IEC 60652

Edition 3.0 2021-07
REDLINE VERSION

INTERNATIONAL STANDARD

colour inside

~~Loading Tests on~~ Overhead line structures – Loading tests

IEC 60652:2021-07 RLV(en)

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ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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~~LOADING TESTS ON~~ OVERHEAD LINE STRUCTURES – LOADING TESTS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60652:2002. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 60652 has been prepared by IEC technical committee 11: Overhead lines. It is an International Standard.

This third edition cancels and replaces the second edition published in 2002. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Title modified;
b) Added reference to CIGRE Brochure 399;
c) In Clause 7, added test limitation for wind speed and direction during testing;
d) In paragraph 10.5, added load increments for destruction tests;
e) In paragraph 10.7, added a requirement for an agreement between client and testing station when testing supports made of creep-sensitive materials;
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~~LOADING TESTS ON~~ OVERHEAD LINE STRUCTURES – LOADING TESTS

1 Scope

This document ~~codifies~~ specifies the methods and procedures of testing supports for overhead lines.

It applies to the testing of supports and structures of overhead lines ~~for voltages above 45 kV; it can also serve as reference to the testing of lower voltage supports~~.

There is no restriction on the type of material used in the fabrication of the supports which may include, but not be limited to, metallic alloys, concrete, timber, laminated wood and composite materials. If required by the client, this document ~~may~~ can also be applied to the testing of telecommunication supports, railway/tramway overhead electrification supports, electrical substation gantries, street lighting columns, wind turbine towers, ski-lift supports, etc.

Tests on reduced scale models of supports are not covered by this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-466:1990, *International Electrotechnical Vocabulary (IEV) – Part 466: Overhead lines*
IEC 60050-466:1990/AMD1:2020

ISO/IEC 17025:~~1999~~2017, *General requirements for the competence of testing and calibration laboratories*

CIGRE Brochure 399:2009, *Improvement on the Tower Testing Methodology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-466:1990 and the following apply.

3.1
client
organization which contracts with the testing station and provides the test specification

3.2
design load
load for which the support has been designed

3.3
failure load
~~point~~ limit state loads value at which the support cannot carry any additional load as determined during the destruction test of the support

~~NOTE It is also known as the limit state failure load and is determined during a destruction test on the support.~~

3.4
realignment
process used for restoring the original 'vertical' position of the tower after being permanently deformed due to an intermediate loading case testing

Note 1 to entry: This process usually requires release of bolts in connections, pulling back the tower to its original position, and finally re-tightening bolts. This procedure is not recommended.

3.5
test report
document summarizing all the relevant aspects of the tests

4 Categories of tests

4.1 General

The objective of support tests is to verify the design method and inherent assumptions, the method of member detailing and the quality of fabrication, manufacture and material.

With respect to the purpose of the test, the level of instrumentation and the method of execution, this document refers to two categories of tests:

a) design tests;

b) sample tests.

4.2 Design tests

Design tests are normally carried out on full scale prototype supports, with one or more of the following objectives:

a) as part of a research and/or development programme in the design of an innovative support;

b) to verify compliance of the support design with the specifications (also known as type tests on a prototype support);

c) to develop and/or validate a new design standard or methodology;

d) to develop and/or validate new fabrication processes.

When tests are carried out to verify design parameters, the test support shall be identical as far as possible to the serial production supports (see Clause 5, first paragraph). Tests on full scale sections or part of the support may also be undertaken.

Design tests shall be carried out to at least the design load or to failure, especially when testing according to 4.2b) and/or 4.2c).

4.3 Sample tests

These are intended for use either prior to or during the fabrication of the production of a batch of supports to act as a check on the quality of the fabrication, or on the materials being used. The support ~~may~~ shall be taken at random from the serial production supports during manufacture. The test constitutes the acceptance of the production.

Sample tests are taken to a specific percentage of the design load (usually 100 %), as stipulated in the test specification.

5 General test criteria

For a design test (according to 4.2b) or 4.2c)), the material(s) and the manufacturing processes used in the fabrication of the prototype support shall be to the same specifications as those used during the serial fabrication of the ~~production~~ supports. These specifications shall include the member sectional properties, connection details, e.g. bolt or weld sizes, material grades and fabrication processes. Prior to the commencement of the prototype support fabrication, agreement shall be made with regard to the surface coating of the support.

Agreement shall also be made with respect to the organization responsible for the checking of the support prior to the testing.

If a sample test is required on a production support, the components ~~may~~ shall be chosen at random from the batch.

Whether it is for the design test (according to 4.2b)) or the sample test, the support shall successfully withstand the loads specified by the client.

6 Acceptability of test station

If required by the client, the testing station shall be accredited by an external organization to perform this type of test according to the procedures of quality assurance defined by ISO/IEC 17025:2017.

The following minimum requirements shall be fulfilled by the test station:

- the layout of the station is generally safe (e.g. in case of structure collapse the control building and the observation area are not located in the danger zone)
- the station has adequate provision to limit the severity of the collapse of the tower in the event of a failure (e.g. back-stays or others)
- all personnel is provided with adequate personal safety equipment, have received proper training, and all procedures has been validated from the safety point of view
- all lifting equipment has been regularly maintained, tested and certified
- the station pad is clear of loose material during the test
- the rigging equipment is well maintained (e.g. pulley blocks greased), tested and certified
- the load application devices (e.g. winches, hydraulic rams) do not impart dynamic effects when operated
- the equipment employed for the mechanical testing of the steel is calibrated
- the load measuring devices are calibrated against an instrument which itself is calibrated by a recognized independent calibration organization.

