Minutes of Meeting May 6, 2014

WG: C37.04 - Standard Ratings and Requirements for AC High Voltage Circuit Breakers with rated maximum voltage above 1000 V

Chair: Jeff Nelson
Vice Chair: Mike Crawford
Secretary: Stephen Cary

Location: Orlando
Participants:
Members:
Guests:

The meeting started with the chair introducing the attendees. The chair asked for all attendees to sign the roster and provided affiliation if not noted on the roster.

The meeting minutes were shown by the projector and the chairman reviewed the MOM for the meeting in Galveston. Minutes of the meeting were posted on the committee web site http://www.ewh.ieee.org/soc/pes/switchgear under the "Minutes of Meeting (Archive)".

The chair entertained a motion from John Webb to approve the minutes. Xi Zhu seconded the motion. The motion passed unanimously.

Status of Working Group - It was noted the PAR expires December 2015. A one year extension was discussed. A PAR extension was announced, and Erin Spiewak agreed to help with the application.

Topics discussed:

1. Indoor vs. Outdoor and Temperature ratings were discussed: It was discussed if two different ratings were required. At this time the WG decided to keep the wording as is.
2. C37.06.1: It was reaffirmed that C37.06.1 will not be included in C37.04
3. Terminal Loading: Victor Hermosillo presented what he has worked on based on IEEE 605 and the previously submitted Jeff Nelson table. The WG decided to leave the standard as is, harmonized with the bushing standard.
4. Alternate Mechanisms: A presentation from Denis Dufournet was made to show that contact wear and current was directly proportional but power of 1.7 to 1.8 depending on design. It was a WG decision to use wording from IEC as IEC has used it for 10+ years. It was also briefly discussed that short time and peak withstand tests are not addressed with the IEC proposal. Denis volunteered to suggest wording.
5. References were discussed. It was decided to not date references to agree with other C37 standards. If specific tables or figures are referenced it will be dated.
6. Inclusion of C37.04b into C37.04. All normative parts shall be brought into the main of C37.04. Ken Edwards and Denis Dufournet to work on the parts/pieces to be included.

7. TRV: TRV is not considered a rating. It will be considered a 'Performance Requirements'.
8. 800% endurance requirement was discussed. Reference IEC 62271-310. Denis Dufournet again presented proposal for 800% rating. The WG decided to keep the draft written as is, and let comments be made on first ballot.

The meeting adjourned on time.

Attendance:

IEEE PES Switchgear Committee
HVCB_C37.04

Place / Date of meeting : ____________________

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PC37.04 (C37.06, NEMA SG4)

Jeff Nelson - Chair

Mike Crawford - Vice Chair

Stephen Cary - Secretary

C37.04

Agenda

- Introductions
- Approval of Fall 2013 Minutes
- Moving forward
  - PAR expires December 2015
- Items to discuss

C37.04

- Indoor vs. Outdoor ambient temperature rating:
  - Shall there be two ratings?
- C37.06.1 into C37.04?
  - Previously discussed, to not include as part of this revision
- Terminal Loading:
  - Victor H (BRIEF overview of proposed table)

C37.04

- Definitions to remain in C37.100.1
- Piecewise Testing
  - Ken Edwards, Denis; C37.09 use C37.59 as starting point?
- Inclusion of C37.04b
  - Document merger, pertinent parts, etc
- TRV: Rating or not?
  - Shall we call a horse a horse? (Or a Rating a Requirement?)

C37.04

- References: Dated or Un-Dated?
  - C37.04 is planning on using Un-dated References (as in C37.010)
- 800%
  - Denis' proposal

Definitions

3.5.124

operating mechanism

part of the circuit-breaker that actuates the main contacts

3.5.125

power kinematic chain

mechanical connecting system from and including the operating mechanism up to and including the moving contacts

NOTE See also A.3.5.111 of IEC 62271-102.

3.5.126

alternative operating mechanism

an alternative operating mechanism is obtained when a change in the power kinematic chain of the original operating mechanism or the use of an entirely different operating mechanism leads to the same mechanical characteristics.

NOTE 1 Mechanical characteristics are defined in 6.101.1.1. The use of mechanical characteristics and related requirements are described in Annex N.

NOTE 2 An alternative operating mechanism can utilise an operating principle different from the original one (for example the alternative mechanism can be spring-operated and the original hydraulic).

