

BS EN 60214-1:2014



BSI Standards Publication

Tap-changers

Part 1: Performance requirements
and test methods

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National foreword

This British Standard is the UK implementation of EN 60214-1:2014. It is identical to IEC 60214-1:2014. It supersedes BS EN 60214-1:2003 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/14, Power transformers.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Date	Text affected
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English Version

**Tap-changers - Part 1: Performance requirements and test
methods
(IEC 60214-1:2014)**

Changeurs de prises - Partie 1: Prescriptions de
performances et méthodes d'essai
(CEI 60214-1:2014)

Stufenschalter - Teil 1: Leistungsanforderungen und
Prüfverfahren
(IEC 60214-1:2014)

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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 14/746/CDV, future edition 2 of IEC 60214-1, prepared by IEC/TC 14 "Power transformers" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60214-1:2014.

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- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2015-03-26
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2017-06-26

This document supersedes EN 60214-1:2003.

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Endorsement notice

The text of the International Standard IEC 60214-1:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60076-1:2011	NOTE	Harmonized in EN 60076-1:2011.
IEC 60076-11	NOTE	Harmonized as EN 60076-11.
IEC 60376	NOTE	Harmonized as EN 60376.
IEC 60599	NOTE	Harmonized as EN 60599.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u> <u>series</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u> <u>series</u>
IEC 60050		International Electrotechnical Vocabulary -- Electrical and electronic measurements and measuring		
IEC 60060-1	-	High-voltage test techniques -- Part 1:EN 60060-1 General definitions and test requirements		-
IEC 60076-3	2013	Power transformers -- Part 3: InsulationEN 60076-3 levels, dielectric tests and external clearances in air		2013
IEC 60076-7	2005	Power transformers -- Part 7: Loading- guide for oil-immersed power transformers		-
IEC 60076-21	2011		-	-
IEC 60137	2008	Insulated bushings for alternating voltagesEN 60137 above 1 000 V		2008
IEC 60214-2	2004	Tap changers -- Part 2: Application guide -		-
IEC 60270	-	High-voltage test techniques - PartialEN 60270 discharge measurements		-
IEC 60296	-	Fluids for electrotechnical applications -EN 60296 Unused mineral insulating oils for transformers and switchgear		-
IEC 60529	-	Degrees of protection provided by- enclosures (IP Code)		-

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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, de-energized tap-changers, and their motor-drive mechanisms.

It applies mainly to tap-changers immersed in mineral insulating oil according to IEC 60296 but may also be used for tap-changers with air or gas insulation or immersed in other insulating liquids insofar as conditions are applicable.

It applies mainly to tap-changers with arcing contacts but may also be used for arcing-free on-load tap-changers (such as electronic switching) insofar as conditions are applicable.

This part of IEC 60214 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 documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org>)

IEC 60050-421, *International Electrotechnical Vocabulary – Chapter 421: Power transformers and reactors*

IEC 60060-1, *High voltage test techniques – Part 1: General definitions and test requirements*

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

IEC 60076-7:2005, *Power transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60076-21:2011, *Power transformers – Part 21: Standard requirements, terminology, and test code for step-voltage regulators*

IEC 60137:2008, *Insulated bushings for alternating voltages above 1 000 V*

IEC 60214-2:2004, *Tap-changers – Part 2: Application guide*

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

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-421 as well as the following apply.

3.1

on-load tap-changer

OLTC

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

Note 1 to entry: On-load tap-changers are sometimes called load tap-changers (LTC).

3.2

non-vacuum type on-load tap-changer

on-load tap-changer with contacts that break and make the load and circulating currents and where the arcing takes place in a liquid or gas, the tap-changer itself being placed in liquid or gas

Note 1 to entry: This definition does not apply to arcing-free on-load tap-changers.

3.3

vacuum type on-load tap-changer

on-load tap-changer where vacuum interrupters (VI) break and make the load and circulating currents, the tap-changer itself being placed in a different medium such as liquid or gas

3.4

tap selector

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

3.5

diverter switch

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

Note 1 to entry: Diverter switches are sometimes called arcing switches.

