



IEEE Recommended Practice for Measuring Method of Electromagnetic Environment for the Corridor of High- Voltage Overhead Power Transmission Lines in Parallel Mixed with Alternating Current and Direct Current

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 2819™-2022

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Abstract: Uniform procedures for the measurement of the power frequency electric field and dc electric field when ac/dc power transmission lines are installed in parallel or on shared towers are established in this recommended practice. Based on the mutual influence analysis between parallel ac/dc power transmission lines through the theoretical calculation and on-site measurements, the specification requirements and calibration methods of electric field meters are specified. The measurement ranges and layout of measurement points, data recording and processing, and result evaluation methods of parallel power transmission lines of different voltage levels are standardized. This recommended practice is applicable to electromagnetic environment measurement of ac transmission lines with a voltage not less than 100 kV, dc transmission lines with a voltage not less than ± 400 kV, and parallel transmission lines with a distance not over 100 m.

Keywords: dc electric field, electric field measurement, IEEE 2819™, parallel ac/dc power transmission lines, power frequency electric field

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Introduction

This introduction is not part of IEEE Std 2819-2022, IEEE Recommended Practice for Measuring Method of Electromagnetic Environment for the Corridor of High-Voltage Overhead Power Transmission Lines in Parallel Mixed with Alternating Current and Direct Current.

This recommended practice introduces the procedures for measuring the electromagnetic environment in a transmission corridor for overhead parallel ac/dc power transmission lines in terms of layout principles of measurement points, measurement methods, data analysis and result evaluation, thus providing a guidance for electromagnetic environment measurement, engineering design, and equipment selection of transmission lines.

This recommended practice is applicable to electromagnetic environment measurement of ac transmission lines with a voltage not less than 100 kV, dc transmission lines with a voltage not less than ± 400 kV, and parallel transmission lines with a distance not greater than 100 m. This recommended practice may be used as a reference for ac/dc transmission lines installed on shared towers.

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IEEE Recommended Practice for Measuring Method of Electromagnetic Environment for the Corridor of High-Voltage Overhead Power Transmission Lines in Parallel Mixed with Alternating Current and Direct Current

1. Overview

1.1 Scope

This document provides a recommended practice for the arrangement principle of measurement points, the method of measurement, the analysis of measurement data, and the evaluation of measurement results for the corridor of overhead power transmission lines in parallel mixed with alternating current (ac) and direct current (dc), which can provide guidance for monitoring electromagnetic environmental of power transmission lines, as well as engineering design and equipment selection.

This document is applicable to measure the electromagnetic environment of the joint region under the ac and dc parallel transmission lines, whose maximum distance shall not exceed 100 m, the voltage shall not be less than 100 kV for ac transmission line and ± 400 kV for dc transmission line.

1.2 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}

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*).

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

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC 61786-1:2013, Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings—Part 1: Requirements for measuring instruments.³

IEC 61786-2:2014, Measurement of DC magnetic, AC magnetic and AC electric fields from 1 Hz to 100 kHz with regard to exposure of human beings—Part 2: Basic standard for measurements.

IEC 62110:2009, Electric and magnetic field levels generated by AC power systems—Measurement procedures with regard to public exposure.

IEC 62232:2017, Determination of RF field strength, power density and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure.

IEC TR 62681:2014, Electromagnetic performance of high voltage direct current (HVDC) overhead transmission lines.

IEEE Std 644TM-2019, IEEE Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines.^{4, 5}

IEEE Std 1227TM-1990 (Reaff 2010), IEEE Guide for the Measurement of DC Electric-Field Strength and Ion Related Quantities.

IEEE Std 1309TM-2013, IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes (Excluding Antennas) from 9 kHz to 40 GHz.

3. Definitions, acronyms, and abbreviations

3.1 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.⁶

center line: The line between the center points of two adjacent tower bases.

³IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

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⁶*IEEE 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.

mutual influence zone: A zone within a certain range of parallel ac/dc power transmission lines that is simultaneously affected by power frequency electric field, dc electric field and other electromagnetic conditions.

parallel ac/dc power transmission lines: The ac/dc overhead power transmission lines with the ground projection distance between the adjacent ac side conductor and dc polar conductor being not over 100 m, including that ac/dc transmission lines share the same towers or cross each other.

parallel distance: The ground projection distance between the adjacent side conductor and polar conductor of parallel ac/dc transmission lines.

undistorted field: A field whose amplitude and direction are not changed by the intervention of matters.

3.2 Acronyms and abbreviations

ac	alternating current
dc	direct current

4. Electromagnetic environment around parallel ac/dc transmission lines

The electromagnetic environment around parallel ac/dc transmission lines can generally be described by the power frequency electric field, power frequency magnetic field, dc electric field, ion-current density, dc magnetic field, and noises. Considering that the measurement points layout principles and measurement methods for the magnetic field and noises of parallel ac/dc transmission lines are consistent with those of independent ac or dc lines, this recommended practice only specifies the measuring methods for power frequency electric field and dc electric-field in an undistorted electromagnetic environment near parallel ac/dc transmission lines.

