



IEEE Guide for Forecast and Early Warning of Icing on Overhead Transmission Lines in Microtopographic Areas

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 2797™-2024

STANDARDS

IEEE Guide for Forecast and Early Warning of Icing on Overhead Transmission Lines in Microtopographic Areas

Developed by the

Transmission and Distribution Committee
of the
IEEE Power and Energy Society

Approved 11 December 2024

IEEE SA Standards Board

Abstract: This guide is applicable to The prediction and early warning of icing on overhead transmission lines (OHLs) in micro-topographic areas is covered in this guide. Criteria for identifying micro-topographic areas and methods for predicting the icing thickness of OHLs is presented. This guide aims to provide guidelines for the observation, monitoring, prediction, early warning, and melting of ice on OHLs in micro-topographic areas, serving as references for anti-icing design and maintenance of OHLs in icing-prone areas.

Keywords: de-icing, equivalent ice thickness, icing prediction, IEEE 2797™, manual ice observation, micro-topographic areas, OHLs, online icing monitoring, overhead transmission lines

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2025 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 2 April 2025. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

PDF: ISBN 979-8-8557-1958-1 STD27774
Print: ISBN 979-8-8557-1959-8 STDPD27774

IEEE prohibits discrimination, harassment, and bullying.

For more information, visit <https://www.ieee.org/about/corporate/governance/p9-26.html>.

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE Standards documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page (<https://standards.ieee.org/ipr/disclaimers.html>), appear in all IEEE standards and may be found under the heading “Important Notices and Disclaimers Concerning IEEE Standards Documents.”

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents are developed within IEEE Societies and subcommittees of IEEE Standards Association (IEEE SA) Board of Governors. IEEE develops its standards through an accredited consensus development process, which brings together volunteers representing varied viewpoints and interests to achieve the final product. IEEE standards are documents developed by volunteers with scientific, academic, and industry-based expertise in technical working groups. Volunteers involved in technical working groups are not necessarily members of IEEE or IEEE SA and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE makes no warranties or representations concerning its standards, and expressly disclaims all warranties, express or implied, concerning all standards, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. IEEE Standards documents do not guarantee safety, security, health, or environmental protection, or compliance with law, or guarantee against interference with or from other devices or networks. In addition, IEEE does not warrant or represent that the use of the material contained in its standards is free from patent infringement. IEEE Standards documents are supplied “AS IS” and “WITH ALL FAULTS.”

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity, nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document should rely upon their own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: THE NEED TO PROCURE SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus balloting process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English language version published by IEEE is the approved IEEE standard.

Use by artificial intelligence systems

In no event shall material in any IEEE Standards documents be used for the purpose of creating, training, enhancing, developing, maintaining, or contributing to any artificial intelligence systems without the express, written consent of IEEE SA in advance. “Artificial intelligence” refers to any software, application, or other system that uses artificial intelligence, machine learning, or similar technologies, to analyze, train, process, or generate content. Requests for consent can be submitted using the [Contact Us](#) form.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE SA Standards Board Operations Manual is not, and shall not be considered or inferred to be, the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE or IEEE SA. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that the presenter’s views should be considered the personal views of that individual rather than the formal position of IEEE, IEEE SA, the Standards Committee, or the Working Group. Statements made by volunteers may not represent the formal position of their employer(s) or affiliation(s). News releases about IEEE standards issued by entities other than IEEE SA should be considered the view of the entity issuing the release rather than the formal position of IEEE or IEEE SA.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE or IEEE SA. However, **IEEE does not provide interpretations, consulting information, or advice pertaining to IEEE Standards documents.**

Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its Societies and subcommittees of the IEEE SA Board of Governors are not able to provide an instant response to comments or questions, except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in evaluating comments or revisions to an IEEE standard is welcome to join the relevant IEEE SA working group. You can indicate interest in a working group using the Interests tab in the Manage Profile and Interests area of the [IEEE SA myProject system](#).¹ An IEEE Account is needed to access the application.

Comments on standards should be submitted using the [Contact Us](#) form.²

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not constitute compliance to any applicable regulatory

¹Available at: <https://development.standards.ieee.org/myproject-web/public/view.html#landing>.

