

Tap-changers —

Part 1: Performance requirements and test methods

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National foreword

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Foreword

The text of document 14/457/FDIS, future edition 1 of IEC 60214-1, prepared by IEC TC 14, Power transformers, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60214-1 on 2003-03-01.

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Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annexes A, B, C and ZA are normative and annex D is informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60214-1:2003 was approved by CENELEC as a European Standard without any modification.

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TAP-CHANGERS –

Part 1: Performance requirements and test methods

1 Scope

This part of IEC 60214 applies to on-load tap-changers of both resistor and reactor types, off-circuit tap-changers, and their motor drive mechanisms. It applies mainly to tap-changers immersed in transformer oil according to IEC 60296 but may also be used for tap-changers with gas insulation or immersed in other insulating liquids insofar as conditions are applicable.

It applies to power and distribution transformers of all types and also to reactors.

It does not apply to transformers and reactors mounted on railway rolling stock.

2 Normative references

The following referenced documents are indispensable for the application 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 60060, *High voltage test techniques*

IEC 60076-1:2000, *Power transformers – Part 1: General*

IEC 60076-3:2000, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60137, *Insulated Bushings for alternating voltages above 1 000 volts*¹

IEC 60214-2, *Tap-changers – Part 2: Application guide*²

IEC 60270, *High voltage test techniques – Partial discharge measurements*

IEC 60296, *Specification for unused mineral insulating oils for transformers and switchgear*

IEC 60354, *Loading guide for oil-immersed transformers*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

¹ To be published.

² At present under revision, document currently IEC 60542.

3 Terms and definitions

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

3.1

on-load tap-changer

device for changing the tap of a winding, suitable for operation whilst the transformer is energized or on load

3.2

tap selector

device designed to carry, but not to make or break, current, used in conjunction with a diverter switch to select tap connections

3.3

diverter switch

switching device used in conjunction with a tap selector to carry, make or break currents in circuits which have already been selected

NOTE Diverter switches are sometimes called arcing switches.

3.4

selector switch

switching device capable of making, carrying and breaking current, combining the duties of a tap selector and a diverter switch

NOTE Selector switches are sometimes called arcing tap switches.

3.5

off-circuit tap-changer

device for changing the tap of a winding, suitable for operation only when the transformer is de-energized

3.6

change-over selector

device designed to carry, but not to make or break, current, used in conjunction with the tap selector or selector switch to enable its contacts and the connection taps to be used more than once when moving from one extreme position to the other

3.7

coarse change-over selector

change-over selector connecting the tapped winding to either the coarse winding or the main winding or parts thereof

3.8

reversing change-over selector

change-over selector connecting either end of the tapped winding to the main winding

3.9

transition impedance

resistor or reactor consisting of one or more units bridging the tap in use and the tap next to be used, for the purpose of transferring load from one tap to the other without interruption or appreciable change in the load current, at the same time limiting the circulating current for the period that both taps are used

NOTE For reactor type tap-changers, the transition impedance (reactor) is commonly called a preventive auto transformer. Reactor type tap-changers normally use the bridging position as a service position (mid-point or centre tapped reactor tap-changers) and, therefore the reactor is designed for continuous operation.

3.10

preventive auto transformer

auto transformer (or centre tapped reactor) used in on-load tap-changing and regulating transformers, or step voltage regulators to limit the circulating current when operating on a position in which two adjacent taps are bridged, or during the change of tap between adjacent positions

3.11

equalizer winding

winding on the same magnetic circuit (core) as the excitation and tapped winding of a reactor type regulating transformer with approximately half the number of turns of each tap section

3.12

drive mechanism

means by which the drive to the tap-changer is actuated

NOTE The mechanism may include an independent means of storing energy to control the operation.

3.13

set of contacts

pair of individual fixed and moving contacts or a combination of such pairs operating substantially simultaneously

3.14

diverter switch and selector switch main contacts (resistor type tap-changer)

set of through-current-carrying contacts which has no transition impedance between the transformer winding and the contacts and does not switch any current

3.15

diverter switch and selector switch main switching contacts (resistor type tap-changer)

set of contacts which has no transition impedance between the transformer winding and the contacts and makes and breaks current

3.16

diverter switch and selector switch transition contacts (resistor type tap-changer)

set of contacts which is connected in series with a transition impedance and makes or breaks current

3.17

transfer contacts (reactor type tap-changer)

set of contacts that makes or breaks current

NOTE Where by-pass contacts are not provided, the transfer contact is a continuous current-carrying contact.