7 Test specification

The client shall prepare and transmit to the testing station, at an agreed time prior to the delivery of the support, the following appropriate information:

- Workshop and/or erection drawings of the support.
- The mass of each section of the support.
- Precautions to be observed during the unloading and unpacking.
- Requirements for the support assembly or disassembly, including if necessary details for lifting the support from the horizontal.
- Bolt tightening requirements.

- The tensions for any guys.
- Nominal force to be applied during slip-joining of sections and/or slip-joint length and their respective tolerances.
- Foundation setting tolerances and verticality tolerances of the support.
- The category of the test (design or sample).
- The exact position of the load application points for each loading case.
- ~~The design loads to be applied on the support for each loading case.~~
- (The point of application of the wind loads to be applied on the tower body shall be agreed between the designer and the test station.)
- The loading cases to be used for tower testing as selected from the tower design load cases as well as the detailed tower forces at attachment points and tower body to be applied on the support for each loading case.
- All reactions induced on the foundations of the test support for each loading case to be tested.
- ~~If the support is to be realigned between individual tests.~~
- The location of the deflection measuring points for each loading case.
- The position and the orientation of strain gauges, if applicable.
- The areas of the test support to be filmed during the test.
- Limitation of wind speed and wind direction during the test, if applicable.

8 Test programme

The test programme shall be submitted to the client at an agreed date before the test. This document shall be approved by the client and returned to the testing station within an agreed period.

The test programme shall include but not be limited to the following information:

- The expected test date.
- A description of the proposed foundations for the test support.
- The method of load application.
- A drawing of the test rigging arrangement and attachment details.
- The position of the dynamometers and/or load cells and the position of angle transducers in the case of resultant load applications.
- The position of deflection measurement points.
- The position and orientation of strain gauges if appropriate.
- The tolerances (loads, resultant angles, deflections, strain gauges).
- Details of applied loads as per rigging scheme for each test load case, load increment and holding period.
- Holding period for the final level.
- Loading rate for elastic-plastic materials and creep-sensitive materials. This requirement is not important or required for steel towers, but could be for some support types such as reinforced concrete structures subjected to permanent bending or to fibre reinforced structures.
- The category of the test (design or sample).

9 Assembly of support

~~The test support shall be erected on a footing that simulates the design assumption.~~

Footing(s) on which the test report to be erected shall simulate the design assumption.

The testing station shall proceed with the assembly of the support in accordance with the instructions provided by the client.

In the case where the testing station encounters a difficulty in the assembly or erection of the support, the client shall be informed and shall decide on the modifications required.

If requested by the client, a report of assembly shall be provided by the testing station. This report may include a video of the different phases of the assembly and any particular difficulty encountered.

10 Load application

10.1 General

Loading cases (loads, directions, and load application points) are stated by the client in the test specification.

10.2 Combined loads

If, for practical purposes, certain loads (e.g. due to wind on the support) have to be combined, the value of the resultant, its direction, and its application point shall be shown in the test programme.

10.3 Precautions for load application

The dynamometer/load cells shall be located in the test rigging as close as practical to the load application point on the support. When this cannot be ensured and/or multi-sheave rigging blocks are applied between load cells and load attachment point, allowance shall be made for the friction resistance in the rigging ropes and blocks (refer to Annexes C and D of CIGRE Brochure 399:2009, for further information) as agreed between the test station and the client.

Similarly, it is recommended that the test rigging ~~should~~ shall be arranged so as to minimize any load eccentricity. Fittings of the planned insulator strings shall preferably be used for the load application.

The testing station shall minimize the influence of any contact between the test rigging and the support; where this is not practical, this shall be drawn to the client's attention.

~~Unless otherwise agreed, it is recommended that the difference between the required load and the measured load at any individual load application point and at any time during the test should not exceed 5 %.~~

Loads shall be applied in such a way as to avoid any dynamic effect. However, joint slippage during the support test shall be accepted.

10.4 Load levels

The test loads shall be applied in increments to 50 %, 75 %, 90 %, 95 % and 100 % of the specified loads.

If required by the client, additional load levels may be considered.

10.5 Destruction tests

If required by the client, destruction tests shall be performed. These tests are to be applied for normal load cases or anti-cascading loads respectively. For load steps above 100 % of the specified loads, only horizontal loads shall be increased further. For load cases considering ice, both horizontal and vertical loads shall be increased further.

For destruction tests (i.e. for each load level above 100 % of the specified loads), it is suggested that a 5 % load increment be applied for each load step and the load step duration complying with 10.6.

10.6 Tolerances on applied loads

For each load level, the applied load measurements shall be considered acceptable if they are within the limits shown in Table 1.

Table 1 – Load tolerances

~~Load level~~ ~~%~~	~~Acceptable range~~ ~~%~~
~~50~~	~~49 to 51~~
~~75~~	~~74 to 76~~
~~90~~	~~89 to 91~~
~~95~~	~~94 to 96~~
~~100~~	~~100 to102~~

Load level %	Acceptable range for individual load components %	Acceptable range for the average of all loads %
50	48 to 53	48 to 53
75	73 to 78	73 to 78
90	88 to 93	88 to 93
95	93 to 98	94 to 96
100	100 to 105	100 to 102

10.7 Loading rate and holding period

For each load increment, the time taken for the load application depends upon the facilities of the testing station and the time needed for the loads to be adjusted in accordance with ~~9.4~~ 10.5.

