



IEEE Guide for Overhead Transmission Lines with Composite Insulated Crossarm Supports

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Standards Committee

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STANDARDS

IEEE Guide for Overhead Transmission Lines with Composite Insulated Crossarm Supports

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Transmission and Distribution Standards Committee
of the
IEEE Power and Energy Society

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Abstract: The technical requirements for overhead transmission lines with composite insulated crossarm (CICA) supports, which include design and functional provisions; component requirements; tests; installation and acceptance needs; and operation and maintenance procedures are specified in this Guide.

Keywords: CICA, composite insulator, composite insulated crossarm, compact transmission line, IEEE 2833™

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Introduction

This introduction is not part of IEEE 2833-2024, IEEE Guide for Overhead Transmission Lines with Composite Insulated Crossarm Supports.

This guide applies to ac overhead transmission lines utilizing composite insulated crossarm (CICA) supports with nominal voltage from 66 kV to 1000 kV. It specifies the design provisions, component technology, test requirements, overall construction and acceptance, and operation and maintenance specifications of compact new-build or retrofitted transmission lines using CICA.

The designers and users of this guide can choose the design methods suitable for the line's geography, environment, and importance. The annexes supplement the contents of this guide by providing additional information and parameters.

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IEEE Guide for Overhead Transmission Lines with Composite Insulated Crossarm Supports

1. Overview

1.1 Scope

This guide specifies the technical requirements for overhead transmission lines with composite insulated crossarm (CICA) support, which include design requirements, component technology, test technology, construction and acceptance, and operation and maintenance specifications.

1.2 Purpose

The purpose of this guide is to describe a complete set of technical requirements for CICA overhead transmission lines, to enable the following:

- Designers to design optimized overhead transmission lines with CICA more quickly to reduce design duplication.
- Manufacturers to conduct product tests using the test types and methods recommended in this guide to reduce unnecessary test inputs and time.
- Construction personnel to carry out construction of overhead transmission lines with CICA more efficiently and economically and reduce the damage rate of CICA in transportation, lifting, and installation.
- Operation and maintenance personnel to carry out the operation and maintenance of overhead transmission lines with CICA in a more targeted and differentiated way to reduce the input cost of operation and maintenance.

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*).^{6,7}

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The 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. 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.

ANSI/AISC 360, Specification for Structural Steel Buildings.⁸

ANSI C29.12, American National Standard for Composite Insulators—Transmission Suspension Type.

ANSI C29.17, American National Standard for Composite Insulators—Transmission Line Post Type.

ASCE/SEI 10, Design of Latticed Steel Transmission Structures.

ASTM D695, Standard Test Method for Compressive Properties of Rigid Plastics.⁹

CIGRE TB 63, Guide to procedures for estimating the lightning performance of transmission lines.¹⁰

CIGRE TB 555, Artificial pollution test for polymer insulators.

CIGRE TB 691, Pollution test of naturally and artificially contaminated insulators.

EN 50341-1, Overhead electrical lines exceeding AC 1 kV—Part 1: General requirements—Common specifications.¹¹

IEC 60060-1, High-voltage test techniques—Part 1: General definitions and test requirements.¹²

IEC 60071-2, Insulation co-ordination—Part 2: Application guidelines.

IEC 60243-1, Electric strength of insulating materials—Test methods—Part 1: Tests at power frequencies.

IEC 60383-2, Insulators for overhead lines with a nominal voltage above 1000 V—Part 2: Insulator strings and insulator sets for a.c. systems—Definitions, test methods and acceptance criteria.

IEC 60437, Radio interference test on high-voltage insulators.

IEC 60507, Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems.

⁸ANSI publications are available from the American National Standards Institute (<https://www.ansi.org/>).

⁹ASTM publications are available from the American Society for Testing and Materials (<https://www.astm.org/>).

¹⁰CIGRE publications are available from the Council on Large Electric Systems (<https://www.e-cigre.org/>).

¹¹EN publications are available from the European Committee for Standardization (CEN) (<https://www.cen.eu/>).

¹²IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

IEC 60587, Electrical insulating materials used under severe ambient conditions—Test methods for evaluating resistance to tracking and erosion.

IEC 60652, Overhead line structures—Loading tests.

IEC 60826, Design criteria of overhead transmission lines.

IEC 61109, Insulators for overhead lines—Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000 V—Definitions, test methods and acceptance criteria.

IEC 61284, Overhead lines—Requirements and tests for fittings.

