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IEC/IEEE 60214-2:2019



Australian/New Zealand Standard™

Tap-changers

Part 2: Application guidelines



AS/NZS IEC/IEEE 60214.2:2024

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Part 2: Application guidelines

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Preface

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-008, Power Transformers, to supersede AS 60214.2—2006.

The objective of this document is to assist in the selection of tap-changers designed in accordance with AS/NZS 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 AS/NZS 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. 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; and
- (i) safety aspects have been updated.

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- (ii) A full point substitutes for a comma when referring to a decimal marker.

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The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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Foreword

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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.

Australian/New Zealand Standard

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, TM2015 *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

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

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

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

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

IEEE Std C57.131, TM2012 *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.

3.1.2

mechanically rotary

de-energized tap-changer, where the stationary contacts are arranged along a circumference surrounding a central axis and the moving contacts operate in a rotational manner around that same central axis

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.

3.1.3

fritting

electrically intimate metal-to-metal contact created by the dielectric breakdown of a very thin film of oil, oxides, sulfites, etc.

3.1.4

continuous consecutive operation

uninterrupted operation with the driving mechanism operating at its normal speed

3.2 Abbreviations

ARS	Advance retard switch
DETC	De-energized tap-changer
DGA	Dissolved and free gases analysis
EAF	Electrical arc furnace
GIC	Geomagnetic induced current
HV	High-voltage
HVDC	High-voltage direct current
IGBT	Insulated-gate bipolar transistor
LCSET	Lowest cold start energizing temperature (see IEC 60296)
LV	Low-voltage
OLTC	On-load tap-changer
PD	Partial discharge
PST	Phase-shifting transformer
VI	Vacuum interrupter
VSR	Variable shunt reactor

4 Use of normative references

This document can be used with either IEC or IEEE normative references but the references shall not be mixed. The purchaser shall include in the enquiry and order which normative references are to be used. If the choice of normative references is not specified, then IEC standards shall be used except for tap-changers intended for installation in North America where IEEE standards shall be used.

If only one alternative is given in a certain part of the document, i.e. only IEC reference(s) or only IEEE reference(s), then that/these reference(s) is/are valid independently of the choice of normative references.

5 Application of tap-changers for transformers and reactors

5.1 General

Tap-changers are devices that vary the active turns in a winding of a transformer or reactor. Tap-changers can perform this operation either on-load or with the transformer de-energized. Therefore, they can broadly be divided into two fundamental types as follows:

- on-load tap-changers;
- de-energized tap-changers.

When the operation of the tap-changer changes the excitation level of the device to which it is applied, then the volts per turn of all windings wound on the same core will change.

Tap-changers are used with all types of distribution and power transformers as well as with reactors. Also transformers for special applications (e.g. HVDC-transformers, phase-shifting transformers (PSTs), transformers for electrical arc furnace (EAF) applications) are equipped with tap-changers.

5.2 Typical circuits for regulation

[Figure 1](#) shows a common winding arrangement for a typical star-connected winding with the regulating winding located at the neutral point. In those applications a compact three-phase tap-changer without a full insulation between phases can be used, when applicable.

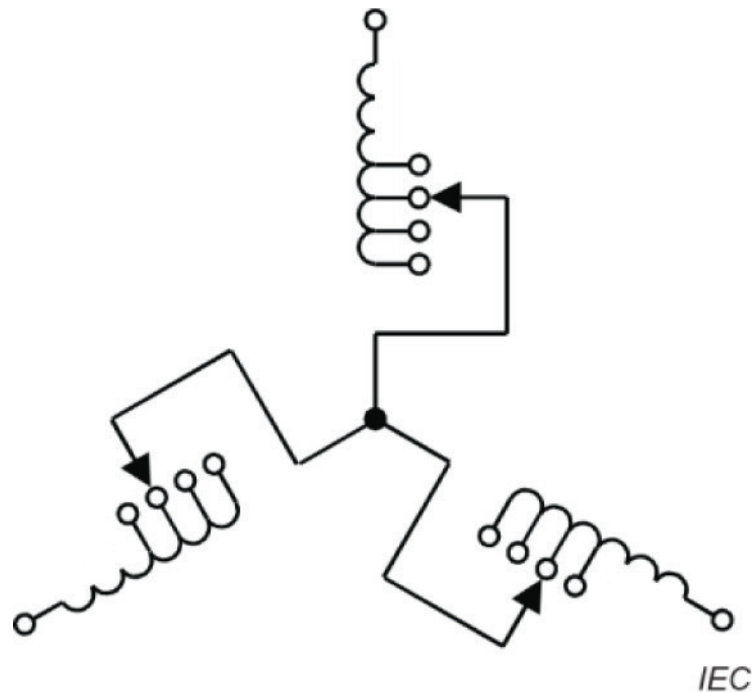


Figure 1 — Tap-changers in a star-connected winding

Series transformers ([Figure 2](#)) when applied to tap-changers are completely separate transformers or autotransformers used to trade off high current for increased voltage or high voltage for increased current. These devices, when applied, are supplied by and added to a larger main transformer where voltage regulation via an OLTC is needed. They are called series transformers because their output voltage is connected in series with the windings of the main transformer.

