### A1 Table 26 – Standard values of prospective transient recovery voltage – Rated voltages of 100 kV and above A1

| Rated voltage | Test-duty | First-pole-to-clear factor | Amplitude factor | First reference voltage | Time | TRV peak value | Time | Time delay | Voltage | Time | Rate-of-rise |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_r$ | | $k_{pp}$ | $k_{af}$ | $u_1$ | $t_1$ | $u_c$ | $t_2$ or $t_3$ | $t_d$ | $u$© | $t$© | $u_1/t_1$ <br> $u_c/t_3$ |
| kV | | p.u. | p.u. | kV | µs | kV | µs | µs | kV | µs | kV/µs |
| 100 | T100 | 1,3 | 1,40 | 80 | 40 | 149 | 160 | 2 (11) | 40 | 22 (31) | 2 |
| | T60 | 1,3 | 1,50 | 80 | 27 | 159 | 162 | 2-8 | 40 | 15-21 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 163 | 33 | 5 | 54 | 16 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 187 | 27 | 4 | 62 | 13 | 7 |
| | OP1-OP2 | 2 | 1,25 | 122 | 80 | 204 | 160-320 | 2-8 | 61 | 42-48 | 1,54 |
| 123 | T100 | 1,3 | 1,40 | 98 | 49 | 183 | 196 | 2 (14) | 49 | 26 (38) | 2 |
| | T60 | 1,3 | 1,50 | 98 | 33 | 196 | 198 | 2-10 | 49 | 18-26 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 201 | 40 | 6 | 67 | 19 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 230 | 33 | 5 | 77 | 16 | 7 |
| | OP1-OP2 | 2 | 1,25 | 151 | 98 | 251 | 196-392 | 2-10 | 75 | 51-59 | 1,54 |
| 145 | T100 | 1,3 | 1,40 | 115 | 58 | 215 | 232 | 2 (16) | 58 | 31 (45) | 2 |
| | T60 | 1,3 | 1,50 | 115 | 38 | 231 | 228 | 2-12 | 58 | 21-31 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 237 | 47 | 7 | 79 | 23 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 272 | 39 | 6 | 91 | 19 | 7 |
| | OP1-OP2 | 2 | 1,25 | 178 | 116 | 296 | 232-464 | 2-12 | 89 | 60-70 | 1,54 |
| 170 | T100 | 1,3 | 1,40 | 135 | 68 | 253 | 272 | 2 (19) | 68 | 36 (53) | 2 |
| | T60 | 1,3 | 1,50 | 135 | 45 | 271 | 270 | 2-14 | 68 | 25-36 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 278 | 56 | 8 | 93 | 27 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 319 | 46 | 7 | 106 | 22 | 7 |
| | OP1-OP2 | 2 | 1,25 | 208 | 136 | 347 | 272-544 | 2-14 | 104 | 70-82 | 1,54 |
| 245 | T100 | 1,3 | 1,40 | 195 | 98 | 364 | 392 | 2 (27) | 98 | 51 (76) | 2 |
| | T60 | 1,3 | 1,50 | 195 | 65 | 390 | 390 | 2-20 | 98 | 35-52 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 400 | 80 | 12 | 133 | 39 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 459 | 66 | 10 | 153 | 32 | 7 |
| | OP1-OP2 | 2 | 1,25 | 300 | 196 | 500 | 392-784 | 2-20 | 150 | 99-117 | 1,54 |
| 300 | T100 | 1,3 | 1,40 | 239 | 119 | 446 | 476 | 2 (33) | 119 | 62 (93) | 2 |
| | T60 | 1,3 | 1,50 | 239 | 80 | 478 | 480 | 2-24 | 119 | 42-64 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 490 | 98 | 15 | 163 | 47 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 562 | 80 | 12 | 187 | 39 | 7 |
| | OP1-OP2 | 2 | 1,25 | 367 | 238 | 612 | 476-952 | 2-24 | 184 | 121-143 | 1,54 |
| 362 | T100 | 1,3 | 1,40 | 288 | 144 | 538 | 576 | 2 (40) | 144 | 74 (112) | 2 |
| | T60 | 1,3 | 1,50 | 288 | 96 | 576 | 576 | 2-29 | 144 | 50-77 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 592 | 118 | 18 | 197 | 57 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 678 | 97 | 15 | 226 | 47 | 7 |
| | OP1-OP2 | 2 | 1,25 | 443 | 288 | 739 | 576-1152 | 2-29 | 222 | 146-173 | 1,54 |