IEC 61462, Composite hollow insulators—Pressurized and unpressurized insulators for use in electrical equipment with rated voltage greater than 1 000 V—Definitions, test methods, acceptance criteria and design recommendations.

IEC 61467, Insulators for overhead lines—Insulator strings and sets for lines with a nominal voltage greater than 1 000 V—AC power arc tests.

IEC 61952, Insulators for overhead lines—Composite line post insulators for A.C. systems with a nominal voltage greater than 1 000 V—Definitions, test methods and acceptance criteria.

IEC 62217, Polymeric HV insulators for indoor and outdoor use—General definitions, test methods and acceptance criteria.

IEC 62631-3-1, Dielectric and resistive properties of solid insulating materials—Part 3-1: Determination of resistive properties (DC methods)—Volume resistance and volume resistivity—General method.

IEC/TR 62039, Selection guidelines for polymeric materials for outdoor use under HV stress.

IEC/TS 60815-3, Selection and dimensioning of high-voltage insulators intended for use in polluted conditions—Part 3: Polymer insulators for a.c. systems.

IEC/TS 62073, Guidance on the measurement of hydrophobicity of insulator surfaces.

IEEE Std 4TM, IEEE Standard for High-Voltage Testing Techniques.^{13,14}

IEEE Std 1243TM, IEEE Guide for Improving the Lightning Performance of Transmission Lines.

IEEE Std 1820TM, IEEE Guide on the Selection of Transmission and Distribution Insulators with Respect to Cold Weather Conditions.

IEEE Std 1862TM, IEEE Recommended Practice for Overvoltage and Insulation Coordination of Transmission Systems at 1000 kV AC and Above.

IEEE Std C62.82.2TM, IEEE Guide for the Application of Insulation Coordination.

ISO 34-1, Rubber, vulcanized or thermoplastic—Determination of tear strength—Part 1: Trouser, angle and crescent test pieces.¹⁵

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¹⁴IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹⁵ISO publications are available from the International Organization for Standardization (<https://www.iso.org/>) and the American National Standards Institute (<https://www.ansi.org/>).

ISO 37, Rubber, vulcanized or thermoplastic—Determination of tensile stress-strain properties.

ISO 62, Plastics—Determination of water absorption.

ISO 527-4, Plastics—Determination of tensile properties—Part 4: Test conditions for isotropic and orthotropic fiber-reinforced plastic composites.

ISO 604, Plastics—Determination of compressive properties.

ISO 2781, Rubber, vulcanized or thermoplastic—Determination of density.

ISO 14125, Fibre-reinforced plastic composites—Determination of flexural properties.

CISPR TR 18-2, Radio interference characteristics of overhead power lines and high-voltage equipment—Part 2: Methods of measurement and procedure for determining limits.¹⁶

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.¹⁷

arcing horn: Protective metal electrode that is connected in parallel to an insulator and partially bridges them.

arcing ring: A device that combines the function of the arcing horn and insulator corona ring.

composite insulated crossarm (CICA): The composite insulator members of CICA consist of load bearing cylindrical (solid or hollow core) fiberglass reinforced resin insulating core, a housing made of polymeric material, and metallic end fittings permanently attached to the insulating core. The typical CICA configurations are shown in [Annex A](#). The attachment of composite insulators to the corresponding transmission support can be a rigid or pivoted connection.

composite line post insulator: Insulator consisting of a load-bearing fiberglass reinforced plastic insulating solid or hollow core, a high temperature vulcanized silicone rubber housing and metal end fittings attached to the insulating core. It is intended to be subjected to cantilever, tensile and compressive loads. In this guide, it is also referred to as **line post insulator**.

composite suspension insulator: Insulator consisting of a load-bearing fiberglass reinforced plastic insulating solid cylindrical core, a high temperature vulcanized silicone rubber housing and metal end fittings attached to the insulating core. It is intended to be subjected to tensile loads only. In this guide, it is also referred to as **suspension post insulator**.

core: The internal insulating part of a composite suspension insulator and line post insulator made of fiberglass reinforced plastic, which is designed to ensure the mechanical characteristics.

corona ring: A grading device used to control and limit the electric field on the housing and triple point of composite insulators.

¹⁶CISPR documents are available from the International Electrotechnical Commission (<https://www.iec.ch/>) and the American National Standards Institute (<http://www.ansi.org/>).