~~For the final 100 % level, the loads shall be maintained for a minimum of 1 min and for a maximum of 5 min. The holding period chosen for the final level shall be included in the test programme.~~

For the final 100 % level, the loads shall be maintained for a contractual period of time, usually 1 min (this is the minimum holding period criteria for accepting the test and any longer duration can be agreed upon between the testing station operator and the client prior to testing. Without previous agreement, the holding period criteria shall be the default value of 1 min). In addition to the above holding period criteria, an extended holding period, usually of 4 min beyond the contractual value, can be requested by the client for engineering purposes, but any failure during this extended period shall not be a criterion for rejecting the test. In order to avoid possible disputes regarding acceptance or rejection of testing results, it is recommended that the contractual duration for acceptance of the tests as well as the extended duration be clearly defined prior to testing.

Before start counting the holding period, the loads shall be in balance. Balance means that the applied loads are stable.

For supports made of creep-sensitive materials, different loading rates and holding periods may ~~apply~~ be applied subject to client and testing operator agreement.

11 Measurements

11.1 Load and angle measurements

The accuracy of the dynamometers and/or load cells and/or angle transducers shall be such that errors in measurement are not greater than 1 % at full scale ~~(including the effect of the test rigging). The accuracy specified assumes a standard deviation of 3 σ~~.

All dynamometers and/or load cells and/or angle transducers shall be calibrated before and after every test series. ~~The calibration instruments shall be certified at least once a year.~~ The client can specify that at least three load cells shall be calibrated in his presence. This specification requires the client to be present at the station in due time before the test.

All applied loads and/or resultant angles shall be recorded.

11.2 Deflection measurements

At each load level and when the support is stable, support deflection shall be measured in accordance with the test specification. The accuracy of measurements shall be ~~25~~ 10 mm. ~~The accuracy specified assumes a standard deviation of 3 σ.~~

11.3 Strain measurements

If requested by the client, strain measurement shall be obtained in accordance with accepted industry standards. The testing station shall provide the accuracy of measurement of the strain gauges and/or the instrumented members and synchronize the measurements with applied loads.

12 Sequence of test loading cases

The sequence of test loading cases shall be determined by the client and stated in the test specification. It is recommended to choose first those tests having the least influence on the results of the successive tests. If agreed by the client, the testing station may adjust the test sequence to simplify the test operations or to reduce the cost of the test.

13 Video documentation

It is recommended that the entire test should be video recorded and the video cross-referenced with the measurements.

14 Acceptance criteria

The performance of the support shall be considered acceptable if it resists the specified design loads (at 100 %) for the contractual duration period agreed upon in 10.6 (default value of 1 min) without failure of any components or assemblies ~~even though a longer holding period may have been specified~~.

Permanent local deformations such as bowing or twisting of secondary members and components are acceptable. Ovalization of holes and permanent deformation of bolts shall be accepted as long as the support meets the above contractual duration period.

Additionally, the requirement of Clause 16 shall be fulfilled.

15 Premature failure

15.1 Design tests

In the event of failure at less than 95 % of the specified design load, the failed component(s) ~~may~~ shall be replaced by other component(s). The modified structure shall be retested to resist 100 % of the specified design loads.

In the event of failure between 95 % and less than 100 % of the specified design loads, with the exception of the final load case (frequently the destruction load case), the support shall be modified and retested. If failure occurs in the final load case, the client may elect not to retest the modified support.

In the event of failure at 100 % of the specified design loads but ~~at less than 1 min into~~ before the contractual holding period defined in 10.6 is reached, the client may accept the support without modification.

15.2 Sample tests

In the event of a failure at less than 100 % of the specified design load, the failed component(s) shall be replaced by identical components and the support retested. In the event of a subsequent failure, the client may reject the batch of supports from which the test support has been drawn.

In the event of a failure at 100 % of the specified design load but at less than ~~1 min into~~ the contractual holding period defined in 10.6, the client may accept the batch of supports from which the test support has been drawn.

15.3 Replacement of components

The partial or complete replacement or modification of elements, assemblies and complete sections of the support is the responsibility of the client. In case one or a few members are replaced during testing, previous successful tests do not need to be repeated.

16 Material specification

The selection of materials, manufacturing tolerances and engineering properties (i.e. geometrical and mechanical characteristics) for the support are the responsibility of the client.

The materials used for the fabrication of a prototype support shall be representative of the materials used in serial production structures and within the specified industry standards.

On completion of the test series, it is recommended to take samples from the prototype support and perform tensile tests in order to verify the compliance of the material with the specifications.

The number and location of samples are the responsibility of the client. Minimum five samples shall be taken from the most highly stressed members.

If the components of the support do not fulfil the requirements of the applicable industry standards, the client may declare the test invalid and reject the support.

17 Test report

The testing station shall document all relevant test information and data.