**Table 26** *(continued)*

| Rated voltage | Test-duty | First-pole-to-clear factor | Amplitude factor | First reference voltage | Time | TRV peak value | Time | Time delay | Voltage | Time | Rate-of-rise |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_r$ | | $k_{pp}$ | $k_{af}$ | $u_1$ | $t_1$ | $u_c$ | $t_2$ or $t_3$ | $t_d$ | $u'$ | $t'$ | $u_1/t_1$<br>$u_c/t_3$ |
| kV | | p.u. | p.u. | kV | µs | kV | µs | µs | kV | µs | kV/µs |
| 420 | T100 | 1,3 | 1,40 | 334 | 167 | 624 | 668 | 2 (47) | 167 | 86 (130) | 2 |
| | T60 | 1,3 | 1,50 | 334 | 111 | 669 | 666 | 2-33 | 167 | 58-89 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 687 | 137 | 21 | 229 | 66 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 787 | 112 | 17 | 262 | 54 | 7 |
| | OP1-OP2 | 2 | 1,25 | 514 | 334 | 857 | 668-1336 | 2-33 | 257 | 169-200 | 1,54 |
| 550 | T100 | 1,3 | 1,40 | 438 | 219 | 817 | 876 | 2 (61) | 219 | 111 (171) | 2 |
| | T60 | 1,3 | 1,50 | 438 | 146 | 876 | 876 | 2-44 | 219 | 75-117 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 899 | 180 | 27 | 300 | 87 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 1031 | 147 | 22 | 344 | 71 | 7 |
| | OP1-OP2 | 2 | 1,25 | 674 | 438 | 1123 | 876-1752 | 2-44 | 337 | 221-263 | 1,54 |
| 800 | T100 | 1,3 | 1,40 | 637 | 318 | 1189 | 1272 | 2 (89) | 318 | 161 (248) | 2 |
| | T60 | 1,3 | 1,50 | 637 | 212 | 1274 | 1272 | 2-64 | 318 | 108-170 | 3 |
| | T30 | 1,3 | 1,54 | - | - | 1308 | 262 | 39 | 436 | 126 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 1499 | 214 | 32 | 500 | 103 | 7 |
| | OP1-OP2 | 2 | 1,25 | 980 | 636 | 1633 | 1272-2544 | 2-64 | 490 | 320-382 | 1,54 |
| A1) 1 100 | T100 | 1,2 | 1,50 | 808 | 404 | 1617 | 1212 | 2 (113) | 404 | 204 (315) | 2 |
| | T60 | 1,2 | 1,50 | 808 | 269 | 1617 | 1212 | 2-81 | 404 | 137-216 | 3 |
| | T30 | 1,2 | 1,54 | - | - | 1660 | 332 | 50 | 553 | 161 | 5 |
| | T10 | 1,2 | 1,76 | - | - | 1897 | 271 | 41 | 632 | 131 | 7 |
| | OP1-OP2 | 2 | 1,25 | - | - | 2245 | 1458 | 2-73 | 748 | 488-559 | 1,54 |
| 1 200 | T100 | 1,2 | 1,50 | 882 | 441 | 1764 | 1323 | 2 (123) | 441 | 222 (343) | 2 |
| | T60 | 1,2 | 1,50 | 882 | 294 | 1764 | 1323 | 2-88 | 441 | 149-235 | 3 |
| | T30 | 1,2 | 1,54 | - | - | 1811 | 362 | 54 | 604 | 175 | 5 |
| | T10 | 1,2 | 1,76 | - | - | 2069 | 296 | 44 | 690 | 143 | 7 |
| | OP1-OP2 | 2 | 1,25 | - | - | 2449 | 1590 | 2-80 | 816 | 532-610 | 1,54 (A1 |

A1) NOTE 1 Where two values of times $t_d$ and $t'$ are given for test duty T100 separated by brackets, the time $t_d$ in brackets is the upper limit of the time delay $t_d$ that can be used for test-duty T100 if short-line fault tests are also made. For such cases, the delay line terminates at $t'$ given in brackets. If this is not the case, the lower values of $t_d$ and $t'$ apply.

Where two values of times $t_d$ and $t'$ are given for terminal fault test duties T60 and out-of-phase test duties OP1 and OP2, those indicate the lower and upper limits which should be used for testing. The time delay $t_d$ and the time $t'$ during testing should not be shorter than their respective lower limits and should not be longer than their respective upper limits. (A1

NOTE 2 First-pole-to-clear factor $k_{pp}$= 1,5 is specified to cover transformer-limited fault conditions with $X_0/X_1$ higher than 3,2 (for example non-effectively earthed transformers in effectively earthed neutral systems, or cases of transformers having one side effectively earthed and the other connected to non-effectively earthed neutral systems). The TRV specified covers also cases of 3-phase line faults with effectively earthed neutral systems ($k_{pp}$ = 1,3) where coupling between phases can lead to an amplitude factor of 1,76. Therefore the arcing time window for effectively earthed neutral systems has to be demonstrated for T10 (see 6.102.10.2.2.1).

