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NORME INTERNATIONALE

colour inside

Overhead lines – Method for fatigue testing of conductors

Lignes aériennes – Méthode d'essai de fatigue des conducteurs

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OVERHEAD LINES – METHOD FOR FATIGUE TESTING OF CONDUCTORS

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International Standard IEC 62568 has been prepared by IEC technical committee 7: Overhead electrical conductors.

The text of this standard is based on the following documents:

FDIS	Report on voting
7/638/FDIS	7/640/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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INTRODUCTION

Fatigue behaviour of conductors cannot simply be calculated from the fatigue characteristics of the materials used and the stresses that occur. Fatigue characteristics of conductors must be determined by fatigue tests conducted on specific conductor/clamp systems reproducing as closely as possible the field loading conditions. In such tests, the fatigue life must be determined as a function of some measure of vibration intensity rather than of the stress or stress combination that causes the failure.

Fatigue test data are available for only a small fraction of the conductor sizes and types that are in use, and such data are expensive to acquire. Since none of the above parameters is simply related to the fatigue-initiating stresses, results from tests on one conductor size are not necessarily applicable to others.

This IEC Standard is based on these considerations and others explained in Annex A. The user of this standard is encouraged to consult this annex in order to understand the origin of some of the requirements herein.

OVERHEAD LINES – METHOD FOR FATIGUE TESTING OF CONDUCTORS

1 Scope

This International Standard provides test procedures to measure the fatigue characteristics of conductor/clamp systems. For the purposes of this standard, clamps shall be of the metallic type only.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
antinode amplitude
mid-loop single peak vibration amplitude

2.2
bending amplitude
peak-to-peak vibration amplitude of conductor with respect to the clamp, measured 89 mm from the last point of contact between the conductor and the clamp

2.3
failure criterion
benchmark at which the test is deemed terminated.

Note 1 to entry: Two different failure criteria may be chosen:

a) failure of the first wire, or
b) failure of three wires or of 10% of the total number of envelope wires for composite conductors, or of the total number of wires for homogeneous conductors

2.4
idealized bending stress
alternating stress amplitude calculated based on the measured bending amplitude

2.5
idealized dynamic stress
alternating stress amplitude calculated based on the measured fy_{max} product

2.6
idealized strain
computed dynamic bending alternating strain obtained by dividing the idealised stress by the Young’s modulus of the outer layer material

Note 1 to entry: This calculated idealized strain does not correspond to the strain measured on given wires at the exit of the clamp

2.7
resonance fatigue test
cyclic motion imposed on a conductor in a vertical plane at a resonant frequency of the system

3 Symbols and abbreviated terms

f	frequency (Hz)
i	occurrence of wire failure (first = 1, second = 2, third = 3 …)
N	number of cycles of vibration
N_i	number of cycles corresponding to wire failure i
*M*c	million cycle
T	conductor mechanical tension
Y_b	bending amplitude
y_{max}	antinode amplitude
$\sigma_a(Y_b)$	idealized bending stress
$\sigma_a(fy_{max})$	idealized dynamic stress
S/N	calculated idealised stress S – number of cycles of vibration N
LPC	the last point of contact of the conductor with the clamp in the calculation of an idealized bending stress on an external wire of the conductor in a plane
p-p	peak-to-peak (bending amplitude)
RTS	rated tensile strength
LVDT	linear variable differential transformer

4 Requirements

Fatigue tests on conductor/clamp systems shall be in accordance with the method described in this standard.

5 Test method

5.1 Test set-up

5.1.1 General

The test set-up shall be conceptually in accordance with Figure 1. The following elements shall be adhered to:

5.1.2 Clamp

The test bench shall be such as to reproduce the exit angle of the conductor at the clamp. The clamp shall be fixed in such a way as to prevent any movement.

5.1.3 Length of bench

Behind the clamp where the conductor experiences no motion, there shall be a minimum of 1 m of free conductor between the clamp under test and the dead-end clamp.

There shall be a minimum of 5 m between the clamp under test and the point of excitation.

The active length of the test bench shall be long enough to allow the formation of at least 5 vibrating free loops at the resonant frequency chosen for the test.

5.1.4 Conductor tension

The conductor tension shall be maintained at a constant value with a maximum variation of ± 2,5 %.

5.1.5 Sinusoidal excitation

A shaker, or any other appropriate means, shall be placed at the end of the test span opposite to the clamp under test and shall be capable of maintaining constant (± 5 %) free loop amplitude and frequency.

