

Australian Standard™

**High voltage switchgear and controlgear
Part 308: Guide for asymmetrical short-
circuit breaking test duty T100a**



This Australian Standard was prepared by Committee EL-007, Power Switchgear. It was approved on behalf of the Council of Standards Australia on 20 July 2005.
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**High voltage switchgear and controlgear
Part 308: Guide for asymmetrical short-
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PREFACE

This Standard was prepared by the Standards Australia Committee EL-007, Power Switchgear.

The objective of this Standard is to provide information and test procedures for type testing of circuit breakers relevant to short-circuit breaking performance during asymmetrical test duty (T100a) as required by AS 62271.100.

This Standard is identical with, and has been reproduced from IEC 62271-308, Ed.1.0 (2002), *High-voltage switchgear and controlgear – Part 308: Guide for asymmetrical short-circuit breaking test duty T100a*.

Common numbering of standards falling under the responsibility of EL-007

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AS 62271 Series	High-voltage switchgear and controlgear	Old AS Number
1	Common specifications	*AS 2650
100*	High-voltage alternating current circuit-breakers	AS 2006
102*	Alternating current disconnectors and earthing switches	AS 1306 and AS 4298
103	Switches for rated voltages above 1 kV and less than 52 kV	*AS/NZS 60265.1
104	Switches for rated voltages of 52 kV and above	*AS 60265.2
106	Alternating current contactors and contactor based motor-starters	*AS 2024
110	Inductive load switching	*AS 4372
200*	AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	AS 2086
201	AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV up to and including 38 kV	*AS 2264
202	High-voltage/low-voltage prefabricated substations	*AS 61330
203*	Gas-insulated metal enclosed switchgear for rated voltages above 52 kV	AS 2263
301*	Dimensional standardization of terminals	AS 2395
303	Use and handling of sulphur hexafluoride (SF ₆) in high-voltage switchgear and controlgear	*AS 2791
304	Additional requirements for enclosed switchgear and controlgear from 1 kV to 72,5 kV to be used in severe climatic conditions	*AS 4243
308*	Guide for asymmetrical short-circuit breaking test duty T100a	—

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- (a) Its number does not appear on each page of text and its identity is shown only on the cover and title page.
- (b) In the source text 'IEC 62271-308' should read 'AS 62271.308'.
- (c) A full point should be substituted for a comma when referring to a decimal marker.

The terms 'normative' and 'informative' are used to define the application of the annex to which they apply. A normative annex is an integral part of a standard, whereas an informative annex is only for information and guidance.

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STANDARDS AUSTRALIA

Australia Standard

High voltage switchgear and controlgear

Part 308: Guide for asymmetrical short-circuit breaking test duty T100a

1 General

1.1 Scope

This technical report contains information and test procedures for type testing of circuit-breakers relevant to short-circuit breaking performance during asymmetrical test duty (T100a) as required by IEC 62271-100.

This technical report covers all possible testing cases, i.e. single-phase, three-phase, direct tests, synthetic tests, first pole-to-clear factors 1,3 and 1,5.

IEC 62271-100 testing procedures for short-circuit breaking performance during asymmetrical test duty (T100a) are valid only when the d.c. time constant of the test circuit is equal or close to the rated d.c. time constant of the rated short-circuit breaking current.

This technical report can be generally applied, and it gives rules to be followed when the d.c. time constant of the test circuit is equal to, or different from, the rated d.c. time constant of the rated short-circuit breaking current. Tolerances on the test parameters are also given in order to allow that more than one rated d.c. time constant with a single test series be covered. This concept of asymmetry equivalence may also help the user in establishing equivalence between system needs and the rating requirements.

When the d.c. time constant of the test circuit is different from the rated d.c. time constant of the rated short-circuit breaking current, the testing procedures given in IEC 62271-100 cannot be applied directly and the testing procedure given in this technical report should be followed. The procedures given in this guide are also fully valid when the d.c. time constant of the test circuit is equal to the rated d.c. time constant of the rated short-circuit breaking current.