**Table 27 ± Standard values of prospective transient recovery voltage ± Rated voltages of 100 kV to 170 kV for non-effectively earthed neutral systems ± Representation by four parameters (T100, T60, OP1 and OP2) or two parameters (T30 and T10)**

| Rated voltage | Test-duty | First-pole-to-clear factor | Amplitude factor | First reference voltage | Time | TRV peak value | Time | Time delay | Voltage | Time | Rate-of-rise |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $U_r$ | | $k_{pp}$ | $k_{af}$ | $u_1$ | $t_1$ | $u_c$ | $t_2$ or $t_3$ | $t_d$ | $u$© | $t$© | $u_1/t_1$<br>$u_c/t_3$ |
| kV | | p.u. | p.u. | kV | µs | kV | µs | µs | kV | µs | kV/µs |
| 100 | T100 | 1,5 | 1,40 | 92 | 46 | 171 | 184 | 2 (13) | 46 | 25 (36) | 2 |
| | T60 | 1,5 | 1,50 | 92 | 31 | 184 | 186 | 2-8 | 46 | 15-21 | 3 |
| | T30 | 1,5 | 1,54 | - | - | 189 | 38 | 5 | 63 | 16 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 187 | 27 | 4 | 62 | 13 | 7 |
| | OP1-OP2 | 2,5 | 1,25 | 153 | 92 | 255 | 184-368 | 2-8 | 77 | 42-48 | 1,67 |
| 123 | T100 | 1,5 | 1,40 | 113 | 56 | 211 | 224 | 2 (16) | 56 | 30 (44) | 2 |
| | T60 | 1,5 | 1,50 | 113 | 38 | 226 | 228 | 2-10 | 56 | 18-26 | 3 |
| | T30 | 1,5 | 1,54 | - | - | 232 | 46 | 6 | 77 | 19 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 230 | 33 | 5 | 77 | 16 | 7 |
| | OP1-OP2 | 2,5 | 1,25 | 188 | 112 | 314 | 224-448 | 2-10 | 94 | 51-59 | 1,67 |
| 145 | T100 | 1,5 | 1,40 | 133 | 67 | 249 | 268 | 2 (19) | 67 | 35 (52) | 2 |
| | T60 | 1,5 | 1,50 | 133 | 44 | 266 | 264 | 2-12 | 67 | 21-31 | 3 |
| | T30 | 1,5 | 1,54 | - | - | 273 | 55 | 7 | 91 | 23 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 272 | 39 | 6 | 91 | 19 | 7 |
| | OP1-OP2 | 2,5 | 1,25 | 222 | 134 | 370 | 268-536 | 2-12 | 111 | 60-70 | 1,67 |
| 170 | T100 | 1,5 | 1,40 | 156 | 78 | 291 | 312 | 2 (22) | 78 | 41 (61) | 2 |
| | T60 | 1,5 | 1,50 | 156 | 52 | 312 | 312 | 2-14 | 78 | 25-36 | 3 |
| | T30 | 1,5 | 1,54 | - | - | 321 | 64 | 8 | 107 | 27 | 5 |
| | T10 | 1,5 | 0,9 x 1,7 | - | - | 319 | 46 | 7 | 106 | 22 | 7 |
| | OP1-OP2 | 2,5 | 1,25 | 260 | 156 | 434 | 312-624 | 2-14 | 130 | 70-82 | 1,67 |

A1) NOTE 1 Where two values of times $t_d$ and $t'$ are given for test duty T100 separated by brackets, the time $t_d$ in brackets is the upper limit of the time delay $t_d$ that can be used for test-duty T100 if short-line fault tests are also made. For such cases, the delay line terminates at $t'$ given in brackets. If this is not the case, the lower values of $t_d$ and $t'$ apply.

Where two values of times $t_d$ and $t'$ are given for terminal fault test duties T60 and out-of-phase test duties OP1 and OP2, those indicate the lower and upper limits which should be used for testing. The time delay $t_d$ and the time $t'$ during testing should not be shorter than their respective lower limits and should not be longer than their respective upper limits. (A1

NOTE 2 First-pole-to-clear factor $k_{pp}$ = 1,5 is specified to cover transformer-limited fault conditions with $X_0/X_1$ higher than 3,2 (e.g. non-effectively earthed transformers in effectively earthed neutral systems, or cases of transformers having one side effectively earthed and the other connected to non-effectively earthed neutral systems). The TRV specified covers also cases of 3-phase line faults with effectively earthed neutral systems ($k_{pp}$ = 1,3) where coupling between phases can lead to an amplitude factor of 1,76. Therefore the arcing time window for effectively earthed neutral systems has to be demonstrated for T10 (see 6.102.10.2.2.1).