3.18

by-pass contacts (reactor type tap-changer)

set of through-current-carrying contacts that commutates the current to the transfer contacts without any arc

3.19

bridging contacts

moveable current-carrying contacts that bridge between two fixed contacts when on-position

3.20**circulating current**

that part of the current that flows through the transition impedance at the time when two taps are momentarily bridged during a tap-change operation for a resistor type tap-changer or when bridged in an operating position for a reactor type tap-changer. The circulating current is due to the voltage difference between the taps.

3.21**switched current**

prospective current to be broken during switching operation by each set of main switching or transition contacts (resistor type tap-changer) or transfer contacts (reactor type tap-changer) incorporated in the diverter switch or the selector switch

3.22**recovery voltage**

power-frequency voltage which appears across each set of main switching or transition contacts (resistor type tap-changer) or transfer contacts (reactor type tap-changer) of the diverter switch or selector switch after these contacts have broken the switched current

3.23**tap-change operation**

complete sequence of events from the initiation to the completion of a tap change from one service tap position to an adjacent position

3.24**cycle of operation**

movement of the tap-changer from one end of its range to the other end and the return to its original position

3.25**rated insulation level**

withstand values of the impulse and separate source AC withstand voltages to earth, and where appropriate between phases, and between those parts where insulation is required

3.26**rated through-current (I_u)**

current flowing through an on-load tap-changer towards the external circuit, which the apparatus is capable of transferring from one tap to the other at the relevant rated step voltage and which can be carried continuously while meeting the requirements of this standard

3.27**maximum rated through-current (I_{um})**

highest rated through-current for which the tap-changer is designed for and which forms the basis for all current related tests

3.28**rated step voltage (U_i)**

for each value of rated through-current, highest permissible voltage between terminals which are intended to be connected to successive taps of the transformer

3.29**relevant rated step voltage**

highest step voltage allowable in connection with a given rated through-current

3.30

maximum rated step voltage (U_{im})

highest value of the rated step voltage for which the tap-changer is designed

3.31

rated frequency

frequency of the alternating current for which the tap-changer is designed

3.32

number of inherent tap positions

highest number of tap positions for half a cycle of operation for which a tap-changer can be used according to its design

NOTE The term "tap positions" is generally given as the $\pm$ value of the relevant number, for example, ± 11 positions. They are in principle also valid for the motor-driven mechanism. When using a "number of tap positions" in connection with a transformer, this always refers to the number of service tap positions of the transformer.

3.33

number of service tap positions

number of tap positions for half a cycle of operation for which a tap-changer is used in the transformer

NOTE The term "tap position" is generally given as the $\pm$ values of the relevant number, for example, ± 11 positions. They are in principle also valid for the motor-driven mechanism. When using the term 'number of tap positions' in connection with a transformer, this always refers to the number of service tap positions of the transformer.

3.34

type test

test made on a tap-changer or the components of a tap-changer or a range of tap-changers or components all based on the same design, to prove compliance with this standard

NOTE A range of tap-changers is a number of tap-changers based on the same design and having the same characteristics, with the exception of the insulation levels to earth and possibly between phases, the number of steps and the value of the transition impedance.

3.35

routine test

test made on each completed tap-changer, the design of which has been verified by type test, to establish that the tap-changer is without manufacturing defects

3.36

motor drive mechanism

driving mechanism which incorporates an electric motor and a control circuit

3.37

step-by-step control of a motor-drive mechanism

device for stopping the motor-drive mechanism after completion of a tap-change, independently of the operating sequence of the control switch

3.38

tap position indicator

device for indicating the tap position of the tap-changer

3.39

tap-change in progress indicator

device for indicating that the motor-drive mechanism is running

3.40

limit switches

devices for preventing operation of the tap-changer beyond either end position, but allowing operation in the opposite direction

3.41

mechanical end stop

device which physically prevents operation of the tap-changer beyond either end position, but allows operation in the opposite direction

3.42

parallel control devices

control devices to move, in the case of parallel operation of several transformers with taps, all tap-changers to the required position and to avoid divergence of the respective motor-drive mechanisms

NOTE Such devices would be necessary also in the case of single-phase transformers forming a three-phase bank when each single-phase tap-changer is fitted with its own motor-drive mechanisms.