1.2 Reference documents

References to international standards that are struck through in this clause are replaced by references to Australian Standards that are listed immediately thereafter and identified by shading. Any Australian Standard that is identical to the International Standard it replaces is identified as such.

~~IEC 62271-100:2001, High voltage switchgear and controlgear — Part 100: High voltage alternating current circuit-breakers~~

AS 62271.100, High-voltage switchgear and controlgear, Part 100: High-voltage alternating-current circuit-breakers

IEC 60427:2000, Synthetic testing of high-voltage alternating current circuit-breakers

2 Definitions

2.1

minimum clearing time

sum of the minimum opening time, minimum relay time (0,5 cycle), and the minimum arcing time of the first pole-to-clear, during test duty T100a only, as declared by the manufacturer. This definition should be used only for the determination of the test parameters during short-circuit breaking tests according to test duty T100a

NOTE 1 The minimum clearing time obtained during the tests should not be lower than the value declared by the manufacturer. Prior to the tests, the minimum opening time should be measured at maximum trip coil voltage, maximum pressure for operation and minimum pressure for interruption. If the minimum opening time measured prior to the tests is lower than the one declared by the manufacturer then the minimum clearing time declared by the manufacturer should be reviewed accordingly. A value equal to, or lower than, the revised value should be used for the determination of the required test parameters.

NOTE 2 This definition assumes that the minimum clearing time obtained with the minimum pressure for interruption is similar to the one that would be obtained with the maximum pressure for interruption. The minimum clearing time is determined, for practical considerations, by using the minimum pressure for interruption. Normally, the minimum clearing time is obtained with the maximum pressure for interruption. If such pressure condition is giving a minimum clearing time such that the minimum clearing time range applicable (as given in tables 1a to 2d) for tests is different than the one obtained at minimum pressure for interruption, then it is permissible to verify the minimum clearing time by using the maximum pressure for interruption.

3 Ratings

3.1 DC time constant of the rated short-circuit breaking current

This clause has been introduced as an alternative to 4.101.2 of IEC 62271-100 since the concept of percentage of asymmetry at contact separation is only valid if the d.c. time constant of the actual short-circuit current (in service or during tests) is equal or close to the rated d.c. time constant of the rated short-circuit breaking current.

The standard d.c. time constant is 45 ms. The following are special case d.c. time constants, related to the rated voltage of the circuit-breaker:

- 120 ms for rated voltages up to and including 52 kV;
- 60 ms for rated voltages from 72,5 kV up to and including 420 kV;
- 75 ms for rated voltages 550 kV and above.

These special case time constants recognize that the standard value may be inadequate in some systems. They are provided as unified values for such special system needs, taking into account the characteristics of the different ranges of rated voltage, for example, their particular system structures, design of lines, etc.

NOTE 1 In addition, some applications may require even higher values, for example if a circuit-breaker is close to generators. In these circumstances, the required d.c. time constant and any additional test requirements should be specified in the inquiry.

NOTE 2 More detailed information on the use of the standard time constant and the special case time constants is given in the explanatory note I.2.1 of IEC 62271-100.

4 Test procedure

This technical report should be used in conjunction with IEC 62271-100.

4.1 Demonstration of arcing times during three-phase tests for test-duty T100a

This subclause has been introduced as an alternative to 6.102.10.1.2 of IEC 62271-100 since the concept of percentage of asymmetry at contact separation is only valid if the d.c. time constant of the actual short-circuit current (in service or during tests) is equal or close to the rated d.c. time constant of the rated short-circuit breaking current.

See 6.106.5 of IEC 62271-100.

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Since the severity of the tests for this duty can vary widely depending on the moment of contact separation, a procedure has been developed in order to arrive at realistic stresses on the circuit-breaker under test. The intention is to arrive at a series of three valid tests. The initiation of the short-circuit changes 60° between tests in order to transfer the required asymmetry criteria from phase to phase.