#### 6.104.7 Power frequency recovery voltage

The power frequency recovery voltage of the test circuit may be stated as a percentage of the power frequency recovery voltage specified below. It shall not be less than 95 % of the specified value and shall be maintained for at least 0,3 s.

For synthetic test circuits, details and tolerances are given in IEC 62271-101.

For the basic short-circuit test-duties of 6.106, the power frequency recovery voltage shall be as follows, subject to the 95 % minimum stated above:

a) For three-phase tests on a three-pole circuit-breaker, the average value of the power frequency recovery voltage shall be equal to the rated voltage $U_r$ of the circuit-breaker divided by $\sqrt{3}$ .

   The power frequency recovery voltage of any pole should not deviate by more than 20 % from the average value at the end of the time for which it is maintained.

   For an effectively earthed neutral system, it shall be proved that the insufficient build-up of dielectric strength in one pole will not lead to prolonged arcing and possible failure. The single-phase test (6.108) shall be applied as a demonstration.

b) A1⟩ For single-phase tests on a three-pole circuit-breaker, the power frequency recovery voltage shall be equal to the product of the phase-to-earth value $U_r/\sqrt{3}$ and the first-pole-to-clear factor (1,2 or 1,3 or 1,5); the power frequency recovery voltage may be reduced to $U_r/\sqrt{3}$ after an interval of one cycle of rated frequency. ⟨A1

c) For a single-pole circuit-breaker, the power frequency recovery voltage shall be equal to the rated voltage $U_r$ of the circuit-breaker.

The power frequency recovery voltage shall be measured between terminals of a pole in each phase of the test circuit. Its r.m.s. value shall be determined on the oscillogram within the time interval of one half-cycle and one cycle of test frequency after final arc extinction, as indicated in Figure 44. The vertical distance ($V_1$, $V_2$ and $V_3$ respectively) between the peak of the second half-wave and the straight line drawn between the respective peaks of the preceding and succeeding half-waves shall be measured, and this, when divided by $2\sqrt{2}$ and multiplied by the appropriate calibration factor, gives the r.m.s. value of the power frequency recovery voltage recorded.

### 6.105 Short-circuit test procedure

#### 6.105.1 Time interval between tests

The basic short-circuit tests and, if applicable, short-line fault tests, consist of the series of test-duties specified in 6.106 and 6.109.

The time intervals between individual operations of a test sequence shall be the time intervals of the rated operating sequence of the circuit-breaker, given in 4.104, A1⟩ but taking into account 6.105.3, ⟨A1 subject to the following provision:

Due to test plant limitations, it may not be possible to achieve the 15 s, 1 min or 3 min time interval of the rated operating sequence. In such cases the time interval may be extended to 10 min without the test being disqualified; time intervals even longer than 10 min may be required. Prolonged time intervals shall not be due to faulty operation of the circuit-breaker. The actual time interval between operations shall be stated in the test report. If it is longer than 10 min the reason for such a delay shall be recorded in the test report.

For circuit-breakers with a rated operating sequence of O – $t$ – CO – $t$©– CO rated for different time intervals of $t'$, the test may be performed with the shortest time interval $t$© This test is considered to cover all rated operating sequences with longer $t$©time intervals. This makes it possible to combine the testing for rated operating sequences according to 4.104 a) and b). The actual time interval shall be recorded.

#### 6.105.2 Application of auxiliary power to the opening release ± Breaking tests

Auxiliary power shall be applied to the opening release after the initiation of the short-circuit, but when due to test plant limitations this is impracticable the power may be applied before the initiation of the short-circuit (with the limitation that contacts shall not start to move before the initiation of the short-circuit).

#### 6.105.3 Application of auxiliary power to the opening release ± Make-break tests

A1 In make-break tests the auxiliary power shall not be applied to the opening release before the circuit-breaker has reached the closed position. In the close-open operations of the short-circuit test-duties the power shall not be applied until at least one half-cycle has elapsed from the instant of contact touch. The close-open time shall remain as close as possible to the minimum close-open time (see Note of 3.7.143), but it is permissible to delay the circuit-breaker opening such that the d.c. component at contact separation is within the permissible limits. A1

#### 6.105.4 Latching on short-circuit

A circuit-breaker is latched when the main current-carrying contacts have achieved a stationary, fully engaged position at closing and this position is maintained until intentionally released, either mechanically or electrically. Unless the circuit-breaker is fitted with a making current release, or equivalent device, it shall be verified that it latches satisfactorily without undue hesitation when there is negligible decrement of the a.c. component of the current during the closing period.