3.43

emergency tripping device

device for stopping the motor-drive mechanism at any time in such a way that a special action has to be performed before the next tap-change operation can be started

3.44

overcurrent blocking device

device for preventing or interrupting operation of the motor-drive mechanism for the period in which an overcurrent exceeding a pre-set value is flowing in the transformer winding

NOTE Where diverter switches are actuated by spring energy systems, interruption of the operation of the motor-drive mechanism will not prevent operation of the diverter switch if the spring release has been actuated.

3.45

restarting device

device designed to restart the motor-drive mechanism after an interruption of the supply voltage to complete a tap-change operation already initiated

3.46

operation counter

device for indicating the number of tap-changes accomplished

3.47

manual operation of a motor-drive mechanism

operation of the tap-changer manually by a mechanical device, blocking at the same time operation by the electric motor

3.48

motor-drive cubicle

cubicle that houses the motor-drive mechanism

3.49

protective device against running-through

device that stops the motor-drive mechanism in case of a failure of the step-by-step control circuit which would cause the motor drive mechanism to run through several tap positions

3.50

flag cycle³

method of performing a tap-change operation in which the through-current is diverted from the main switching contacts before the circulating current starts to flow

NOTE This cycle requires that the through-current connection is at the midpoint of the transition impedance when this is carrying the circulating current.

3.51

symmetrical pennant cycle³

method of performing a tap-change operation in which the circulating current starts to flow before the through-current is diverted from the main switching contacts

NOTE This cycle requires that the through-current connection is at the midpoint of the transition impedance when this is carrying the circulating current.

3.52

asymmetrical pennant cycle³

method of performing a tap-change operation in which, in one direction of movement of the switch, the circulating current starts to flow before the through-current is diverted from the main switching contacts, while in the other direction of movement the through-current is diverted before the circulating current starts to flow

NOTE 1 This cycle requires that the through-current connection is at one end of the transition impedance when this is carrying circulating current.

NOTE 2 Tap-changers employing the asymmetrical pennant cycle are normally used with load flow in one direction only.

3.53

class I tap-changer

tap-changer only suitable for use at the neutral point of windings

3.54

class II tap-changer

a tap-changer suitable for use at a position other than the neutral point of windings

NOTE Classes I and II tap-changers have no relation with classes I and II transformers described in IEC 60076-3.

3.55

liquid environment tap-changer

tap-changer mounted inside the main transformer tank and immersed in the insulating liquid of the transformer

3.56

air environment tap-changer

tap-changer mounted in a container outside the main transformer tank and immersed in its own insulating liquid

3.57

highest voltage for equipment, U_m

highest r.m.s. phase-to-phase voltage in a three-phase system for which a tap-changer is designed with respect to its insulation

³ The derivation of the designations 'flag cycle' and 'pennant cycle' arises from the appearance of the vector diagrams showing the change in output voltage of the transformer in moving from one tapping to the adjacent one. In the 'flag cycle' the change of voltage comprises four steps, while in the 'pennant cycle' only two steps occur, see Figure A.1.

4 Service conditions

4.1 Temperature of tap-changer environment

Unless more onerous conditions are specified by the purchaser, tap-changers shall be regarded as suitable for operation over the ranges of temperature given in Table 1.

Table 1 – Temperature of tap-changer environment

Tap-changer environment	Temperature	
	Minimum	Maximum
Air	–25 °C	40 °C
Liquid	–25 °C	100 °C
NOTE 1 For the definitions of the tap-changer environments, see 3.55 and 3.56. NOTE 2 The value of 100 °C quoted above is based on normal rated load and a maximum ambient temperature of 40 °C as specified in IEC 60076-1.		

4.2 Temperature of motor-drive mechanism environment

Unless more onerous conditions are specified by the purchaser, motor drive mechanisms shall be regarded as suitable for operation in any ambient temperature between –25 °C and 40 °C.

NOTE For more onerous conditions for tap-changer or motor-drive mechanism environments, reference should be made to IEC 60214-2.

4.3 Overload conditions

Tap-changers which comply with this standard and are selected and installed in accordance with IEC 60214-2 shall not restrict emergency loading of the transformer according to IEC 60354, which could result in top oil temperatures as high as 115 °C.

5 Requirements for on-load tap-changers

5.1 General requirements

5.1.1 Rating

5.1.1.1 Rated characteristics

The rated characteristics of an on-load tap-changer are:

- rated through-current;
- maximum rated through current;
- rated step voltage;
- maximum rated step voltage;
- rated frequency;
- rated insulation level.