The test report shall include the following data:

a) Indication of the applicable standard for testing supports (IEC 60652:2021).
b) Designation, type, and description of the support.
c) Name of the support manufacturer.
d) Name of the support designer.
e) Name of the client.
f) Dates and location of testing.
g) Sampling method for selection of the structure to be tested.
h) Names of the persons present during the tests.
i) List of workshop and/or erection drawings of the test support, including any modifications.
j) Methods and measurements of the joints assembly.
k) Description of all anomalies and difficulties met during the assembly as well as corrective measures adopted by the client.
l) Rigging drawing used to apply the test loads.
m) Brief description of the test facility including the number, location, range and calibration charts or tables of every load and angle transducer or other load measuring devices, as well as the accuracy of the equipment used to measure the test loads.
n) Loads required at the various points on the support and at each load level.
o) Holding period for the final level.
p) Calibration records.
q) Deflection measurements.
r) Strain gauge measurements if appropriate.
s) In case of failure:
    - maximum loads applied to the support prior to failure;
    - a description of the failure;
    - when required by the client, engineering properties of the failed component(s);
    - if required by the client, a video film of the failure.
t) Summary results.
u) Photographs showing the whole support before, during and after tests and, where appropriate, details of any failure.
v) Local meteorological data during the tests series (e.g. wind speed and direction, temperature, etc.).
w) If required by the client, observations of noticeable permanent deformations during the dismantling.
x) When applicable, the number of the certificate of quality assurance of the station according to ISO/IEC 17025:2017.
y) If required by the client, the engineering properties of component samples taken from the support.

18 Record and traceability

The testing station shall keep a record of all relevant information for a time period of at least 10 years or as required by the client. Relevant information includes the test report, calibration

and test data, deflection and load time histories, rigging drawings and available video and still images.

The disposition or storage of the test support is the responsibility of the client.

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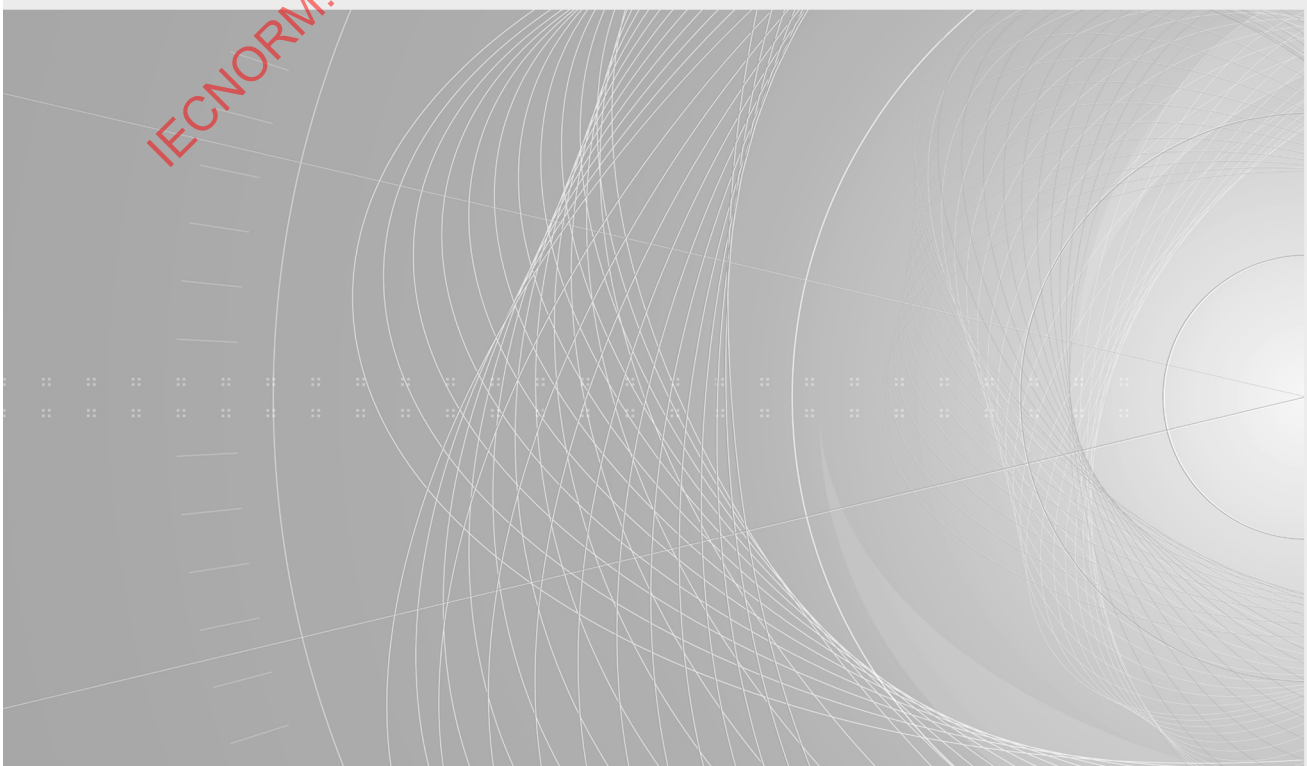
INTERNATIONAL STANDARD

NORME INTERNATIONALE

Overhead line structures – Loading tests

Structures des lignes aériennes – Essais mécaniques



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Tests on reduced scale models of supports are not covered by this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-466:1990, *International Electrotechnical Vocabulary (IEV) – Part 466: Overhead lines*
IEC 60050-466:1990/AMD1:2020

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

CIGRE Brochure 399:2009, *Improvement on the Tower Testing Methodology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-466:1990 and the following apply.

3.1
client
organization which contracts with the testing station and provides the test specification

3.2
design load
load for which the support has been designed

3.3
failure load
limit state loads value at which the support cannot carry any additional load as determined during the destruction test of the support

3.4
realignment
process used for restoring the original 'vertical' position of the tower after being permanently deformed due to an intermediate loading case testing

Note 1 to entry: This process usually requires release of bolts in connections, pulling back the tower to its original position, and finally re-tightening bolts. This procedure is not recommended.

