

IEEE Standard Requirements for Load Tap Changers

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Abstract: Electrical and mechanical performance and test requirements for load tap changers installed in power transformers and voltage regulating transformers of all voltage and kVA ratings are covered.

Keywords: load tap changer, phase shifting transformer, regulating transformer

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Introduction

(This introduction is not a part of IEEE Std C57.131-1995, IEEE Standard Requirements for Load Tap Changers.)

In the interest of furthering international standardization for load tap changers, portions of this standard have been reproduced by permission of the International Electrotechnical Commission (IEC), which retains the copyright.

This document is a new standard that has been developed by the Load Tap Changer Performance Requirements Working Group of the Transformers Committee. Its main intent is to provide standard performance and test requirements for both resistance and reactance type load tap changers. In many respects this standard parallels the IEC-214 (1989), Standard for On-Load Tap Changers, which covers resistance-type load tap changers in great detail, but reactance type load tap changers in lesser detail. This IEEE standard complements the IEC standard insofar as it provides additional performance and test requirements for reactance-type load tap changers, while essentially adopting, although sometimes with modification, the IEC requirements for resistance type load tap changers.

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CLAUSE	PAGE
1. Overview	1
1.1 Scope	1
1.2 Purpose	1
2. References	1
3. Definitions	2
4. Service conditions	4
5. Rating	4
5.1 Rated characteristics	4
5.2 Interrelation between rated through current and rated step voltage	4
6. Design tests	4
6.1 Temperature rise of contacts	5
6.2 Switching tests	5
6.3 Short-circuit current test	7
6.4 Transition impedance test	8
6.5 Mechanical tests	9
6.6 Dielectric tests	9
7. Routine tests	13
7.1 Mechanical test	13
7.2 Sequence test	13
7.3 Auxiliary circuits insulation test	13
8. Nameplate	13
9. Test report	14
9.1 Design test report	14
9.2 Routine test report	14
10. Motor-drive mechanism	14
10.1 Temperature of motor-drive mechanism environment	14
10.2 Permissible variation of auxiliary supply	14
10.3 Design tests for motor-drive mechanisms	14
10.4 Routine tests for motor-drive mechanism	15
10.5 Nameplate for motor-drive mechanism	15
10.6 Test report for motor-drive mechanism	16
Annex A (Informative) Switching duty relating to load tap changers with resistor transition	17
Annex B (Informative) Switching duty relating to Icad tap changers with reactor transition	21
Annex C (Informative) Method of determining the equivalent temperature of the transition resistor using power pulse currents	30

CLAUSE	PAGE
Annex D (Informative) Simulated circuits for service duty and breaking capacity tests for resistance-type LTCs.....	31
Annex E (Informative) Tutorial information on LTC application.....	34
Annex F (Informative) Bibliography	40

IEEE Standard Requirements for Load Tap Changers

1. Overview

1.1 Scope

This standard covers electrical and mechanical performance and test requirements for load tap changers installed in power transformers and voltage regulating transformers of all voltage and kVA ratings. It relates mainly to load tap changers immersed in transformer mineral oil, but may also be used for other insulating fluids insofar as conditions are applicable.

1.2 Purpose

The purpose of this standard is to provide standard performance and test requirements for load tap changers.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI C57.12.10-1987, American National Standard for Transformers, 230 kV and Below, 833/958 through 8333/10 417 kVA, Single-Phase, and 750/862 through 60 000/80 000/100 000 kVA, Three-Phase without Load Tap Changing; and 3750/4687 through 60 000/80 000/100 000 kVA with Load Tap Changing—Safety Requirements.¹

IEEE Std 4-1995, IEEE Standard Techniques for High Voltage Testing.²

IEEE Std 100-1992, The New Standard Dictionary of Electrical and Electronics Terms (ANSI).³

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

²As this standard goes to press, IEEE Std 4-1995 is approved but not yet published. The draft standard is, however, available from the IEEE. Anticipated publication date is fall 1995. Contact the IEEE Standards Department at 1 (908) 562-3800 for status information.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

IEEE Std C57.12.00-1993, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power and Regulating Transformers (ANSI).