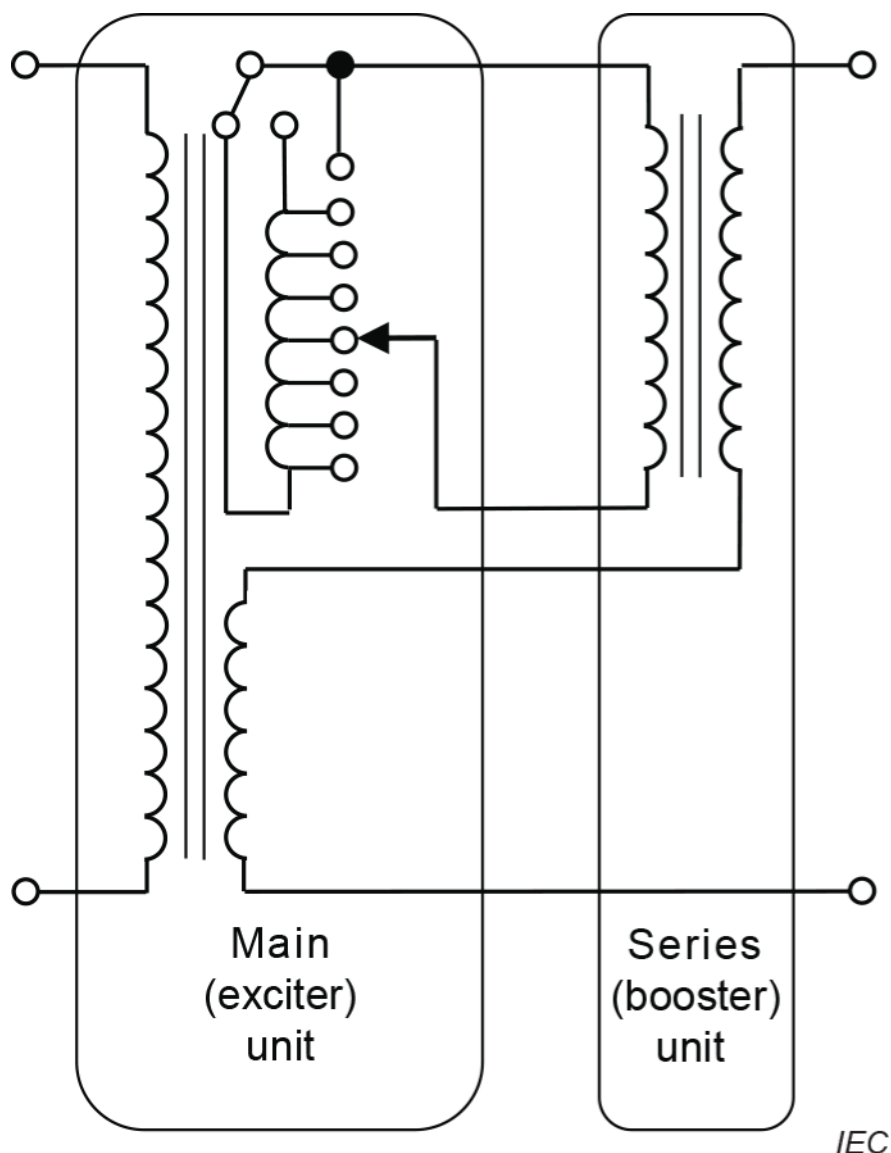
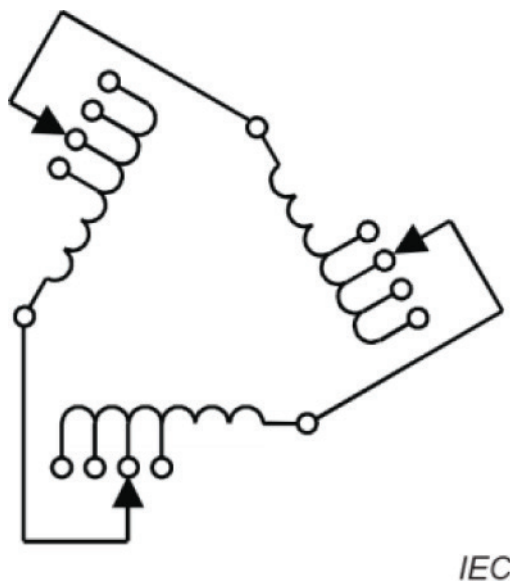
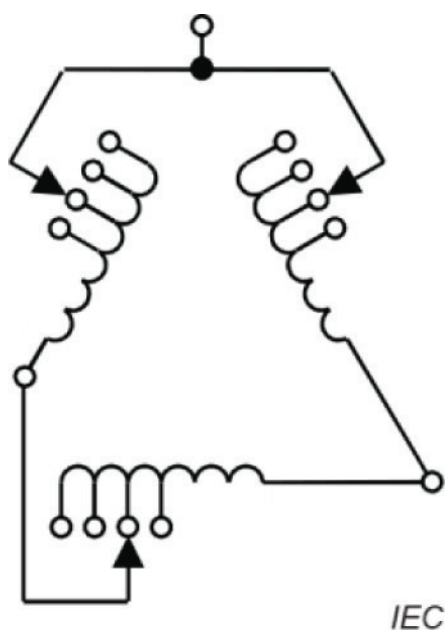