²Available at: <https://standards.ieee.org/about/contact/>.

requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Data privacy

Users of IEEE Standards documents should evaluate the standards for considerations of data privacy and data ownership in the context of assessing and using the standards in compliance with applicable laws and regulations.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under US and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, neither IEEE nor its licensors waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate licensing fees, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400; <https://www.copyright.com/>. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every 10 years. When a document is more than 10 years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit [IEEE Xplore](#) or [contact IEEE](#).³ For more information about the IEEE SA or IEEE's standards development process, visit the IEEE SA Website.

Errata

Errata, if any, for all IEEE standards can be accessed on the [IEEE SA Website](#).⁴ Search for standard number and year of approval to access the web page of the published standard. Errata links are located under the Additional

³Available at: <https://ieeexplore.ieee.org/browse/standards/collection/ieee>.

⁴Available at: <https://standards.ieee.org/standard/index.html>.

Resources Details section. Errata are also available in [IEEE Xplore](#). Users are encouraged to periodically check for errata.

Patents

IEEE standards are developed in compliance with the [IEEE SA Patent Policy](#).⁵

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE SA Website at <https://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

IMPORTANT NOTICE

Technologies, application of technologies, and recommended procedures in various industries evolve over time. The IEEE standards development process allows participants to review developments in industries, technologies, and practices, and to determine what, if any, updates should be made to the IEEE standard. During this evolution, the technologies and recommendations in IEEE standards may be implemented in ways not foreseen during the standard's development. IEEE standards development activities consider research and information presented to the standards development group in developing any safety recommendations. Other information about safety practices, changes in technology or technology implementation, or impact by peripheral systems also may be pertinent to safety considerations during implementation of the standard. Implementers and users of IEEE Standards documents are responsible for determining and complying with all appropriate safety, security, environmental, health, data privacy, and interference protection practices and all applicable laws and regulations.

⁵Available at: <https://standards.ieee.org/about/sasb/patcom/materials.html>.

Participants

At the time this standard was completed, the Forecast and Early Warning of Icing on Overhead Transmission Lines in Micro-topographic Areas had the following membership:

Songhai Fan, Chair
Zhijin Zhang, Vice Chair

<i>Organization Represented</i>	<i>Name of Representative</i>
China Power Engineering Consulting Group Co., Ltd.....	Deping Liu
China Southern Power Grid Co., Ltd.	Huan Huang
ChongQing University.....	Zhijing Zhang
Power Construction Corporation of China.....	Lizhi Cao
Sichuan University.....	Junwen Ren
Southwest Jiaotong University.....	Yujun Guo
State Grid Corporation of China (SGCC)	Xiaojiang Liu
Tsinghua Shenzhen International Graduate School	Zhidong Jia
University of Electronic Science and Technology	Yan Chen
Xi'an Jiaotong University.....	Xiaoang Li

The Working Group gratefully acknowledges the contributions of the following participants. Without their assistance and dedication, this standard would not have been completed.

Aijuan Bai	Xuxu Li	Ruoyun Wang
Shaoqing Chen	Fan Liu	Xilin Wang
Zhigang Cheng	Xi Liu	Hao Wu
XinSheng Dong	Yicen Liu	Tianbao Wu
Yiyu Gong	Wei Long	Fanghui Yin
Shenbing Hua	Xiaomin Ma	Lihua Zhao
Shuqi Li	Jian Wang	Fangrong Zhou

The following members of the entity Standards Association balloting group voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

China Power Engineering Consulting Group Co., Ltd.	Institute of Biomedical Engineering	Southwest Jiaotong University
China Southern Power Grid Co., Ltd.	North China Electric Power University	State Grid Corporation of China (SGCC)
China Three Gorges University	Power Construction Corporation of China	Tsinghua Shenzhen International Graduate School
ChongQing University	Siemens Energy	Tsinghua University

When the IEEE SA Standards Board approved this standard on 11 December, it had the following membership:

David J. Law, *Chair*
Jon Walter Rosdahl, *Vice Chair*
Gary Hoffman, *Past Chair*
Alpesh Shah, *Secretary*

Sara R. Biyabani
Ted Burse
Stephen Dukes
Doug Edwards
J. Travis Griffith
Guido R. Hiertz
Ronald W. Hotchkiss

Hao Hu
Yousef Kimiagar
Joseph L. Koepfinger*
Howard Li
Xiaohui Liu
John Haiying Lu
Kevin W. Lu
Hiroshi Mano

Paul Nikolich
Robby Robson
Lei Wang
F. Keith Waters
Sha Wei
Philip B. Winston
Don Wright

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 2797-2024, IEEE Guide for Forecast and Early Warning of Icing on Overhead Transmission Lines in Microtopographic Areas.