IEEE Std C57.12.80-1978, Terminology for Power and Distribution Transformers (ANSI).

IEEE Std C57.12.90-1993, IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers, and Guide for Short-Circuit Testing of Distribution and Power Transformers (ANSI).

IEEE Std C57.91-1995, IEEE Guide for Loading Mineral-Oil-Immersed Transformers.⁴

IEEE Std C57.113-1991, IEEE Guide for Partial Discharge Measurement in Liquid-Filled Power Transformers and Shunt Reactors (ANSI).

3. Definitions

3.1 arcing switch: A switching device used in conjunction with a tap selector to carry, make, and break current in circuits that have already been selected.

3.2 arcing tap switch: A switching device capable of carrying current and also breaking and making current while selecting a tap position. It, thereby, combines the duties of an arcing switch and a tap selector.

3.3 bypass contacts: For reactance-type load tap changers (LTCs), a set of through current-carrying contacts that commutates the current to the transfer contacts without any arc.

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

3.5 circulating current: The current that flows through the transition impedance as a result of two taps being bridged during a tap change operation for resistance-type LTCs or being in the bridging position for reactance-type LTCs.

3.6 coarse change-over selector: A change-over selector that connects the tap winding to a coarse winding, a main winding, or to portions of the main winding.

3.7 coarse/fine operation: A winding arrangement in which a coarse change-over selector connects the tap winding to the coarse or main winding, and allows the use of the taps twice when travelling through the tapping range.

3.8 coarse winding: A winding that extends the regulating range beyond the range of the finely tapped winding.

3.9 cycle of operation: The movement of the LTC from one end of its range to the other and back to its original position.

3.10 design test: A test made on an LTC or the components of an LTC, or a range of LTCs or components all based on the same design, to prove compliance with this standard.

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

3.11 drive mechanism: The means by which the LTC is actuated.

3.12 insulation level: The withstand values of the impulse and power frequency test voltages to ground, and where appropriate, between the phases, and between those parts where insulation is required.

3.13 linear operation: A winding arrangement in which the tap winding is directly connected to the main winding and where the taps can be used only once when travelling through the tapping range.

⁴As this standard goes to press, IEEE Std C57.91-1995 is approved but not yet published. The draft standard is, however, available from the IEEE. Anticipated publication date is winter 1996. Contact the IEEE Standards Department at 1 (908) 562-3800 for status information.

3.14 load tap changer (LTC): A selector switch device, which may include current interrupting contactors, used to change transformer taps with the transformer energized and carrying full load.

3.15 main contacts: For resistance-type LTCs, a set of through current-carrying contacts that have no transition impedance between the transformer winding and the contacts and commutates the current to the main switching contacts without any arc.

3.16 main switching contacts: For resistance-type LTCs, a set of contacts that has no transition impedance between the transformer winding and the contacts and makes and breaks current.

3.17 maximum rated step voltage: The highest value of rated step voltage for which the LTC is designed.

3.18 maximum rated through current: The rated through current for which both the temperature rise of the contacts and the service duty test apply.

3.19 number of inherent tap positions: The highest number of tap positions for half a cycle of operation for which an LTC is designed.

3.20 number of service tap positions: The number of tap positions for half a cycle of operation for which an LTC is used in a transformer.

NOTE — The above two terms, 3.19 and 3.20, are generally given as the $\pm$ values of the relevant numbers, e.g., ± 16 positions. They are, in principle, valid also for the motor-drive mechanism. When the term *number of tap positions* is used in connection with a transformer, this always refers to the number of service tap positions of the LTC.

3.21 plus/minus operation: A winding arrangement in which one or the other end of the tap winding is connected by a reversing change-over selector to the main winding, and allows use of the taps in a buck or boost mode when travelling through the tapping range.

3.22 preventive autotransformer: An autotransformer (or center-tapped reactor) used in 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 taps between adjacent position.

