IEC TS 60034-32

Edition 1.0 2016-12

TECHNICAL SPECIFICATION

colour
inside

Rotating electrical machines –
Part 32: Measurement of stator end-winding vibration at form-wound windings

IEC TS 60034-32:2016-12(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

IEC TS 60034-32

Edition 1.0 2016-12

TECHNICAL SPECIFICATION

colour inside

Rotating electrical machines –
Part 32: Measurement of stator end-winding vibration at form-wound windings

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.160.01

ISBN 978-2-8322-3714-4

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ROTATING ELECTRICAL MACHINES –

Part 32: Measurement of stator end-winding vibration at form-wound windings

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 60034-32, which is a Technical Specification, has been prepared by IEC technical committee 2: Rotating machinery.

The text of this Technical Specification is based on the following documents:

Enquiry draft	Report on voting
2/1810/DTS	2/1849/RVC

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

NOTE A table of cross-references of all IEC TC 2 publications can be found on the IEC TC 2 dashboard on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

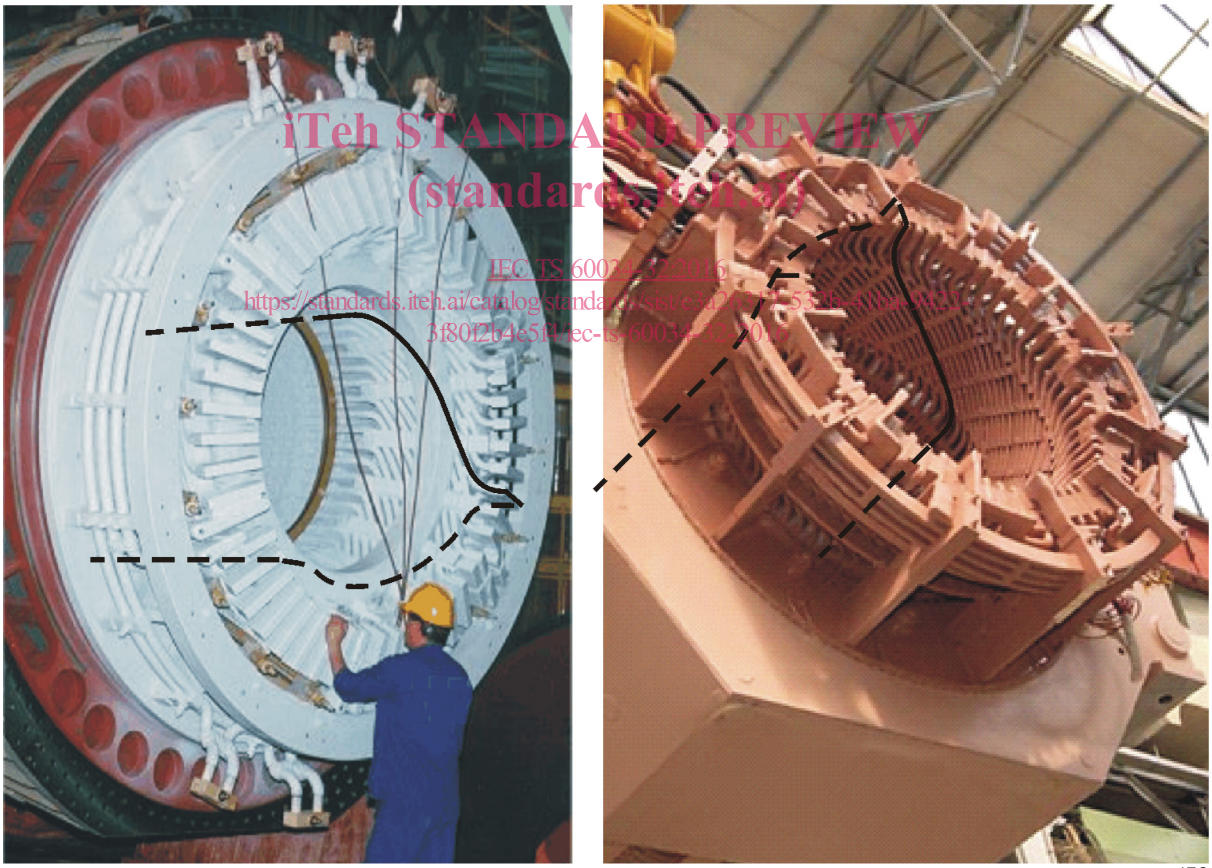
IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Large alternating current (AC) machines are equipped with multiphase stator windings. The information in this document is based on a dual-layer design. Such windings are connected to a multiphase voltage system (multiphase current system), which establishes a rotating magnetic field in the air gap between the rotor surface and stator bore. The voltage and current can vary during operation in order to adapt to varying mechanical load. Electrical machines are normally designed for motor or generator operating mode. The majority of AC machines are equipped with symmetrical three-phase windings, consisting of three, electrically isolated, spatially distributed winding parts that are intended for common operation.

Large AC rotating electrical machines are typically equipped with form-wound windings consisting of form wound coils (as defined in IEC 60034-15:2009, 2.3), single winding coils (single winding bars) which are given their shape before being assembled into the machine.