NOTE 3 A change in the secondary equipment does not lead to an alternative operating mechanism. However, it has to be checked that changes in the opening time/minimum clearing time does not entail different requirements for test-duty T100a (see 6.102.10).

Subclause 6.101.1.1

6.101.1.1 Mechanical characteristics

At the beginning of the type tests, the mechanical characteristics of the circuit-breaker shall be established, for example, by recording no-load travel curves. This may be done also by the use of characteristic parameters, for example, momentary speed at a certain stroke etc. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behaviour of the circuit-breaker. Furthermore, the mechanical characteristics shall be used to confirm that the different test samples used during the mechanical, making, breaking and switching type tests behave mechanically in a similar way. The test in which this reference is gained is referred to as reference no-load test and the curves or other parameters resulting from it as reference mechanical characteristics. The reference no-load test may be taken from any appropriate no-load test being part of an individual type test.

The following operating characteristics shall be recorded:

– mechanical characteristics for opening and closing operation;

– closing time;

– opening time.

The mechanical characteristics shall be produced during a no-load test made with a single O operation and a single C operation at rated supply voltage of operating devices and of auxiliary and control circuits, rated functional pressure for operation and, for convenience of testing, at the minimum functional pressure for interruption.

The opening time and the closing time recorded in the reference no-load test shall be used as reference closing and reference opening time. The allowable deviations from these reference times correspond to the tolerances given by the manufacturer when performed under the same conditions as used for the procedure to produce the reference mechanical characteristics.

Annex N gives requirements and explanation on the use of mechanical characteristics.

Annex N

Use of mechanical characteristics and related requirements

At the beginning of the type tests, the mechanical characteristics of the circuit-breaker shall be established, for example, by recording no-load travel curves. This may be done also by the use of characteristic parameters, for example momentary speed at a certain stroke etc. The mechanical characteristics will serve as the reference for the purpose of characterising the mechanical behaviour of the circuit-breaker.

The mechanical characteristics shall be used to confirm that the different test samples used during the mechanical, making, breaking and switching type tests behave mechanically in a similar way. All test samples used for mechanical, making, breaking and switching type tests shall have a mechanical characteristic within the following described envelopes. Care should be exercised in the interpretation of the curves when, due to variable measuring methods at different laboratories, a direct comparison between the envelopes cannot be made.

The type and location of the sensor used for the record of the mechanical characteristics shall be stated in the test report. The mechanical characteristic curve which can be measured at any part of the power kinematic chain may be recorded continuously or discretely. In case of discrete measurement, at least 20 discrete values should be given for the complete stroke.

The mechanical characteristics shall be used for determining the limits of the allowable deviations over or under this reference curve. From this reference curve, two envelope curves shall be drawn from the instant of contact separation to the end of the contact travel for the opening operation and from the beginning of the contact travel to the instant of contact touch for the closing operation. The distance of the two envelopes from the original course shall be $\pm$ 5 % of the total stroke as shown in Figure 23b. In case of circuit-breakers with a total stroke of 40 mm or less the distance of the two envelopes from the original course shall be $\pm$2 mm. It is recognised that for some designs of circuit-breakers, these methods may be unsuitable, as for example for vacuum circuit-breakers or for some circuit-breakers rated less than 52 kV. In such cases the manufacturer shall define an appropriate method to verify the proper operation of the circuit-breaker.

If mechanical characteristics other than curves are used, the manufacturer shall define the alternative method and the tolerances used.

The series of Figures 23a to 23d are for illustrative purposes and only illustrate the opening operation. They are idealised, and do not show the variation in profile caused by the friction effect of the contacts or the end of travel damping. In particular, it is important to note that the effects of damping are not shown in these diagrams. The oscillations produced at the end of travel are dependent upon the efficiency of the damping of the drive system. The shape of these oscillations may be a deliberate function of the design and may slightly vary from one specimen to another. Therefore, it is important that any variations in the curve at the end of the stroke, which are outside the tolerance margin given by the envelope, are fully explained and understood before they are rejected or accepted as showing equivalence with the reference curves. In general, all curves should fall within the envelopes for acceptance.

The envelopes can be moved in the vertical direction until one of the curves covers the reference curve. This gives maximum tolerances over the mechanical characteristics of –0 %, +10 % and –10 %, +0 %, respectively as shown in Figures 23c and 23d. The displacement of the envelope can be used only once for the complete procedure in each test in order to get a maximum total deviation from the reference characteristic of 10 %.

