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HV AC CIRCUIT BREAKERS

IEC 62271-100, 2001

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IEEE / PES - HVCB Subcommittee

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HV AC Circuit-breakers

The major changes introduced in the 2001 issue of:

IEC 62271-100

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Scope and applicability

- V>1000 V
- 50 & 60 Hz only (no 16 2/3 Hz)
- 3- and 1-phase breakers (no 2-phase CBs)
- no traction breakers (IEC77)
- no generator breakers (IEEE C37.013)

New definitions

- 3.1.126 NSDD
- 3.1.127 restrike performance (restrike free CBs no longer exist!)
- 3.4.112-117 CBs type E1-E2 for electrical endurance,M1-M2 for mechanical endurance and C1-C2 for capacitive switching performance

New definitions (continued)

- **pressure values:**
  - **3.7.157 minimum functional pressure for operation (also interlocking pressure)**
  - **3.7.158 minimum functional pressure for interruption and insulation**

4-ratings

- 50 & 60 Hz
- pressure values for operation, interruption and insulation (when relevant) are a rating
- additional mandatory rating :

  ≤ 52 kV rating of cable charging

  ≥72.5kV rating of line charging
- higher p.f. withstand voltage value across the open switching device may be applied if voltage factor of 1.4 is applied for 1-phase capacitive test

4.101.2 DC component of short-circuit current

- 45 ms standard value

- special case time constants are:
  - ➡ 120 ms for MV up to 52 kV included
  - ➡ 60 ms up to 420 kV included
  - ➡ 75 ms for V>420 kV

4.103 making current - peak/rms ratio

- 2.5 for 50 Hz @ 45 ms
- 2.6 for 60 Hz @ 45 ms
- 2.7 for time constants other than 45 ms, both 50 and 60 Hz

4.107 capacitive current ratings

- table 5 provides “preferred” not mandatory values
- values are given also for single and back-to- back current switching
- back-to-back covers single capacitor bank
- values of back-to-back capacitor bank inrush making current and frequency equal for all the rated voltage values

4.110 mechanical endurance

- Standard circuit-breaker (normal mechanical endurance)
  class M1: 2,000 operating sequences

- Circuit-breaker for special service requirements (extended mechanical endurance)
  class M2: 10,000 operating sequences

4.111 electrical endurance

- for the time being, for MV CBs only, up to and including 52 kV (in progress for HV)
- class E2, for CBs intended for autoreclosing duty, as for overhead line systems; they perform additional tests as per Table 21
- class E2, for CBs without autoreclosing duty, as for cable-connected systems; they perform the basic short-circuit test-duties (clause 6.106) without intermediate maintenance
- class E1, not requiring electrical endurance

New naming for tests

- **Basic short-circuit:**
  T10, T30, T60, T100s, T100a
- **Short-line fault: ……., (L60)**
- **out of phase: (OP1), OP2**
- **capacitive current switching:**
  - **lines: LC1, LC2**
  - **cables: CC1, CC2**
  - **capacitor banks (single & back-to-back): BC1, BC2**

6.2 dielectric tests

- 6.2.4 criteria to pass the tests
  - ➡ no disruptive discharges on non-self restoring insulation shall occur
  - ➡ up to 2 discharges admitted (out of 15 impulses) if self-restoring insulation is concerned
  - ➡ in case of discharge, each discharge shall be followed by at least 5 impulses without any discharge
  - ➡ if discrimination (internal/external) is impossible, then inspection

6.2.11 voltage test as a condition check

- for V≤ 72.5 kV, power frequency test at 80% of the rated p.f. withstand value
- 72.5 < V ≤ 245 kV: T10 TRV with peak equal to 60% of the rated lightning impulse; No. 5 impulses per polarity
- 245< V ≤ 420 kV: T10 TRV with peak equal to 80% of the rated switching impulse; No. 5 impulses per polarity
- 420< V ≤ 800 kV: T10 TRV with peak equal to 90% of the rated switching impulse; No. 5 impulses per polarity
- Standard “LI” or “SI” required but impractical

6.101.1.1 reference mechanical travel characteristic

- the mechanical travel characteristic is of peculiar interest both for closing and opening operations

- reference no load test (contractual item) against which comparing (max deviation is 10%) any additional specimen or after maintenance