The winding overhang, or end-winding, is the portion of the stator winding that extends beyond the end of the magnetic core and is, in most cases, formed as a circular cone, see some examples in Figure 1 below.



IEC

NOTE Individual coil end marked with black line.

Figure 1 – Stator end-winding of a turbogenerator (left) and a large motor (right) at connection end with parallel rings

The majority of large AC machines with form-wound stator windings are equipped with a stator end-winding support structure. Among other functions it is expected to withstand the high electromagnetic force loading when the machine is exposed to an electrical fault in the electrical supply system. This includes a fault in the supply lines of an electrical grid or in an electronic supply device. In many cases the stator end-winding support structure is not only designed to increase the structural strength, but also provide appropriate structural stiffness and inertia to systematically influence structural dynamics and thus the vibration level during operation.

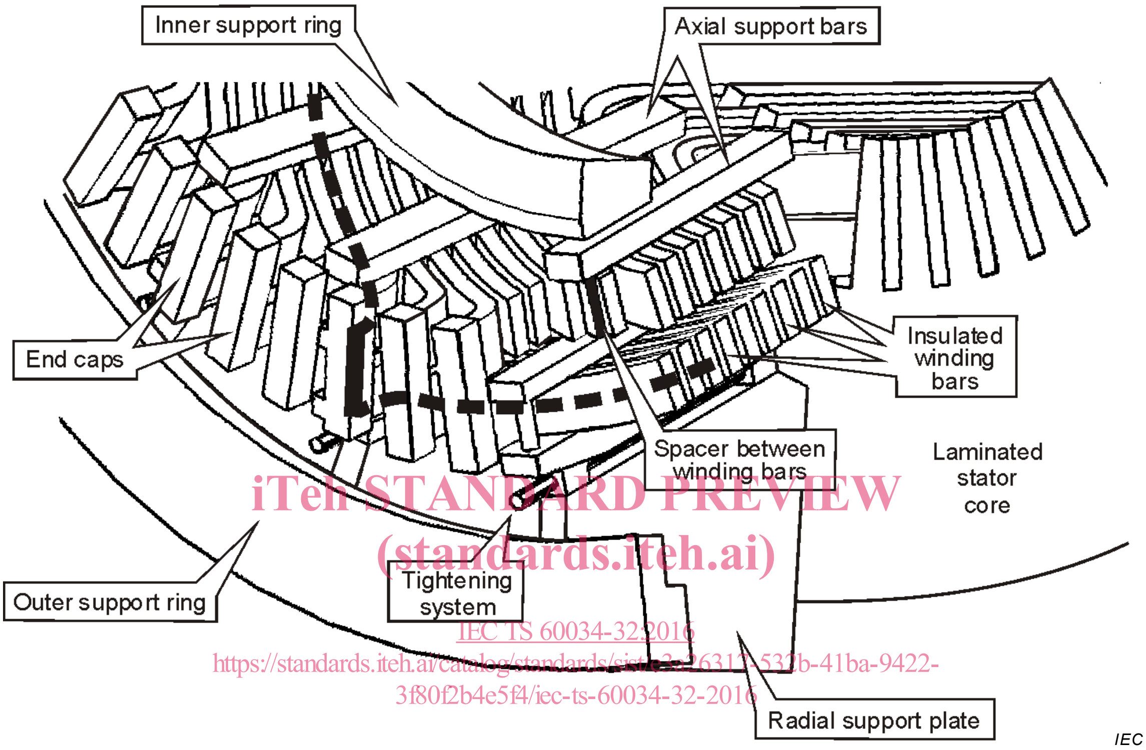


Figure 2 – Example for an end-winding structure of an indirect cooled machine

Typical support elements are plates and rings, which support the end-winding cone as a whole. Moreover, the distance between coils (or bars) of the end-winding are defined by spacing elements and their positions are fixed by fastening components. The typical materials used for support elements, spacers and fasteners are composites containing glass fibre materials as well as resin impregnated felts, cords and bandings (see Figure 2). Also, high electrical fields surrounding metal parts could produce electrical discharges compromising long term electrical strength.

Until now there existed no general Technical Specification to get reliable and comparable results for the identification of natural frequencies during stand-still and for vibration behaviour of stator end-windings during operation.

The experimental modal analysis of stator end-windings is a well-established tool which has also been used for the verification of natural frequencies and mode shapes of large electrical machines worldwide. The goal is to avoid operation of the machine with increased end-winding vibration levels under the influence of natural frequencies. Measurement of transfer functions and identification of structural dynamic properties (e.g. natural frequencies, mode shapes and other modal parameters) with an impact test is a common testing procedure. It is applied to new machines by the manufacturer and also used as a maintenance tool by the user or contractor during a major overhaul of large rotating machines.

Operational measurement of vibrational behaviour of stator end-windings can be performed by the installation of special vibration transducers at selected end-winding locations for periodic measurements or permanent on-line monitoring.

Although measurements of natural frequencies and vibration levels of stator end-windings are well established techniques, the interpretation of results is still a matter of further improvement and development. Therefore this first edition is a Technical Specification and not an International Standard.

