



IEEE Standard for 50 Hz and 60 Hz Synchronous Generators and Generator/Motors Coupled to Hydraulic Turbines and Rated 5 MVA and Above

IEEE Power and Energy Society

Developed by the
Electric Machinery Committee

IEEE Std C50.12™-2025
(Revision of IEEE Std C50.12-2005)

STANDARDS

IEEE Standard for 50 Hz and 60 Hz Synchronous Generators and Generator/Motors Coupled to Hydraulic Turbines and Rated 5 MVA and Above

Sponsor

Electric Machinery Committee
of the
IEEE Power and Energy Society

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Abstract: This standard contains requirements for all types of 50 Hz and 60 Hz synchronous generators and generator/motors rated 5 MVA and above to be used for hydraulic turbine or hydraulic pump/turbine applications.

Keywords: cylindrical-rotor, generator, generator/motor, hydrogenerator, IEEE C50.12™, salient-pole rotor

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Participants

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Russ Fostiak, *Chair*
Robert Thornton-Jones, *Vice Chair*

William Bloethe	Tariq Humayun	Johnny Rocha
Stefano Bomben	Haran Karmaker	Alexander Schwery
Edson Bortoni	Stephen Kuznetsov	Dinemayer Silva
Gustavo Brunello	Werner Ladstaetter	Roberto Siniscalchi
Ritwik Chowdhury	Jim Lau	Davi Squaiella
Scott Cotner	Oscar Sebastian	Bruno Tonsic
Jason Erunio	Marin-Agudelo	Allen Windhorn
Yannick Ferland	Shawn Patterson	Dean Yager
Les Hajagos	Robert Pettigrew	Murty Yalla
Thomas Hildinger	Krzysztof Pyc	Marc Zeidman

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

Ian Backus	Glenn Griffin	Vicente Alonso
Blake Bailey	J Travis Griffith	Navarro Valencia
Gilles Bargone	Keith Grzegorzczuk	William Newman
Michael Basler	Haiping Guo	Sivaraman P
Steven Bezner	Paul Hamer	Lorraine Padden
Sebastien Billaut	Randy Hamilton	Bansi Patel
Thomas Bishop	Gene Henneberg	Dhiru Patel
Stefano Bomben	Thomas Hildinger	Shawn Patterson
Gustavo Brunello	Werner Hoelzl	Howard Penrose
Paul Cardinal	Ryan Hogg	Charles Rogers
Pin Chang	Richard Jackson	Bartien Sayogo
Yuan Chi	Jonathan Jenkins	Ashfak Shaikh
Ritwik Chowdhury	Aleksandra Jeremic	Greg Stone
Stephen Conrad	Haran Karmaker	Nick Stranges
Scott Cotner	John Kay	Jose Taborda
Paul Elkin	Gary Kobet	David Tepen
William English	Lucas Kunz	Michael Thompson
Namal Fernando	Mikhail Lagoda	Wayne Timm
Russ Fostiak	Melanie Levesque	John Vergis
Carl Fredericks	William Lockley	Iain Wright
Nancy Frost	Greg Luri	Dean Yager
Kamal Garg	Todd Martin	Marc Zeidman
Shubhanker Garg	Daleep Mohla	Hugh Zhu

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Thomas Koshy
Howard Li
Xiaohui Liu
Kevin W. Lu
Hiroshi Mano

Daleep C. Mohla
Annette D. Reilly
Robby Robson
Jon Walter Rosdahl
Daniel Sabin
F. Keith Waters
Sha Wei
Luyang (Eric) Zhang

Introduction

This introduction is not part of IEEE Std C50.12–2025, IEEE Standard for 50 Hz and 60 Hz Synchronous Generators and Generator/Motors Coupled to Hydraulic Turbines and Rated 5 MVA and Above

This introduction provides background to the development of this standard. This information is meant to aid in the understanding and usage of this standard.