Figure 2 — Tap-changers in series transformers

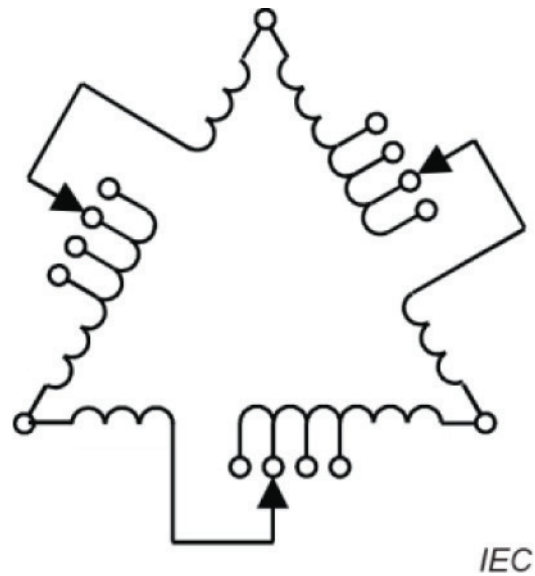
[Figure 3 a\)](#) to [Figure 3 c\)](#) show the regulation in delta-connected windings. [Figure 3 a\)](#) shows a winding arrangement where a three-phase tap-changer is needed with full insulation between phases dictated by the highest voltage for equipment U_m . The winding arrangement shown in [Figure 3 c\)](#) allows the use of a tap-changer with reduced phase-to-phase insulation (around half of U_m). However, the insulation distance-to-ground shall be dimensioned for U_m because of the applied voltage test (AV) of the transformer (see IEC 60076-3:2013, Clause 10). If three-phase tap-changers of the required insulation level are not available, both above-mentioned arrangements can be used, of course, with three single-phase line-end tap-changers. When using a winding arrangement as shown in [Figure 3 b\)](#), the number of tap-changer units can be reduced to two, a two-phase and a single-phase unit.



a) Line-end arrangement



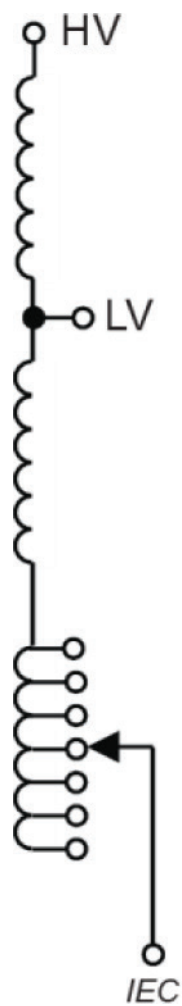
b) Line-end arrangement with two units



c) Mid-winding arrangement

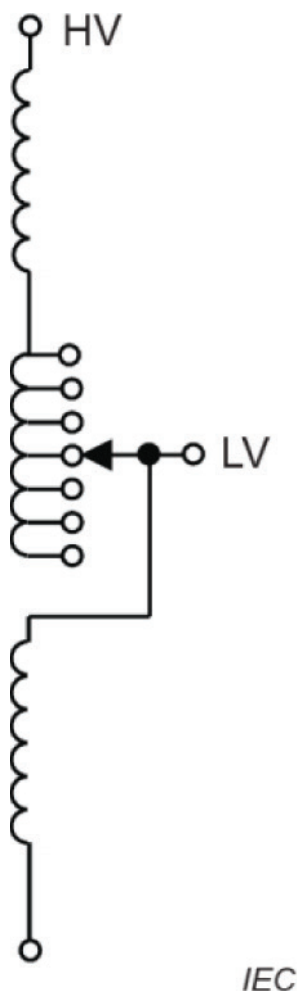
Figure 3 — Tap-changers in delta-connected windings