3.6

selector switch

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

Note 1 to entry: Selector switches are sometimes called arcing tap switches.

Note 2 to entry: In non-vacuum type selector switches the selection of tap connections (tap selector duty) and the diversion of the through-current (diverter switch duty) are carried out by the same contacts.

Note 3 to entry: In vacuum type selector switches the selection of tap connections (tap selector duty) and the diversion of the through-current (diverter switch duty) are carried out by different contacts.

3.7**de-energized tap-changer****DETC**

device for changing the tap connections of a winding, suitable for operation only while the transformer is de-energized (isolated from the system)

Note 1 to entry: De-energized tap-changers are sometimes called off-circuit tap-changers.

Note 2 to entry: De-energized tap-changers are sometimes abbreviated as DTC.

3.8**change-over selector**

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

3.9**coarse change-over selector**

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

3.10**reversing change-over selector**

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

3.11**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 1 to entry: 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.

3.12**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

3.13**equalizer winding**

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

3.14**drive mechanism**

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

Note 1 to entry: The mechanism may include an independent means of storing energy to control the operation.

3.15**set of contacts**

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

3.16

diverter switch and selector switch main contacts <of a resistor type tap-changer>

set of through-current carrying contacts which usually by-passes the main switching contact and only commutates any current (sparking often occurs)

3.17

diverter switch and selector switch main switching contacts <of a resistor type tap-changer>

set of contacts which has no transition resistor between the transformer winding and the contacts and makes and breaks current (arcing will occur)

Note 1 to entry: In case of vacuum type tap-changers, these contact systems are replaced by vacuum interrupters.

3.18

diverter switch and selector switch transition contacts, <of a resistor type tap-changer>

set of contacts which is connected in series with a transition resistor and makes or breaks current (arcing will occur)

Note 1 to entry: In case of vacuum type tap-changers, these contact systems are replaced by vacuum interrupters.

3.19

transfer contacts <of a reactor type tap-changer>

set of contacts that makes or breaks current

Note 1 to entry: Where by-pass contacts are not provided, the transfer contact is a continuous current-carrying contact.

3.20

by-pass contacts <of a reactor type tap-changer>

set of through-current carrying contacts that commutates the current to the transfer contacts without any arc (sparking may occur)

3.21

bridging position

position of a reactor type tap-changer with the selector and transfer contacts being on two adjacent taps and with the output terminal being electrically in the middle between two adjacent taps

3.22

non-bridging position

position of a reactor type tap-changer with the selector and transfer contacts being on the same tap

3.23

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

Note 1 to entry: The circulating current is due to the voltage difference between the taps.

3.24

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

3.25**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

3.26**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

3.27**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

3.28**rated insulation level**

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

3.29**rated through-current** I_r

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

3.30**maximum rated through-current** I_{rm}

highest rated through-current for which the tap-changer is designed for and all the current related tests are based on

3.31**rated step voltage** U_{ir}

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

3.32**relevant rated step voltage**

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

3.33**maximum rated step voltage** U_{irm}

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

3.34**rated frequency**

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

3.35**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 1 to entry: 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.

3.36

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 1 to entry: 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.

3.37

type test

test made on a tap-changer which is representative of other tap-changers, to demonstrate that these tap-changers comply with the specified requirements not covered by the routine tests: a tap-changer is considered to be representative of others if it is built to the same drawings using the same techniques and same materials

Note 1 to entry: In general a type test can be carried out on a tap-changer or the components of a tap-changer or a family of tap-changers or components.

Note 2 to entry: A family 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 in the case of OLTCs the value of the transition impedance.

Note 3 to entry: Design variations that are clearly irrelevant to a particular type test would not require that type test to be repeated.

Note 4 to entry: Design variations that cause a reduction in values and stresses relevant to a particular type test do not require a new type test if accepted by the purchaser and the manufacturer.

3.38

routine test

test to which each individual tap-changer is subjected

Note 1 to entry: In general a routine test can be carried out on a tap-changer or the components of a tap-changer.