From the early 1990s until the date of issue of this standard, two different working groups of the Electrical Machinery Committee (EMC) of the IEEE Power Engineering Society have carefully pursued the modernization of the ANSI C50 standards for large steam turbine and combustion turbine generators. Throughout the mid-1990s, the first working group (IEEE PES EMC Task Force on Standards Harmonization) compared American National Standards Institute (ANSI) standards for several different types of electrical machines with corresponding International Electrotechnical Commission (IEC) standards. In the late 1990s, members of the EMC Task Force published several summaries of their work (see [B7], [B20], [B29], and [B24]).

In association with the general initiative by the Electric Machinery Committee to compare different standards for electric machines, the Synchronous Machinery Subcommittee (SMSC) of the EMC commissioned a second working group in 1998 to focus on clarifying and modernizing the ANSI C50 series of standards for synchronous generators. The SMSC Working Group (WG) No. 4 (Revision of ANSI C50.1X series) included the following ANSI C50.1X standards in their scope:

- a) ANSI C50.10-1990, Rotating Electrical Machinery—Synchronous Machines [B2].
- b) ANSI C50.12-1982 (Reaff 1989), Requirements for Salient-Pole Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications [B3].
- c) ANSI C50.13-1989, Requirements for Cylindrical-Rotor Synchronous Generators [B4].
- d) ANSI C50.14-1977, Requirements for Combustion Gas Turbine Driven Cylindrical Rotor Synchronous Generators [B5].
- e) ANSI C50.15-1989, Hydrogen-Cooled, Combustion-Gas-Turbine-Driven, Cylindrical-Rotor Synchronous Generators [B6].

The SMSC WG No. 4 periodically reported their progress ([B9], [B10], [B11], and [B22]). As has been communicated in these papers, where it had been possible for this group to agree to the appropriateness of requirements recorded in IEC 60034 standards ([B12], [B13]) those requirements were incorporated into the revised ANSI C50.1X series of standards.

As the most workable approach to clarify and modernize the IEEE/ANSI standards for cylindrical-rotor synchronous generators the SMSC WG No. 4 chose to consolidate the previously separate ANSI C50.10, ANSI C50.13, ANSI C50.14, and ANSI C50.15 standards into one consolidated IEEE Std C50.13™ standard for cylindrical-rotor synchronous generators driven by steam turbines and/or by combustion gas turbines. This modernized IEEE Std C50.13-2005 was written to consolidate the previously separate ANSI C50.13, ANSI C50.14, and ANSI C50.15 standards in their entire scope and to incorporate applicable parts of ANSI C50.10. Similarly, WG No. 4 chose to modify ANSI C50.12 to become a consolidated standard for large salient-pole generators and generator/motors for hydraulic turbine applications. All applicable parts of ANSI C50.10 were incorporated into the modernized IEEE Std C50.12-2015. Also, wherever possible, the modernized IEEE Std C50.12-2005 and IEEE Std C50.13-2005 were harmonized with each other.

The intent was that IEEE C50.12™-2005 would contain the requirements for synchronous generators and generator/motors driven by hydroelectric turbines and that IEEE C50.13™-2005 would contain the requirements for synchronous generators driven by steam turbines and/or by combustion gas turbines.

IEEE C50.12-2005 was specifically written for salient-pole machines. At the time, the use of cylindrical rotor machines driven by hydroelectric turbines was either unknown or considered extremely rare and not deemed significant for inclusion into the standard. A similar philosophy was used to exclude consideration of salient pole machines driven by steam and/or combustion gas turbines.

In 2018, the Generator subcommittee of the IEEE approved formation of a working group to revise IEEE C50.12-2005 to include both types of machines (i.e., salient-pole and cylindrical-rotor) into the standard for hydroelectric generators and generator/motors. A similar effort was started to revise IEEE C50.13 to include salient pole machines.