[Figure 4](#) shows winding arrangements for regulated autotransformers. The most appropriate arrangement is chosen depending on the regulating range, system conditions and/or weight and transportation restrictions.



a) Neutral end arrangement





c) Series winding (HV) arrangement

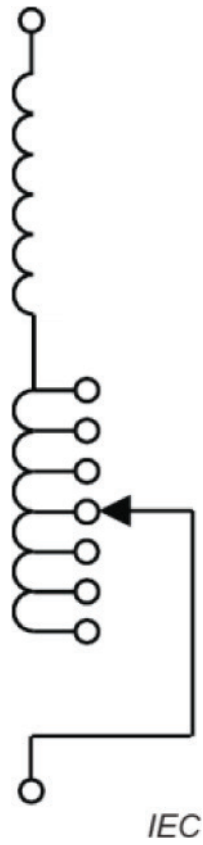
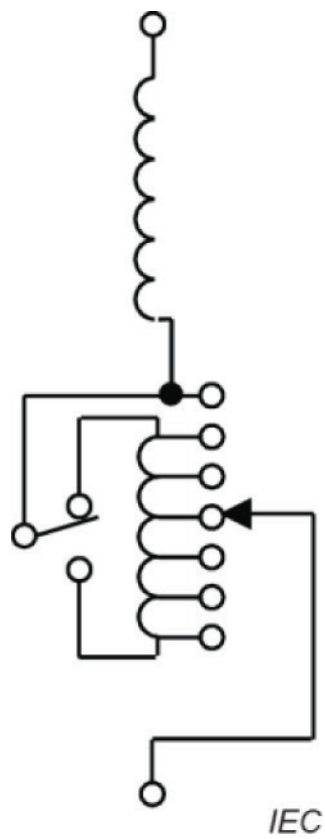
Figure 4 — Tap-changers in autotransformers

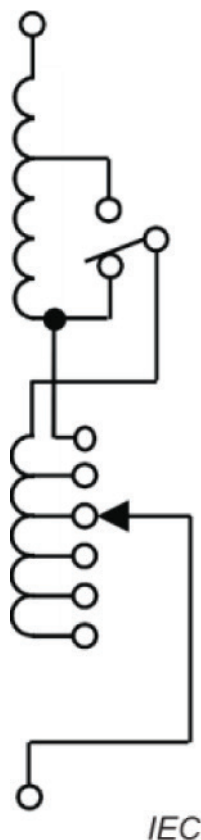
The arrangement in [Figure 4 a\)](#) shows the tap-changer at the neutral end, which allows, with respect to its insulation, the use of a compact design with a three-phase neutral end tap-changer. Such an autotransformer is used to compensate voltage fluctuations either on the HV or on the LV; however, this arrangement always has variable flux taps.

[Figure 4 b\)](#) shows an arrangement mainly to vary the LV of the transformer. Using this arrangement to compensate for voltage fluctuations on the LV leads to constant flux taps. The compensation of voltage fluctuations on the HV leads to variable flux taps. The situation changes when using an arrangement according to [Figure 4 c\)](#). In this case, the constant flux taps exist with the compensation of HV and the variable flux taps of LV voltage fluctuations. Single-column, three-phase tap-changers with full insulation between phases according to the U_m of the LV or three single-column line-end tap-changers have to be used in applications shown in [Figure 4 b\)](#) and [Figure 4 c\)](#).

5.3 Basic arrangements of tapped windings with on-load tap-changers

Each of the [Figures 1](#) to [4](#) only shows one exemplary arrangement (linear regulation) of the tapped windings. For all these examples, one of the following three basic arrangements of the regulating winding ([Figure 5](#)) can be used. Depending on the system and design parameters of the transformer application, any of these arrangements can be used.

**a) Linear****b) Reversing**



c) Coarse/fine

Figure 5 — Basic arrangements of the regulating winding

On power transformers, the linear connecting scheme ([Figure 5 a\)](#)) is generally applied for a moderate regulating range up to typically 20 %. Industrial process transformers often work with a variable flux density and this scheme allows a variable number of turns between taps for optimum process control.

The regulating range can be approximately doubled by using a tap winding in conjunction with a change-over selector. A reversing change-over selector ([Figure 5 b\)](#)) allows the tap winding to be connected in vectorial addition (boost) or subtraction (buck) to the main winding. [Figure 5 c\)](#) shows a scheme with coarse and fine tap winding arrangements. The electrical length of the coarse winding is approximately the same as the fine tap winding. From the dielectric point of view this arrangement, however, requires a more sophisticated winding layout.