The mutual influence of parallel ac/dc transmission lines change the electric field strength on the surface of the conductors, which affects the corona characteristics of the lines (Yang, et al. [B14]).⁷ The dc line-generated space charge moves under the common effects of the power frequency electric field, dc electric field, and wind; therefore, the space charge distribution would be changed, and both the power frequency electric field and the dc electric-field would be affected around the transmission lines [B5], [B8], [B10], [B12]. The detailed analysis of the mutual influence of parallel ac/dc transmission lines is presented in Annex A.

4.1 Power frequency electric field

The electric field is the physical field that surrounds electrically-charged particles and exerts force on all other charged particles in the field. It is generated by the electric charges carried on a transmission line when it is operating (Melo, et al. [B9]). The power frequency electric field refers to the electric field generated by charges that vary sinusoidally with time at a frequency of 50 Hz or 60 Hz. It is generated by an operating ac transmission line (Lee, et al. [B3], Radwan, et al. [B11]).

The power frequency electric field strength around parallel ac/dc transmission lines can be calculated as follows in 4.1.1 and 4.1.2.

⁷ The numbers in brackets correspond to those of the bibliography in Annex C.

4.1.1 Calculation of equivalent charge per unit length of a conductor.

The equivalent charge on a high-voltage transmission line is a line charge. Because the radius r of a high-voltage transmission conductor is much smaller than its installation height h , the position of the equivalent charge may be considered the geometric center of the transmission conductor.

It should be assumed that the conductor of a transmission line is infinitely long and parallel to the ground, and the ground is a good conductor. With the consideration of the influence of the dc electric field, the equivalent charge on the conductor of a transmission line can be calculated by the method of mirror image. The matrix equation can be obtained as shown in Equation (1).

$$\begin{bmatrix} U_1 \\ U_2 \\ \vdots \\ U_m \end{bmatrix} = \begin{bmatrix} \lambda_{11} & \lambda_{12} & \cdots & \lambda_{1m} \\ \lambda_{21} & \lambda_{22} & \cdots & \lambda_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \lambda_{m1} & \lambda_{m2} & \cdots & \lambda_{mm} \end{bmatrix} \begin{bmatrix} Q_1 \\ Q_2 \\ \vdots \\ Q_m \end{bmatrix} \quad (1)$$

where

- U is the voltage matrix of each conductor with respect to the ground
- Q is the equivalent charge matrix of each conductor
- λ is the m -order square matrix formed by the potential coefficient of each conductor (m is the number of conductors)

For a three-phase ac line, because the voltage is a vector varying with time, the voltage of the conductor in each phase is a complex number, and it can be expressed as shown in Equation (2).

$$\bar{U}_i = U_{iR} + jU_{iI} \quad (2)$$

The corresponding charge quantity is also a complex number, and it can be expressed as in Equation (3):

$$\bar{Q}_i = Q_{iR} + jQ_{iI} \quad (3)$$

Correspondingly, Equation (1) can also be expressed using the real and imaginary parts as follows in Equation (4) and Equation (5):

$$[U_R] = [\lambda][Q_R] \quad (4)$$

$$[U_I] = [\lambda][Q_I] \quad (5)$$

4.1.2 Calculation of electric field generated by equivalent charge

Taking the minimum height of a conductor to ground, and considering the influence of the dc electric-field, the horizontal and vertical components of the electric field strength at P (x, y) in the space can be obtained respectively according to Equation (6) and Equation (7) (Lunca, et al. [B4], Abdel-Salam, et al. [B1]).

$$\bar{E}_x = \sum_{i=1}^m E_{ixR} + j \sum_{i=1}^m E_{ixI} = E_{xR} + jE_{xI} \quad (6)$$

$$\bar{E}_y = \sum_{i=1}^m E_{iyR} + j \sum_{i=1}^m E_{iyI} = E_{yR} + jE_{yI} \quad (7)$$

where

- E_{xR} is the horizontal component of the field strength generated by the real part of conductor charge at P (x, y)
- E_{xI} is the horizontal component of the field strength generated by the imaginary part of conductor charge at P (x, y)
- E_{yR} is the vertical component of the field strength generated by the real part of conductor charge at P (x, y)
- E_{yI} is the vertical component of the field strength generated by the imaginary part of conductor charge at P (x, y)

Then, the total power frequency electric field strength at P (x, y) can be calculated as follows in Equation (8):

$$\bar{E} = (E_{xR} + jE_{xI})\bar{x} + (E_{yR} + jE_{yI})\bar{y} = \bar{E}_x + \bar{E}_y \quad (8)$$

where the amplitudes of the two components of the total power frequency electric field strength are calculated as follows in Equation (9) and Equation (10):

$$E_x = \sqrt{E_{xR}^2 + E_{xI}^2} \quad (9)$$

$$E_y = \sqrt{E_{yR}^2 + E_{yI}^2} \quad (10)$$

4.2 DC electric field

When a dc transmission line is in operation, the electric charges on the current-carrying conductors generate an electric field. When the strength of the electric field on the surface of the conductors exceeds the breakdown field strength of air, the corona discharge phenomenon occurs. Driven by electric field force, the charged ions generated by the corona discharge move to the nearby space and form an ion current (Maruvada [B7], Yang, et al. [B13]).

Generally, the dc electric field is the superposition of the nominal electric field generated by the electric charges on a dc transmission conductor and the ion current field generated by the charged ions in the space. The dc electric field strength around parallel ac/dc power transmission lines can be calculated as follows in 4.2.1, 4.2.2, and 4.2.3.