Table N.1 lists type tests and relevant reference mechanical characteristics for no-load, making and breaking tests.

Table N.1 – Summary of type tests related to mechanical characteristics

Applicable subclauses	**Tests where the records shall be taken**	**Evaluation method**	**Application/Notes**
6.101.1.1 Mechanical characteristics	No-load test before the beginning of type tests	Not applicable	General guide for reference mechanical characteristics
6.101.1.3 Characteristics and settings of the circuit-breaker to be recorded before and after the tests	Before and after the mechanical and environmental tests	Not applicable	Items listed in 6.101.1.3 to be recorded
6.101.2.2 Condition of the circuit-breaker before the (mechanical) test	No-load test before the mechanical test	[a]	Mechanical test on a separately operated single pole of a three-pole circuit-breaker
6.101.2.5 Acceptance criteria for the mechanical operation tests	No-load test after the mechanical test	[b]	
6.101.3.3 Low temperature test	No-load test before and after the low temperature test	[b]	Depending on minimum temperature specification
6.101.3.4 High temperature test	No-load test before and after the high temperature test	[b]	
6.101.4.2 Test procedure (humidity test)	During and after the tests (no-load operations)	[b]	Conditional test when required
6.101.6 Static terminal load test	No-load test before and after the terminal load test	[a]	Refer also to the note in 6.101.6
6.102.2 Number of test specimens	No-load test before making and breaking tests	[a]	For the second test specimen, if more than one specimen is used
6.102.3.3 Multi-enclosure type	No-load test before the test	[a]	For commonly operated multi-enclosure type

	Making and breaking operation based on T100s	[c]	
6.102.4.1 Single-phase testing of a single pole of a three-pole circuit-breaker	No-load test before the test	[a]	For circuit-breakers with common operating mechanism
	Making and breaking operation based on T100s	[c]	
6.102.4.2 Unit testing	No-load test before the test	[a]	For circuit-breakers with two or more units not separately operated within one pole
	Making and breaking operation based on T100s	[c]	
6.102.6 No-load operation before (making and breaking) tests	No-load tests before the test [d]	[a, d]	For all making and breaking tests
6.102.7 Alternative operating mechanism	No-load test before the test	[a]	For equivalent alternative operating mechanisms
	Making and breaking operation based on T100s	[c]	
6.102.9.3 Condition after a short-circuit test-duty	No-load tests after the test-duty	[d]	If components are changed or maintenance is carried out after the test-duty
6.102.9.3 Condition after a short-circuit test series	No-load tests after the test series	[d]	
6.112.2 Class E2 circuit-breakers intended for auto-reclosing duty	No-load tests after the test series	[d]	Conditional test when required

[a] evaluation to the method given in 6.101.1.1; comparison of the mechanical characteristics

[b] evaluation to the method given in subclauses 6.101.1.3 and 6.101.1.4

[c] evaluation to the method given in subclauses 6.102.4.1 for single-pole testing

