



IEEE

IEC/IEEE 60214-2

Edition 2.0 2019-06

INTERNATIONAL STANDARD

**TAP-changers –
Part 2: Application guidelines**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 IEC, Geneva, Switzerland

Copyright © 2019 IEEE

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing being secured. Requests for permission to reproduce should be addressed to either IEC at the address below or IEC's member National Committee in the country of the requester or from IEEE.

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue
New York, NY 10016-5997
United States of America
stds.ipr@ieee.org
www.ieee.org

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 the IEEE

IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

About IEC/IEEE publications

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

IEC publications search - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.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 once a month by email.

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: sales@iec.ch.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 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.

generated by EVS



IEEE

IEC/IEEE 60214-2

Edition 2.0 2019-06

INTERNATIONAL STANDARD

**TAP-changers –
Part 2: Application guidelines**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.180

ISBN 978-2-8322-6722-6

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

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	10
1 Scope.....	11
2 Normative references	11
2.1 IEC references.....	11
2.2 IEEE references.....	12
3 Terms, definitions and abbreviated terms	12
3.1 Terms and definitions.....	12
3.2 Abbreviated terms.....	13
4 Use of normative references.....	13
5 Application of tap-changers for transformers and reactors	14
5.1 General.....	14
5.2 Typical circuits for regulation	14
5.3 Basic arrangements of tapped windings with on-load tap-changers	16
5.4 Basic arrangements of tapped windings with step-voltage regulator on-load tap-changers.....	17
5.5 Basic arrangements of tapped windings with de-energized tap-changers	17
5.5.1 Bridging contact scheme for DETC	17
5.5.2 Linear contact scheme for DETC	18
5.5.3 WYE (star) contact scheme for DETC	18
5.5.4 Most common basic arrangements for different combinations	18
6 Types of tap-changers	19
6.1 On-load tap-changers (OLTCs)	19
6.1.1 General	19
6.1.2 Principles of operation	20
6.1.3 Physical layouts.....	27
6.2 De-energized tap-changers (DETCs)	32
6.2.1 General	32
6.2.2 Types of DETC	32
6.2.3 Location of DETC in the transformer tank or enclosure	32
6.3 Tap-changer environment	34
6.3.1 Liquid immersed tap-changers.....	34
6.3.2 Dry-type tap-changers (OLTC and DETC).....	35
6.3.3 Gas-immersed tap-changers (SF ₆ -insulated tap-changers).....	36
6.4 Other types	38
6.4.1 General	38
6.4.2 Electronic tap-changers	38
6.4.3 Step-voltage regulators.....	38
6.4.4 Advance retard switch (ARS).....	38
6.4.5 OLTCs for distribution transformers	39
7 On-load tap-changers	39
7.1 General.....	39
7.2 Selection of OLTCs.....	39
7.2.1 Basic parameters.....	39
7.2.2 Additional data.....	45
7.3 Application of OLTCs	45