5.1.1.2 Interrelation between rated through-current and rated step voltage

Up to the maximum rated through-current of the on-load tap-changer there may be different assigned combinations of values of rated through-current and corresponding rated step voltage. When a value of rated step voltage is referred to a specific value of rated through-current it is called the 'relevant rated step voltage'.

5.1.2 Liquid filled compartments for diverter and selector switches

The liquid filled compartments for diverter and selector switches shall be liquid-tight. Where appropriate, pressure and vacuum withstand values shall be declared by the manufacturer.

NOTE If the transformer oil is to be supervised by gas-in-oil analysis, the liquid filled compartment of the diverter or selector switch should be provided with a liquid conservator which has no connection to the conservator of the transformer.

5.1.3 Liquid-level gauges

Liquid compartments for diverter or selector switches with integral expansion volume or separate conservators for these compartments, when fitted, shall be provided with liquid-level gauges.

5.1.4 Safety requirements for protection against increase in pressure

In order to minimize the risk of fire or explosion resulting from an internal failure within the diverter or selector switch compartment, one or more of the following protective devices shall be fitted.

NOTE 1 The tap selector compartments of air environment on-load tap-changers are usually piped to the main transformer buchholz relay. Consideration should also be given to fitting a separate buchholz relay between the tap-selector compartment and the conservator.

NOTE 2 For those types of on-load tap-changers that do not create an arc and are installed in sealed compartments, other protective devices may be used.

5.1.4.1 Liquid-flow controlled relay

The liquid-flow controlled relay, installed in the pipe between the top of the diverter or selector switch and the liquid conservator, shall respond at a predetermined liquid flow and enable the transformer to be tripped.

5.1.4.2 Overpressure relay

The overpressure relay shall respond in the event of the pressure in the diverter or selector switch liquid compartment exceeding a predetermined value, and enable the transformer to be tripped.

5.1.4.3 Pressure relief device

The pressure relief device shall open when a predetermined pressure is exceeded and its opening shall protect the diverter or selector switch liquid compartment.

Where a pressure relief device is the sole protection, it shall also be arranged with contacts to enable the transformer to be tripped.

NOTE If a pressure relief device is fitted, the use of a self-sealing diaphragm type is possible. Consideration should also be given to fitting an outlet such as ducting or trunking from the pressure relief device to protect personnel from the displaced liquid. The use of such devices should be subject to agreement between the manufacturer and the purchaser.

5.1.5 Limiting devices for the protection against transient overvoltages

For on-load tap-changers which incorporate limiting devices for transient overvoltages, the manufacturer of the on-load tap-changer shall give full details of the protective characteristics, together with any limitations which might be imposed during tests on the completed transformer.

When spark gaps are used, care shall be taken to ensure that, after spark-over, the discharge is quenched automatically.

5.1.6 Change-over selector recovery voltages

When coarse or reversing change-over selectors operate they momentarily disconnect the tap winding. This can cause high recovery voltages across the change-over selector contacts during contact separation due to capacitive coupling between the tap winding and adjacent winding(s). The on-load tap-changer manufacturer shall declare any limiting switching parameters for change-over selectors incorporated in an on-load tap-changer.

NOTE See IEC 60214-2 for further details of selection, control circuits and devices and transformer testing recommendations.

5.1.7 Coarse fine regulation leakage inductance switching

When changing from the end of the fine winding to the end of the coarse winding with resistor type tap-changers, a high leakage inductance can be set up with the two windings in series opposition. This can cause a phase shift between the switched current and recovery voltage of the diverter or selector switch. This may result in extended arcing of the switch.

The on-load tap-changer manufacturer shall declare any switching limitations.

NOTE See IEC 60214-2 for further details of selection and winding configurations regarding leakage inductance.

5.2 Type tests

The following type tests shall be performed on samples of the relevant on-load tap-changers after their final development or on equivalent components provided that the manufacturer can demonstrate that the relevant test conditions and results are not influenced by testing only components instead of the complete tap-changer.

- Temperature rise of contacts (5.2.1);
- Switching tests (5.2.2);
- Short-circuit current test (5.2.3);
- Transition impedance test (5.2.4);
- Mechanical tests (5.2.5);
- Dielectric tests (5.2.6).