3.5
test report
document summarizing all the relevant aspects of the tests

4 Categories of tests

4.1 General

The objective of support tests is to verify the design method and inherent assumptions, the method of member detailing and the quality of fabrication, manufacture and material.

With respect to the purpose of the test, the level of instrumentation and the method of execution, this document refers to two categories of tests:

a) design tests;

b) sample tests.

4.2 Design tests

Design tests are normally carried out on full scale prototype supports, with one or more of the following objectives:

a) as part of a research and/or development programme in the design of an innovative support;

b) to verify compliance of the support design with the specifications (also known as type tests on a prototype support);

c) to develop and/or validate a new design standard or methodology;

d) to develop and/or validate new fabrication processes.

When tests are carried out to verify design parameters, the test support shall be identical as far as possible to the serial production supports (see Clause 5, first paragraph). Tests on full scale sections or part of the support may also be undertaken.

Design tests shall be carried out to at least the design load or to failure, especially when testing according to 4.2b) and/or 4.2c).

4.3 Sample tests

These are intended for use either prior to or during the fabrication of the production of a batch of supports to act as a check on the quality of the fabrication, or on the materials being used. The support shall be taken at random from the serial production supports during manufacture. The test constitutes the acceptance of the production.

Sample tests are taken to a specific percentage of the design load (usually 100 %), as stipulated in the test specification.

5 General test criteria

For a design test (according to 4.2b) or 4.2c)), the material(s) and the manufacturing processes used in the fabrication of the prototype support shall be to the same specifications as those used during the serial fabrication of the supports. These specifications shall include the member sectional properties, connection details, e.g. bolt or weld sizes, material grades and fabrication processes. Prior to the commencement of the prototype support fabrication, agreement shall be made with regard to the surface coating of the support.

Agreement shall also be made with respect to the organization responsible for the checking of the support prior to the testing.

If a sample test is required on a production support, the components shall be chosen at random from the batch.

Whether it is for the design test (according to 4.2b)) or the sample test, the support shall successfully withstand the loads specified by the client.

6 Acceptability of test station

If required by the client, the testing station shall be accredited by an external organization to perform this type of test according to the procedures of quality assurance defined by ISO/IEC 17025:2017.

The following minimum requirements shall be fulfilled by the test station:

- the layout of the station is generally safe (e.g. in case of structure collapse the control building and the observation area are not located in the danger zone)
- the station has adequate provision to limit the severity of the collapse of the tower in the event of a failure (e.g. back-stays or others)
- all personnel is provided with adequate personal safety equipment, have received proper training, and all procedures has been validated from the safety point of view
- all lifting equipment has been regularly maintained, tested and certified
- the station pad is clear of loose material during the test
- the rigging equipment is well maintained (e.g. pulley blocks greased), tested and certified
- the load application devices (e.g. winches, hydraulic rams) do not impart dynamic effects when operated
- the equipment employed for the mechanical testing of the steel is calibrated
- the load measuring devices are calibrated against an instrument which itself is calibrated by a recognized independent calibration organization.

7 Test specification

The client shall prepare and transmit to the testing station, at an agreed time prior to the delivery of the support, the following appropriate information:

- Workshop and/or erection drawings of the support.
- The mass of each section of the support.
- Precautions to be observed during the unloading and unpacking.
- Requirements for the support assembly or disassembly, including if necessary details for lifting the support from the horizontal.
- Bolt tightening requirements.

- The tensions for any guys.
- Nominal force to be applied during slip-joining of sections and/or slip-joint length and their respective tolerances.
- Foundation setting tolerances and verticality tolerances of the support.
- The category of the test (design or sample).
- The exact position of the load application points for each loading case.
- (The point of application of the wind loads to be applied on the tower body shall be agreed between the designer and the test station.)
- The loading cases to be used for tower testing as selected from the tower design load cases as well as the detailed tower forces at attachment points and tower body to be applied on the support for each loading case.
- All reactions induced on the foundations of the test support for each loading case to be tested.
- The location of the deflection measuring points for each loading case.
- The position and the orientation of strain gauges, if applicable.
- The areas of the test support to be filmed during the test.
- Limitation of wind speed and wind direction during the test, if applicable.

8 Test programme

The test programme shall be submitted to the client at an agreed date before the test. This document shall be approved by the client and returned to the testing station within an agreed period.

The test programme shall include but not be limited to the following information:

- The expected test date.
- A description of the proposed foundations for the test support.
- The method of load application.
- A drawing of the test rigging arrangement and attachment details.
- The position of the dynamometers and/or load cells and the position of angle transducers in the case of resultant load applications.
- The position of deflection measurement points.
- The position and orientation of strain gauges if appropriate.
- The tolerances (loads, resultant angles, deflections, strain gauges).
- Details of applied loads as per rigging scheme for each test load case, load increment and holding period.
- Holding period for the final level.
- Loading rate for elastic-plastic materials and creep-sensitive materials. This requirement is not important or required for steel towers, but could be for some support types such as reinforced concrete structures subjected to permanent bending or to fibre reinforced structures.
- The category of the test (design or sample).

9 Assembly of support

Footing(s) on which the test report to be erected shall simulate the design assumption.

The testing station shall proceed with the assembly of the support in accordance with the instructions provided by the client.