The ability of the circuit-breaker to latch on short-circuit making current may be verified in test-duty T100s (see 6.106.4) or in the verification test for making (see 6.102.4.1). During this test the following applies:

– for three-phase tests on a three-pole circuit-breaker, the closing angle should be chosen in order to stress the pole most remote from the drive with the peak making current;
– if a single-phase test is carried out, care should be taken to stress the pole most remote from the mechanism in the same way as during a three-phase test in respect to applied voltage across the pole and current through the pole.

If the characteristics of the test plant are such that it is impossible to carry out test-duty T100s within the specified limits of the applied voltage stated in 6.104.1, the test shall be repeated at reduced voltage using a test circuit which gives the rated short-circuit making current, with negligible decrement of the a.c. component.

Several methods may be used to establish whether a circuit-breaker has closed and latched, for example:

– by proper recording the auxiliary contacts or the contact travel;
– by visually checking the latching position after the performance of the making test;
– by recording the action of the device in order to detect latching (for example a micro-switch suitably fitted to the mechanism).

The method employed to prove satisfactory latching shall be recorded in the test report.

### 6.106 Basic short-circuit test-duties

The basic short-circuit test series shall consist of test-duties T10, T30, T60, T100s and T100a, as specified below.

The breaking current may deviate from the specified values by not more than 20 % of the specified values for test-duties T10 and T30 and by not more than 10 % for test-duty T60.

The peak short-circuit current during the breaking-current tests of test-duties T100s, T100s(b) and T100a shall not exceed 110 % of the rated short-circuit making current of the circuit-breaker.

NOTE In the cases explained in 6.106.4, it may be necessary to separate the making and breaking tests of test-duty T100s. In this case, the part consisting of the making operations is designated T100s(a) and the part consisting of the breaking operations is designated T100s(b).

For test-duties T10, T30 and T60, it is permissible to omit the making operation before any breaking operation for convenience in testing. The time intervals between the individual breaking operations, shall be the time intervals of the rated operating sequence of the circuit-breaker (see 6.105.1).

### 6.106.1 Test-duty T10

Test-duty T10 consists of the rated operating sequence at 10 % of the rated short-circuit breaking current with a d.c. component at contact separation not exceeding 20 % and a transient and power frequency recovery voltage as specified in 6.104.5.5 and 6.104.7 (see also Tables 24, 25, 26 and 27).

### 6.106.2 Test-duty T30

Test-duty T30 consists of the rated operating sequence at 30 % of the rated short-circuit breaking current with a d.c. component at contact separation not exceeding 20 % and a transient and power frequency recovery voltage as specified in 6.104.5.4 and 6.104.7 (see also Tables 24, 25, 26 and 27).

### 6.106.3 Test-duty T60

Test-duty T60 consists of the rated operating sequence at 60 % of the rated short-circuit breaking current with a d.c. component at contact separation not exceeding 20 % and a transient and power frequency recovery voltage as specified in 6.104.5.3 and 6.104.7 (see also Tables 24, 25, 26 and 27).

### 6.106.4 Test-duty T100s

Test-duty T100s consists of the rated operating sequence at 100 % of the rated short-circuit breaking current taking account of 6.104.3, and with a transient and power frequency recovery voltage as specified in 6.104.7 (see also Tables 24, 25, 26 and 27) and 100 % of the rated short-circuit making current taking account of 6.104.2 and an applied voltage as specified in 6.104.1.

For this test-duty, the percentage of the d.c. component at contact separation shall not exceed 20 % of the a.c. component.

When making single-phase tests on one pole of a three-pole circuit-breaker, or when the characteristics of the test plant are such that it is impossible to carry out test-duty T100s within the specified limits of applied voltage in 6.104.1, making current in 6.104.2, breaking current in 6.104.3 and transient and power frequency recovery voltages in 6.104.5.2 and 6.104.7 taking account also of 6.105.3 and 6.105.4 the making and breaking tests in test-duty T100s may be made separately. The short-circuit current in the separate making operations shall be maintained for an interval of at least 100 ms. The test procedures are as follows.

#### 6.106.4.1 Time constant of the d.c. component of the test circuit equal to the specified value

Where the time constant of the d.c. component of the test circuit is equal to the specified value as defined by 4.101.2, the alternative for performing test-duty T100s described above is as follows:

a) making tests, test-duty T100s(a)

The sequence C – $t'$ – C or C – $t''$ – C shall be carried out for the rated operating sequence O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO respectively, with the first closing operation against a symmetrical current equal to the rated short-circuit breaking current and the second closing operation against the rated short-circuit making current according to 6.104.2. The first closing operation shall be carried out at the applied voltage specified in 6.104.1;

b) breaking tests, test-duty T100s(b)

These closing operations detailed in a) shall be followed by O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO for the rated operating sequence O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO respectively, at 100 % of the rated short-circuit breaking current and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7.