ROTATING ELECTRICAL MACHINES –

Part 32: Measurement of stator end-winding vibration at form-wound windings

1 Scope

This part of IEC 60034 is intended to provide consistent guidelines for measuring and reporting end-winding vibration behaviour during operation and at standstill. It

– defines terms for measuring, analysis and evaluation of stator end-winding vibration and related structural dynamics,

– gives guidelines for measuring dynamic / structural characteristics offline and stator end-winding vibrations online,

– describes instrumentation and installation practices for end-winding vibration measurement equipment,

– establishes general principles for documentation of test results,

– describes the theoretical background of stator end-winding vibrations.

This part of IEC 60034 is applicable to:

– three-phase synchronous generators, having rated outputs of 150 MVA and above driven by steam turbines or combustion turbines;

– three-phase synchronous direct online (DOL) motors, having rated output of 30 MW and above.

This document is limited to the description of measurement procedures for 2-pole and 4-pole machines. For smaller ratings of machines than defined in this document, agreement can be made between the vendor and the purchaser for the selection of measurements in this document to be applied.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-15, *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*

IEC 60079 (all parts), *Explosive atmospheres*

ISO 7626-5:1994, *Vibration and shock – Experimental determination of mechanical mobility – Part 5: Measurements using impact excitation with an exciter which is not attached to the structure*

ISO 18431-1, *Mechanical vibration and shock – Signal processing – Part 1: General introduction*

ISO 18431-2, *Mechanical vibration and shock – Signal processing – Part 2: Time domain windows for Fourier Transform analysis*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
turbine driven generator
three-phase synchronous generator with cylindrical rotor with 2 or 4 poles driven by a steam turbine or combustion turbine

Note 1 to entry: In this document, the term turbogenerator will be used.

3.1.2
partial discharge
electrical discharge that only partially bridges the insulation between conductors

Note 1 to entry: A transient gaseous ionization occurs in an insulation system when the electric stress exceeds a critical value, and this ionization produces partial discharges.

Note 2 to entry: See IEC TS 60034-27.

3.1.3
stator end-winding
portion of the stator winding that extends beyond the end of the core and is formed as a circular cone

3.1.4
stator end-winding support structure
components like rings, plates, spacers and fasteners as well as components for tightening, blocking and roving which are supporting and fixing the stator end-winding

3.1.5
stator end-winding structure
assembly of both the stator end-winding and the stator end-winding support structure

3.1.6
stator bar
single electrical slot conductor as part of the stator winding

3.1.7
parallel rings
electrical components connecting the stator winding to the main leads

Note 1 to entry: Parallel rings are also called connection rings, phase rings or circuits rings.

3.1.8
displacement amplitude
amplitude of displacement vector

Note 1 to entry: See ISO 2041.

3.1.9
phase angle
angle of a complex response which characterizes a shift in time at a given frequency

Note 1 to entry: See ISO 2041.

3.1.10
measurement position
measurement location and direction

3.1.11
1x-vibration
vibration with rotational frequency

3.1.12
2x-vibration
vibration with twice rotational frequency

3.1.13
1f-vibration
vibration with once line frequency

3.1.14
2f-vibration
vibration with twice line frequency

3.1.15
mode shapes
shapes of a natural mode of vibration of a mechanical system, usually normalized to a specified deflection magnitude

Note 1 to entry: See ISO 2041.

3.1.16
local modes
vibration involving part of a stator end-winding structure with typically small spatial expansion relative to the circumference of the stator end-winding

3.1.17
global modes
vibration involving a large part of the stator end-winding structure, i.e. the winding bars outside the stator core and the support components

Note 1 to entry: See 8.1.3.

3.1.18
4-node mode
global vibration mode, which exhibits 4 nodes over the circumference of the stator end winding

Note 1 to entry: See 8.1.3.

3.1.19
8-node mode
global vibration mode, which exhibits 8 nodes over the circumference of the stator end winding

Note 1 to entry: See 8.1.3.

3.1.20
modal force
generalized force which is equal to the dot (scalar) product of the mode shape and the physical force vector (that is, the projection of the force distribution on the mode shape)

Note 1 to entry: Individual modes are excited by the modal force.

3.1.21
impact test
test to obtain the vibration response characteristics of a structure with a calibrated impact force

3.1.22
modal test
test to obtain modal parameters of a structure, including natural frequencies, mode shapes, modal damping

3.1.23
transient load condition
operational parameter outside of steady state operation regime

3.1.24
single bar end connection
electrical connection between bars in a stator

3.1.25
coherence
degree of linear relationship between the response and the force for each sampled frequency

Note 1 to entry: The value of the coherence function is always between 1 and 0.

3.1.26
operating deflection shape
ODS
vibration pattern of measured points on a structure under given operating conditions

3.2 Abbreviated terms

Abbreviated term	Definition
ADC	analog digital converter
DOL	direct on line
DPA	driving point analysis
DP-FRF	driving point frequency response function
EMA	experimental modal analysis
FFT	Fast-Fourier transformation
FRF	frequency response function (see ISO 7626-1 and ISO 2041)
IEPE	internal electronic piezoelectric