5.2.1 Temperature rise of contacts

Tests shall be performed to verify that the temperature rise above the medium surrounding each type of contact which carries current continuously in service does not exceed the values given in Table 2 when the contacts have reached a steady temperature when carrying 1,2 times the maximum rated through-current.

For reactor type tap-changers, the highest temperature rises will be experienced in the bridging position. The current in the bridging position is determined by the through-current, as well as by the circulating current and the power factor of the through current. The type test shall be performed in the bridging position and with currents calculated on the following basis:

- a) through-current equal to 1,2 times the maximum rated through-current;
- b) circulating current equal to 50 % of the maximum rated through-current (or otherwise specified by the manufacturer and stated in the type test report);
- c) power factor equal to 80 %.

Meeting these conditions proves the overload capacity as referred to in 4.3.

Table 2 – Contact temperature-rise limits

Contact material	In air K	In liquid K
Plain copper	35	20
Silver-faced copper/alloys	65	20
Other materials	By agreement	20

NOTE Where contacts remain in one position for long periods of time, pyrolytic carbon formation may occur.

When the surrounding medium is liquid, the test shall be performed at ambient temperature.

The temperature of the surrounding medium shall be measured at not less than 25 mm below the contacts.

The temperature shall be measured by thermocouples or other suitable means positioned on the surface of the contacts as near the point of contact as is practicable.

The temperature is considered to be steady when the difference of the temperature between the contact and the surrounding medium does not change more than 1 K over an hour.

NOTE The cross-section and insulation of the conductor carrying the current into the on-load tap-changer or components under test should be stated.

5.2.2 Switching tests

Switching tests which include service duty tests and breaking capacity tests, shall simulate the most onerous conditions for which the on-load tap-changer is rated. Refer to Annexes A and B for the most onerous conditions for resistor and reactor type tap-changers, respectively, for the majority of contact arrangements.

NOTE Where reactor transition switching is concerned, the most onerous conditions should be subject to agreement between the manufacturer and the purchaser.

In the case of an asymmetrical pennant cycle, see Table A.1, it is assumed that no reversal of power-flow occurs in service.

The switching tests may be limited to the diverter or selector switch after proving that the contact operating conditions are not affected by such limitations.

If the diverter or selector switch has several sets of contacts which operate in a definite sequence, it is not permitted to test each set of contacts separately from the others unless it can be proved that the operating conditions of any one set of contacts are not affected by the operation of the other sets of contacts.

Where resistors are used as transition impedances, these may be placed outside the apparatus if necessitated by the construction of the on-load tap-changer or the test circuit, and they may have a higher thermal capacity than those which are employed in service, unless otherwise specified.

The value and type of transition impedance shall be stated.

Contacts and transformer liquid in the case of liquid-immersed tap-changers, shall not be renewed during the tests.

In the case of three-phase switches, it is normally sufficient to test the contacts of one phase.

If a particular on-load tap-changer has more than one combination of rated through-current and rated step voltage, at least two breaking capacity tests shall be performed, one at maximum rated through-current I_{um} and its relevant step voltage U_i and one at the maximum rated step voltage U_{im} and its relevant rated through-current I_u .

The switching curve can be drawn using the results of the two tests above and a value of voltage at mid-current calculated from the following formula:

$$\frac{I_{um} + I_u}{2} (U_x) = \sqrt{U_i I_{um} \times U_{im} I_u}$$

The arrangement for testing shall be such that, except where otherwise specified, the switched current, the recovery voltage, or the product of these shall not, in any case, be less than 95 % of the calculated values appropriate to the switching cycle, see Table A.1 and Tables B.1, B.2, B.3 and B.4 at the appropriate through-current and relevant rated step voltage.

5.2.2.1 Service duty test

This test shall be performed in accordance with one of the tests in 5.2.2.1.1 to 5.2.2.1.3, the appropriate method to be decided by the manufacturer. After the tests, inspections of contact wear shall take place, the results of these leaving no doubt as to the suitability of the on-load tap-changer for service.

NOTE The results of this test may be used by the manufacturer to demonstrate that the contacts used for making and breaking current are capable of performing, without replacement of the contacts, the number of tap-change operations declared by the manufacturer at the maximum rated through-current and at the relevant rated step voltage.

5.2.2.1.1 Service duty test at rated step voltage

The contacts of the diverter and selector switches shall be subjected to a number of operations corresponding to 50 000 tap-change operations in normal service when carrying a current corresponding to not less than the maximum rated through-current and the relevant rated step voltage.