Icing is one of the major natural disasters faced by overhead transmission lines in many regions that may result in line breakage and even tower collapse. Icing monitoring, early warning, and line de-icing are critical to mitigating and preventing icing disasters.

This guide aims to focus on the prevention and treatment of icing on transmission lines, and involves elements and methods of micro-meteorological online monitoring, elements and site selection of ice observation stations, methods and result analysis of online icing monitoring and manual icing observation, methods used for ice prediction, and ratings and countermeasures of icing early warning.

Contents

1. Overview	11
1.1 Scope	11
1.2 Purpose	11
1.3 Word usage	11
2. Normative references	12
3. Definitions	12
4. Ice-prone microtopography	13
4.1 Classification	13
4.2 Characteristics	13
4.3 Identification methods	14
4.4 Identification process	15
5. Icing observation	15
5.1 Micrometeorological observation	15
5.2 Icing monitoring	18
6. Icing prediction	24
6.1 Method of icing prediction	24
6.2 Data processing	25
6.3 Prediction method	25
7. Early warning of icing	26
7.1 Applicable range	26
7.2 Indexes of early warning	26
7.3 Classification of early warning	26
7.4 Countermeasures	26
Annex A (informative) Typical ice-prone microtopography	27
Annex B (informative) Rotating cylindrical ice-accretion indicator and the inverse algorithm of icing parameters	39
Annex C (informative) Process of calculating the equivalent ice thickness of overhead transmission lines	44
Annex D (informative) Prediction model of equivalent ice thickness of overhead transmission Lines	50
Annex E (informative) Bibliography	53

IEEE Guide for Forecast and Early Warning of Icing on Overhead Transmission Lines in Microtopographic Areas

1. Overview

1.1 Scope

This guide involves online monitoring of the ice on overhead lines (OHL), weather forecasting, terrain identification, and icing prediction. It can serve the high-precision demands of forecasting line icing in specific micro-topographic areas during the design, operation, and maintenance of OHLs.

This guide can also provide references for other industries like the communications industry.

1.2 Purpose

This guide intends to provide basic principles and recommended method to predict icing on overhead lines in micro-topographic areas so as to help ensure secure operation of OHLs in the winter. Based on the results of online monitoring, microtopography identification and meteorological forecast, this guide can provide references for early warning of icing on OHLs, for selecting the best time of ice melting and for assessing icing risks to facilitate the design of OHLs in icing-prone areas.

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}

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*).

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 *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.

IEEE Std 1820™-2020, IEEE Guide on the Selection of Transmission and Distribution Insulators with Respect to Cold Weather Conditions.^{8,9}

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* can be consulted for terms not defined in this clause.¹⁰

design ice thickness: Ice thickness equivalent to an ice density of 0.9 kg/m³ based on the specified recurrence period.

equivalent ice thickness: Radial ice thickness calculated on the premise that ice is distributed evenly along the surface of the ground wire with a density of 0.9 kg/m³ and on the basis of the measured weight of ice on the ground wire.

glaze: Ice formed in the mode of wet growth when super-cooled water droplets with large particles hit an object, spread out into water films, and then freeze.

NOTE—This kind of ice is transparent and solid, with a large specific gravity and high adhesion, and usually comes along with icicles.¹¹

hard rime: Ice formed in either dry or wet growth mode when supercooled water droplets of various particle sizes flow with the air, collide with an object, and freeze.