In the extreme "boost" position both regulating schemes with change-over selector show all windings in the circuit. In the extreme "buck" position, the reversing arrangement utilizes the main winding and the entire tap winding in the circuit, whereas the coarse/fine arrangement only utilizes the main winding, which furthermore has fewer turns. This leads to additional load losses with the reversing scheme when in buck tap-change position.

5.4 Basic arrangements of tapped windings with step-voltage regulator on-load tap-changers

See the latest edition of IEC 60076-21 or IEEE Std C57.15 for the different step-voltage regulator constructions such as:

- Type A,
- Type B,

- series transformer,
- equalizer winding.

5.5 Basic arrangements of tapped windings with de-energized tap-changers

5.5.1 Bridging contact scheme for DETC

The arrangement of the interaction of stationary and moving contacts on a DETC is such that the moving contact connects two of the stationary contacts per phase on the DETC (see [Figure 6 a\)](#)). Multiple connections can be made providing a wide variety of connection options (see [Figure 6 b\)](#)).

5.5.2 Linear contact scheme for DETC

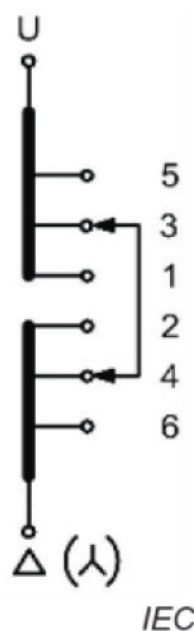
The arrangement of the interaction of stationary and moving contacts on a DETC is such that the moving contact connects a desired stationary contact to an output terminal (see [Figure 6 c\)](#) and [Figure 6 d\)](#)).

5.5.3 WYE (star) contact scheme for DETC

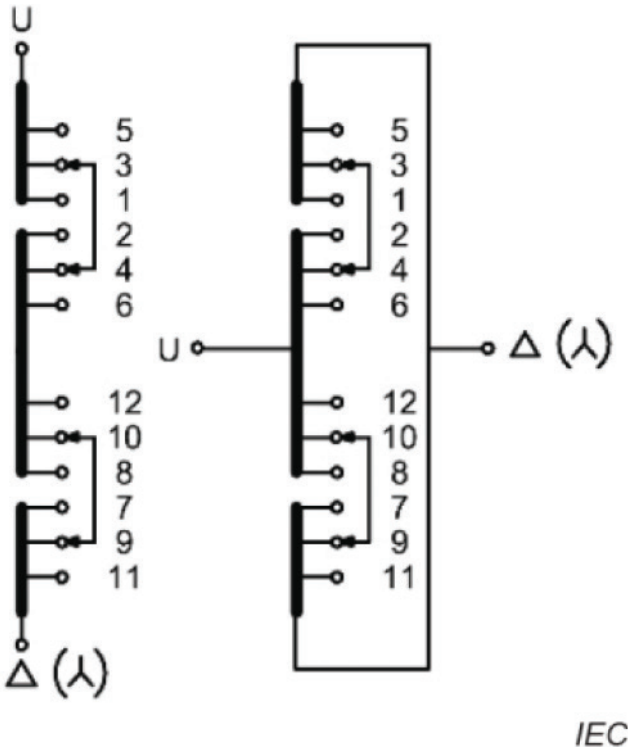
The arrangement of the interaction of stationary and moving contacts on a DETC is such that the three simultaneously operated moving contacts (one for each phase) connect three desired stationary contacts (one for each phase) to the star point, with or without a common neutral output (see [Figure 6 e\)](#)).

5.5.4 Most common basic arrangements for different combinations

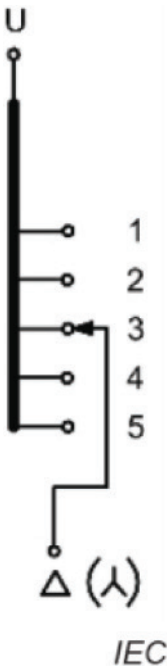
The choice of an electrically bridging contact scheme, electrically linear contact scheme, or combinations of the schemes is defined by the specific winding connections required. Various mechanical arrangements of the DETC are available. The tap-changer manufacturers should be consulted for specific options.