During this test sequence, the following applies:

– no maintenance is allowed between a) and b);
– the second closing operation of a) can be omitted, provided that during b) one of the closing operations is such that the rated short-circuit making current is achieved;
– for synthetic testing IEC 62271-101 applies.

#### 6.106.4.2 Time constant of the d.c. component of the test circuit less than the specified value

Where the time constant of the d.c. component of the test circuit is less than the specified value as defined by 4.101.2, the alternative for performing test-duty T100s described above is as follows:

a) making tests, test-duty T100s(a)

A single closing operation against the rated short-circuit making current according to 6.104.2 shall be performed. This closing operation may be performed at reduced voltage with the limitations stated in 6.104.2;

b) breaking tests, test-duty T100s(b)

This closing operation shall be followed by O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO for the rated operating sequence O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO respectively, at 100 % of the rated short-circuit breaking current, at the applied voltage specified in 6.104.1 and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. In this second part, one of the closing operations shall be such that it closes against a symmetrical current equal to the rated short-circuit breaking current.

NOTE Due to the smaller time constant of the d.c. component of the test circuit with respect to the specified value used for the rated short-circuit breaking current, the symmetrical value of the current during a) will need to be greater than the rated value. During b), for the same reason, the current peak, already demonstrated during a), will be smaller than the rated short-circuit making current.

During this test sequence the following applies:

– no maintenance is allowed between a) and b);
– for synthetic testing IEC 62271-101 applies.

### 6.106.4.3 Time constant of the d.c. component of the test circuit greater than the specified value

Where the time constant of the d.c. component of the test circuit is greater than the specified value as defined by 4.101.2, the alternative for performing test-duty T100s described above is as follows:

a) The sequence O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO shall be carried out for rated operating sequence O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO respectively, at 100 % of the rated short-circuit breaking current, at the applied voltage specified in 6.104.1 and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. During this sequence, one of the closing operations shall be such that the circuit-breaker closes against a symmetrical current equal to the rated short-circuit breaking current, and the other one against a full asymmetrical current. Due to the larger time constant of the d.c. component of the test circuit with respect to the specified value as per 4.101.2, the current peak during the asymmetrical closing will be larger than the rated short-circuit making current. Therefore, the closing operation may be controlled by use of point on wave control to obtain the required rated short-circuit making current. The performance of the test procedure a) is, however, subject to the consent of the manufacturer;

NOTE 1 Because of the larger peak of the current during the asymmetrical closing, a separate closing operation against the rated short-circuit making current according to 6.104.2 is not required.

b) Alternatively the above sequence a) can be performed with the first closing operation against a symmetrical current equal to the rated short-circuit breaking current and the second closing operation at no load, i.e. O – $t$ – CO – $t'$ – O or CO – $t''$ – O for the rated operating sequence O – $t$ – CO – $t'$ – CO or CO – $t''$ – CO respectively, at 100 % of the rated short-circuit breaking current, at the applied voltage specified in 6.104.1 and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7.

   In this case evidence of the ability of the circuit-breaker to perform the rated operating sequence will be demonstrated by repeating the test sequence a), with relevant requirements, and with a symmetrical current smaller than the rated short-circuit breaking current in such a manner that the rated short-circuit making current is obtained in one of the closing operations. During this repeated duty, the closing operations may be performed at reduced voltage with the limitations stated in 6.104.2.

NOTE 2 Since the ability of the circuit-breaker to close against the rated short-circuit making current is proven during the repeated duty, a separate closing operation against the rated short-circuit making current according to 6.104.2 is not required.

During this test sequence the following applies:

– where sequence b) is adopted, maintenance before repetition of the rated operating sequence is permitted;
– for synthetic testing IEC 62271-101 applies.

### 6.106.4.4 Significant decay of the a.c. component of the test circuit

Where the decay of the a.c. component of the test circuit is significant, it may be impossible to test the rated operating sequence without overstressing the circuit-breaker extensively. In such cases it is permitted to split the making and the breaking tests in test-duty T100s as follows, providing that the time constant of the a.c. component of the test circuit, corresponding to the decay of the a.c. component, is at least three times longer than the specified d.c. time constant of the system the circuit-breaker under test is intended to be used for:

a) Making tests, test-duty T100s(a)

   C – $t'$ – C in case of a rated operating sequence O – $t$ – CO – $t'$ – CO,

   C – $t''$ – C in case of a rated operating sequence CO – $t''$ – CO

   with the making current as specified in 6.104.2 and the applied voltage as specified in 6.104.1. For the time interval between the individual tests 6.105.1 applies.

b) Breaking tests, test-duty T100s(b)

The testing procedure depends upon the rated operating sequence.