The intention is to achieve a series of three valid tests and the duty is considered satisfactory if the following conditions are met.

- a) One operation where in the first pole-to-clear arc extinction occurs at the end of a major current loop with the longest possible arc duration and with the required asymmetry criteria as given in clause 5 in order to comply with the TRV requirements.

NOTE Some circuit-breakers will not clear at the end of a major loop. Arcing then continues during the subsequent minor current loop and becomes a last pole-to-clear. However, this test is considered valid if, during a subsequent test, it is proven that the longest possible arc-duration was achieved.

- b) One operation where in one of the last poles-to-clear arc extinction occurs at the end of a major extended current loop with the longest possible arc duration and with the required asymmetry criteria as given in clause 5.

A test where the circuit-breaker clears at the end of a reduced major current loop or a minor loop in the phase meeting the asymmetry criteria is invalid (with the exception of the situation described in the note to a) above.

- c) One operation with the required asymmetry criteria as given in clause 5 to prove the validity of test conditions outlined in a) and b) above.

The sequence of the tests is of no consequence as long as the series of tests fulfils the test conditions mentioned in a), b) and c).

If it is not possible to achieve the above requirements because of the characteristics of the circuit-breaker, the number of operations should be extended to prove that, in this particular case, the most severe test conditions have been achieved. The circuit-breaker should not be subjected to more than six opening operations when attempting to meet the above requirements.

The circuit-breaker may be reconditioned with renewable parts before the extended operations (see 6.102.9.5 of IEC 62271-100). An additional test sample can also be used for the extended operations.

The procedure is as follows.

For the first valid operation the initiation of short circuit and the setting of the control of the tripping impulse should be such that

- the required asymmetry criteria are obtained in one phase;
- arc extinction occurs in the phase with the required asymmetry criteria after a major loop (or the greatest possible part of that loop) in the case of the first phase-to-clear or after a major extended loop (or the greatest possible part of that loop) in the case of one of the last phases-to-clear.

For the second valid operation, the initiation of short-circuit should be advanced by 60° and the setting of the control of the tripping impulse should be as follows:

- if the first operation was valid because the arc extinction occurred in the phase with the required asymmetry criteria after a major loop, the setting of the control of the tripping impulse should be advanced by approximately 130° with respect to the first valid operation;
- if the first operation was valid because the arc extinction occurred in the phase with the required asymmetry criteria after a major extended loop, then the setting of the control of the tripping impulse should be advanced by approximately 25° with respect to the first valid operation.

For the third operation, the procedure for the second operation may be repeated. The initiation of short circuit should be advanced by 60° with respect to the second operation and the setting of the control of the tripping impulse should be as follows:

- if the second operation was valid because the arc extinction occurred in the phase with the required asymmetry criteria after a major loop, the setting of the control of the tripping impulse should be advanced by approximately 130° with respect to the second operation;
- if the second operation was valid because the arc extinction occurred in the phase with the required asymmetry criteria after a major extended loop, the setting of the control of the tripping impulse should be advanced by approximately 25° with respect to the second operation.

If the characteristics of the circuit-breaker are not constant it may be necessary to use other procedures to achieve the three valid operations described above.

This test procedure is applicable to non-solidly earthed neutral systems (first pole-to-clear factor 1,5) and to solidly earthed neutral systems (first pole-to-clear factor 1,3).

Figures 1 and 2 give graphical examples of the three valid breaking operations.

4.2 Demonstration of arcing times during single-phase tests in substitution of three-phase conditions in a non-solidly earthed neutral system (first pole-to-clear factor 1,5) for test-duty T100a

This subclause has been introduced as an alternative to 6.102.10.2.1.2 of IEC 62271-100 since the concept of percentage of asymmetry at contact separation is only valid if the d.c. time constant of the actual short-circuit current (in service or during tests) is equal or close to the rated d.c. time constant of the rated short-circuit breaking current.