NOTE—This kind of ice is translucent, has a moderate specific gravity and a certain amount of adhesion, and often forms on the windward side.

microtopography: Surface features of the earth of small dimensions that have a significant effect on the local climatic environment.

micrometeorology: Small-scale climates formed in near-surface atmosphere by certain structural characteristics of the underlying surface, which may manifest as weather phenomena like wind, fog, frost, and glaze.

ratio of equivalent ice thickness: Ratio of the equivalent ice thickness of the conductor in the monitoring section obtained through online icing monitoring or manual ice observation to the design ice thickness of the ground wire in the same section.

⁸The IEEE standards or products referred to in [Clause 2](#) are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

⁹IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹⁰*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.

¹¹Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

soft rime: Ice formed in the mode of dry growth when supercooled water droplets with a small particle flow with the air, collide with an object and freeze.

NOTE—This kind of ice is white and loose, has a small specific gravity and low adhesion, and usually forms on the windward side.

4. Ice-prone microtopography

4.1 Classification

Ice-prone microtopography refers to surface features at micro, small or local dimensions that will significantly impact the local climatic environments for icing.

Ice-prone microtopography often appears in complex types, and in this guide is primarily classified into the following:

- I: Air convergence duct/gap-type pass or saddle
- II: Air lifting duct/gap-type watershed or ridge
- III: Air lifting convergence sloping field or bench terrace (hill)
- IV: Area of influence of waters with large water vapor convergence

Based on the above classification, the sub-types for type-I and type-III as per low altitudes (below 500 m) and microtopography characteristics are as follows:

- I₁: Air convergence duct/gap-type saddle
- I₂: Air convergence duct-type pass
- III₁: Air lifting convergence sloping field
- III₂: Air lifting convergence bench terrace (hill)

[Annex A](#) can be referred to for the classification of ice-prone microtopography of overhead transmission lines.

4.2 Characteristics

Micrometeorology refers to small-scale climate characteristics in near-surface atmosphere and upper soil layer caused by the unevenness of underlying surface, the shape of microtopography, the existence of waters, vegetation variation, etc. It generally manifests in meteorological values or sometimes in weather phenomena, which leads to strong local climatic factors (e.g., wind speed and humidity) exceeding the average values of general sections. However, such changes in the factor will not cause large differences to the weather and climate characteristics determined by large-scale processes (e.g., advection and frontal surface).

The common features of icing micrometeorology resulting from microtopography include the following:

- a) Small spatial scale. Typical icing micrometeorology generally ranges from 10 m to 2000 m horizontally and from 0.1 m to 100 m vertically.
- b) Great variation in terms of value and distribution of certain meteorological elements (e.g., temperature, wind speed, and wind direction) and weather phenomena (e.g., wind, fog, glaze, hard rime, and soft rime).

- c) Discontinuous distribution of meteorological elements, the severity of icing, and icing types when micrometeorology and microtopography of icing transits from one to another horizontally.
- d) Distinct diurnal variation in meteorological elements over the course of icing.
- e) Stable micrometeorological behaviors of icing.

4.3 Identification methods

The main methods of identifying icing-prone microtopography are topographic map contour analysis, DEM (digital elevation model) analysis, and field investigation. These methods are outlined as follows:

a) Topographic map contour analysis

Contour analysis is an indoor identification and analysis method for icing-prone microtopography and should comply with the following rules:

- 1) Based on middle- and large-scale background terrains, topographic maps of proper scale are collected and chosen from the mapping departments. Generally, the scale for topographic maps of mountainous regions and plateaus is 1:5000 to 1:50000 while the scale for basins and hilly areas is 1:2000 to 1:10000.
- 2) Implement preliminary analysis and identification for ice-prone microtopography based on the contour lines of topographic maps, the characteristics of the main influences of main microtopography, comprehensive auxiliary identification conditions (factors), and representative topographic maps and cross-section diagrams, as described in [Annex A](#).

b) DEM analysis

DEM analysis is an indoor method of identifying icing-prone microtopography and should conform to the following rules:

- 1) Collect and select the satellite images and 3D network topographic maps of the line section from public websites.
- 2) Implement preliminary analysis and identification for icing-prone microtopography based on the 3D network topographic maps, characteristics of the main influences of main microtopography, comprehensive auxiliary identification conditions (factors), and representative topographic maps and cross-section diagrams, as referred to by [Annex A](#).

c) Field investigation

Field investigation is an outdoor method of identifying icing-prone microtopography and should comply with the following rules:

- 1) Implement site survey and review the field microtopographical factors based on preliminary microtopography identified indoors.
- 2) Adopt portable meteorological equipment for comparative microtopographical measurement of wind elements to assist analysis.
- 3) Observe the distribution and status of vegetation in local underlying surface.
- 4) Meteorological research of icing.
- 5) Deliver final identification and judgment based on the characteristics of major microtopographical effects and the characteristics of icing micrometeorology, as referred to by [Annex A](#).