7.3.1	General	45
7.3.2	OLTCs for application in special transformers with non-sinusoidal currents (HVDC, rectifier transformers, converter transformers, etc.)	45
7.3.3	OLTCs for PSTs	46
7.3.4	OLTCs for arc furnace transformers	47
7.3.5	OLTCs for shunt reactors	47
7.3.6	OLTCs for series reactors	48
7.3.7	OLTCs for unit auxiliary transformers	48
7.3.8	OLTCs for railway supply transformers	48
7.3.9	Transformers and phases out-of-step condition	48
7.4	Other important parameters for OLTCs	49
7.4.1	Current wave shapes other than sinusoidal	49
7.4.2	Operating pressure	49
7.4.3	Operational life of breaking and making contacts	50
7.4.4	Tap-changer mechanical life	51
7.4.5	Motor-drive mechanism	51
7.4.6	Pressure and vacuum test	51
7.4.7	Temperature conditions	52
7.4.8	Overloading conditions	52
7.4.9	Continuous consecutive operations	53
7.4.10	Preventive autotransformer circuit (reactor type tap-changer only)	53
8	De-energized tap-changers	54
8.1	General	54
8.2	Selection of DETCs	54
8.2.1	Currents	54
8.2.2	Rated step voltage	55
8.2.3	Insulation level	55
8.2.4	Number of tap positions	55
8.3	Application of DETCs	55
8.3.1	General	55
8.3.2	Frequencies	55
8.3.3	Application involving non-sinusoidal currents (HVDCs, rectifier transformers, converter transformers, etc.)	56
8.3.4	DETCs for arc furnace transformers and other high load cycle applications	56
8.3.5	DETCs for peaking pulsing loads	56
8.4	Other important parameters for DETCs	56
8.4.1	Tap-changer mechanical life	56
8.4.2	Motor-drive	56
8.4.3	Paralleling de-energized tap-changers/current splitting	56
9	Protective devices for OLTCs	57
9.1	General	57
9.2	Increase of pressure within diverter or selector switch liquid compartments	58
9.2.1	General	58
9.2.2	Liquid flow controlled relay	58
9.2.3	Overpressure relay	58
9.2.4	Sudden pressure relay	59
9.2.5	Pressure relief device	59
9.3	Increase of pressure within a diverter or selector switch in SF ₆	59

9.3.1	General	59
9.3.2	Pressure gauge (compound gauge)	59
9.3.3	Sudden pressure relay	60
9.4	Switching under excessive overload	60
9.5	Extreme medium temperatures	60
9.6	Increase of pressure within separate tap selector liquid compartments	60
9.6.1	General	60
9.6.2	Double element gas and liquid operated relay (Buchholz)	61
9.6.3	Overpressure relay	61
9.6.4	Pressure relief device	61
9.7	Tap-change supervisory circuit and phase unbalance protection	61
9.8	Vacuum interrupter monitoring system	62
10	Fittings and accessories for OLTCs	62
10.1	General	62
10.2	Valves, air release vents and liquid-sampling devices	62
10.3	Liquid-level gauges	62
10.4	Low liquid-level alarms	63
10.5	Dehydrating breathers	63
10.6	Oil filtering equipment	63
10.7	Devices to aid maintenance	63
10.8	Nameplate and other plates	63
11	Storage and installation of the tap-changer	64
11.1	Storage of OLTC and DETC when not in operation	64
11.1.1	General	64
11.1.2	Storage prior to installation	64
11.1.3	Storage after installation	64
11.2	Leads assembly to/at the tap-changer	65
11.3	Tap-changer mounting to the transformer tank	65
11.4	Processing and filling	66
11.5	Operation of OLTC for ratio measurement	66
12	Field service (operation, maintenance and monitoring)	67
12.1	Commissioning	67
12.1.1	General	67
12.1.2	Transformer ratio measurement	67
12.1.3	Tap-changer concerns during winding resistance measurement	68
12.1.4	Check of the synchronization of the drive system	68
12.1.5	General functional checks	69
12.2	Operation	69
12.2.1	Parallel operation	69
12.2.2	Contact erosion and liquid contamination	69
12.2.3	Overheating of contacts when operating in fixed tap position	70
12.2.4	Discharges during the operation of change-over selectors	71
12.3	Maintenance	71
12.3.1	General	71
12.3.2	Maintenance intervals	71
12.3.3	Performance of maintenance	71
12.3.4	Maintenance work	71
12.3.5	Contact resistance measurement	72
12.3.6	Motor-drives and shafts	72