See 6.106.5 of IEC 62271-100.

a) Arcing times

The first valid breaking operation should demonstrate interruption at the end of the minor loop with an arc duration as small as possible. The resultant arc duration is known in this technical report as the minimum arcing time ($t_{\text{arc min}}$). This is established when any extra delay in the contact separation with respect to the current waveform results in interruption at the next current zero which will be at the end of a major loop. This minimum arc duration is found by changing the setting of the tripping impulse by steps of approximately 18° ($d\alpha$).

NOTE 1 Some circuit-breakers may exhibit a shorter minimum arcing time on the major loop than on the minor loop. In such cases, the minimum arcing time obtained on the major loop should be used as the minimum arcing time. For such cases, the manufacturer should demonstrate this behaviour by some additional tests by using the same methodology as the described above for the minor loop. If additional tests are necessary, reconditioning of the circuit-breaker according to 6.102.9.5 of IEC 62271-100 or the use of an additional test sample according to 6.102.2 of IEC 62271-100 are permitted

The second valid breaking operation should demonstrate interruption with the maximum arcing time. The required maximum arcing time is known in this technical report as $t_{\text{arc max}}$ and is determined by

$$t_{\text{arc max}} \geq t_{\text{arc min}} + \Delta t_1 - T \times \frac{30^\circ + d\alpha}{360^\circ}$$

where the time interval Δt_1 is the duration of the major loop given in tables 1 and 2.

The time interval Δt_1 is a function of the system circuit time constant (τ), the rated frequency of the system, the opening time and the minimum arcing time of the circuit-breaker. The time interval Δt_1 is equal to the duration (rounded) of the subsequent major loop (on the appropriate asymmetrical current waveform) which will occur after the minimum clearing time. Interruption should occur after a major loop or after the subsequent minor loop if the circuit-breaker failed to interrupt after the required major loop. This is achieved by setting the tripping impulse later than that of the first valid breaking operation.

Tables 1 and 2 consider a relay time of 0,5 cycle of the rated frequency (10 ms at 50 Hz and 8,3 ms at 60 Hz). If the circuit-breaker fails to interrupt after the required major loop and interrupts after the subsequent minor loop, the required maximum arcing time is extended by the duration of the appropriate minor loop (Δt_2) given in tables 1 and 2.

NOTE 2 In a direct test circuit, any delay of the tripping impulse after the test at $t_{\text{arc min}}$ will result in a subsequent major loop with an arc duration of

$$t_{\text{arc max}} = t_{\text{arc min}} + \Delta t_1 - T \times \frac{d \alpha}{360^\circ}$$

Therefore, only an arcing window of 180° can be demonstrated in a single-phase test circuit. This condition may lead to overstressing of the circuit-breaker. If that is the case, for non-solidly earthed neutral applications only, it is permissible to further delay the tripping impulse in order to obtain the required maximum arcing time.

The third valid breaking operation should demonstrate interruption with an arcing time that is approximately equal to the average value of those of the first and second valid breaking operations. This arcing time is known in this document as the medium arcing time ($t_{\text{arc med}}$) and is determined by

$$t_{\text{arc med}} = (t_{\text{arc max}} + t_{\text{arc min}}) / 2$$

This interruption should also occur after a major loop or after the subsequent minor loop if the circuit-breaker failed to interrupt after the required major loop.

NOTE 3 In the specific cases where a circuit-breaker interrupts after a minor current loop during the maximum arcing time test, the medium arcing time should be determined by using the prospective maximum arcing time considering an interruption following a major current loop.

The tripping impulse for the third valid breaking operation should be delayed from that of the second valid breaking operation in order to achieve this arcing time.

Figure 3 gives a graphical example of the three valid breaking operations.

b) Short-circuit current during arcing interval

The breaking operations are valid if the following conditions are met:

- the peak short-circuit current during the last loop prior to the interruption is between 90 % and 110 % of the required value and
- the duration of the short-circuit current loop prior to the interruption is between 90 % and 110 % of the required value.

or if the tolerances on the current amplitude cannot be fulfilled:

- the product " $I \times t$ ", " I " being the required peak value of the last short-circuit current loop and " t " being the required duration of the last short-circuit current loop, is between 81 % and 121 % of the required values provided that the last current-loop duration prior to the interruption is between 90 % and 110 % of the required value.

