outside of a cell, usually about 80 mV, with the inside negative relative to the outside.

A.6.16 Hazard

A threat to the health, survival, or reproduction of an organism from some natural or artificial agent or event.

A.6.16.1 Risk

A measure of the probability of experiencing harm from one or more hazards (e.g., accidents, toxic chemicals).

A.6.17 Cancer Promoter

An agent that advances carcinogenesis after its initiation.

A.6.18 Carcinogen

An agent that tends to produce cancer.

A.7 Epidemiology

The study of the frequency and distribution of a disease, or a physiological condition in human populations, and of the factors that influence its frequency and distribution.

A.7.1 Hypothesis

Statement of a concept that attempts to explain or predict some phenomenon in such a way that the hypothesis is testable.

A.7.2 Mechanism

In the context of biological effects, the process(es) by which an agent (physical or chemical) causes the effect, e.g., causing a change in hormone production or in the function of cell membranes.

A.7.3 Endpoint

A measurable response of interest in a biological experiment.

A.7.4 Proportionate Mortality Ratio (PMR)

An index used in occupational epidemiological studies that expresses the proportion of deaths from a single cause. It is not a mortality rate and, therefore, does not necessarily indicate a risk value. Rather, it indicates within a group the relative importance of specific causes of death.

A.7.5 Replication

1) Theoretically, repetition of an experiment in exact detail.
2) Obtaining similar results from similar experiments.

A.7.6 Circadian Rhythm

Oscillation of biological processes with an approximate 24 h period regulated by external stimuli.

A.7.6.1 Diurnal

Pertaining to daytime, as in the daily biological rhythm.

A.7.7 Prospective Study

An epidemiological study of a group exposed to some factor over time to determine if this factor is associated with the development of a particular disease, as compared to a nonexposed control group.

A.7.7.1 Biophysical Study

One approach used to assess the potential for biological effects of artificial electric or magnetic fields. The magnitude of induced body currents and fields is compared with levels known to cause biological effects by certain physical mechanisms, e.g., heating of tissues.

A.7.7.2 *in situ* Study

Referring to studies involving organisms in their natural condition or environment.

A.7.7.3 *in utero* Study

Referring to studies involving the unborn animal.

A.7.7.4 *in vitro* Study

Referring to studies and/or effects that occur outside the living organism, e.g., within a test tube or Petri dish.

A.7.7.5 *in vivo* Study

Referring to studies and/or effects that occur within the body of living organisms.

A.7.7.6 Psychophysics

Study of correlations between stimulus parameters and detection or perception of stimuli.

A.7.7.7 Teratology

The study of developmental abnormalities in the fetus.

A.7.7.8 Blind Study

See A.7.7.8.1 and A.7.7.8.2.

A.7.7.8.1 Single-Blind Study

A study in which the subject is unaware of his or her role as experimental or control subject in an experiment.

A.7.7.8.2 Double-Blind Study

To reduce possible effects of bias, a study in which neither the experimenter nor the subject knows what treatment an individual subject receives until after the experiment has been completed.

A.7.8 Control

In experiments, establishment of an untreated group of animals, plants, cells, etc., that serve as the basis for comparing responses of a similar, but treated, group that has been subjected (exposed) to some agent (i.e., an electric field).

A.7.8.1 Sham Control

In an experiment, a group of organisms that is not exposed to the treatment, but is maintained, handled, observed, etc., in an identical manner as the treatment group, and whose overall characteristics are as similar as possible to the treatment organisms.

A.7.9 Uncontrolled Variable

A factor affecting the outcome of an experiment that is designed to assess other factors and which is unknown to, or unaccounted for, by the experimenter. Also called a confounding variable.