



IEEE Standard for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 644™-2019
(Revision of IEEE Std 644-2008)



STANDARDS

IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines

Developed by the

Transmission and Distribution Committee
of the
IEEE Power and Energy Society

Approved 7 November 2019

IEEE SA Standards Board

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1 **Abstract:** Uniform procedures for the measurement of power frequency electric and magnetic
2 fields from alternating current (ac) overhead power lines and for the calibration of the meters used
3 in these measurements are established in this standard. The procedures apply to the
4 measurement of electric and magnetic fields close to ground level. The procedures can also be
5 tentatively applied (with limitations, as specified in the standard) to electric fields near an
6 energized conductor or structure.

7
8 **Keywords:** ac power lines, electric field, IEEE 644™, magnetic field, measurement
9

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Introduction

This introduction is not part of IEEE Std 644-2019, IEEE Standard for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines.

This standard is a revision of IEEE Std 644TM-2008 (a reaffirmation of IEEE Std 644-1994), which establishes uniform procedures for measuring power frequency electric and magnetic fields in the vicinity of ac power lines. The following revisions have been made and are intended to improve the usefulness of the document:

- a) Text and revisions to some figures have been introduced to address the increasing likelihood that transmission lines are constructed on multi-line rights-of-way. Selection of measurement locations and extent of measurements have been altered accordingly.
- b) Text (with appropriate bibliographical references) has been added to note that electro-optic meters are available for performing some electric field measurements.

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IEEE Standard ~~Procedures~~ for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines

1. Overview

1.1 Scope

~~The purpose of~~ This standard establishes ~~is to establish~~ uniform procedures for the measurement of power frequency electric and magnetic fields from alternating current (ac) overhead power lines and for the calibration of the meters used in these measurements. A uniform procedure is a prerequisite to comparisons of electric and magnetic fields of various ac overhead power lines. These procedures apply to the measurement of electric and magnetic fields close to ground level. They can also be tentatively applied to electric field measurements near an energized conductor or structure with the limitations outlined in 34.5.

1.2 Purpose

The purpose of this standard is to establish uniform procedures for the measurement of electric and magnetic field levels from overhead ac power lines, and to establish calibration procedures for the meters used in these measurements. A uniform measurement procedure with established instrumentation and calibration is a prerequisite to comparisons or validation, or both, of the electric and magnetic field strength associated with various overhead power lines.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (shall equals is required to).^{1,2}

¹ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

² The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (should equals is recommended that).

The word *may* is used to indicate a course of action permissible within the limits of the standard (may equals is permitted to).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (can equals is able to).

2. References

~~This standard shall be used in conjunction with the following publication.~~

~~IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).¹~~

2. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.³ Additional definitions related to corona and field effects can be found in IEEE Std 539™ [B28].⁴

~~For additional definitions, see IEEE Std 100-1992.²~~

~~3.1 crosstalk:~~ The noise or extraneous signal caused by ac or pulse-type signals in adjacent circuits (measurement of power frequency magnetic fields).

~~¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.~~

~~²Information on references can be found in clause 2.~~

³IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

⁴³ The numbers in brackets correspond to those of the bibliography bibliographical items listed in Annex A clause 9.

electric field: A vector field of electric field strength, E , or of electric flux density, D .

NOTE 1—The term is also used to denote a region in which such vector fields have a significant magnitude.⁵

NOTE 2—*Vector field*. The totality of vectors in a given region represented by a vector function $V(x, y, z)$ of the space coordinates x, y, z . A vector field (in this case, the electric field) associates a vector-valued quantity (in this case, the electric field strength, E , or electric flux density, D) with every point in a given region.

3.2 electric field strength (~~E~~ electric field): At a given point in space, the ratio of force on a positive test charge placed at the point to the magnitude of the test charge, in the limit that the magnitude of the test charge goes to zero. The electric field strength (~~E-field~~) at a point in space in an electric field is a vector defined by ~~it~~ space components along three orthogonal axes. For steady-state sinusoidal fields, each space component is a complex number or phasor. The magnitudes of the components, expressed by their root-mean-square (rms) values in volts per meter (V/m), and the phases need not be the same (see Adler [B1]).³ See also: maximum value of the electric field strength, phasor, vertical component of the electric field strength.

NOTE 1—~~The~~ 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 E can be expressed in rectangular coordinates as:

$$\vec{E} = \hat{a}_x E_x + \hat{a}_y E_y + \hat{a}_z E_z \quad (1)$$

The space component in the x direction is:

$$E_x = \text{Re}(E_{x0} e^{j\phi_x} e^{j\omega t}) = E_{x0} \cos(\phi_x + \omega t) \quad (2)$$

The magnitude, phase angle, 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 $\hat{a}_x$.

⁵ Notes to text, tables, and figures are for information only and do not contain requirements needed to implement the standard.

NOTE 2—The magnitudes and the phase angles of the space components need not be the same.

An alternative general representation of a steady-state sinusoidal electric E -field strength can be derived—derivable algebraically from Equation (1). In this case, the electric field strength—and perhaps more useful in characterizing power-line fields, is a vector rotating in a plane where it describes an ellipse for which the rms value of the ~~whose~~ semi-major axis represents the magnitude and direction of the maximum value of the electric field strength, and whose semi-minor axis represents the magnitude and direction of the field a quarter cycle later (see [B1] and [B5])—[B4]. This representation is perhaps more useful in characterizing power-line electric fields where the electric field strength along in the direction of the line are small and can usually be neglected. Thus, the electric field strength vector from a power line with parallel conductors is assumed to sweep out an ellipse in a vertical plane perpendicular to the direction ~~plane~~ of the power line ~~ellipse is zero~~.