3.39

motor-drive mechanism

driving mechanism which incorporates an electric motor and a control circuit

3.40

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

3.41

tap position indicator

device for indicating the tap position of the tap-changer

3.42

tap-change in progress indicator

device for indicating that the motor-drive mechanism is running

3.43

limit switches

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

3.44**mechanical end stop**

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

3.45**parallel control device**

control device 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 1 to entry: 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.

3.46**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

3.47**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 1 to entry: Where diverter or selector switches are actuated by spring energy systems, interruption of the operation of the motor-drive mechanism will not prevent operation of the diverter or selector switch if the spring release has been actuated.

3.48**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

3.49**operation counter**

device for indicating the number of tap-changes accomplished

3.50**manual operation of a motor-drive mechanism**

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

3.51**motor-drive cubicle**

cubicle that houses the motor-drive mechanism

3.52**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

3.53**class I tap-changer**

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

3.54**class II tap-changer**

tap-changer suitable for use at any position in the windings

3.55**in-tank tap-changer**

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

Note 1 to entry: See IEC 60214-2 for further details.

3.56**compartment type tap-changer**

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

Note 1 to entry: See IEC 60214-2 for further details.

3.57**gas immersed tap-changer**

tap-changer mounted inside the main tank of the gas filled type transformer or in a container outside the main tank and immersed in the insulating gas

Note 1 to entry: Usually the insulating gas is SF₆.

3.58**air insulated tap-changer**

tap-changer where the insulation medium is the air at atmospheric pressure

Note 1 to entry: This kind of tap-changer is usually mounted to a dry-type transformer and does not need its own container.

3.59**maintenance**

measure on the tap-changer that needs the transformer to be taken out of service

Note 1 to entry: Inspection is a measure on the tap-changer that does not need the transformer to be taken out of service.

Note 2 to entry: Replacement of parts is dependent on the findings resulting from the maintenance.

3.60**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

4 Service conditions**4.1 Temperature of tap-changer environment**

Unless more onerous conditions are specified by the purchaser, liquid immersed 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	Temperature	
	Minimum	Maximum
Compartment type tap-changer	–25 °C	40 °C
In-tank tap-changer	–25 °C	105 °C
NOTE 1 For the definitions of the tap-changer, see 3.55 and 3.56.		
NOTE 2 The value of 105 °C quoted above is based on the maximum top oil temperature in case of normal cyclic loading as specified in IEC 60076-7.		
NOTE 3 Minimum and maximum liquid temperatures of step-voltage regulators established in IEC 60076-21 take precedence.		

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.

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 60076-7, which could result in top oil temperatures as high as 115 °C.

See Note 3 in Table 1 in which maximum liquid temperature limit of step-voltage regulators relates to 200 % overload for half an hour.

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 Compartments for diverter and selector switches

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

If the insulating liquid is to be supervised by dissolved and free gases analysis (DGA), the liquid filled compartment of the diverter or selector switch should be provided with a liquid conservator which has a liquid and gas-tight barrier. In case of vacuum type OLTCs this matter should be discussed between transformer manufacturer and customer

5.1.3 Liquid-level gauges and gas monitoring devices

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.

Gas compartments for diverter or selector switches shall be provided with gas monitoring devices.

5.1.4 Safety requirements for protection against internal failure

5.1.4.1 General

In order to reduce the consequences resulting from an internal failure within the diverter or selector switch compartment, a protective device shall be fitted. The protective device shall have a function to detect a failure arc or a failure mode that finally will lead to a failure arc.

It is up to the manufacturer to recommend a protection device for the selected OLTC. At least one protective device shall be fitted.

The most common types of protection devices for liquid immersed OLTC are described below.

The tap selector compartments of compartment type 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 For those types of on-load tap-changers that do not create an arc and are installed in sealed compartments, other protective devices can be used.

5.1.4.2 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.

5.1.4.3 Overpressure relay

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

5.1.4.4 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 compartment.

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

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

5.1.7 Leakage inductance in coarse fine regulation arrangements

When changing from the end of the tap winding to the end of the coarse winding or vice versa 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 IEC 60214-2 gives further details of selection and winding configurations regarding leakage inductance.