6.102 miscellaneous for making breaking and switching

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- before commencing the tests the manufacturer shall declare
  - the minimum conditions for the command guaranteeing the rated operating sequence (e.g. minimum functional pressure for operation, see definitions)
  - the minimum conditions for the interruption guaranteeing the rated operating sequence (e.g. minimum functional pressure for interruption, see definitions)

6.102.2 max # of specimens for making & breaking & switching tests

- preferably 1 single specimen + maintenance

- max 2 specimens for
  - basic short-circuit
  - short-time current
  - short-line fault
  - out of phase
  - capacitive current switching

6.102.2 max # of specimens for making & breaking & switching tests (continued)

- the 2 specimens must be “equal” (same travel curve and times as per 6.101.1.1) and shall be identified as per 6.1.2 IEC 60694
- maintenance is allowed
- for the only case of CBs having independent mechanism per pole, 1-phase and full-pole tested, 2 specimens plus interrupting unit of up to 2 poles
- visual inspection to verify the ability of the non renewable parts to withstand all type tests

6.102.3.1 arrangement of circuit-breaker for tests; general

- for T100a, capacitive and 1-phase test (6.108), release voltages at their maximum values
- pressure for interruption (SF_6) at its minimum functional value (3.7.158)
- pressure for operation at commencement of the rated operating sequence, is set at its minimum functional value (3.7.157)

6.102.3.1 arrangement of circuit-breaker for tests; general (continued)

- if, for any reason, the single test duty consists of separate O, CO and O-CO:
  - ➡ at no load the pressure values during the rated operating sequence shall be measured
  - ➡ values are compared with the ones declared by the manufacturer
  - ➡ the single operations (O, CO, O-CO) shall be performed at the minimum pressure resulting from the comparison whatever is the lower, for the corresponding operation in the test duty; the used values shall be included in the Test Report
  - ➡ interlocks made inoperative

6.102.4.1 single-phase testing of a single pole of a three-phase circuit-breaker

- checking of the operating mechanism also in the making operation

- two three-phase tests for making (T100s): one with the full symmetrical current and the max. pre-arcing time in one pole and one with the maximum asymmetrical current in one pole

6.102.7 alternative mechanism

- if 2 different mechanisms, (same interrupting unit) giving “same” speed and times, in a no-load operation and in the test of T100s with the longest arcing time, validity of short circuit tests can be extended to the second mechanism
- T100s shall however be repeated
- mechanical, environmental tests,.... to be carried out twice in any case

6.102.9. Condition of circuit-breaker after tests

clause 6.2.11 (voltage test as a condition check) mandatory after

- L90 or, if not performed, after T100s
- capacitive test-duties if 1 restrike occurs, before visual inspection
- capacitive test-duties on sealed for life circuit-breaker (even in the case of no restrike)

6.102.10.2.1.1& 6.102.10.2.2.1 demonstration of arcing times (single-phase) T10, T30, T60, T100s, OP1,OP2 L90, L75, L60

- fixed sequence for arcing times : minimum, maximum and medium
- medium : $(t_{max} + t_{min}) / 2$
- arcing times specified also for out-of-phase

6.102.10.2.1.2& 6.102.10.2.2.2 demonstration of arcing times (single-phase) T100a

- required values of current peak and loop duration of the last loop prior to the interruption; due to this, in principle, there is no possibility to cover the different “To” with reduced number of tests
- fixed sequence for arcing times: minimum, maximum and medium
- medium : $(t_{max} + t_{min}) / 2$
- open point about test procedures in case of time constants of the test circuit different from the rated one (in progress,see IEC 62215 to be published)

6.102.10.2.5 splitting of test duties in test series taking into account the associated TRV for each pole-to-clear

- brand new test procedure
- each test-duty (more likely T100s and T100a) split into two or three separate test series, each one demonstrating the minimum, medium and maximum arcing time
- increased number of tests to be performed

6.105.5 invalid test

- simple “common good sense” applied
- the advantage is that it is stated and ruled, so guidance is given how to continue the tests

6.106.4 test-duty T100s

- brand new, accounting for the new time constants
- test methods are given to consider that the test circuit may have a time constant different than the standard one
- one making operation at full voltage is mandatory

6.107 critical current tests

- the applicability is defined :

  the minimum arcing time in any of the test duties T10,T30 or T60 is 1/2 cycle or longer than the minimum arcing times in the adjacent test duties

- current values are defined

- test duty is defined

6.108 single phase and double earth fault tests

- brand new clause for isolated neutral systems in case of double fault to ground open by a single pole only
- confirmed applicability for earthed neutral systems (single-phase to ground fault)
- one single operation (for each of the two fault cases) at specified arcing time

