

INTERNATIONAL STANDARD



Railway applications – Fixed installations – Electric traction overhead contact lines systems



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IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS – FIXED INSTALLATIONS –
ELECTRIC TRACTION OVERHEAD CONTACT LINE SYSTEMS**

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This commented version (CMV) of the official standard IEC 60913:2024 edition 3.0 allows the user to identify the changes made to the previous IEC 60913:2013 edition 2.0. Furthermore, comments from IEC TC 9 experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.

IEC 60913 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways. It is an International Standard.

This third edition cancels and replaces the second edition published in 2013. This edition constitutes a technical revision.

The European standard EN 50119 has served as a basis for the elaboration of this document.

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

- a) title modified;
- b) requirements for urban rail systems are included;
- c) requirements for rigid overhead contact line (ROCL) are included;
- d) additional definitions for new terms are included (Clause 3);
- e) clearances and geometry of overhead contact line are improved (Clause 5);
- f) urban aspects are added, for example wall anchors (Clause 6);
- g) requirements for monitoring devices, automatic earthing and short-circuiting equipment are included (Clause 7);
- h) requirements for overhead contact line for electric vehicles with pantograph on electrified roads are added (Annex E)
- i) improvements on the basis of EN 50119:2020 and the questionnaire 9/2619A/Q

The text of this International Standard is based on the following documents:

Draft	Report on voting
9/3031/FDIS	9/3052/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The reader's attention is drawn to the fact that Annex H lists all of the "in-some-country" clauses on differing practices of a less permanent nature relating to the subject of this document.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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RAILWAY APPLICATIONS – FIXED INSTALLATIONS – ELECTRIC TRACTION OVERHEAD CONTACT LINE SYSTEMS

1 Scope

~~This International Standard applies to electric traction overhead contact line systems in heavy railways, light railways, trolley busses and industrial railways of public and private operators.~~

~~It applies to new installations of overhead contact line systems and for the complete reconstruction of existing overhead contact line systems.~~

This document specifies the requirements and tests for the design of overhead contact line systems, requirements for structures and their structural calculations and verifications as well as the requirements and tests for the design of assemblies and individual parts.

~~This standard does not provide requirements for conductor rail systems where the conductor rails are located adjacent to the running rails.~~

This document is applicable to electric traction overhead contact line systems in heavy railways, light railways, for trolley bus lines, electric road systems **1** (Annex E) and industrial railways of public and private operators. This document is applicable to new installations of overhead contact line systems and for the complete renewal of existing overhead contact line systems.

This document does not apply to ground level conductor rail systems (see Figure 1).

NOTE Ground level conductor rail means conductor rails located adjacent to the running rail, e.g. the third rail or a conductor rail in the ground.

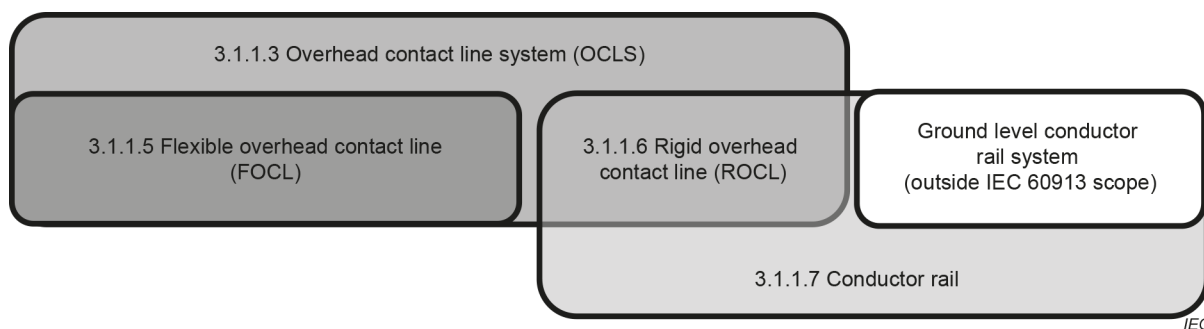


Figure 1 – Scope of contact line systems **2**

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.