¹⁷*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.

dry arc distance: The shortest distance in the air external to the composite insulated crossarm (CICA) insulators between those parts that normally have the operating voltage between them. It is generally taken as the straight-line distance.

housing: External insulating part of a composite insulator made of high temperature vulcanized silicone rubber providing the necessary creepage distance and protecting the core from the environment. The housing consists of both the external insulator sheath and sheds.

line post insulator: *See: composite line post insulator.*

node: The metal hardware connector at the high voltage end of the composite insulated crossarm (CICA) where the suspension insulator, line post insulator, and suspension fittings string are connected.

pivoting horizontal vee: *See: rotating composite insulated crossarm (RoCICA).*

rotating composite insulated crossarm (RoCICA): A rotatable (pivoting) type composite insulated crossarm (CICA) attached to the transmission support through an articulated fitting, which can rotate in the direction of the unbalance longitudinal load. *Syn: pivoting horizontal vee.*

shielding ring: A grading device used to control and limit the electric field on the composite insulated crossarm (CICA) node and suspension fitting string.

strike distance: The strike distance is the shortest distance from the energized hardware of the composite insulated crossarm (CICA) (including phase conductor attachment) to the grounded hardware of the CICA or support. The strike distance may correspond to the dry arc distance of the composite suspension insulator or line post insulator of the CICA.

support: Structures of suspension and tension (dead-end) types supporting phase conductors and ground wires in overhead transmission lines.

suspension fittings string: The assembly of metal fitting (hardware) components connected between the composite insulated crossarm (CICA) node and the transmission line conductor(s). These also include the conductor clamps.

suspension post insulator: *See: composite suspension insulator.*

triple point: The interface boundary between air-housing and metal end fitting of a composite suspension insulator and line post insulator.

3.2 Acronyms and abbreviations

BFR	back flashover rate
CFO	critical flashover
CICA	composite insulated crossarm
EDS	everyday strength
FRP	fiber-reinforced plastic
ICNIRP	International Commission on Non-Ionizing Radiation Protection
HC	hydrophobic
MAD	minimum approach distance
MDCL	maximum design cantilever load

OHGW	overhead ground wires
PPAG	portable protective air gaps
RIV	radio interference voltage
RoCICA	rotatable composite insulated crossarm
ROW	right of way
RSL	residual static load
SSFOR	shielding failure flashover rate
SFL	specified failure load
SIL	surge impedance loading
SML	specified mechanical load
SPS	site pollution severity
SSFOR	switching surge flashover rate
STL	specified tensile load
USCD	unified specific creepage distance

4. Route selection and support spotting

4.1 Route selection

Route selection can be designed in accordance with national laws, regulations, and related policies; combined with geological and geomorphic conditions; and natural environmental protection requirements to ensure the safety and reliability of transmission lines.

Narrow right of way (ROW) of transmission lines with CICA may allow more flexible route siting because the line footprint and ROW land requirements are reduced due to the compactness of CICA.

When selecting the route, the ROW can be determined considering both electrical and electromagnetic requirements, detailed in [Clause 7](#).

4.2 Support spotting

The support spotting can follow the local design standards or regulations of a transmission line; the optimal layout is decided according to line cost and construction, safe and convenient operation, and effective design.

The supports should be spotted according to the economic span of the CICA support. The span can be roughly uniform. The design span of the support can be utilized to the maximum.

When carrying on support spotting in mountain and hill terrain, attention may be paid to controlling the large span difference of the ahead and back span of a support. Special design of the CICA support can be adopted to increase safety if the large span difference is unavoidable.

For the support spotting considering the application of RoCICA, wind stability analysis is used to determine the number and the utilization condition of supports with RoCICA in one section. [\[B2\]¹⁸](#) provides guidelines for wind stability, which may be followed when designing transmissions lines employing RoCICA.

Compact CICA supports can be advantageous in situations where the cost of ROW easement is expensive or the corridor is congested.

¹⁸The numbers in brackets correspond to those of the bibliography in [Annex G](#).

5. Insulation coordination

In essence, the insulation coordination of transmission lines with the CICA is similar to the procedure of conventional transmission lines, which involves specification of the following basic dimensions and parameters:

- Strike distance and insulator dry arc distances of the whole CICA assembly
- Insulator creepage/leakage distance
- Phase to phase clearance
- Lighting protection and grounding

For transmission lines employing RoCICA, strike distance to the support and ground clearance can be verified by analyzing the cascade pivoting motion under the relevant load cases.

5.1 Strike distance and insulator dry arc distances

The external insulation of the CICA support shall withstand all types of voltage and environmental stresses occurring on the overhead transmission line, including power frequency voltage and transient overvoltages caused by lightning and switching. The overvoltage insulation withstand characteristics of the CICA are defined by shortest strike distance of the whole assembly.