Fig. 45- Necessity of additional single-phase tests and requirements for testing

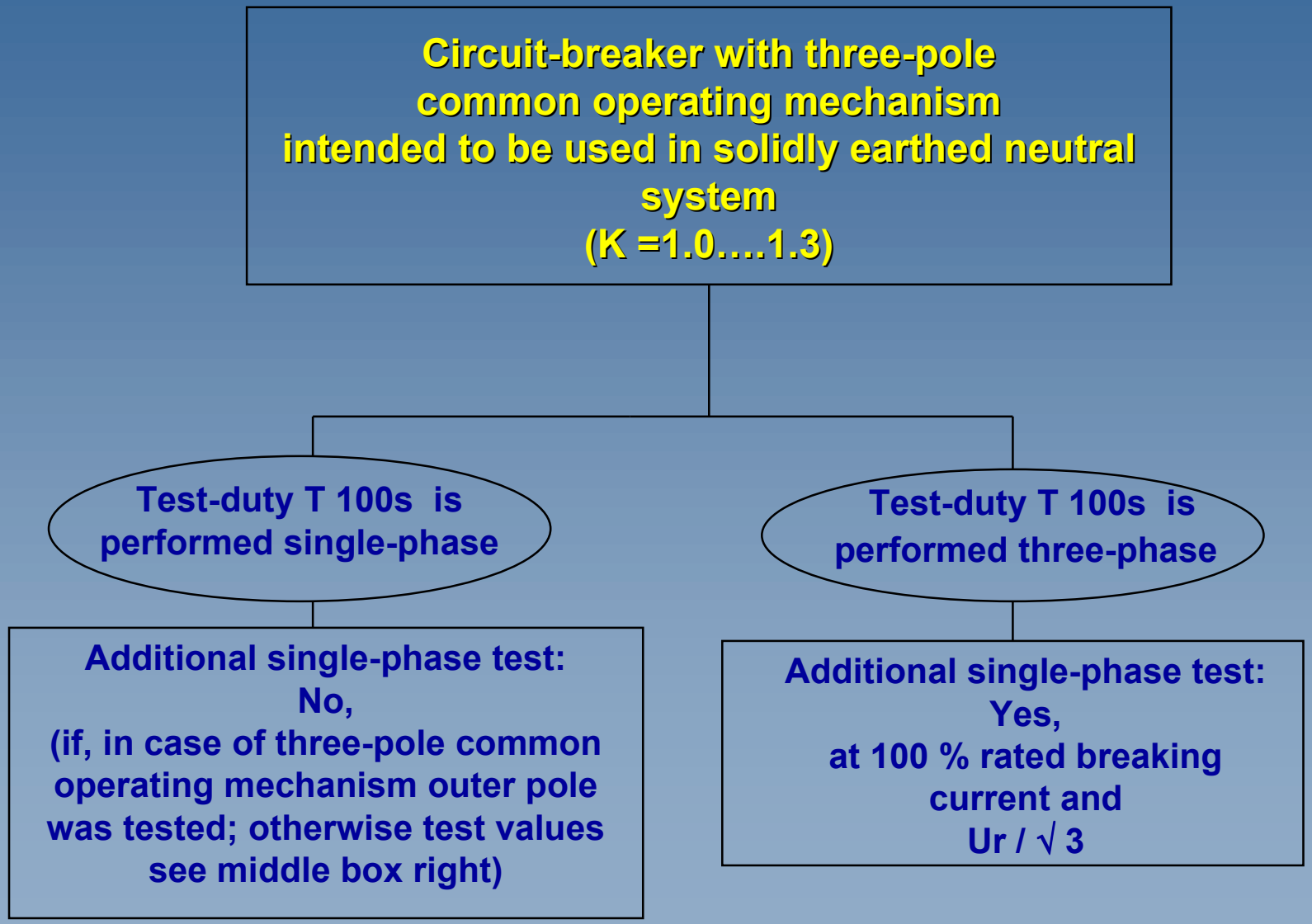
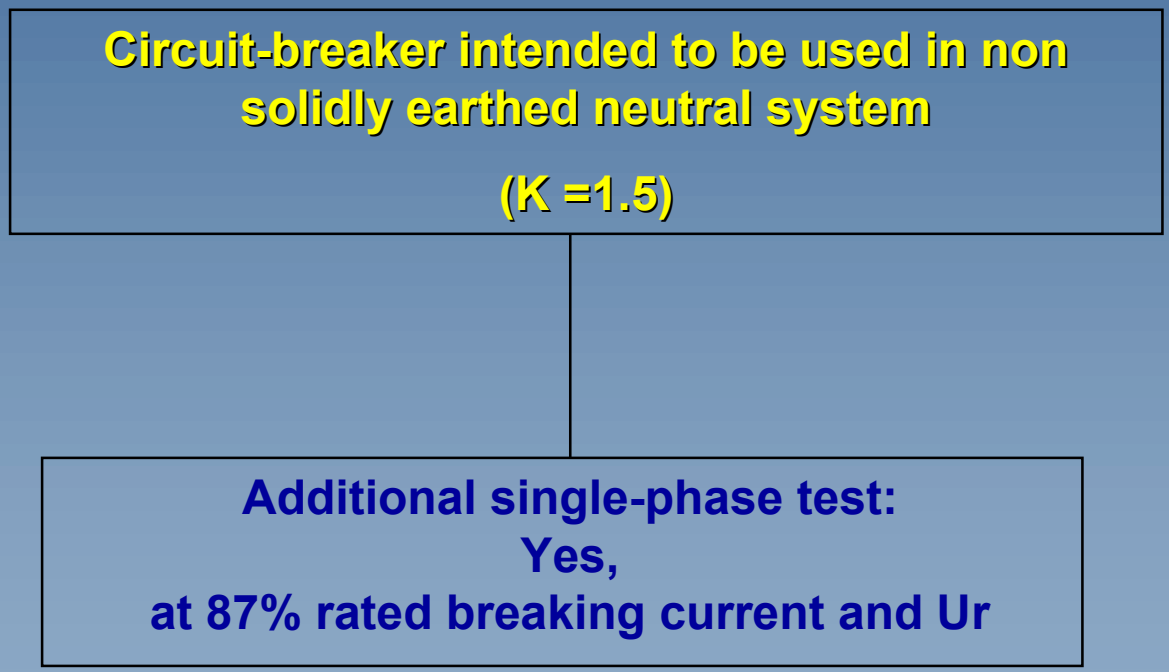