In the case where the testing station encounters a difficulty in the assembly or erection of the support, the client shall be informed and shall decide on the modifications required.

If requested by the client, a report of assembly shall be provided by the testing station. This report may include a video of the different phases of the assembly and any particular difficulty encountered.

10 Load application

10.1 General

Loading cases (loads, directions, and load application points) are stated by the client in the test specification.

10.2 Combined loads

If, for practical purposes, certain loads (e.g. due to wind on the support) have to be combined, the value of the resultant, its direction, and its application point shall be shown in the test programme.

10.3 Precautions for load application

The dynamometer/load cells shall be located in the test rigging as close as practical to the load application point on the support. When this cannot be ensured and/or multi-sheave rigging blocks are applied between load cells and load attachment point, allowance shall be made for the friction resistance in the rigging ropes and blocks (refer to Annexes C and D of CIGRE Brochure 399:2009, for further information) as agreed between the test station and the client.

Similarly, it is recommended that the test rigging shall be arranged so as to minimize any load eccentricity. Fittings of the planned insulator strings shall preferably be used for the load application.

The testing station shall minimize the influence of any contact between the test rigging and the support; where this is not practical, this shall be drawn to the client's attention.

Loads shall be applied in such a way as to avoid any dynamic effect. However, joint slippage during the support test shall be accepted.

10.4 Load levels

The test loads shall be applied in increments to 50 %, 75 %, 90 %, 95 % and 100 % of the specified loads.

If required by the client, additional load levels may be considered.

10.5 Destruction tests

If required by the client, destruction tests shall be performed. These tests are to be applied for normal load cases or anti-cascading loads respectively. For load steps above 100 % of the specified loads, only horizontal loads shall be increased further. For load cases considering ice, both horizontal and vertical loads shall be increased further.

For destruction tests (i.e. for each load level above 100 % of the specified loads), it is suggested that a 5 % load increment be applied for each load step and the load step duration complying with 10.6.

10.6 Tolerances on applied loads

For each load level, the applied load measurements shall be considered acceptable if they are within the limits shown in Table 1.

Table 1 – Load tolerances

Load level %	Acceptable range for individual load components %	Acceptable range for the average of all loads %
50	48 to 53	48 to 53
75	73 to 78	73 to 78
90	88 to 93	88 to 93
95	93 to 98	94 to 96
100	100 to 105	100 to 102

10.7 Loading rate and holding period

For each load increment, the time taken for the load application depends upon the facilities of the testing station and the time needed for the loads to be adjusted in accordance with 10.5.

For the final 100 % level, the loads shall be maintained for a contractual period of time, usually 1 min (this is the minimum holding period criteria for accepting the test and any longer duration can be agreed upon between the testing station operator and the client prior to testing. Without previous agreement, the holding period criteria shall be the default value of 1 min). In addition to the above holding period criteria, an extended holding period, usually of 4 min beyond the contractual value, can be requested by the client for engineering purposes, but any failure during this extended period shall not be a criterion for rejecting the test. In order to avoid possible disputes regarding acceptance or rejection of testing results, it is recommended that the contractual duration for acceptance of the tests as well as the extended duration be clearly defined prior to testing.

Before start counting the holding period, the loads shall be in balance. Balance means that the applied loads are stable.

For supports made of creep-sensitive materials, different loading rates and holding periods may be applied subject to client and testing operator agreement.

11 Measurements

11.1 Load and angle measurements

The accuracy of the dynamometers and/or load cells and/or angle transducers shall be such that errors in measurement are not greater than 1 % at full scale.

All dynamometers and/or load cells and/or angle transducers shall be calibrated before and after every test series. The client can specify that at least three load cells shall be calibrated in his presence. This specification requires the client to be present at the station in due time before the test.

All applied loads and/or resultant angles shall be recorded.

11.2 Deflection measurements

At each load level and when the support is stable, support deflection shall be measured in accordance with the test specification. The accuracy of measurements shall be 10 mm.

11.3 Strain measurements

If requested by the client, strain measurement shall be obtained in accordance with accepted industry standards. The testing station shall provide the accuracy of measurement of the strain gauges and/or the instrumented members and synchronize the measurements with applied loads.

12 Sequence of test loading cases

The sequence of test loading cases shall be determined by the client and stated in the test specification. It is recommended to choose first those tests having the least influence on the results of the successive tests. If agreed by the client, the testing station may adjust the test sequence to simplify the test operations or to reduce the cost of the test.

13 Video documentation

It is recommended that the entire test should be video recorded and the video cross-referenced with the measurements.

14 Acceptance criteria

The performance of the support shall be considered acceptable if it resists the specified design loads (at 100 %) for the contractual duration period agreed upon in 10.6 (default value of 1 min) without failure of any components or assemblies.

Permanent local deformations such as bowing or twisting of secondary members and components are acceptable. Ovalization of holes and permanent deformation of bolts shall be accepted as long as the support meets the above contractual duration period.

Additionally, the requirement of Clause 16 shall be fulfilled.

15 Premature failure

15.1 Design tests

In the event of failure at less than 95 % of the specified design load, the failed component(s) shall be replaced by other component(s). The modified structure shall be retested to resist 100 % of the specified design loads.

In the event of failure between 95 % and less than 100 % of the specified design loads, with the exception of the final load case (frequently the destruction load case), the support shall be modified and retested. If failure occurs in the final load case, the client may elect not to retest the modified support.