Tables 1 and 2 give required values of the peak short-circuit current and loop duration that should be attained by the last loop prior to the interruption. The required product " $I \times t$ " can also be derived from these tables.

NOTE 1 For direct tests, these conditions apply to the prospective short-circuit current only provided that the instant of current initiation is within $\pm 10^\circ$ of that obtained during the prospective current calibration test.

NOTE 2 For circuit-breakers having relatively high arc voltages, the procedure to obtain the required current-loop amplitude and duration during synthetic tests is explained in IEC 60427.

NOTE 3 The corresponding di/dt values given in tables 1 and 2 are only applicable to the first pole-to-clear. For the second and third pole-to-clear, the di/dt can be approximated as the di/dt of the second and third pole-to-clear in case of a symmetrical fault current. See table 2 of IEC 62271-100.

Table 1a – Last current loop parameters for 50 Hz operation in relation with short-circuit test-duty T100a
 $\tau = 45 \text{ ms}$

$\tau = 45 \text{ ms}$		Major loop				Minor loop		
Minimum clearing time	$\hat{I}$	ΔI_1	Percentage of asymmetry level at current zero	Corresponding dI/dt at current zero (percentage of the dI/dt of the rated symmetrical current)	$\hat{I}$	ΔI_2	Percentage of asymmetry level at current zero	Corresponding dI/dt at current zero (percentage of the dI/dt of the rated symmetrical current)
ms	p.u.	ms	%	%	p.u.	ms	%	%
$10,0 < t \leq 22,5$	1,51	13,5	44,6	92,6	0,36	5,5	60,2	75,6
$22,5 < t \leq 43,0$	1,33	12,0	28,9	97,8	0,59	7,5	37,9	89,9
$43,0 < t \leq 63,5$	1,21	11,5	18,7	99,6	0,74	8,5	24,0	95,4
$63,5 < t \leq 84,0$	a	a	a	a	a	a	a	a
$84,0 < t \leq 104,0$	a	a	a	a	a	a	a	a
$\hat{I}$ p.u. value of the peak current related to the peak value of the symmetrical short-circuit current								
ΔI_1 duration of major loop (rounded to 0,5 ms)								
ΔI_2 duration of minor loop (rounded to 0,5 ms)								
τ system circuit time constant								
All values in this table have been calculated with a protection relay time of 10 ms.								
^a Test duty T100a is not applicable, asymmetry level lower than 20 % for both current loops.								
NOTE 1 The system circuit time constant $\tau = 45 \text{ ms}$ is the standard time constant, $\tau = 60 \text{ ms}$, 75 ms and 120 ms are the special case time constants according to 4.1.								
NOTE 2 If the minimum arcing time obtained during test is different from the value declared by the manufacturer and if the real minimum arcing time leads to another minimum clearing time class (interruption to another current loop), then it could be necessary to repeat the test with the appropriate current loop values. If a repetition is necessary, reconditioning of the circuit-breaker according to 6.102.9.5 of IEC 62271-100 or the use of an additional test sample according to 6.102.2 of IEC 62271-100 are permitted.								