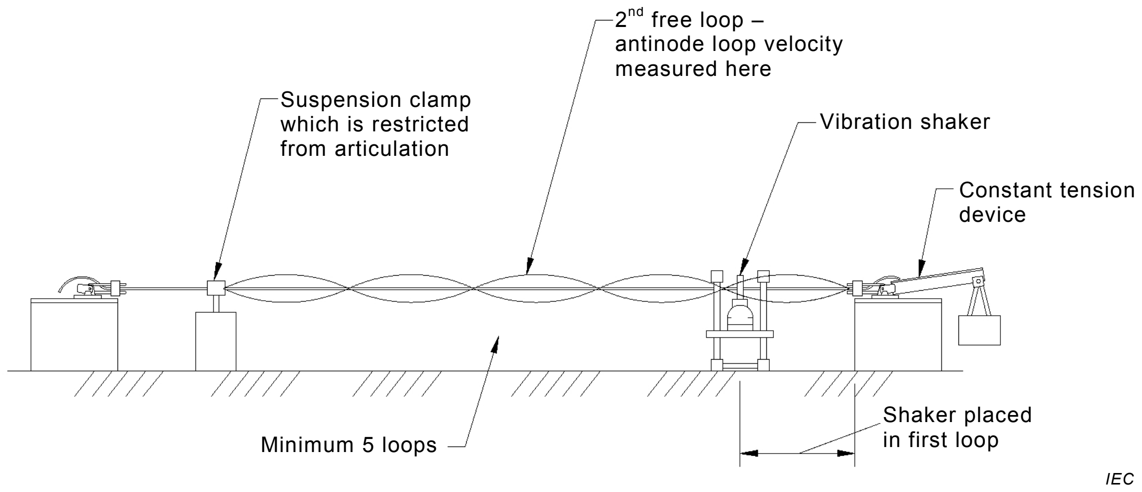

Figure 1 – Schematic representation of a resonance-type test bench

5.1.6 Excitation frequency

The frequency of excitation shall be in the range of (10 to 60) Hz.

5.2 Test parameters for resonance type benches

The following parameters shall be monitored:

– bending amplitude Y_b
– antinode amplitude y_{max}
– frequency f
– conductor mechanical tension T
– number of cycles N
– each occurrence of wire failure and the corresponding number of cycles N_i

5.3 Termination of a test

The test shall be terminated when a predetermined number of wire failures i is recorded or when the test has reached N = 500 Mc.

At the end of each test, the clamp region of the conductor shall be dissected and the number of wire failures found shall correspond to the number of failures recorded by the wire failure detector. If the results cannot be reconciled, the test shall be discarded.

5.4 Number of tests

A minimum of 12 tests shall be performed to determine the endurance limit of a conductor/clamp system. Three of these tests shall be at an amplitude that shall produce no wire failure up to 500 Mc. The vibration amplitude of the other nine tests shall be determined in order to distribute, as evenly as possible, the wire failures between (0,8 and 500) Mc.

6 Test results

The following information shall be provided in the report for each test:

- the failure criterion used
- number of cycles corresponding to wire failure(s) N_i
- number of cycles N completed if there was no failure
- mapping of the wire failure locations in the transverse and the longitudinal planes with respect to the support clamp
- frequency f, antinode amplitude y_{max} and, the resulting fatigue indicator fy_{max}
- bending amplitude Y_b
- conductor mechanical tension T
- S/N diagram of the idealized bending stress $\sigma_a(Y_b)$ using the Poffenberger-Swart relationship. (see A.7.2)
- S/N diagram of the idealized dynamic stress $\sigma_a(fy_{max})$ (see A.7.2)
- The endurance limits $\sigma_a(Y_b)$ and $\sigma_a(fy_{max})$which correspond to the maximum vibration amplitude under which the conductor has experienced no fatigue damage up to 500 Mc.

Annex A
(informative)

Fatigue testing of conductors

A.1 Background

It has long been recognized that conductor fatigue and its resulting consequence, the breaking of conductor strands, was due to a phenomenon known as fretting fatigue, in locations on the conductor where its motion is restrained, e.g. suspension clamps, spacer clamps or damper clamps.

Relating the measurable vibration of an overhead span of conductor to the likelihood of fatigue of its strand is a complicated matter. The stresses that cause the failures are not related in a simple way to the gross motions of the conductor. The failures originate at locations where there is surface contact and fretting between components (wire/wire or wire/support contacts). A valid analysis relating the fretting fatigue mechanism to the vibration of the conductor has yet to be published.

Fatigue behaviour of conductors cannot simply be calculated from the fatigue characteristics of the materials used and the stresses that occur. Fatigue characteristics of conductors must be determined by fatigue tests conducted on specific conductor/clamp systems reproducing as closely as possible the field loading conditions. In such tests, the fatigue life must be determined as a function of some measure of vibration intensity rather than of the stress or stress combination that causes the failure.

Several parameters of vibration intensities have been employed. None came out as outstanding to relate results from tests on laboratory spans to actual in situ measurements of conductor vibration with different conductor/clamp systems. For practical reasons, the bending amplitude Y_b and the product of the free loop amplitude y_{max} and the frequency f (fy_{max}) have gradually been accepted with their inherent limitations.

Fatigue test data are available for only a small fraction of the conductor sizes and types that are in use, and such data is expensive to acquire. Since none of the above parameters is simply related to the fatigue-initiating stresses, results from tests on one conductor size are not necessarily applicable to others. To deal with that situation, an idealized stress (or strain) that can be calculated from vibration amplitude and that correlates well enough with conductor fatigue life to permit its use in establishing a single endurance limit for a range of conductor sizes and type of support was assumed.

Use of such an idealized stress lacks a fundamental analytical basis. However, ranges of conductor size and support arrangement have been found where its use gives results that are reliable enough to be usefully applied. It is important and useful to propose an IEC Standard based on the previous considerations to characterize the fatigue behaviour of conductor/clamp systems.

The scope of the new standard is to provide test procedures based on the experience gained in the recent years. The following three references are particularly relevant:

- CIGRE SC 22 WG 04 *Guide for Endurance Tests of Conductors Inside Clamps*, ELECTRA No 100, 1985, May pp.77-86
- CIGRE SC B2 WG11 TF7 *Fatigue Endurance capability of Conductor/Clamp Systems – Update of Present Knowledge,* CIGRE TB # 332, 2007, Paris
- EPRI *Chapter 3, Fatigue of Overhead Conductors, EPRI Transmission Line Reference Book: Wind-Induced Conductor Motion,* 2nd Ed., EPRI, Palo Alto, CA 2006