This present revision of IEEE C50.12 incorporates cylindrical-rotor machines and also constitutes a major revision of the standard requirements to better align with those of the International Electrotechnical Commission (IEC) [B14] and with current developments in the hydroelectric industry. Among the most significant of these changes are the following:

- The range of voltage and frequency variation (5.6) has been increased to address modern-day requirements for grid operation imposed by national regulatory agencies.
- A requirement for total harmonic distortion (5.12.2) has replaced the obsolete requirements for telephone influence factor (TIF).
- A single value of 8% (6.5.1) for the machine continuous negative phase current unbalance capability has been added. This value applies to all hydrogenerators – with or without continuous amortisseur windings. It replaces separate values of continuous negative phase current unbalance contained in the previous version of the standard for machines with continuous (10%) and non-continuous (5%) amortisseur windings.
- The negative phase sequence current capability expressed as $I_2^2 t$ has been reduced from 40 to 20 (6.7.2.2) to align with IEC standards.
- The limiting observable temperature rises of indirectly cooled (Table 4) hydrogenerators have been increased to align with IEC standards and to recognize the improved thermal characteristics of modern insulation systems.
- A requirement for the maximum difference in embedded temperature detector measured temperature (8.3) has been added to align with IEC standards.
- Testing requirements (Part 10) have been expanded to better identify and clarify hydrogenerator testing. Voltage withstand testing at the various stages of winding manufacturing and installation have been added to align with modern industry practices.

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IEEE Standard for 50 Hz and 60 Hz Synchronous Generators and Generator/Motors Coupled to Hydraulic Turbines and Rated 5 MVA and Above

1. Overview

1.1 Scope

This standard contains requirements for all types of 50 Hz and 60 Hz synchronous generators and generator/motors rated 5 MVA and above to be used for hydraulic turbine or hydraulic pump/turbine applications.

Generators and generator/motors below this rating are generally covered by NEMA MG 1-2021[B23].⁶

1.2 Purpose

The purpose of this standard is to establish a base set of accepted requirements for 50 Hz and 60 Hz electrical generators and generator/motors rated 5 MVA and above driven by hydraulic turbines or pump/turbines that can be used in the specification of a new generator or generator/motor. It is also intended that the standard provide guidance for determining other requirements that may stem from coordination with the specific application including the prime mover characteristics, site conditions, and system interconnection details.

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).^{7,8}

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).

⁶ The numbers in brackets correspond to those of the Bibliography in Annex A

⁷ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements, *must* is used only to describe unavoidable situations.

⁸ The use of *will* is deprecated and cannot be used when stating mandatory requirements, *will* is only used in statements of fact.

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.

ASME Std PTC 29, Speed Governing Systems for Hydraulic Turbine-Generator Units.⁹

IEEE Std C37.102, IEEE Guide for AC Generator Protection.

IEEE Std C50.13, IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above.^{10,11}

IEEE Std 1™, IEEE Recommended Practice—General Principles for Temperature Limits in the Rating of Electrical Equipment and for the Evaluation of Electrical Insulation.

IEEE Std 4™, IEEE Standard Techniques for High-Voltage Testing.

IEEE Std 43™, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.

IEEE Std 62.2™, IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus—Electrical Machinery.

IEEE Std 95™, IEEE Recommended Practice for Insulation Testing of AC Electric Machinery (2300 V and Above) with High Direct Voltage.

IEEE Std 115™, IEEE Guide for Test Procedures for Synchronous Machines including Acceptance and Performance Testing and Parameter Determination for Dynamic Analysis.

IEEE Std 286™, IEEE Recommended Practice for the Measurement of Power Factor Tip-Up of Electric Machinery Stator Coil Insulation.

IEEE Std 421.1™, IEEE Standard Definitions for Excitation Systems for Synchronous Machines.

IEEE Std 433™, IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Voltage at Very Low Frequency.

IEEE Std 434™, IEEE Guide for Functional Evaluation of Insulation Systems for AC Electric Machines Rated 2300 V and Above.

IEEE Std 522™, IEEE Guide for Testing Turn-to-Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electrical Machines.

⁹ ASM International publications are available from the American Society for Metals (<https://www.asminternational.org/>) ASME publications are available from the American Society of Mechanical Engineers (<https://www.asme.org/>).

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IEEE Std 1043™, IEEE Recommended Practice for Voltage-Endurance Testing of Form-Wound Bars and Coils.

IEEE Std 1207™, IEEE Guide for the Application of Turbine Governing Systems for Hydroelectric Generating Units.

IEEE Std 1310™, IEEE Recommended Practice for Thermal Cycle Testing of Form-Wound Stator Bars and Coils for Large Generators.

IEEE Std 1434™, IEEE Guide to Measurement of Partial Discharges in Rotating Machinery.