4.4 Identification process

The identification process is as follows:

- a) Collect documents on icing zone division for constructed lines at the investigation phase (including line diagrams, construction drawings, ice zone division sheet of towers, etc.), thereby acquiring the microtopographical judgment at the investigation phase.
- b) Adopt indoor topographic map contour analysis method or 3D network topographic map analysis method to review and re-identify the typical microtopography of different ice zones of the line, especially the icing-prone microtopography that is incorrectly judged or omitted at the investigation phase.
- c) Implement field investigation to research and review the results on the site in a targeted way and identify icing-prone microtopography accurately based on preliminary results identified indoors and the demands of operation and maintenance.

5. Icing observation

5.1 Micrometeorological observation

5.1.1 Online micrometeorological monitoring

5.1.1.1 Temperature

The criteria for the temperature is given as follows:

- a) Measuring range: $-55\text{ }^{\circ}\text{C}$ to $50\text{ }^{\circ}\text{C}$
- b) Resolution: $0.1\text{ }^{\circ}\text{C}$
- c) Accuracy: $\pm 0.5\text{ }^{\circ}\text{C}$

5.1.1.2 Relative humidity

The criteria for relative humidity is given as follows:

- a) Measuring range: 0% RH (relative humidity) to 100% RH
- b) Resolution: 1% RH
- c) Accuracy: $\pm 4\%$ ($< 80\%$ RH); $\pm 8\%$ ($\geq 80\%$ RH)

5.1.1.3 Wind direction

The criteria for wind direction is given as follows:

- a) Measuring range: 0° to 360°
- b) Resolution: 3°
- c) Accuracy: $\pm 5^{\circ}$
- d) Starting wind speed in the wind direction: $< 0.5\text{ m/s}$
- e) Wind resistance: 75 m/s

5.1.1.4 Wind speed

The criteria for wind speed is given as follows:

- a) Measuring range: 0 m/s to 60 m/s
- b) Resolution: 0.1 m/s
- c) Accuracy: $\pm (0.5 + 0.03 v)$ m/s; where v is the standard wind speed
- d) Starting wind speed: < 0.5 m/s
- e) Wind resistance: 75 m/s

5.1.1.5 Atmospheric pressure

The criteria for atmospheric pressure is given in hectopascals (hPa) as follows:

- a) Measuring range: 500 hPa to 1 060 hPa
- b) Resolution: 0.1 hPa
- c) Accuracy: ± 0.3 hPa

5.1.1.6 Precipitation

The criteria for precipitation is given as follows:

- a) Intensity: 0 mm/min to 4 mm/min (tipping bucket rain gauge)
- b) Resolution: 0.2 mm
- c) Accuracy: ± 0.4 mm (≤ 10 mm); $\pm 4\%$ (> 10 mm)

5.1.2 Meteorological observation by ice observation stations

5.1.2.1 Observation elements

Icing observations can acquire accurate basic data for the icing characteristics and icing distribution patterns of areas with different orographic features and climates within a line right-of-way (see IEEE Std 1820™-2020).¹²

The icing observation station focuses on six meteorological elements (i.e., wind speed, wind direction, temperature, humidity, precipitation, and atmospheric pressure), liquid water content, and the median volume and diameter of droplets.

There are direct and indirect observations.

For direct observation, sensors of meteorological parameters are used to measure and record during the icing period.

For indirect observation, icing sensors like rotating multi-conductor ice-accretion indicators are used (see [Annex C](#)) while using the inversion model of icing parameters. Values that are not easy to measure directly, e.g., liquid water content and the median volume and diameter of droplets, can be acquired in real-time.

¹²Information on references can be found in [Clause 2](#).