5.2 Type tests

5.2.1 General

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:

NOTE No differentiation has to be made with respect to the test supplies with frequencies of 50 Hz or 60 Hz. The tests can be carried out with either frequency.

- temperature rise of contacts (5.2.2);
- switching tests (5.2.3);
- short-circuit current test (5.2.4);
- transition impedance test (5.2.5);
- mechanical tests (5.2.6);
- tightness test (5.2.7)
- dielectric tests (5.2.8).

5.2.2 Temperature rise of contacts

Tests shall be performed to verify that the temperature rise above the medium surrounding each type of contact which carries through-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. Contacts that should be tested are those which carry current continuously in service and are opened and closed or being moved at some instant during service life or maintenance, except bolted connections.

NOTE 1 If a current carrying contact carries at least 90 % of the through-current, it is not necessary to measure the temperature rise of the contacts being by-passed.

NOTE 2 Contacts operating in vacuum do not need to be measured.

For reactor type tap-changers without an equalizer winding the highest temperature rise is experienced in the bridging position which has the highest tap voltage impressed upon it.

For reactor type tap-changers with an equalizer winding the highest temperature rise will be experienced in either the bridging or non-bridging positions. The preventive autotransformer (reactor) is energized in all tap positions (non-bridging and bridging). Highest temperature rise will be experienced in the bridging or non-bridging position that has the highest total tap voltage impressed upon the reactor.

The current in these positions 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 position in which the highest total current flows through the tap-changer. The currents are calculated on the following basis:

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

Refer to Annex A and Annex B for the most onerous conditions for resistor and reactor type tap-changers, respectively, for the majority of contact arrangements.

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

Table 2 – Contact temperature-rise limits for on-load tap-changers

Contact material	In air K	In SF ₆ K	In liquid K
Plain copper	35	40	20
Silver-faced copper/alloys	65	40	20
Other materials	By agreement	By agreement	20
In SF ₆ the maximum allowable contact temperature under overload conditions is 150 °C. When the temperature of SF ₆ is controlled by a specific method, the manufacturer shall specify an allowable contact temperature rise, which takes into consideration reduced SF ₆ temperature surrounding the OLTC. Subsequent tests by the manufacturer using that method shall verify that the maximum allowable contact temperature of 150 °C will not be exceeded.			

When the surrounding medium is liquid, the test shall be performed at a starting liquid temperature of not more than 40 °C and not less than 10 °C.

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 in a manner to accurately reflect the actual contact temperature as near the point of contact as possible. The measuring device should be embedded into the contact or brazed or welded onto the contact so that it is measuring the bulk temperature of the contact and not the temperature of the interface between contact and cooling medium.

The temperature condition 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.

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

5.2.3 Switching tests

5.2.3.1 General

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 Annex A and Annex B for the most onerous conditions for resistor and reactor type tap-changers, as well as for vacuum-type and non-vacuum type tap-changers, respectively, for the majority of contact arrangements.

For vacuum type on-load tap-changers the breaking capacity test shall be performed after the completion of the service duty test using the identical test sample.

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_{rm} and its relevant step voltage U_{ir} and one at the maximum rated step voltage U_{irm} and its rated through-current I_r .

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:

$$\frac{I_{rm} + I_r}{2}(U_x) = \sqrt{U_{ir} I_{rm} \times U_{irm} I_r}$$

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 Tables A.1 and A.3 and Tables B.1, B.2, B.3 and B.4 at the appropriate through-current and relevant rated step voltage.

5.2.3.2 Service duty test

5.2.3.2.1 General

This test shall be performed in accordance with one of the tests in 5.2.3.2.2 to 5.2.3.2.6, 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. The number of tap-change operations N to be carried out depends on the type of on-load tap-changer. For non-vacuum type on-load tap-changers N shall be 50 000 tap-change operations. In case of vacuum type on-load tap-changers N shall be equal to 1,2 times the number of tap-change operations between maintenance according to the manufacturer's handbook but N shall not be less than 50 000 operations. This number of operations shall be declared by the tap-changer manufacturer.

NOTE The results of this test can 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.

For non-vacuum type on-load tap-changers, this test can be combined with the tightness test, see 5.2.7.2.

5.2.3.2.2 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 N 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.