12.3.7	Accessories	72
12.4	Monitoring	72
12.4.1	General	72
12.4.2	Periodic monitoring	73
12.4.3	Continuous monitoring	75
12.4.4	Commercial monitoring systems	75
13	Safety	76
13.1	Gases	76
13.2	Operation of an on-load tap-changer	76
13.2.1	General	76
13.2.2	Overpressure protection	76
13.2.3	Pressure relief devices	76
13.3	Operation of de-energized tap-changers	76
13.3.1	General	76
13.3.2	Manual drive operation	77
13.3.3	Motor-drive operation	77
13.4	Immersing medium	78
14	Information to be provided by the transformer manufacturer	78
14.1	Information required at the enquiry or order stage for an OLTC	78
14.2	Information required at the enquiry or order stage for a DETC	80
14.2.1	General	80
14.2.2	Only for rack or slide-type design of DETC	80
14.2.3	Small DETCs	80
14.3	Documentation	81
	Bibliography	82
	Figure 1 – Tap-changers in a star-connected winding	14
	Figure 2 – Tap-changers in series transformers	15
	Figure 3 – Tap-changers in delta-connected windings	15
	Figure 4 – Tap-changers in autotransformers	16
	Figure 5 – Basic arrangements of the regulating winding	17
	Figure 6 – Common connection arrangements	19
	Figure 7 – Operating sequence of a diverter switch (d to i) and tap selector (a to c) (non-vacuum type diverter switch with operating cycle number 1)	21
	Figure 8 – Operating sequence of a selector switch (a to e) (non-vacuum type selector switch with operating cycle number 1)	22
	Figure 9 – Diagram of connections of non-vacuum, resistor type on-load tap-changers (IEC 60214-1:2014, Table A.1, or IEEE Std C57.131-2012, Table A.1)	22
	Figure 10 – Diagram of connections of vacuum, resistor type on-load tap-changers (IEC 60214-1:2014, Table A.3)	24
	Figure 11 – Operating sequence (a) to g)) of a diverter switch and tap selector (non- vacuum type)	26
	Figure 12 – Diagram of connections of non-vacuum, reactor type on-load tap-changers (IEC 60214-1:2014, Annex B, or IEEE Std C57.131-2012, Annex B)	27
	Figure 13 – Diagram of connections of reactor type on-load tap-changer with vacuum interrupter and tap selector (IEC 60214-1:2014, Annex B, or IEEE Std C57.131-2012, Annex B)	27
	Figure 14 – Common layouts for compartment type tap-changers	29

Figure 15 – Common layouts for in-tank-type tap-changers.....	31
Figure 16 – Common arrangements of DETCs in the transformer main tank.....	33
Figure 17 – Externally mounted diverter compartment with an in-tank tap selector and a barrier board.....	37
Figure 18 – ARS application and mode of operation in a PST	39
Figure 19 – Selector at both fine tap and coarse winding	44
Figure 20 – Tap-changer oil conservator arrangement	50
Figure 21 – Current splitting in DETCs.....	57
Figure 22 – Types of in-tank OLTC installations within the transformer	65

This document is a preview generated by EVS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TAP-CHANGERS –

Part 2: Application guidelines

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.

IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. 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 contained in its standards. Use of IEEE Standards documents is wholly voluntary. *IEEE documents are made available for use subject to important notices and legal disclaimers (see <http://standards.ieee.org/IPR/disclaimers.html> for more information).*

IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

- 2) The formal decisions 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. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.
- 3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE 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 (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are 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 IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, 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/IEEE Publication or any other IEC or IEEE 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 implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent 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.

International Standard IEC/IEEE 60214-2 has been prepared by IEC technical committee 14: Power transformers, in cooperation with the Transformers Committee of the IEEE Power and Energy Society, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE.

This publication is published as an IEC/IEEE Dual Logo standard.

This second edition cancels and replaces the first edition published in 2004. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) title has been updated from "Application guide" to "Application guidelines";
- b) tap-changers for gas-filled transformers have been added;
- c) description of typical circuits for regulation has been added;
- d) description of basic arrangements of tapped windings with on-load tap-changers and de-energized tap-changers has been added;
- e) types of tap-changers are explained in more detail (e.g. vacuum type on-load tap-changer) and new types have been added (e.g. step-voltage regulator, advance retard switch (ARS), on-load tap-changers for distribution transformers);
- f) selection of tap-changers (on-load and de-energized) are described in more detail with respect to applications and parameters, which have to be considered (e.g. current wave shapes, operating pressure, temperature conditions, overloading conditions, continuous consecutive operations);
- g) storage and installation has been considered;
- h) field service, including commissioning, operation, maintenance and monitoring, has been considered;
- i) safety aspects have been updated.

