IEEE STANDARDS ASSOCIATION

IEEE Standard for Wind Turbine Aero Acoustic Noise Measurement Techniques

IEEE Instrumentation and Measurement Society

Sponsored by the
Measurements in Power Systems Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 2400™-2016

IEEE Standard for Wind Turbine Aero Acoustic Noise Measurement Techniques

Sponsor

Measurements in Power Systems Committee
of the
IEEE Instrumentation and Measurement Society

Approved 15 May 2016

IEEE-SA Standards Board

Abstract: Techniques to select wind turbine and wind farm aero acoustic noise measurements, including instrumentation standards and metrology technology, measurement set, measurement procedures, data processing, and noise source data analysis are described in this standard. Near-field sound measurement similar to IEC 61400-11 distance and far-field sound measurement both outside and inside concerned houses or buildings are within the scope of this standard. This standard focuses on amplitude modulation noise, however, guidelines for low-frequency noise including infrasound near-field measurement are provided. IEC 61400-11 provides overall wind turbine noise measurement standards, while this standard focuses more on the aero acoustic noise of wind turbines to avoid overlap with IEC 61400-11.

Keywords: aero acoustic noise, amplitude modulation noise, far-field, IEEE 2400™, low-frequency noise including infrasound, near-field, wind farm, wind turbine

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

PDF: ISBN 978-1-5044-2060-0 STD20963
Print: ISBN 978-1-5044-2061-7 STDPD20963

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Standards Documents."

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

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute 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 does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. 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 his or her 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: PROCUREMENT OF 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 development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual 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. At lectures, symposia, seminars, or educational courses, individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide 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 Standards Coordinating Committees 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 revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

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 imply compliance to any applicable regulatory 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.

Copyrights

Photocopies

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 the IEEE-SA Website at http://www.ieee.org/publications_standards/index.html or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

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 http://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.

Participants

At the time this draft standard was completed, the Group: Standard Test Procedure of Wind Turbine Aero Acoustics Noise (IM/MPS/wtaan) Working Group had the following membership:

Cheng Wei Dai, *Chair*
Yang Xue, *Vice Chair*
Ying Huang, *Secretary*
Sidney Xue, *Chief Editor*

XiaoFeng Cai
Wei Gao
BinBin Ho
Jian Kang
Rui Li
Wei Liu
Gunnar Lundmark
Xiao Jin Ma
HongFeng Tang
Bruce Walker
XiaoDong Wang
Xiang Ye

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

Beijing Jiaotong University
BII Group Holdings Ltd.
China Datang Corporation
China Energy Engineering Group Co. Ltd.
China Southern Power Grid Co., Ltd.
Guangzhou Smart Home Technology Standards Promotion Center
Huawei Technologies Co., Ltd
Institute of Electrical Engineering Chinese Academy of Sciences
North China Electric Power University
Rockwell Automation
Southwest Jiaotong University
State Grid Corporation of China (SGCC)
Tianjin University
Tsinghua University
ZTE Corporation

When the IEEE-SA Standards Board approved this standard on 15 May 2016, it had the following membership:

Jean-Philippe Faure, *Chair*
Ted Burse, *Vice Chair*
John D. Kulick, *Past Chair*
Konstantinos Karachalios, *Secretary*

Chuck Adams
Masayuki Ariyoshi
Stephen Dukes
Jianbin Fan
Ronald W. Hotchkiss
J. Travis Griffith
Gary Hoffman
Michael Janezic
Joseph L. Koepfinger*
Hung Ling
Kevin Lu
Gary Robinson
Annette D. Reilly
Mehmet Ulema
Yingli Wen
Howard Wolfman
Don Wright
Yu Yuan
Daidi Zhong

*Member Emeritus

Introduction

This introduction is not part of IEEE Std 2400™-2016, IEEE Standard for Wind Turbine Aero Acoustic Noise Measurement Techniques.

The wind turbine in a wind farm can produce amplitude modulation noise (AMN) caused by rotating airfoil self-noise, particularly trailing edge scattering noise and Doppler effects due to blade motion relative to the observer; it is also recognized as "swish" sound. The envelope of the acoustic wave appears to be blade-passing frequency; therefore, it gives the impression that it is low frequency with blade-passing frequency noise. Meanwhile, the sound pressure pulsation due to blade aerodynamic loading fluctuation and blade tower interaction characterized as low-frequency noise (LFN), including infrasound, were observed from indoor measurement near a wind turbine in operation. The AMN and LFN are both identified as wind turbine aero acoustic noise that has been reported as the most annoying to residents near wind farms, including such complaints as sleep disturbance, nausea, giddiness, etc. The issue becomes a larger public concern as more wind farm projects are built with modern powerful wind turbines deploying larger and longer blades. However, the current IEC 61400-11 noise measurement standard did not address this issue, especially in far-field indoor conditions. To address this issue, IEEE started a standard development project, P2400, in October 2013. This standard establishes standard measurement techniques and methods of analysis to quantify wind turbine and wind farm aero acoustic noise. It can be used to understand wind turbine aero acoustic noise, so-called low-frequency/infrasound and amplitude modulation noise, and potential impacts on surrounding communities. This document provides the standard measurement techniques for wind turbine aero acoustic noise, including instrumentation selection, measurement setup, near-field and far-field outdoor and indoor post-data processing, and noise source data analysis. IEC 61400-11 has provided an overall wind-turbine noise-measurement standard, while this standard focuses more on the aero acoustic noise of wind turbines to avoid the overlap with IEC 61400-11. It is advised that users of this document are also familiar with ANSI S1.1–1994 (R2004) Acoustical Terminology.

Contents