3.23 rated frequency: The frequency of the alternating current for which the LTC is designed.

3.24 rated step voltage: For each value of rated through current, the highest permissible voltage between successive tap positions.

NOTE — Step voltage of resistance-type LTCs means tap to tap voltage (no bridging position).

3.25 rated through current: The current flowing through the LTC towards the external circuit, which the apparatus is capable of transferring from one tap to another at the relevant rated step voltage, and which can be carried continuously while meeting the requirements of this standard.

NOTE — Concerning the relationship between rated through current and the relevant step voltage, see 5.2.

3.26 recovery voltage: The power frequency voltage that appears across each set of main switching, transition, or transfer contacts of the arcing switch or arcing tap switch after these contacts have broken the switched current.

3.27 relevant rated step voltage: The value of rated step voltage that corresponds to a specific value of rated through current.

3.28 reversing change-over selector: A change-over selector that connects one or the other end of the tap winding to the main winding.

3.29 routine test: A test made on each completed LTC to establish that the LTC is without manufacturing defects, with the design having been verified by a design test.

3.30 switched current: The prospective current to be broken during a switching operation by each set of main switching or transition contacts (resistance-type LTC) or transfer contacts (reactance-type LTC) incorporated in the arcing switch or arcing tap switch.

3.31 tap change operation: A complete sequence of events from the initiation to the completion of the transition of the through current from one tap position to an adjacent one.

3.32 tap selector: A device designed to carry, but not to make or break current, used in conjunction with an arcing switch to select tap connections.

3.33 transfer contacts: For reactance-type LTCs, a set of contacts that makes and breaks current.

NOTE — In cases where no bypass contacts are provided, the transfer contact is a continuous current carrying contact.

3.34 transition contacts: For resistance-type LTCs, a set of contacts that is connected in series with a transition impedance and makes and breaks current.

3.35 transition impedance: A resistor or reactor consisting of one or more units that bridge adjacent taps 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. Normally, reactance-type LTCs use the bridging position as a service position and, therefore, the reactor is designed for continuous loading.

4. Service conditions

Unless specified otherwise, LTCs shall be suitable for operation when immersed in insulating fluid over a range of temperatures from $-25\text{ }^{\circ}\text{C}$ to $100\text{ }^{\circ}\text{C}$.

5. Rating

5.1 Rated characteristics

The rated characteristics of an LTC are as follows:

- a) Rated through current
- b) Maximum rated through current
- c) Rated step voltage
- d) Maximum rated step voltage
- e) Rated frequency
- f) Rated insulation level

5.2 Interrelation between rated through current and rated step voltage

Within the maximum rated through current of the LTC 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 as a specific value of rated through current, it is called the *relevant rated step voltage*.

6. Design tests

The following design tests shall be performed on an LTC of each stated rating:

- a) Temperature rise of contacts
- b) Switching
- c) Short-circuit current
- d) Transition impedance
- e) Mechanical
- f) Dielectric

6.1 Temperature rise of contacts

6.1.1 Maximum rated through current

While carrying 1.2 times maximum rated through current continuously, tests shall be performed to verify that the steady-state temperature rise of the contacts does not exceed 20 °C above the temperature of the insulating fluid surrounding the contacts. The temperature rise limit applies to both plain and plated contacts. A temperature rise test is required on only one phase of a three-phase LTC.

6.1.2 Overload capability

LTCs that comply with the above definition of maximum rated through current, and when installed and properly applied in a transformer or regulating transformer, can be loaded in accordance with the applicable ANSI or IEEE loading guide.⁵

6.1.3 Test requirements

Temperature rise tests shall be performed at ambient temperature. The temperature of the surrounding insulating fluid shall be measured at not less than 25 mm below the contacts. Temperatures shall be measured by thermocouples or other suitable means positioned on the surface of the contacts as near to the point of contact as is practicable.

The temperature is considered to be at steady state when the difference of the temperature between the material being measured and the surrounding medium does not change more than 1 °C over a period of 1 h.