Fig. 45- Necessity of additional single-phase tests and requirements for testing (continued)



6.109 short-line fault tests

- tests performed with the rated operating sequence
  - closing may be at no load
  - L60 is performed if minimum arcing time in L75 is a quarter of a cycle or greater than the minimum checked during L90

6.110 out of phase

- OP1 (30%) O;O;O, is performed only if critical current tests (clause 6.107) were required

- OP2 (100%) CO;O;O

6.111 capacitive current switching tests

- restrike free concept no longer exists
- 2 classes of CBs are defined
  - ➡ C2 (very low probability of restrike)
  - ➡ C1 (low probability of restrike)
- the 2 classes may be applied to both HV and MV systems depending on the applications and system characteristics (user responsibility)

6.111 capacitive current switching tests (continued)

- For circuit-breakers with a non-symmetrical current path, the supply and load connections shall be reversed between the two test-duties

- possibility to cover different ratings of application, if the specified values, considering also the stated tolerances, are equal

6.111 capacitive current switching tests (continued)

- 2 test-duties:
  - test-duty 1: current at 10 to 40% of the cap. switching rating
  - test-duty 2: not less than 100% of the rating
- for class C2, tests are performed on a worn CB after T60 (number of operations, current and arcing times as per T60 with no TRV or just after an actual T60 test-duty)
- for class C1 tests are performed on a circuit-breaker in new conditions

6.111 capacitive current switching tests (continued)

- only 1 source side test circuit condition for both test-duties
- power frequency voltage variation (close-open) less than 5% for test duty 2 (100%), less than 2% for test duty 1 (10-40%)
- voltage factor 1.4 in earthed neutral systems of less than 52 kV for belted cable and for line charging current switching

6.111 capacitive current switching tests - class C2

- test-duty 1: rated minimum functional pressure for operation & interruption (or just rated pressure if sealed for life); only "O" operations

- test-duty 2: rated pressure for operation & interruption; "O" and "CO" or only "CO" depending upon applications

6.111 capacitive current switching tests - class C2 (continued)

- Operations number in three-phase & single-phase tests (test-duty 1 + test-duty 2):
  - 24+24 (lines, cables), 24+80 (banks) if three-phase
  - 48+48 (lines, cables), 48+120 (banks) if single-phase
- tests at minimum arcing time and point-on-wave control (15 or 30 degrees)
- if making is performed separately, the “CO” operation is performed with “C” on no-load