For non-parallel conductors, the electric field strength vector describes an ellipse, but the plane of the ellipse may not be vertical. This ellipse may degenerate into a straight line. See also: single-phase ac fields, ~~polyphase ac fields.~~

The use of the term “ac electric field” is deprecated.

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

NOTE ~~Notes:1—~~Electric and magnetic field components have a fundamental frequency equal to that of the power line voltages and currents.

NOTE 2—For ac power lines, the most widely used frequencies are 60 Hz and 50 Hz.

3.4—harmonic content: Distortion of a sinusoidal waveform characterized by ~~indication of~~ the magnitude and order of the Fourier series terms describing the wave.

NOTE —For power lines, the harmonic content is typically small and of little concern for the purpose of field 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. Power equipment such as dc-to-ac and ac-to-dc converters also may produce harmonics. Laboratory installations also may have voltage or current sources with significant harmonic content.

magnetic field: A vector field of magnetic field strength, H , or of magnetic flux density, B . *see also:*
maximum value of the magnetic field, resultant magnetic field.

NOTE 1—The term is also used to denote a region in which such vector fields have a significant magnitude.

NOTE 2—*Vector field.* The totality of vectors in a given region represented by a vector function $v(x, y, z)$ of the space coordinates x, y, z . A vector field (in this case, the magnetic field) associates a vector valued quantity (in this case, the magnetic field strength, H , or magnetic flux density, B) with every point in a given region.

magnetic field strength: A vector quantity, often denoted as H , related to the magnetic flux density, B , by $H = (B/\mu_0) - M$ where μ_0 is the magnetic permeability of free space and M is the magnetization of the magnetic medium. In free space, M vanishes, and the relationship between H and B becomes $H = B/\mu_0$. The preferred unit for H is amperes per meter (A/m).

NOTE 1—This term has sometimes been called the magnetic field intensity, but such use of the word intensity is deprecated in favor of strength.

NOTE 2—Though they are used often, the use of **magnetic field** or **H-field** is deprecated in favor of **magnetic field strength**.

3.5-magnetic flux density (magnetic-field): The vector quantity, often denoted as B , of zero (B -field) ~~of~~ divergence ~~zero~~ at all points, which determines the component of the Coulomb-Lorentz force, that is proportional to the velocity of a moving the charge carrier.

NOTE 1—In a zero electric field, the force, F , is given by:

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

(New)

~~$$\vec{F} = q\vec{v} \times \vec{B}$$~~

(Deleted)

where

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

The vector properties of the magnetic flux density field produced by currents in power-line conductors ~~lines~~ are the same as those given ~~above~~ for the electric field strength, above. The unit for the magnitude ~~magnitudes~~ of the magnetic flux density field components is the tesla (T) ~~are expressed by their rms values in tesla ($1\text{T}=10^4\text{G}$)~~.

NOTE 2—Some documents may refer to the magnitude of the magnetic flux density using gauss for the units. The unit gauss is related to the unit tesla by the equation $1\text{ T} = 10^4\text{ gauss}$.

NOTE 3—For time-varying (ac) fields, values are expressed as their rms values unless stated otherwise.

NOTE 4—Though they are used often, the use of magnetic field or B-field is deprecated in favor of magnetic flux density.

~~3.6~~ maximum value of the electric field strength: At a given point, the rms value of the semi-major axis magnitude of the electric field ellipse. *See also:* **electric field strength.**

~~3.7~~ maximum value of the magnetic field: At a given point, the rms value of the semi-major axis magnitude of the magnetic field ellipse.

~~3.8~~ perturbed field: A field that is changed in magnitude or direction, or both, by the introduction of an object.

NOTE—The electric field at the surface of 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.

3.9-phasor: A complex number expressing the magnitude and phase of a time-varying quantity. Unless otherwise specified, it is used only within the context of steady-state alternating linear systems. 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 ϕ should not be confused with the space angle of a vector. *See also:* **electric field strength.**

3.10-polyphase ac fields: Fields whose space components may not be in phase. These fields ~~are will~~ ~~be~~ produced by polyphase power lines. The field at any point can be described by the field ellipse—that is, by the magnitude and direction of the semi-major axis and the magnitude and direction of its semi-minor axis.

NOTE 1: Such fields are sometimes referred to as being elliptically polarized. Certain power line geometries can produce circularly polarized fields. For polyphase power lines, the electric field at large distances (≥ 15 m) 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 ($< 10\%$) of the major axis when measured at a height of 1 m above ground level. *See also:* **electric field strength.**

3.11-resultant magnetic field: The resultant magnetic field is given by the expression:

$$B_R = \sqrt{B_x^2 + B_y^2 + B_z^2} \quad (3)$$

where

B_x , B_y , and B_z are the rms values of the three orthogonal field components.

NOTES:

NOTE 1—The resultant magnetic field is also given by the expression:

$$B_R = \sqrt{B_{max}^2 + B_{min}^2} \quad (4)$$

where

B_{max} and B_{min} are the rms values of the semi-major and semi-minor axes of the magnetic field ellipse, respectively.