Table 1b – Last current loop parameters for 50 Hz operation in relation with short-circuit test-duty T100a
 $\tau = 60 \text{ ms}$

$\tau = 60 \text{ ms}$		Major loop			Minor loop			
Minimum clearing time	$\hat{I}$	ΔI_1	Percentage of asymmetry level at current zero	Corresponding di/dr at current zero (percentage of the di/dr of the rated symmetrical current)	$\hat{I}$	ΔI_2	Percentage of asymmetry level at current zero	Corresponding di/dr at current zero (percentage of the di/dr of the rated symmetrical current)
ms	p.u.	ms	%	%	p.u.	ms	%	%
$10,0 < t \leq 22,5$	1,61	14,0	54,2	86,9	0,28	5,0	68,7	69,0
$22,5 < t \leq 43,0$	1,44	13,0	39,2	94,1	0,49	7,0	48,6	84,8
$43,0 < t \leq 63,5$	1,31	12,0	28,3	97,4	0,63	8,0	34,5	92,0
$63,5 < t \leq 84,0$	1,22	11,5	20,4	99,0	0,74	8,5	24,6	95,7
$84,0 < t \leq 104,0$	a	a	a	a	a	a	a	a
$\hat{I}$ p.u. value of the peak current related to the peak value of the symmetrical short-circuit current								
ΔI_1 duration of major loop (rounded to 0,5 ms)								
ΔI_2 duration of minor loop (rounded to 0,5 ms)								
τ system circuit time constant								
All values in this table have been calculated with a protection relay time of 10 ms.								
^a Test duty T100a is not applicable, asymmetry level lower than 20 % for both current loops.								
NOTE 1 The system circuit time constant $\tau = 45 \text{ ms}$ is the standard time constant, $\tau = 60 \text{ ms}$, 75 ms and 120 ms are the special case time constants according to 4.1.								
NOTE 2 If the minimum arcing time obtained during test is different from the value declared by the manufacturer and if the real minimum arcing time leads to another minimum clearing time class (interruption to another current loop), then it could be necessary to repeat the test with the appropriate current loop values. If a repetition is necessary, reconditioning of the circuit-breaker according to 6.102.9.5 of IEC 62271-100 or the use of an additional test sample according to 6.102.2 of IEC 62271-100 are permitted.								

Table 1c – Last current loop parameters for 50 Hz operation in relation with short-circuit test-duty T100a
 $\tau = 75 \text{ ms}$

$\tau = 75 \text{ ms}$		Major loop				Minor loop		
Minimum clearing time	$\hat{i}$	Δt_1	Percentage of asymmetry level at current zero	Corresponding di/dr at current zero (percentage of the di/dr of the rated symmetrical current)	$\hat{i}$	Δt_2	Percentage of asymmetry level at current zero	Corresponding di/dr at current zero (percentage of the di/dr of the rated symmetrical current)
ms	p.u.	ms	%	%	p.u.	ms	%	%
$10,0 < t \leq 22,5$	1,67	15,0	61,0	81,9	0,23	4,5	74,3	63,8
$22,5 < t \leq 43,0$	1,51	13,5	47,1	90,2	0,41	6,0	56,3	80,3
$43,0 < t \leq 63,5$	1,39	12,5	36,3	94,7	0,55	6,5	42,9	88,5
$63,5 < t \leq 84,0$	1,30	12,0	27,9	97,2	0,66	8,0	32,7	93,1
$84,0 < t \leq 104,0$	1,23	11,5	21,4	98,6	0,74	8,5	24,9	95,8
$\hat{i}$ p.u. value of the peak current related to the peak value of the symmetrical short-circuit current								
Δt_1 duration of major loop (rounded to 0,5 ms)								
Δt_2 duration of minor loop (rounded to 0,5 ms)								
τ system circuit time constant								
All values in this table have been calculated with a protection relay time of 10 ms.								
NOTE 1 The system circuit time constant $\tau = 45 \text{ ms}$ is the standard time constant, $\tau = 60 \text{ ms}$, 75 ms and 120 ms are the special case time constants according to 4.1.								
NOTE 2 If the minimum arcing time obtained during test is different from the value declared by the manufacturer and if the real minimum arcing time leads to another minimum clearing time class (interruption to another current loop), then it could be necessary to repeat the test with the appropriate current loop values. If a repetition is necessary, reconditioning of the circuit-breaker according to 6.102.9.5 of IEC 62271-100 or the use of an additional test sample according to 6.102.2 of IEC 62271-100 are permitted.								