Comparison of oscillograms taken at regular intervals during the test shall show that there is no significant alteration in the characteristics of the on-load tap-changer in such a way as to endanger the operation of the apparatus. Twenty oscillograms shall be taken at the start of the test, and 20 after each succeeding quarter of the number of N ($N/4$) operations, making a total of 100 oscillograms.

NOTE Generally, it is sufficient to compare the series of oscillograms taken at the beginning and at the end of the test.

5.2.3.2.3 Service duty test at reduced step voltage (non-vacuum type on-load tap-changers)

A test at reduced step voltage may be performed under the following conditions:

- 100 operations at the maximum rated through-current and the relevant rated step voltage shall be performed with new contacts in clean transformer liquid. Each operation shall be oscillographically recorded;
- when the oscillograms taken at a) indicate that no arcing time exceeds $1,2/2f$ s, where f is the rated frequency in hertz, then the number of operations of the service duty test as in d) shall be N ;
- when the oscillograms taken at a) indicate that arcing times in excess of $1,2/2f$ s are occurring, then the number of operations of the service duty test as in d) shall be increased by $(2S/100) \times N$ where S is the total number of half cycles of arcing current, in the 100 operations from item a) above, which exceed $1,2/2f$ s;
- a service duty test of N operations, increased by the number of operations resulting from item c) if applicable, shall be performed with a current not less than the maximum rated

through-current and at reduced step voltage. This voltage shall be such that the switched current is not less than that occurring during operations at the relevant rated step voltage. Furthermore, current chopping shall not significantly affect the contact erosion. In order to obtain the specified test conditions, the value of the transition impedance shall be suitably modified;

- e) without change of contacts or liquid, 100 operations shall be performed at the maximum rated through-current and the relevant rated step voltage, each operation being oscillographically recorded. Comparison of these oscillograms with those taken in the series of operations under item a) shall show no alteration in the characteristics of the on-load tap-changer which might endanger the operation of the apparatus.

The test sequence specified above is designed to give substantially the same contact erosion as would occur during N operations at maximum rated through-current and the relevant rated step voltage.

5.2.3.2.4 Service duty test at reduced step voltage (vacuum type on-load tap-changers)

A test at reduced step voltage may be performed under the following conditions:

- a) 1 000 operations at the maximum rated through-current and the relevant rated step voltage shall be performed with new contacts in clean transformer liquid. Each operation shall be oscillographically recorded. Arcing times exceeding $1,2/2f$ s shall not occur;
- b) a service duty test of N operations shall be performed with a current not less than the maximum rated through-current and at reduced step voltage. This voltage shall be such that the switched current and the arcing times are not less than those occurring during operations. In order to obtain the specified test conditions, the value of the transition impedance shall be suitably modified;
- c) without change of contacts or liquid, 1 000 operations shall be performed at the maximum rated through-current and the relevant rated step voltage, each operation being oscillographically recorded. Arcing times exceeding $1,2/2f$ s shall not occur. Comparison of these oscillograms with those taken in the series of operations under item a) shall show no alteration in the characteristics of the on-load tap-changer which might endanger the operation of the apparatus.

The test sequence specified above is designed to give substantially the same contact erosion as would occur during N operations at maximum rated through-current and the relevant rated step voltage.

5.2.3.2.5 Service duty test in a synthetic test circuit (vacuum type on-load tap-changers)

5.2.3.2.5.1 General

The service duty test is allowed to be performed in a synthetic test circuit as long as the following requirements are fulfilled:

- the charges dissipated in the arcs shall be at least the same as those gained in an a.c. test circuit;
- the current through the breaking arcs shall be tuned to be substantially sinusoidal and the charge shall be at least that of the corresponding sine half wave and the peak value should be at least 95% of that of the corresponding sine half wave;
- the polarity of the breaking current in the arcs shall be changed regularly and ending up with almost the same amount of operations with each polarity;
- the arcing times when breaking shall be varied in substantially the same way as in an a.c. test circuit;
- a statistically correct number of operations shall start at a current range equal to the corresponding a.c. r.m.s.-value times $\sqrt{2}$;