6.111 capacitive current switching tests - class C2 (continued)

- if 1 restrike during a test-duty, the duty shall be completed and repeated without further restrikes (for lines: from 96 to 192 tests if 1-phase, for banks: from 168 to 336 if 1-phase)
- if 1 restrike, application of voltage test as a condition check (6.2.11) + visual inspection
- if sealed for life, application as per 6.2.11 mandatory in any case
- if no restrike, visual inspection only
- possibility to derive a C1 Class from a “failed” C2 Class testing

6.111 capacitive current switching tests - class C1

- test-duties 1 & 2 at rated pressures; test-duty1 only “O”, test-duty 2 only “CO”
- operations number in three-phase & single-phase tests
  - ➡ 24 “O” for test-duty 1
  - ➡ 24 “CO” for test-duty 2
- tests at minimum and maximum arcing times and point-on-wave control (30 degrees)
- if 1 restrike during a test-duty, the duty shall be completed and repeated with no further restrikes (max 96 tests)

6.111 capacitive current switching tests - class C1 (continued)

- if 1 restrike, application of voltage test as a condition check + inspection
- if sealed for life, application as per (6.2.11) mandatory in any case
- if no restrike, visual inspection only

Appendix B: tolerances on test quantities

- Normative
- all tests shall be performed aimed at the required value; max deviations of applied stresses are indicated
- maximum uncertainty in measurements defined as 5%

Appendix C: records and reports of type tests

- normative
- uncertainty of the measurements shall be indicated in the Test Report; reference must be given to procedures existing in the test lab allowing traceability of the measurements

Appendix H: inrush currents of single and back-to-back capacitor banks

- **Informative**

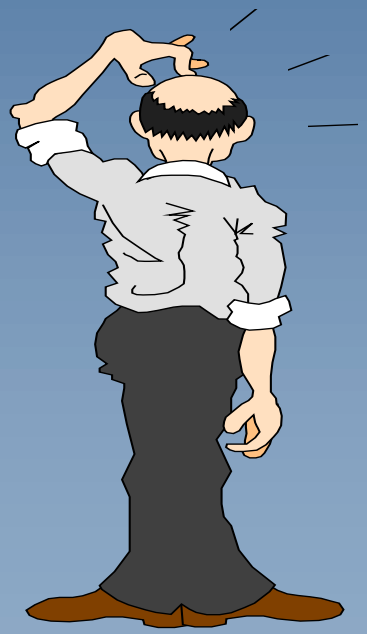
- **the appendix is improved and completed with examples extended also to the back-to-back case**

Appendixes G and I

- Informative
- appendix G: rationale behind introduction of electrical endurance capability of medium voltage circuit-breakers
- appendix I: rationale behind the introduction of time constants (CIGRE WG13.04 TF) alternative to 45 ms

conclusions

- many changes to better represent the actual service conditions
- new testing procedures
- new tests



Extract from STL Guide to IEC 60056, 1987

Testing procedures for combining 50 Hz and 60 Hz rated Power frequency tests

i) **Type Test Certificate of short-circuit performance (sub-clauses 6.5; 6.102 to 6.110)**

ii) **Type Test Certificate of switching performance (sub-clause 6.111)**

i) Type Test Certificate of short-circuit performance (STL Guide)

- **Short-time withstand current and peak withstand current:**

  Peak current 2.6 times the rms value of the ac component, 50Hz or 60Hz power frequency

- **Basic short-circuit**

  ➡**Test duties 1 and 2:**
  50Hz or 60Hz power frequency

  ➡**Test duties 3, 4 (or 4b) and 5:**
  test duties to be performed at both 50Hz and 60Hz power frequency

i) Type Test Certificate of short-circuit performance (continued)

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(STL Guide)

➡Test duties 4a (if relevant):

50Hz or 60Hz power frequency peak making current 2.6 times the rms value of the ac component

➡Single-phase test (if relevant):

50Hz or 60Hz power frequency

- **Short-line fault L90 and L75:**

  Test duties to be performed at both 50Hz and 60Hz power frequency

- **Out-of-phase making and breaking:**

  50Hz or 60Hz power frequency

ii) Type test Certificate of switching performance (STL Guide)

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- **Capacitive current switching:**
  60Hz power frequency (line, cable, single and back-to-back capacitor bank)