[d] testing method given in 6.102.6

Figures

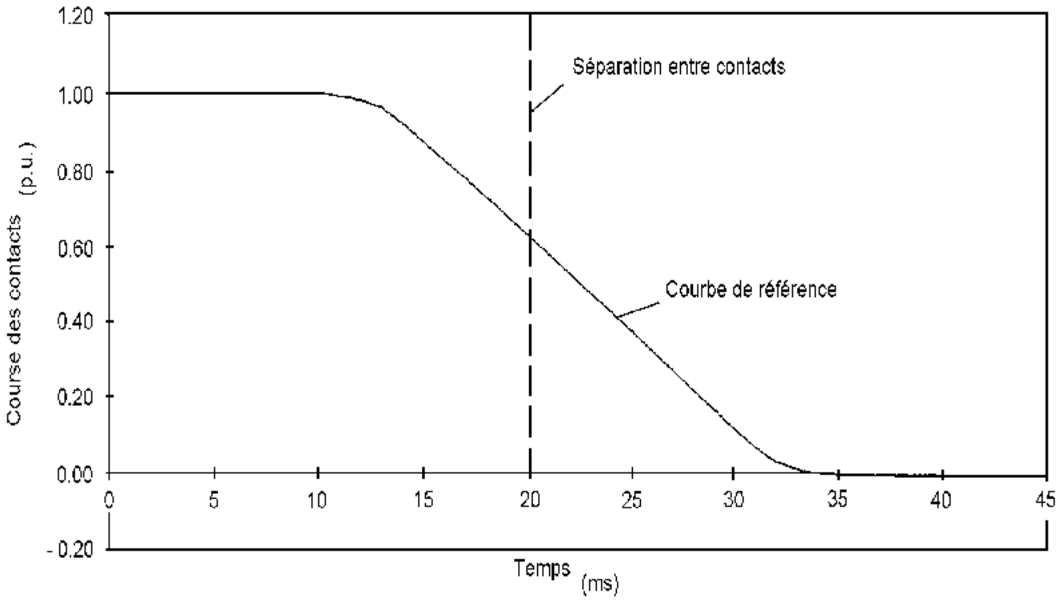


Figure 23a – Reference mechanical travel characteristics (idealised curve)

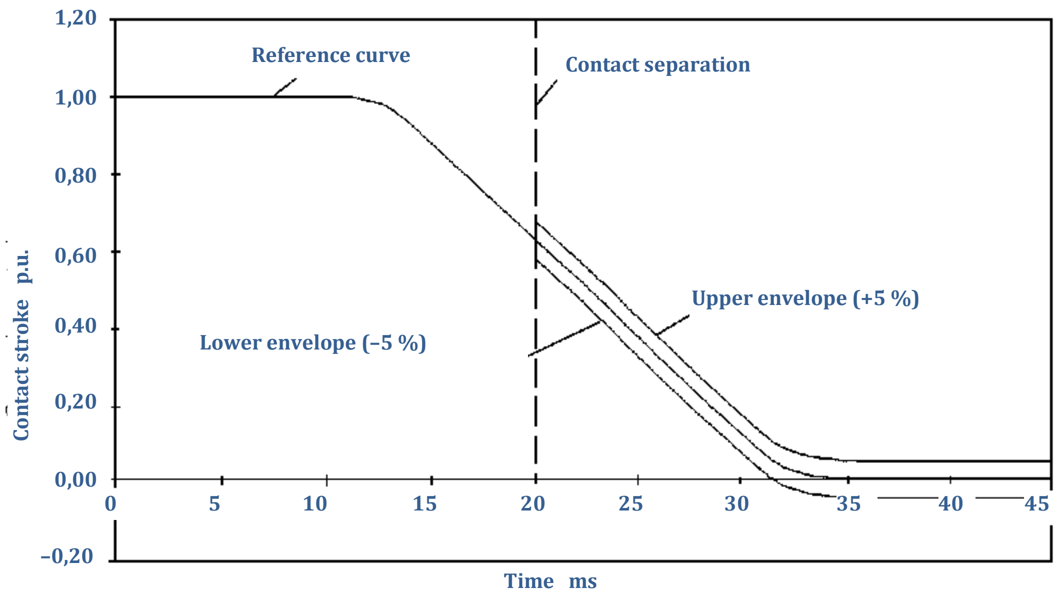


Figure 23b – Reference mechanical travel characteristics (idealised curve) with the prescribed envelopes centered over the reference curve (+5 %, –5 %), contact separation in this example at time *t* = 20 ms