The text of this International Standard is based on the following IEC documents:

FDIS	Report on voting
14/1000/FDIS	14/1006/RVD

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60214 series, published under the general title *Tap-changers*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have 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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

This document is a preview generated by EVS

INTRODUCTION

The recommendations in these application guidelines represent advice to the tap-changer manufacturer, the transformer manufacturer, and the end user. When using these guidelines, the recommendations and instructions of the tap-changer manufacturer should prevail.

These guidelines apply to typical tap-changers currently in production at the time of publication. However, much of the information is applicable to older designs.

It is stressed that the responsibility for the correct application of the fully assembled tap-changers in connection with the transformer lies with the manufacturer of the transformer.

This document is a preview generated by EVS

TAP-CHANGERS –

Part 2: Application guidelines

1 Scope

This part of IEC 60214 is intended to assist in the selection of tap-changers designed in accordance with IEC 60214-1 or IEEE Std C57.131 for use in conjunction with the tapped windings of transformers or reactors. Requirements, references and definitions relevant to either IEC 60214-1 or IEEE Std C57.131 are given and their use is described in Clause 4. It is also intended to assist in understanding the various types of tap-changers and their associated equipment available. These application guidelines cover on-load tap-changers (resistor and reactor types) and de-energized tap-changers.

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.

2.1 IEC references

IEC 60050-421, *International Electrotechnical Vocabulary (IEV) – Chapter 421: Power transformers and reactors* (available at www.electropedia.org)

IEC 60076-1:2011, *Power transformers – Part 1: General*

IEC 60076-3:2013, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5:2006, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-7, *Power transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60076-11, *Power transformers – Part 11: Dry-type transformers*

IEC 60076-21, *Power transformers – Part 21: Standard requirements, terminology, and test code for step-voltage regulators*

IEC 60156, *Insulating liquids – Determination of the breakdown voltage at power frequency – Test method*

IEC 60214-1:2014, *Tap-changers – Part 1: Performance requirements and test methods*

IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear*

IEC 60567, *Oil-filled electrical equipment – Sampling of gases and analysis of free and dissolved gases – Guidance*

IEC 60814, *Insulating liquids – Oil-impregnated paper and pressboard – Determination of water by automatic coulometric Karl Fischer titration*

2.2 IEEE references

ASTM D877 / D877M-2013, *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*

ASTM D1533, *Standard Test Method for Water in Insulating Liquids by Coulometric Karl Fischer Titration*

ASTM D3487, *Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus*

IEEE Std C57.12.00™-2015, *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.12.01™, *IEEE Standard for General Requirements for Dry-Type Distribution and Power Transformers*

IEEE Std C57.12.90™, *IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.15™, *Power transformers – Part 21: Standard requirements, terminology, and test code for step-voltage regulators*

IEEE Std C57.91™, *IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators*

IEEE Std C57.131™-2012, *IEEE Standard Requirements for Tap Changers*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-421, IEC 60214-1 and IEC 60076-21 apply for IEC-specified tap-changers. For IEEE-specified tap-changers, the terms and definitions given in IEEE Std C57.131 and IEEE Std C57.15 apply. For all tap-changers, the following apply and take precedence.

ISO, IEC and IEEE 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>
- IEEE Dictionary Online: available at <http://dictionary.ieee.org>

3.1.1

mechanically linear

de-energized tap-changer, where the stationary contacts are arranged in a line (or series of lines) and the moving contacts operate in an inline manner to connect with the stationary contacts

Note 1 to entry: The definition only applies to the general operational characteristics of the switch, not to the type of contacts or actual operating mechanism.