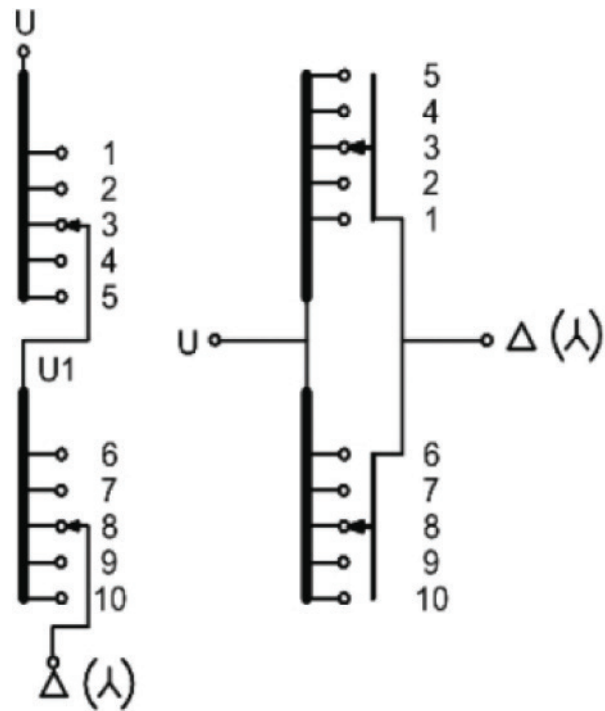
a) Bridging contact scheme (1-Ph)



b) Double bridging contact scheme (1-Ph)

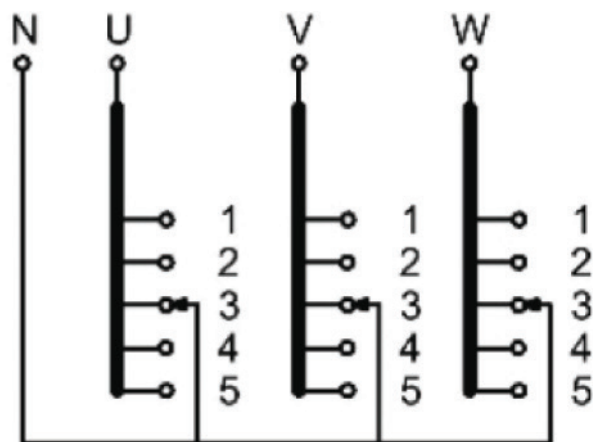


c) Linear contact scheme (1-Ph)



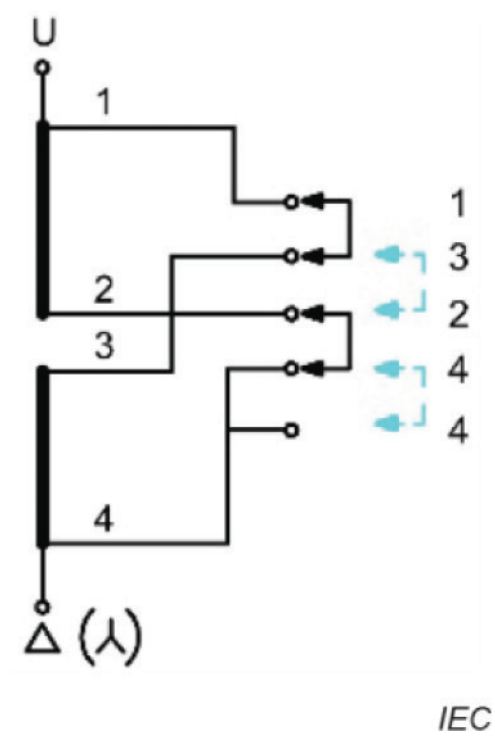
IEC

d) Double linear contact schemes (1-Ph)

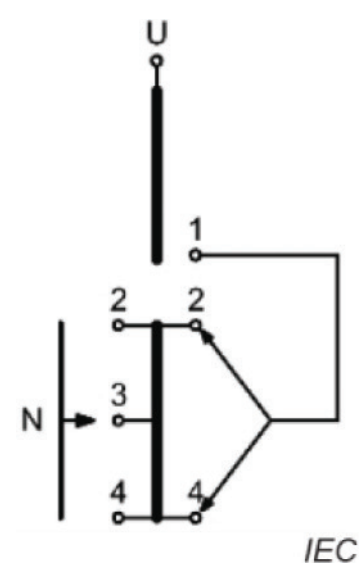


IEC

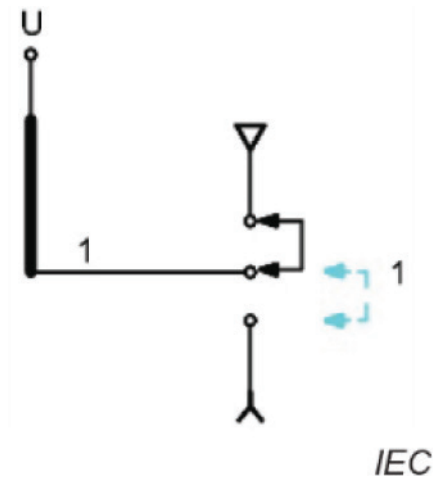
e) WYE (Star) contact scheme (3-Ph)