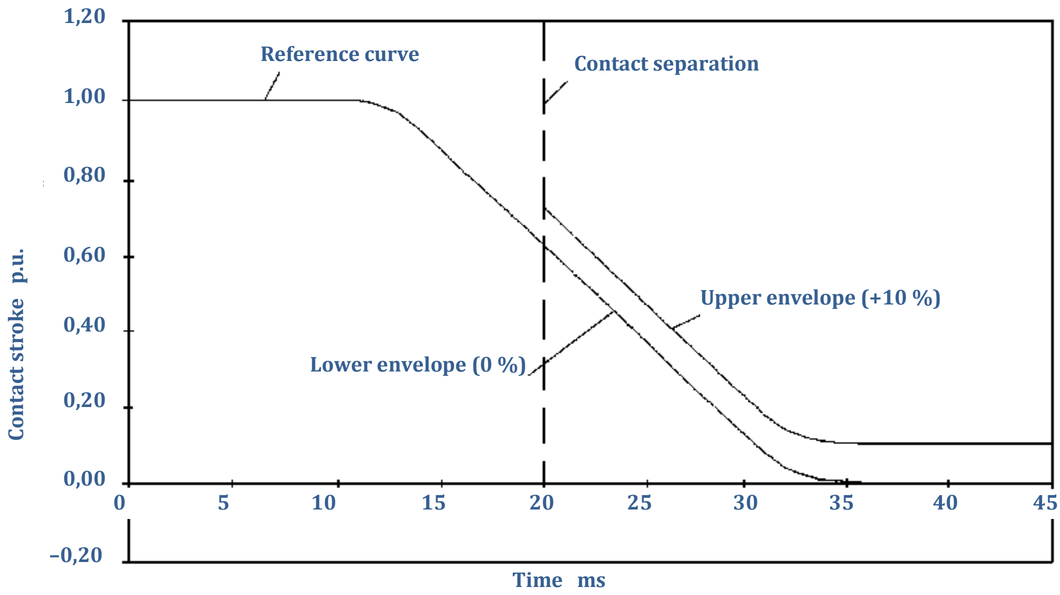


Figure 23c – Reference mechanical travel characteristics (idealised curve) with the prescribed envelopes fully displaced upward from the reference curve (+10 %, –0 %), contact separation in this example at time *t* = 20 ms

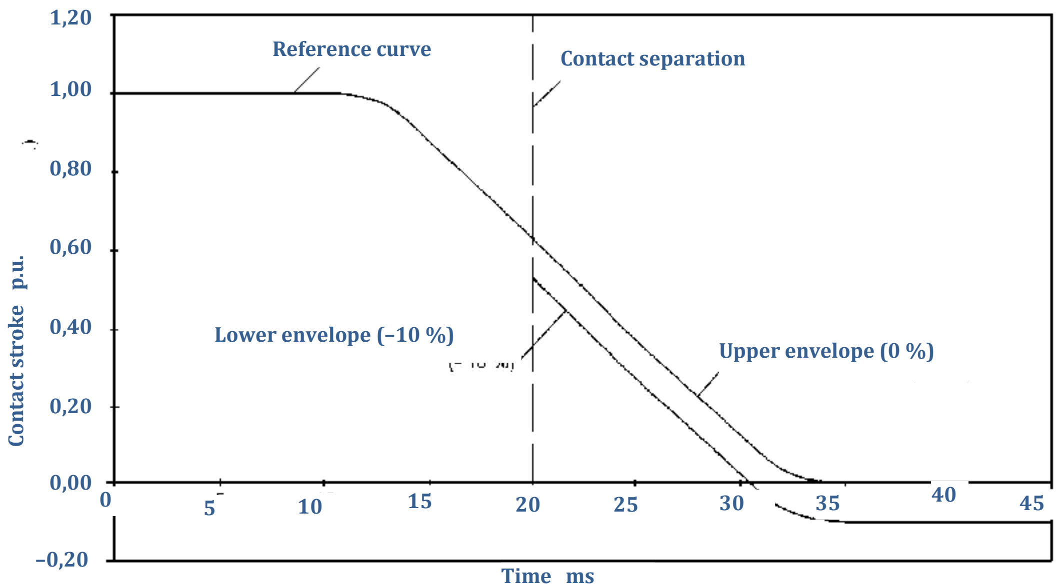


Figure 23d – Reference mechanical travel characteristics (idealised curve) with the prescribed envelopes fully displaced downward from the reference curve (+0 %, –10 %), contact separation in this example at time *t* = 20 ms

Service Capability for Circuit Breakers with Rated Voltages ≥ 72.5kV

Test Program 1 with Method 1 based on accumulation of currents to reach 800% symmetrical interrupting capability

4 interruptions at 100% I_{SC} (T100s, synthetic tests)

14 interruptions at 30% I_{SC}

Total is 400 + 420 = 820 %

Requirement is met

Test Program 2 with Method 2 based on equivalent wear

4 interruptions at 100% I_{SC} (T100s, synthetic tests)

4 interruptions at 60% I_{SC} (T60, synthetic tests) : wear is equivalent to 4 x $(60/30)^2$ = 16 interruptions at 30% I_{SC}

More severe than test program 1, therefore requirement is met

For circuit breakers ≥ 72.5kV: service capability is demonstrated by performing T100s and T60 on the same circuit breaker (3-phase tests) or same pole (single phase tests).