– In case of a rated operating sequence O – $t$ – CO – $t'$ – CO, the closing operations of test-duty T100s(a) shall be followed by the testing sequence O – $t$ – CO – $t'$ – CO at 100 % of the rated short-circuit breaking current as specified in 6.104.3 and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. For the time interval between the individual tests 6.105.1 applies.

  The operating sequence O – $t$ – CO (initial part of the rated operating sequence O – $t$ – CO – $t'$ – CO) may be demonstrated by two tests. In this case the following applies:

  In the first test the first opening operation shall be tested at 100 % of the rated short-circuit breaking current as specified in 6.104.3 and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. The subsequent closing and opening operations shall be tested with making current and applied voltage or breaking current and transient and power frequency recovery voltage respectively as close as possible to the values specified for test-duty T100s.

  In the second test an additional CO operating cycle shall be performed with the opening operation at 100 % of the rated short-circuit current as specified in 6.104.3 and with the transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. This CO operating cycle shall be preceded by a no-load opening operation to complete the operating sequence O – $t$ – CO. For the C operation the provisions of 6.104.1 and 6.104.2 may be omitted, however, the making current and the applied voltage shall meet the specified values as close as possible.

  The operating cycle CO (last part of the rated operating sequence O – $t$ – CO – $t'$ – CO) is demonstrated by another CO operation where the opening operation shall be performed at 100 % of the rated short-circuit current as specified in 6.104.3 and with the transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. For the C operation the provisions of 6.104.1 and 6.104.2 may be omitted, however, the making current and the applied voltage shall meet the specified values as close as possible.

– In case of a rated operating sequence CO – $t''$ – CO the closing operations of test-duty T100s(a) shall be followed by the testing sequence CO – $t''$ – CO at 100 % of the rated short-circuit breaking current as specified in 6.104.3 and with a transient and power frequency recovery voltage as specified in 6.104.5.2 and 6.104.7. For the time interval between the individual tests 6.105.1 applies. For the two C operations the provisions of 6.104.1 and 6.104.2 may be omitted, however, the making current and the applied voltage shall meet the specified values as close as possible.

– Where a closing operation in test-duty T100s(b) fulfils the requirements given in a) above, the respective closing operation in test-duty T100s(a) may be omitted. In order to not overstress the circuit-breaker controlled closing may be necessary in test-duty T100s(b). Where needed an auxiliary circuit-breaker may be used. If due to inconsistency of the opening or the closing time the specified test values cannot be met, it is allowed to supply the releases at their maximum operating voltage; in this case the provisions of 6.102.3.1 as to the supply voltage of closing and opening devices are omitted.

No maintenance is allowed between the test-duties T100s(a) and T100s(b). When this testing procedure results in actual stresses exceeding the limits specified in Table B.1 the consent of the manufacturer is necessary.

### 6.106.5 Test-duty T100a

Test-duty T100a is only applicable when the minimum opening time $T_{op}$ of the circuit-breaker, as stated by the manufacturer, plus the relay time is such that the d.c. component at the instant of contact separation is greater than 20 %. The d.c. component at contact separation is determined by the following equation:

$$\%\,dc = 100 \times e^{\frac{-(T_{op}+T_r)}{\tau}}$$

where

| | |
|---|---|
| % dc | percentage of d.c. component at contact separation; |
| $T_{op}$ | minimum opening time declared by the manufacturer; |
| $T_r$ | relay time (0,5 cycle; 10 ms for 50 Hz and 8,3 ms for 60 Hz); |
| $\tau$ | d.c. time constant of the rated short circuit current (45 ms, 60 ms, 75 ms or 120 ms; see 4.101.2). |

Test-duty T100a consists of three opening operations at intervals $t'$ in accordance with 6.105.1 at 100 % of the rated short-circuit breaking current with the required asymmetry criteria given in 6.106.6 and the prospective transient and power frequency recovery voltages as specified in 6.104.5.2 and 6.104.7 (see also 6.104.6 and Annex P; for table references see 6.104.5.2).

Moreover, depending on the actual test parameters, an individual test may cover several ratings if the applicable asymmetry criteria for each rating with their associated tolerances are met (for details see I.2.1).