5.1.1 Power frequency voltage

The strike distance of the CICA shall be capable of withstanding the rated system voltage during times of maximum conductor swing caused by wind. The minimum air gap necessary to withstand power frequency voltage can be calculated as per the procedure of EN 50341-1 or IEC 60071-2, both of which give the same empirical expression for the calculation of critical flashover voltage (CFO), corresponding to the 50% probability of flashover for an air gap under power frequency voltage.¹⁹ It is recommended that the adopted air gap corresponds to three standard deviations below the CFO. The wind considered for calculation of the associated swing angle is determined by local regulations or standards.

5.1.2 Switching overvoltage

Switching overvoltages need consideration in the insulation coordination of the CICA applied in EHV transmission lines. The insulation design can be carried out in a statistical manner where the probability distribution of overvoltages is combined with insulation strength characteristics to determine the risk of insulation failure or the switching surge flashover rate (SSFOR). The CICA insulation required to provide the desired reliability can be determined according to the procedure detailed in IEEE Std C62.82.2 or IEC 60071-2. For UHV lines, see IEEE Std 1862™.

The maximum transient overvoltage adopted in the design of the CICA dry arc distance and strike distance shall be at least equal to the highest overvoltage indicated in the electromagnetic transient studies. In addition, the risks of line failure shall not be higher than the values specified by local regulations or standards, so does the wind for swing angle calculation under this condition.

5.1.3 Lighting overvoltage

CICA insulation sizing and performance against lightning overvoltage can be determined by considering the following parameters: lightning flash density; the soil type in the region; the geometry of phase conductors and overhead ground wires for the typical support; and the probability distribution of flashover of the CICA under fast front lightning impulse. Both types of lightning induced outages, namely the shielding failure flashover rate (SFFOR) and the back flashover rate (BFR), need to be evaluated separately.

¹⁹Information on references can be found in [Clause 2](#).

Compaction of transmission lines with a CICA can bring improvements to the lightning performance. If one or more overhead ground wires exist, a reduced spacing to adjacent phases creates increased electro-magnetic coupling, resulting in reduced overvoltages. Also, reduced height of the CICA support means that the transmission line collects a smaller number of lightning flashes because of its smaller footprint. Thus, if the dry arc distance and critical impulse flashover level is held constant in the design, then the lightning reliability of transmission lines with a compact CICA is superior in comparison to conventional lines [B2], [B4]. This improvement in performance can be used to optimize the CICA insulation.

Maximum allowable lightning outage rates are specified by local regulations or standards. The procedure given in IEEE Std 1243 or CIGRE TB 63 can be applied to calculate line outages in terms of SFFOR and BFR and, as a result, determine the required dry arc distance or strike distance for CICA supports.

5.2 Icing

In the icing area, the effect of ice and snow accretion can be taken into consideration for determining the necessary dry arc distance of the CICA. The procedure given in IEEE Std 1820™ can be used.

5.3 Creepage/leakage distance

The CICA should be designed to withstand the continuous operating voltage under the relevant site pollution severity (SPS) in combination with the prevailing environmental circumstances and existing experience. The hydrophobic behavior of the CICA silicone rubber housing helps to suppress the flow of leakage current during wet conditions; the horizontal and inclined orientation of insulators in the CICA impart it with better self-cleaning and withstand characteristics.

Selection of the required unified specific creepage distance (USCD) of CICA insulators and their housing (shed) profile shall be based on the recommendations of IEC/TS 60815-3 and corrected to the actual operating altitude of the transmission line according to IEC 60071-2.

5.4 Phase to phase clearance

The phase to phase clearances of transmission lines with CICA should adhere to applicable local regulations or standards. In addition to in-span clearances, the necessary phase to phase strike distance should be maintained between the energized hardware of adjacent CICA assemblies for all stresses occurring on the overhead transmission line, as illustrated in 5.1. In general, the phase to phase spacing in the CICA supports may be reduced in comparison to conventional supports due to absence of grounded steel crossarm between the phases.

Especially in areas of galloping and ice shedding, the motion of conductors and overhead ground wire can be considered; a margin of the phase to phase and phase to ground clearance at no-icing area can be added. In CICA supports the offset between phases can be implemented either by increasing the length of the CICA assembly or adding a steel davit arm/frame.