Service Capability for Circuit Breakers with Rated Voltages ≥ 72.5kV

Justification that the requirement is sufficient

- the requirement should be based on system need during the service life of a circuit breaker.

- It is different for medium voltage and high-voltage (as done now in IEC)

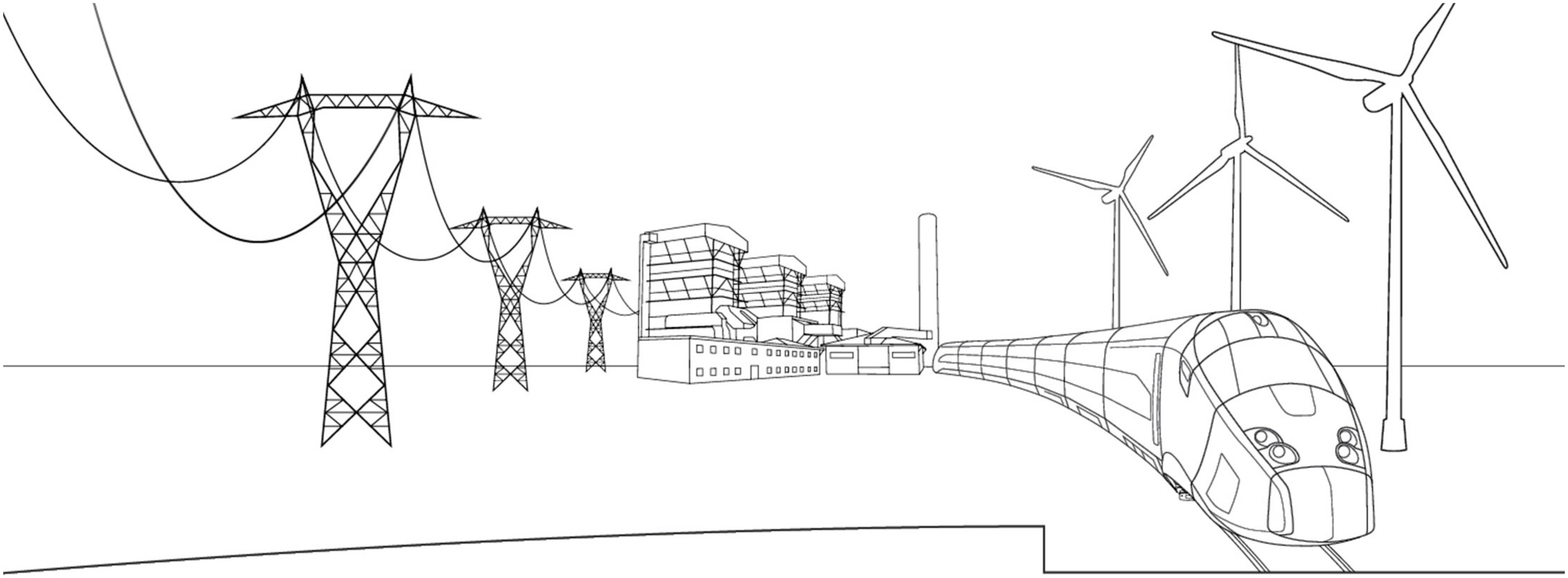
- For rated voltages ≥ 72.5kV

A study done by CIGRE lead to the values in IEC 62271-310.

For a 40kA circuit breaker the need is 10 + 3 interruptions of T60 (see Table 2). In terms of wear, it corresponds to 13 x $(60/100)^{1.8}$ = 13 x 0.4 = 5.2 interruptions at 100% symmetrical interrupting capability.

It is covered by Test Program 2 with 4 interruptions of T100s and the 4 interruptions of T60 (equivalent to 4 + 4 x 0.4 = 5.6 interruptions at 100% symmetrical interrupting capability).

Alternatively 6 interruptions at 100% symmetrical interrupting capability could be done.



Terminal Loads

V. Hermosillo

May 5th, 2014

Terminal Load IEEE C37.09

Table 4—Terminal mechanical loading

Rated maximum voltage	Rated continuous current	Static horizontal force		Static vertical force[a]
		Longitudinal (N)	Transverse (N)	Vertical (N)
Below 100 kV	1200 A and below Above 1200 A	500 750	400 500	500 750
123 kV to 170 kV	2000 A and below Above 2000 A	1000 1250	750 750	750 1000
245 kV	All	1250	1000	1250
362 kV to 800 kV	All	1750	1250	1250

[a]Vertical axis forces are upward and downward.