For reactance-type LTCs, 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 design test shall be performed in the bridging position and with currents calculated on the following bases:

- 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 design test report)
- c) Power factor equal to 80%

6.2 Switching tests

Switching tests, which include service duty tests and breaking capacity tests, shall simulate the most demanding conditions for which the LTC is rated. Refer to annexes A and B for the most demanding conditions for resistance and reactance-type LTCs, respectively, for the majority of contact arrangements.

The switching tests may be limited to the arcing switch or arcing tap switch after proving that the contact operating conditions are not affected by such limitation.

If the arcing switch or arcing tap switch has several sets of contacts that 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, they may be placed outside the apparatus if necessitated by the construction of the LTC or the test circuit, and they may have a higher thermal capacity than those which are employed in service, unless otherwise specified.

⁵Information on references can be found in clause 2

The value and type of the transition impedance shall be stated.

Contacts and insulating fluid shall not be renewed during each of the tests.

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

If a particular LTC 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 and its relevant rated step voltage, and one at the maximum rated step voltage and its relevant rated through-current.

The arrangement for testing shall be such that, except where otherwise specified, neither the switched current, nor the recovery voltage nor the product of these shall, in any case, vary more than -5% to $+10\%$ of the calculated values appropriate to the switching cycle (see table A.1 in annex A for resistance switching or table B.1 in annex B for reactance switching) at the appropriate through current and relevant rated step voltage.

6.2.1 Service duty test

This test shall be performed in accordance with one of the subclauses below.

After the tests, inspection of contact wear shall take place. The results of this inspection shall leave no doubts as to the suitability of the LTC for service.

NOTE — The results of these tests 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 guaranteed by the manufacturer at the rated through current and at the relevant rated step voltage.

6.2.1.1 Service duty test at rated step voltage

The contacts on arcing switches and arcing tap switches shall be subjected to a number of operations corresponding to 50 000 tap change operations when carrying a current corresponding to not less than the maximum rated through current and the relevant rated step voltage.

In order to approximate service conditions, arcing tap switches shall have the test performed over not more than eight tap change positions (excluding dead positions), these being centrally disposed about the change-over selector if such is incorporated into the LTC design.

Comparison of oscillograms taken at regular intervals during the test shall show that there is no significant alteration in the characteristics of the LTC 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 12 500 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.

6.2.1.2 Service duty test at reduced step voltage

A test at reduced step voltage may be performed as follows:

- a) One hundred operations at the maximum rated through current and the relevant rated step voltage shall be performed with new contacts in clean insulating fluid. Each operation shall be recorded by oscillograph.
- b) When the oscillograms taken in item a) indicate that the arcing time does not exceed $1.2/(2f)$ s (f = rated frequency in Hz), then the number of operations of the service duty test as described in item d), below, shall be 50 000.
- c) When the oscillograms taken in item a) indicate that arcing times in excess of $1.2/(2f)$ s are occurring, then the number of operations of the service duty test in item d) shall be increased by the following amount:

$$2S/100 \times 50\ 000$$

where

S is the total number of half-cycles of arcing current in the 100 operations from a), above, which exceed $1.2/(2f)$ s.

- d) A service duty test of 50 000 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 occur. In order to obtain the specified test conditions, the value of the transition impedance shall be suitably modified.
- e) Without change of contacts or of insulating fluid, 100 operations shall be performed at the maximum rated through current and the relevant rated step voltage, with each operation being recorded by oscillograph. Comparison of these oscillograms with those taken in the series of operations under item a) shall show no alteration in the characteristics of the LTC, such as might endanger the operation of the apparatus.

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

6.2.2 Breaking capacity test

Forty operations shall be performed at a current corresponding to twice the maximum rated through current and at the relevant rated step voltage. The forty operations shall be performed over not more than eight tap change positions (excluding dead positions), these being centrally disposed about the change-over selector if such is incorporated in the LTC design.

Oscillograms shall be taken for each operation, and the results shall indicate that in no case is the arcing time such as to endanger the operation of the apparatus. For example, dragging of the arc across the contacts could result in short circuiting the regulating winding of a transformer.

