



**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 <sub>6</sub> -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 <sub>6</sub> .....	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

## 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.

## 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.

## 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](http://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*