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Terminal Load IEEE C37.09

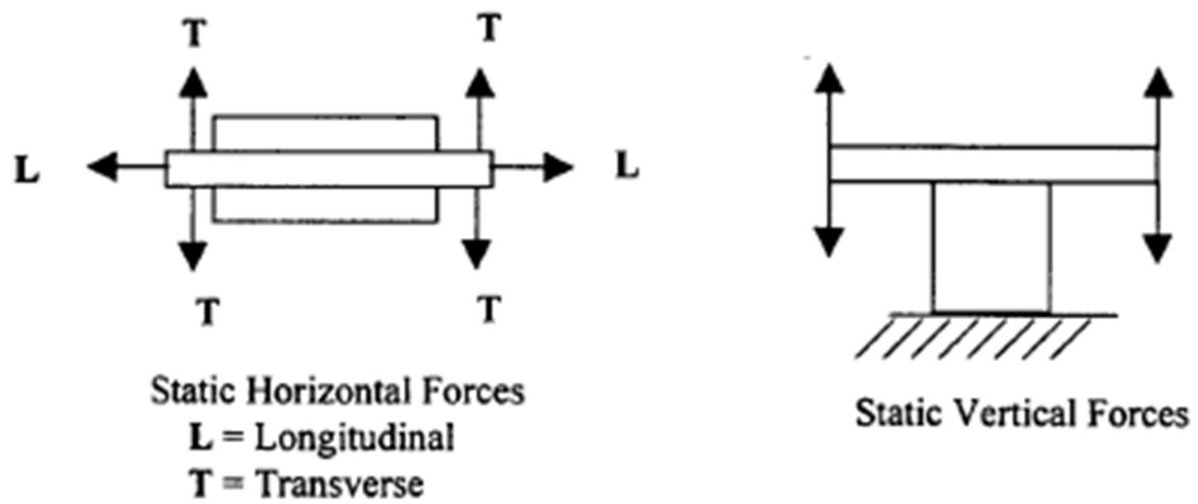

Figure 8—Direction of terminal mechanical loading forces

Terminal Load IEC 62271-100

Table 14 – Examples of static horizontal and vertical forces for static terminal load test

Rated voltage range	Rated current range	Static horizontal force F_{th}		Static vertical force (vertical axis-upward and downward)
		Longitudinal F_{thA}	Transversal F_{thB}	
U_r	I_r			F_{tv}
kV	**A**	**N**	**N**	**N**
< 100	800 – 1 250	500	400	500
< 100	1 600 – 2 500	750	500	750
100 – 170	1 250 – 2 000	1 000	750	750
100 – 170	2 500 – 4 000	1 250	750	1 000
245 – 362	1 600 – 4 000	1 250	1 000	1 250
420 – 800	2 000 – 4 000	1 750	1 250	1 500

Terminal Load – Calculation with Rigid Connections IEEE 605

Rated Maximum	Force from Fault Current [N]								
	Rated Interrupting Current [kA]								
	12.5	16	20	25	31.5	40	50	63	80
<100 kV	500	820	1281	2002	3178	5124	8007	12712	20497
123 to 145	200	328	512	801	1271	2050	3203	5085	8199
170 to 245	167	273	427	667	1059	1708	2669	4237	6832
Over 300	112	184	287	449	712	1149	1795	2849	4594

Using Half-cycle Decrement Factor (Df) for X/R = 17

Rated Maximum	Force from Fault Current [N]								
	Rated Interrupting Current [kA]								
	12.5	16	20	25	31.5	40	50	63	80
<100 kV	420	688	1075	1680	2666	4300	6718	10666	17198
123 to 145	168	275	430	672	1067	1720	2687	4266	6879
170 to 245	140	229	358	560	889	1433	2239	3555	5733
Over 300	94	154	241	376	598	964	1506	2391	3855

Using Half-cycle Decrement Factor (Df) for X/R = 17 & Failure constant (Γ) = 0.866 for 3-phase fault