In the event of failure at 100 % of the specified design loads but before the contractual holding period defined in 10.6 is reached, the client may accept the support without modification.

15.2 Sample tests

In the event of a failure at less than 100 % of the specified design load, the failed component(s) shall be replaced by identical components and the support retested. In the event of a subsequent failure, the client may reject the batch of supports from which the test support has been drawn.

In the event of a failure at 100 % of the specified design load but at less than the contractual holding period defined in 10.6, the client may accept the batch of supports from which the test support has been drawn.

15.3 Replacement of components

The partial or complete replacement or modification of elements, assemblies and complete sections of the support is the responsibility of the client. In case one or a few members are replaced during testing, previous successful tests do not need to be repeated.

16 Material specification

The selection of materials, manufacturing tolerances and engineering properties (i.e. geometrical and mechanical characteristics) for the support are the responsibility of the client.

The materials used for the fabrication of a prototype support shall be representative of the materials used in serial production structures and within the specified industry standards.

On completion of the test series, it is recommended to take samples from the prototype support and perform tensile tests in order to verify the compliance of the material with the specifications.

The number and location of samples are the responsibility of the client. Minimum five samples shall be taken from the most highly stressed members.

If the components of the support do not fulfil the requirements of the applicable industry standards, the client may declare the test invalid and reject the support.

17 Test report

The testing station shall document all relevant test information and data.

The test report shall include the following data:

a) Indication of the applicable standard for testing supports (IEC 60652:2021).
b) Designation, type, and description of the support.
c) Name of the support manufacturer.
d) Name of the support designer.
e) Name of the client.
f) Dates and location of testing.
g) Sampling method for selection of the structure to be tested.
h) Names of the persons present during the tests.
i) List of workshop and/or erection drawings of the test support, including any modifications.
j) Methods and measurements of the joints assembly.
k) Description of all anomalies and difficulties met during the assembly as well as corrective measures adopted by the client.
l) Rigging drawing used to apply the test loads.
m) Brief description of the test facility including the number, location, range and calibration charts or tables of every load and angle transducer or other load measuring devices, as well as the accuracy of the equipment used to measure the test loads.
n) Loads required at the various points on the support and at each load level.
o) Holding period for the final level.

p) Calibration records.

q) Deflection measurements.

r) Strain gauge measurements if appropriate.

s) In case of failure:

- maximum loads applied to the support prior to failure;
- a description of the failure;
- when required by the client, engineering properties of the failed component(s);
- if required by the client, a video film of the failure.

t) Summary results.

u) Photographs showing the whole support before, during and after tests and, where appropriate, details of any failure.

v) Local meteorological data during the tests series (e.g. wind speed and direction, temperature, etc.).

w) If required by the client, observations of noticeable permanent deformations during the dismantling.

x) When applicable, the number of the certificate of quality assurance of the station according to ISO/IEC 17025:2017.

y) If required by the client, the engineering properties of component samples taken from the support.

18 Record and traceability

The testing station shall keep a record of all relevant information for a time period of at least 10 years or as required by the client. Relevant information includes the test report, calibration and test data, deflection and load time histories, rigging drawings and available video and still images.

The disposition or storage of the test support is the responsibility of the client.

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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STRUCTURES DES LIGNES AÉRIENNES – ESSAIS MÉCANIQUES

AVANT-PROPOS

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9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets.

L'IEC 60652 a été établie par le comité d'études 11 de l'IEC: Lignes aériennes. Il s'agit d'une Norme internationale.

Cette troisième édition annule et remplace la deuxième édition parue en 2002. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) le titre a été modifié;
b) une référence à la brochure 399 du CIGRE a été ajoutée;
c) à l'Article 7, des limites d'essai ont été ajoutées pour la vitesse et la direction du vent lors des essais;
d) en 10.5, des incréments de charge ont été ajoutés pour les essais destructifs;

e) en 10.7, une exigence a été ajoutée aux essais de supports constitués de matériaux sensibles au fluage : celle-ci est soumise à l'accord entre la station d'essais et le client;

f) à l'Article 17, des exigences ont été ajoutées pour la procédure d'échantillonnage en vue d'étayer le rapport d'essai.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
11/276/FDIS	11/277/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Le présent document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/standardsdev/publications.

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- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

STRUCTURES DES LIGNES AÉRIENNES – ESSAIS MÉCANIQUES

1 Domaine d'application

Le présent document spécifie les méthodes et procédures d'essai pour les supports de lignes aériennes.

Il s'applique aux essais des supports et structures des lignes aériennes.

Aucune restriction ne s'applique au type de matériau utilisé pour la fabrication des supports qui peuvent, entre autres, être réalisés en alliages métalliques, en béton, en bois (éventuellement stratifié) et en matériaux composites. Si le client l'exige, le présent document peut également être appliqué dans le cadre d'essais concernant les supports de télécommunication, les supports d'électrification de lignes aériennes pour les chemins de fer/tramways, les portiques de postes électriques, les supports d'éclairage public et de signalisation, les mâts d'éoliennes, les supports de téléphériques, etc.

Les essais réalisés sur modèles de supports à échelle réduite ne sont pas couverts par le présent document.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60050-466:1990, *Vocabulaire Electrotechnique International – Chapitre 466: Lignes électriques*
IEC 60050-466:1990/AMD1:2020

ISO/IEC 17025:2017, *Exigences générales concernant la compétence des laboratoires d'étalonnages et d'essais*

Brochure 399:2009 du CIGRE, *Improvement on the Tower Testing Methodology* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 60050-466:1990 ainsi que les suivants s'appliquent.