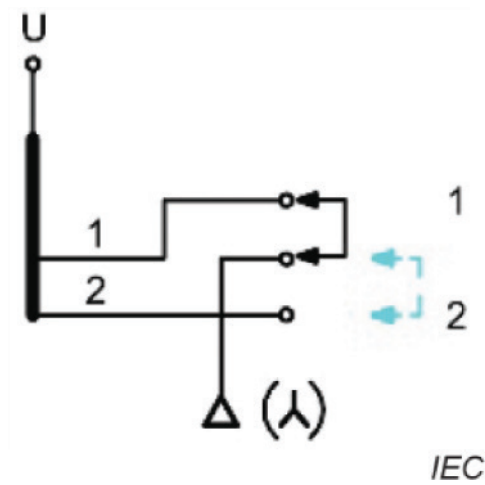
f) Series/parallel contact scheme (1-Ph)



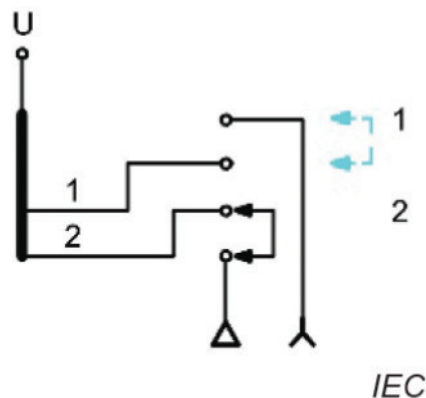
g) Linear contact scheme with polarity inversion (1-Ph)



h) Delta/star contact scheme (1-Ph)



i) Exclusion of turns contact scheme (1-Ph)



k) Delta/star contact scheme with exclusion of turns (1-Ph)

Figure 6 — Common connection arrangements

6 Types of tap-changers

6.1 On-load tap-changers (OLTCs)

6.1.1 General

The on-load tap-changer is designed to change tap connections while the transformer/reactor is both energized and on load. It performs this function without any interruption of the load. This is achieved with the mechanically operated components of the OLTC.

On-load tap-changing can be employed by using various switching principles.

The two most common switching principles can be distinguished by means of the transition impedance:

- resistor type switching, using a resistor as transition impedance (see [6.1.2.1](#));
- reactor type switching, using a reactor (preventive autotransformer) as transition impedance (see [6.1.2.2](#)).

Furthermore, in reactor type tap-changers, both tap selector arms and both sides of the diverter switch are carrying the through-current in parallel in the service positions, whereas in resistor type tap-changers only one tap selector arm and one side of the diverter switch carries the through-current. This allows for reactor type tap-changers to use the position with the two tap selector arms connected to two adjacent taps (bridging position, IEC 60214-1:2014, 3.21) as well as the position with the tap selector arms connected to the same tap (non-bridging position, IEC 60214-1:2014, 3.22) as a service position. In resistor type tap-changers, the position between two taps is only a passage position. Therefore, the regulating winding for reactor type tap-changers needs only half as many taps to gain the same number of positions.

Traditionally, in the USA where tap-changers have been applied at the neutral end of the low-voltage windings, reactor tap-changers have been dominant. Conversely, elsewhere where tap-changers have frequently been applied to the high-voltage windings, resistance tap-changers have been dominant.

Both on-load tap-changer switching principles are available as non-vacuum type and vacuum type tap-changers.

Non-vacuum type tap-changers are equipped with contacts which break and make the load and circulating currents in liquid or gas. The arcing takes place within the same medium which is used as

the insulation medium (and in case of liquids also as the lubrication medium) and causes a degradation of the medium.

Vacuum type tap-changers are not completely under vacuum, but they are equipped with vacuum interrupters (VIs) which break and make the load and circulating currents. However, the VI housing is sealed and therefore the degradation of the surrounding medium is minimized.