NOTE The change of an opening or a closing release does not constitute an alternative operating mechanism. If the opening time of the circuit-breaker is reduced due exclusively, to the use of a faster acting release, it should be checked whether the percentage of the d.c. component, stated in Tables 15 through 22 for this release, is still covered by the actual tests. If a higher percentage of the d.c. component is needed, it is sufficient to repeat test-duty T100a only, the rest of the type tests remains valid, provided the release is tested to the relevant subclauses and standards.

### 6.106.6 Asymmetry criteria

The following asymmetry criteria shall be fulfilled when performing T100a.

- last current loop amplitude;
- last current loop duration;
- d.c. component at current zero (parameter controlling the d$i$/d$t$ and the following TRV parameters).

Several test parameters shall be simultaneously reproduced during T100a in order to obtain a valid interruption. These criteria are different depending on, whether the tests are performed with a direct test circuit or with a synthetic test method.

The prospective percentage of d.c. component at current zero shall be either:

- measured from a prospective current calibration test or;
- calculated from the percentage of d.c. component at contact separation during the test and from the d.c. time constant of the test circuit. The d.c. time constant of the test circuit shall be measured from the oscillogram of a prospective current calibration test in the region corresponding to the instant of contact separation.

The instant of initiation of the short-circuit during the actual tests and during the prospective current calibration test shall be comparable (within ±10°).

For the prospective current calibration test, it is necessary to extend the duration of the current by at least an extra current loop in order to be able to measure accurately the prospective d.c. component at the predicted current zero.

NOTE The percentage of d.c. component at current zero during actual tests can also be calculated by the following equation:

$$p_0 = p_{cs} \times e^{\left(-\frac{t_a}{\tau}\right)}$$

where

$p_o$ is the d.c. component at current zero during the actual test;

$p_{cs}$ is the d.c. component at contact separation measured during the actual test;

$t_a$ is the arcing time;

$\tau$ is the d.c. time constant of the test circuit measured during the prospective current calibration test.

The applicable asymmetry criteria for each particular test method are described in 6.106.6.1 and 6.106.6.2.

### 6.106.6.1 Three-phase tests

#### 6.106.6.1.1 Test current amplitude and last current loop duration

The criteria given in 6.102.10.2.1.2 b) for single-phase tests apply also to the phase having the maximum d.c. component (major loop or extended major loop). The resultant amplitude and duration of the current loops in the other two phases are automatically met within reasonable tolerances.

NOTE The prospective duration of the extended major loop should be determined from the prospective current calibration test. The duration of the major current loop during the prospective current calibration test that will be extended during the actual breaking test should be within the limits given in 6.102.10.2.1.2 b). If the duration of that loop meets the criteria given in 6.102.10.2.1.2 b) then the duration of the extended major loop during the actual breaking test is automatically met within reasonable tolerances.

The circuit-breaker may modify the last current loop shape beyond the criteria given in 6.102.10.2.1.2 b). In such cases, the prospective current loop shape shall be determined from a previous prospective current calibration test. The test is considered to be valid if the moment of current initiation is within ±10° of that obtained during the prospective current calibration test.

#### 6.106.6.1.2 Percentage of d.c. component at current zero

The percentage of the d.c. component at current zero for the phase having the highest d.c. component shall be equal to or less than (see Note 1) those given in Tables 15 through 22. The resultant d.c. component in the two other phases are automatically met.

For the current calibration test, it is recommended to extend the duration of the current by at least an extra current loop in order to be able to measure accurately the prospective d.c. component at the predicted current zero.

If the percentage of the d.c. component at current zero in one opening operation is higher (see Note 1) than the specified value, the circuit-breaker should be considered to have satisfied test-duty T100a provided that the average of the percentage of d.c. component at current zero of the opening operations of the test-duty does not exceed the specified percentage of the d.c. component at current zero. In any one test of the test-duty, the d.c. component at current zero shall not be higher than 110 % of the specified value.

NOTE 1 The d.c. component at current zero is controlling the resultant $di/dt$ and TRV. A lower d.c. component at current zero gives higher $di/dt$ and higher TRV amplitude and $du/dt$. A tolerance of –5 % is given in Annex B.

NOTE 2 The d.c. component at current zero can be difficult to be measured with sufficient accuracy since the circuit-breaker may modify the last loop current shape. The d.c. component at current zero can be determined with the results obtained from a previous prospective current calibration test. The test is considered to be valid if the moment of current initiation is within ±10° of that obtained during the prospective current calibration test.

### 6.106.6.2 Single-phase tests

#### 6.106.6.2.1 Test current amplitude and last current loop duration

The criteria given in 6.102.10.2.1.2 b) shall be met.

The circuit-breaker may modify the last current loop shape beyond the criteria given in 6.102.10.2.1.2 b). In such cases, the prospective current loop shape shall be determined from