3.1
client
organisation qui passe un contrat avec la station d'essais et qui fournit la spécification d'essai

3.2
charge nominale
charge pour laquelle le support a été conçu

3.3
charge de rupture
valeur des charges d'état limite à laquelle le support ne peut soutenir aucune charge supplémentaire, qui est déterminée par la réalisation d'un essai destructif sur le support

3.4
réalignement
processus utilisé pour rétablir la position "verticale" d'origine du pylône après avoir subi une déformation permanente à la suite d'un essai de cas de charge intermédiaire

Note 1 à l'article: Ce processus exige généralement le desserrage des boulons de liaison, le rétablissement du pylône dans sa position d'origine et enfin le resserrage des boulons. Cette procédure n'est pas recommandée.

3.5
rapport d'essai
document qui récapitule l'ensemble des aspects pertinents pour les essais

4 Catégories d'essais

4.1 Généralités

L'objectif des essais de supports est de vérifier la méthode de conception utilisée et les hypothèses intrinsèques, la pertinence des plans de détails des barres, ainsi que la qualité de la fabrication et des matériaux.

En ce qui concerne l'objet, le niveau d'instrumentation et la méthode d'exécution des essais, le présent document s'appuie sur deux catégories d'essais:

a) les essais de conception;

b) les essais sur échantillon.

4.2 Essais de conception

Les essais de conception sont généralement réalisés sur des prototypes de supports en échelle réelle, dans un ou plusieurs objectifs suivants:

a) faire partie d'un programme de recherche et/ou de développement pour la conception d'un support innovant;

b) vérifier la conformité de la conception d'un support aux spécifications établies (ces essais sont également connus sous le nom d'essais de type sur un prototype de support);

c) élaborer et/ou valider une nouvelle norme ou méthodologie de conception;

d) élaborer et/ou valider un nouveau procédé de fabrication.

Lorsque l'objet des essais est de vérifier les paramètres de conception, le support d'essai doit, dans la mesure du possible, être identique aux supports issus de la production en série (voir Article 5, premier alinéa). Des essais à échelle réelle sur des tronçons ou des parties du support peuvent également être effectués.

Les essais de conception doivent être réalisés au moins à la charge nominale ou jusqu'à la rupture, en particulier pour les essais décrits en 4.2b) et/ou 4.2c).

4.3 Essais sur échantillon

Les essais sur échantillon sont réalisés avant ou pendant la production d'un lot de supports dans le but de contrôler la qualité de la fabrication ou les matériaux utilisés. Le support doit être prélevé au hasard parmi ceux issus de la production en série. Cet essai vaut pour acceptation de la production.

Les essais sur échantillon sont réalisés à un pourcentage spécifié de la charge nominale (généralement 100 %), comme cela est indiqué dans la spécification d'essai.

5 Critères d'essai généraux

Dans le cas d'un essai de conception (selon 4.2b) ou 4.2c)), le ou les matériaux ainsi que les procédés de fabrication employés pour la réalisation du prototype de support doivent être répondre aux mêmes spécifications que celles utilisées pour la fabrication en série des supports. Ces spécifications doivent décrire les propriétés en coupe des barres, les liaisons, par exemple les dimensions des boulons ou soudures, la qualité des matériaux et les procédés de fabrication employés. Le revêtement de surface du support doit faire l'objet d'un accord avant la fabrication du prototype de support.

De même, l'organisation responsable de la vérification du support doit être désignée par un accord avant les essais.

Si un essai sur échantillon est exigé sur un support de production, les composants doivent être prélevés au hasard du lot.

Quel que soit le type d'essai: l'essai de conception (selon 4.2b) ou l'essai sur échantillon, le support doit résister de manière satisfaisante aux charges spécifiées par le client.

6 Acceptabilité de la station d'essais

Si le client l'exige, la station d'essais doit être accréditée par une organisation externe pour réaliser ce type d'essai, conformément aux procédures d'assurance qualité définies dans l'ISO/IEC 17025:2017.

La station d'essais doit satisfaire aux exigences minimales suivantes:

- l'agencement de la station est généralement sûr (par exemple, en cas d'effondrement de la structure, le bâtiment de contrôle et la zone d'observation ne sont pas situés dans la zone de danger);
- la station comporte des dispositifs adéquats pour atténuer la gravité de l'effondrement du pylône en cas de rupture (câbles de retenue ou autres, par exemple);
- l'ensemble du personnel dispose d'un équipement de protection individuelle approprié et a suivi une formation adéquate, et toutes les procédures ont été validées du point de vue de la sécurité;
- l'ensemble du matériel de levage est entretenu, soumis à l'essai et certifié à intervalles réguliers;
- aucun matériau épars ne se trouve sur la dalle de la station pendant l'essai;
- le matériel d'élingage est bien entretenu (moufles graissées, par exemple), a été soumis à l'essai et certifié;
- les dispositifs d'application de la charge (treuils, vérins hydrauliques, par exemple) ne produisent pas d'effets dynamiques lorsqu'ils sont en fonctionnement;
- le matériel utilisé pour les essais mécaniques de l'acier est étalonné;
- les dispositifs de mesurage de la charge sont étalonnés par un instrument qui a lui-même été étalonné par un organisme d'étalonnage indépendant reconnu.