6.1.2 Principles of operation

6.1.2.1 Resistor types

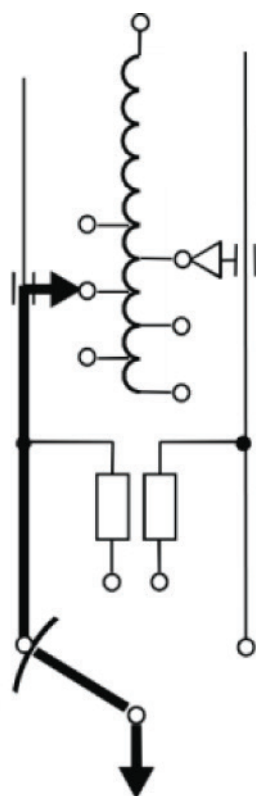
6.1.2.1.1 General

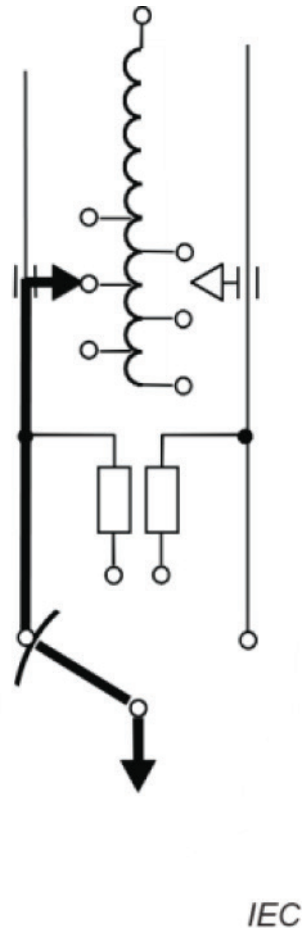
Resistor type OLTCs are realized either as devices with a diverter switch (see IEC 60214-1:2014, 3.5, or IEEE Std C57.131-2012, [Clause 3](#)) and tap selector (see IEC 60214-1:2014, 3.4, or IEEE Std C57.131) or as selector switches (IEC 60214-1:2014, 3.6, or IEEE Std C57.131-2012, [Clause 3](#)). Such devices can be designed as:

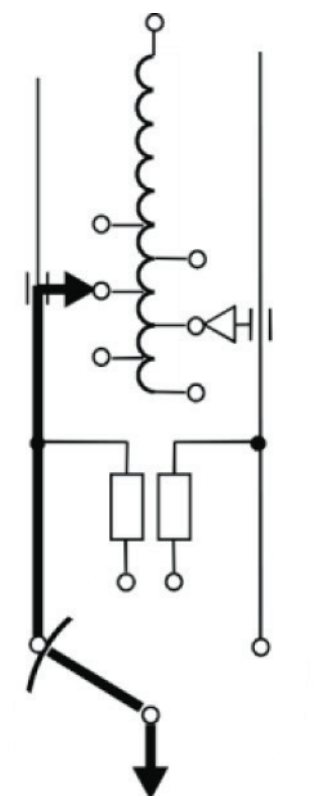
- non-vacuum type on-load tap-changer (see [6.1.2.1.2](#));
- vacuum type on-load tap-changer (see [6.1.2.1.3](#)).

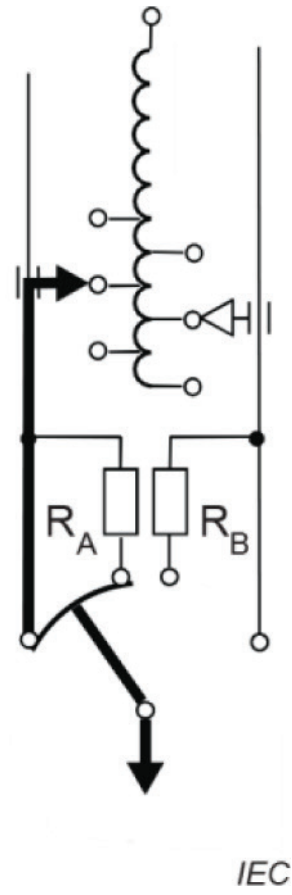
In the diverter switch and tap selector concept, the switching operation is carried out by the positioning of the tap selector followed by the movement of the diverter switch. The basic mode of operation is exemplified in [Figure 7](#) for a non-vacuum type diverter switch and tap selector utilizing operating cycle number 1 (according to IEC 60214-1). The tap selector is equipped with two independently movable contact decks. At first, that contact deck, which is not carrying the through-current, is actuated directly by the motor-drive mechanism. The tap adjacent to the tap in service will be pre-selected without any breaking or making of current (see [Figures 7 a\) to c\)](#) in a time span of some seconds. Then, the diverter switch transfers the load current from the tap in service to the pre-selected one in a time span of around 50 ms to 150 ms (see [Figure 7 d\)](#) to [Figure 7 i\)](#)). This action is actuated in most designs by a spring-loaded energy accumulator, which will be wound up during the tap selector operation and will be mechanically released when the tap selector operation is finished. For this load transfer, the diverter switch of a non-vacuum type is equipped with main switching and transition contacts made from copper or copper-tungsten alloys.

This concept of two consecutive steps of the tap selector and the diverter switch is used for non-vacuum as well as for vacuum type diverter switch and tap selector designs. In vacuum type tap-changers the main switching and transition contacts are replaced by vacuum interrupters.

*IEC***a**

**b**

*IEC***c**



d