Rated Maximum	Force from Fault Current [N]								
	Rated Interrupting Current [kA]								
	12.5	16	20	25	31.5	40	50	63	80
<100 kV	364	596	931	1454	2309	3723	5818	9237	14894
123 to 145	145	238	372	582	924	1489	2327	3695	5958
170 to 245	121	199	310	485	770	1241	1939	3079	4965
Over 300	82	134	209	326	518	835	1304	2070	3338

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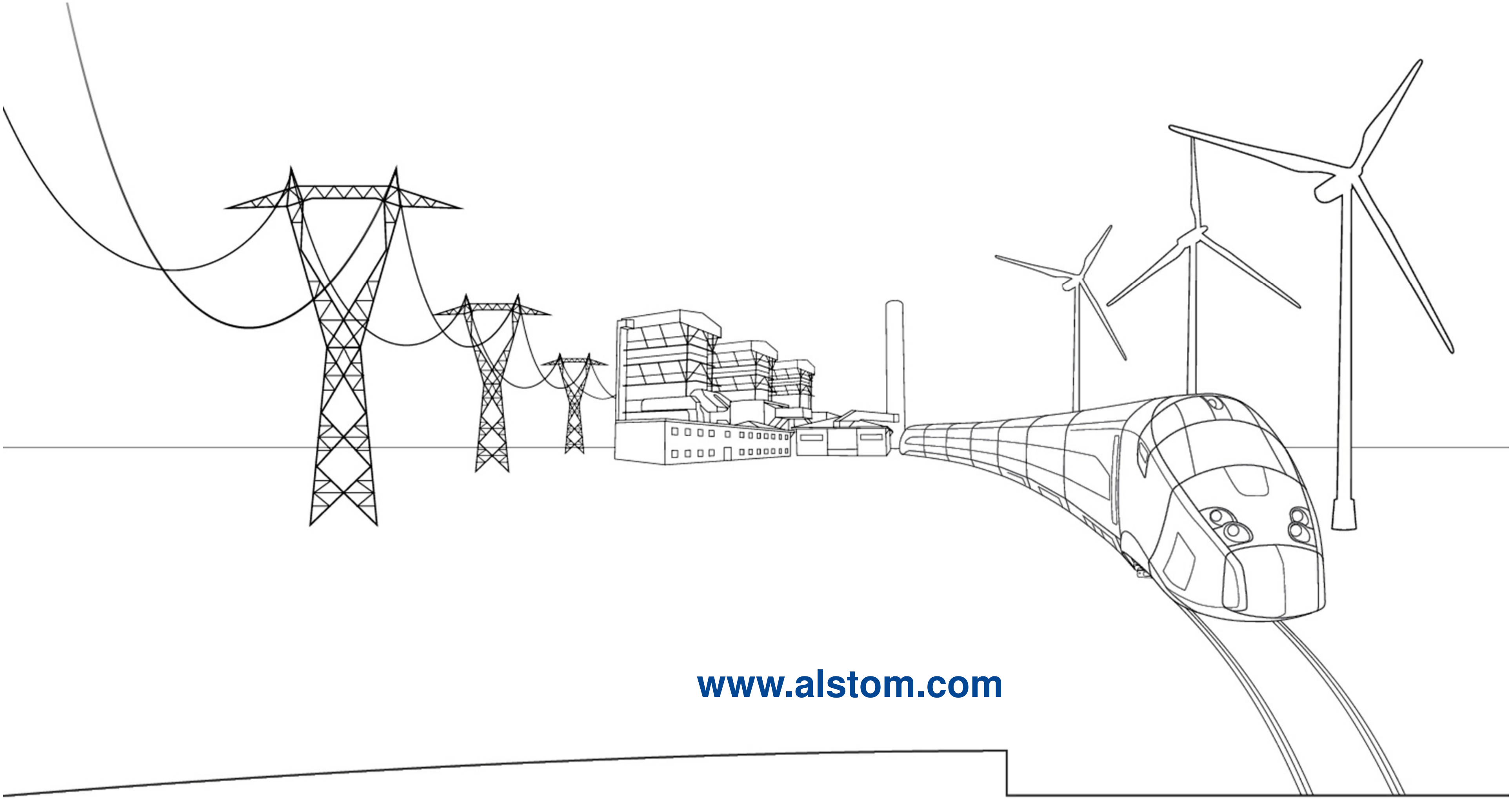

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