The breaking capacity test for resistance-type LTCs shall be performed, if possible, with a transition resistor of the same thermal and ohmic design as that to be employed in service. If this is not possible, the resistor as used in service shall be tested separately in accordance with 6.4.1, but with twice the maximum rated through current for one operation only.

6.2.3 Simulated test circuits

The tests described in 6.2.1 and 6.2.2 may be performed with simulated circuits provided it is proven that the test conditions are substantially equivalent. Two simulated test circuits that are relevant for resistor type LTCs only are described in annex D.

6.3 Short-circuit current test

All contacts of different design that carry current continuously shall be subjected to short-circuit currents, each of at least 2 s duration. In the case of three-phase LTCs, it is sufficient to test the contacts of one phase only unless otherwise specified.

Three applications shall be made with an initial peak current of $2.5 (\pm 5\%)$ times the rms value of the short-circuit test current. The load impedance shall exhibit an X/R ratio of 12 or more in order to accomplish the desired degree of asymmetry. The contacts shall not be moved between these applications.

When there are no facilities for point-on-wave switching, a resistive load may be used. The rms value of the short-circuit test current may be increased so that the peak current is obtained for the three applications and the test duration reduced. When using this method, the product of the square of the increased rms current and the shorter test duration shall be not less than the product of the square of the rated short-circuit rms current and the 2 s duration.

The values of the short-circuit test current to be applied shall be as shown in figure 1.

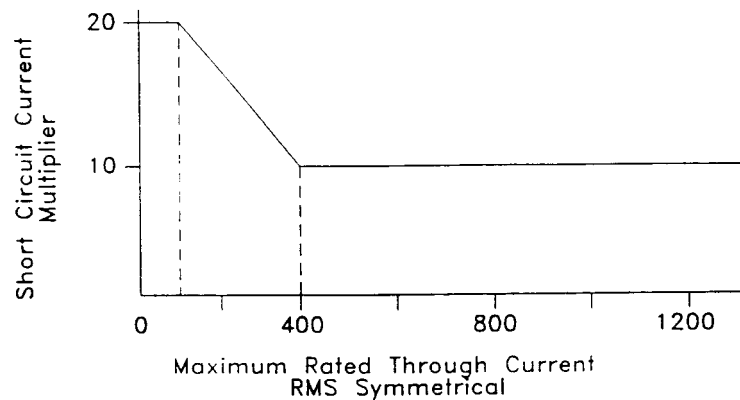


Figure 1—Short-circuit multiple of the maximum rated through current

The open circuit voltage for the test shall be at least 50 V. At the conclusion of the test, the contacts shall not have been damaged so as to prevent continuing correct operation at rated current. Other current-carrying parts shall not show signs of permanent mechanical distortion.

For reactance-type LTCs the short-circuit current is divided into two equal parts at the tap selector or arcing tap switch contacts and the transfer or bypass contacts. Therefore, the test current carried by each contact will be only 50% of the full test current.

6.4 Transition impedance test

6.4.1 Transition resistors

To meet the overload requirements of 6.1.2, the test shall be performed with 1.5 times the maximum rated through current and at the relevant rated step voltage. The resistor shall be mounted in the LTC as in service.

The resistor shall be loaded by operating the LTC. The number of operations shall be equivalent to one-half of an operation cycle (see 3.12). The operations shall be uninterrupted with the driving mechanism operating at its normal speed.

The temperature of the resistor at the final operation shall be determined and recorded. The temperature rise above the surrounding medium at 1.5 times maximum rated through current shall not exceed 350 °C. The temperature of resistors and of parts adjacent to them shall be limited to a value such that the characteristics of the assembly are not affected.

If it is not practicable to determine the temperature of the transition resistor according to the above, the method given in annex C may be employed.

NOTE — In cases when the rated through current or the relevant rated step voltage is different from the maximum rated through current and the relevant rated step voltage, it is permissible to calculate the thermal rating of the resistor from the results of the design test.