5.5 Lighting protection and grounding

5.5.1 Overhead ground wires (OHGW)

CICA supports have higher compactness compared with conventional steel crossarm supports, which can yield better shielding flashover performance. However, out of safety considerations, keeping the same number of OHGW as conventional supports can be an option for transmission lines with CICA. In CICA supports, due to the length decrease of suspension fitting string, the OHGW peak height may need to be increased to retain the same shielding angle or midspan clearance between conductor and ground wire.

5.5.2 Line surge arrester

Because one of the compelling motivations for using CICA is line compaction, the application of line surge arresters on CICA supports can help to maximize this compaction effect by allowing smaller clearances and elimination of OHGWs. If line surge arresters are employed, the insulation coordination of CICA should be coordinated with the protective characteristics of the arresters.

5.5.3 Grounding

Back flashover performance of a line is sensitive to the support grounding resistance. The basic principle of grounding design for lines with CICA is similar to conventional transmission lines. However, it should be noted that the support grounding impedance depends on the area of the steel, grillage, and foundation reinforcing cages in contact with the earth, which are generally smaller for compact CICA supports. Therefore, depending on the soil resistivity and target back flashover reliability, CICA supports may require more supplemental grounding devices in form of vertical driven rod or buried counterpoises.

6. CICA support geometry

6.1 CICA support type

The types of CICA support mainly depend on voltage level, circuit number and topography, geological conditions, and operating conditions. The situation of the transmission line, the specifications of conductor and overhead ground wire, the meteorological conditions, the terrain and geological conditions, transportation, construction, operation and maintenance, etc., may be fully considered when choosing the optimal support type.

CICA supports, including pole and tower, are mainly divided into two main categories that include suspension CICA supports and tension CICA supports. Suspension CICA supports are divided into the following two sub-categories according to how the suspension CICA is connected to the support:

a) Suspension CICA support

Fixed connection. This includes tangent suspension CICA support and suspension CICA support with small deviation floating angle. The connection between the CICA and support is fixed; the conductor is hung by suspension fitting strings to the node.

Pivoting or rotatable connection. This rotatable CICA (RoCICA) is only for suspension support application.

b) Tension CICA support

This includes normal tension CICA support and termination (dead-end) CICA support. The connection between CICA and support is fixed; the conductor is terminated by tension fitting strings to the node.

The typical CICA supports are shown in [Annex B](#).

6.2 Definition of support geometry

The required clearances calculated in process of insulation coordination for power frequency voltage, lightning overvoltage, and switching overvoltage are collectively called internal clearances. This coordination procedure defines the overall support top geometry of CICA support.

6.2.1 Coordination of internal clearances

The coordination of internal clearances is carried at the following two distinct locations:

- a) At the top of the support
- b) Within the span (especially at the mid span)

The internal clearances and their corresponding consideration conditions are shown in [Table 1](#).

In areas with risk of galloping and ice shedding, special attention should be paid to the support top geometry as illustrated in [5.4](#).

Table 1—CICA support matrix of internal clearances

Location	Type of clearance
At top of the support	1) Phase conductor—support body 2) Phase conductor—overhead ground wire 3) Phase conductor—phase conductor
Within the span	1) Phase conductor—overhead ground wire 2) Phase conductor—phase conductor 3) Galloping (if applicable) 4) Ice shedding (if applicable)

6.2.2 Circuit electrical parameter

The circuit parameters that define the electrical function of an overhead transmission line are its resistance, inductance, and capacitance. Due to the compact support top geometry of the CICA, the surge impedance of the transmission line is reduced, which contributes to the increase of surge impedance loading (SIL).

7. ROW consideration

It is necessary to consider the influence of span conductor wind deflection (blow-out), corresponding air clearance to surrounding objects, and electromagnetic parameters when calculating the ROW of a transmission line.

The reduced length of the conductor suspension fitting string and possible compaction of support width with CICA application can lead to a reduction in wind blow-out displacement of span conductors. Compaction of support top geometry can have an opposing effect on the transmission line electromagnetic parameters; the electric and magnetic field is reduced whereas the radio interference and audible noise may be increased.

The limitation and calculation method of electromagnetic parameters can be obtained according to local standards or regulations. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) guide proposed by ICNIRP can be used to set limits of the electric field and magnetic field strength.

8. Loading

8.1 Principle of CICA support load calculation

Reliability-based and probabilistic methods are adopted for the design of transmission lines. The same as traditional supports, CICA supports and all other transmission line components (conductors, suspension or tension fitting strings, foundations, etc.) may be able to withstand the loads associated with the following design requirements:

- Reliability requirements for loads caused by defined climatic events