IEEE Std 1553™, IEEE Standard for Voltage-Endurance Testing of Form-Wound Coils and Bars for Hydrogenerators.

IEEE Std 1665™, IEEE Guide for the Rewind of Synchronous Generators, 50 and 60 Hz, rated 1 MVA and above.

IEEE Std 1799™, IEEE Recommended Practice for Quality Control Testing of External Discharges on Stator Coils, Bars, and Windings.

IEEE Std 2465™, IEEE Trial-Use Recommended Practice for Pulse-Type Partial Discharge Measurements on Individual Stator Coils and Bars.

ISO 3746, Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure-Survey Method Using an Enveloping Measurement Surface Over a Reflecting Plane.¹²

ISO 20816-5, Mechanical Vibration—Measurement and evaluation of machine vibration—Part 5: Machine sets in hydraulic power generation and pump storage plants.

3. Definitions, abbreviations and acronyms

3.1 Definitions

For 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.¹³

controlled full-load rejection: Sudden disconnection of a machine from the grid (usually by operation of a system or unit circuit breaker) with the machine operating at 100% load; and, with the governor or gate operator, excitation system, and the associated protective circuitry fully operational.

directly cooled windings: Directly cooled stator windings or field windings are those in which coolant flows inside and in close contact with the conductor so that the heat generated within the principal portion of the windings reaches the cooling medium without flowing through the major ground insulation.

grid: Network, usually of a power company, for transmitting and distributing electric power.

grid code: A standardized set of rules and regulations for operation of the grid, including requirements for interconnection of generating and pumped/storage stations to the grid. Grid codes differ among various grid operators, but most include connection requirements with regard to the delivery of active and reactive

¹² ISO publications are available from the International Organization for Standardization (<https://www.iso.org/>) and the American National Standards Institute (<https://www.ansi.org/>).

¹³ IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>

power; operation under normal and abnormal conditions of grid voltage and frequency; and, behavior of the generators and generator/motors during power system disturbances.

hydrogenerator: A synchronous ac generator or generator/motor driven by a hydraulic turbine or pump/turbine. Although hydrogenerators are predominantly constructed with salient-pole rotors, the term as used in this standard shall apply equally to cylindrical-pole machines driven by hydraulic turbines or pump/turbines.

indirectly cooled windings: Indirectly cooled stator windings or field windings are those in which the heat generated within the principal portion of the windings must flow through the major ground insulation before reaching the cooling medium and the coolant flow outside the conductor.

primary coolant: A medium, liquid or gas, that, being at a lower temperature than a part of a machine and in contact with it, removes heat from that part. For open ventilated air-cooled synchronous machines, the primary coolant is the ambient air entering the machine. For closed circuit cooled synchronous machines, the primary coolant is the air or water entering the machine from the coolers.

secondary coolant: A medium, liquid or gas, that, being at a lower temperature than the primary coolant, removes heat given up by the primary coolant by means of a heat exchanger or through the external surface of the machine.

sustained runaway speed: The steady-state speed of the hydrogenerator at full gate opening while operating at its maximum design head with the hydrogenerator disconnected from the grid and unexcited.

uncontrolled full-load rejection: Sudden disconnection of the machine from the grid (usually by operation of a system or unit circuit breaker) with the machine operating at 100% load, under the most severe dynamic hydraulic conditions, and with the governor or gate operator inoperative. In case of high-speed/high-head turbines (pump/turbines) the speed under this condition may be higher than the sustained runaway speed, especially when two or more machines are connected to the same penstock.

user: The organization, or representative of the organization, that specifies and orders the purchase of the hydrogenerator and will own and operate the hydrogenerator when it is placed into service. As used in the introductory sections of this standard before the contents, the term refers to the reader of this standard.

3.2 Abbreviations and acronyms

AMSL	above mean sea level
ETD	embedded temperature detector
GSU	generator step-up
OV	open ventilated
P	active (real) power
Q	reactive power
RTD	resistance temperature detector
S	apparent power
TEWAC	totally-enclosed, water-to-air cooled
THD	total harmonic distortion
VPI	vacuum pressure impregnated