~~NOTE Normative references are made to ISO and IEC standards. For some necessary references, ISO and IEC standards do not exist. In these cases, references are made to European Standards which are normative for Europe according to EN 50110. For non-European countries these references are only informative and listed in the bibliography.~~

~~IEC 60050-811, International Electrotechnical Vocabulary (IEV) – Chapter 811: Electric traction~~

~~IEC 60071 (all parts), Insulation co-ordination~~

~~IEC 60099 (all parts), Surge arresters~~

~~IEC 60099-1, Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems~~

IEC 60099-4, Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems

IEC 60168, Tests on indoor and outdoor post insulators of ceramic material or glass for systems with nominal voltages greater than 1 000 V

IEC 60273, Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1 000 V

IEC 60305, Insulators for overhead lines with a nominal voltage above 1 000 V – Ceramic or glass insulator units for AC systems – Characteristics of insulator units of the cap and pin type

IEC 60383 (all parts), Insulators for overhead lines with nominal voltage above 1 000 V

IEC 60433, Insulators for overhead lines with a nominal voltage above 1 000 V – Ceramic insulators for AC systems – Characteristics of insulator units of the long rod type

~~IEC 60494 (all parts), Railway applications – Rolling stock – Pantographs – Characteristics and tests~~

IEC 60494-1, Railway applications – Rolling stock – Pantographs – Characteristics and tests – Part 1: Pantographs for main line vehicles

IEC 60494-2, Railway applications – Rolling stock – Pantographs – Characteristics and tests – Part 2: Pantographs for metros and light rail vehicles

IEC 60529, Degrees of protection provided by enclosures (IP Code)

IEC 60660, Insulators – Tests on indoor post insulators of organic material for systems with nominal voltages greater than 1 000 V up to but not including 300 kV

IEC 60672-1, Ceramic and glass insulating materials – Part 1: Definitions and classification

IEC 60672-2, Ceramic and glass insulating materials – Part 2: Methods of test

IEC 60672-3, Ceramic and glass-insulating materials – Part 3: Specifications for individual materials

IEC 60850, Railway applications – Supply voltages of traction systems

~~IEC 60889, Hard-drawn aluminium wire for overhead line conductors~~

IEC 60947-1, Low-voltage switchgear and controlgear – Part 1: General rules

IEC 61089, Round wire concentric lay overhead electrical stranded conductors

~~IEC 61109, Insulators for overhead lines – Composite suspension and tension insulators for a.c. systems with a nominal voltage greater than 1 000 V – Definitions, test methods and acceptance criteria~~

~~IEC 61232, Aluminium-clad steel wires for electrical purposes~~

IEC/TR TS 61245, Artificial pollution tests on high-voltage ceramic and glass insulators to be used on d.c. systems

IEC 61325, Insulators for overhead lines with a nominal voltage above 1 000 V – Ceramic or glass insulator units for d.c. systems – Definitions, test methods and acceptance criteria

IEC 61284:1997, Overhead lines – Requirements and tests for fittings

IEC 61773, Overhead lines – Testing of foundations for structures

~~IEC 61952, Insulators for overhead lines – Composite line post insulators for a.c. systems with a nominal voltage greater than 1 000 V – Definitions, test methods and acceptance criteria~~

~~IEC 61992 (all parts), Railway applications – Fixed installations – DC switchgear~~

IEC 61992-1, Railway applications – Fixed installations – DC switchgear – Part 1: General

IEC 61992-4, Railway applications – Fixed installations – DC switchgear – Part 4: Outdoor d.c. disconnectors, switch-disconnectors and earthing switches

~~IEC 61992-5, Railway applications – Fixed installations – DC switchgear – Part 5: Surge arresters and low-voltage limiters for specific use in d.c. systems~~

IEC 62128 (all parts), Railway applications – Fixed installations – Electrical safety, earthing and the return circuit

~~IEC 62128-1:2003, Railway applications – Fixed installations – Part 1: Protective provisions relating to electrical safety and earthing~~

~~IEC 62128-2:2003, Railway applications – Fixed installations – Part 2: Protective provisions against the effects of stray currents caused by d.c. traction systems~~

IEC 62236-2:2008, Railway applications – Electromagnetic compatibility – Part 2: Emission of the whole railway system to the outside world

~~IEC 62271-102, High voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches~~

~~IEC 62271-103:2011, High voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV~~

IEC 62313, Railway applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock

IEC 62486:2017, Railway applications – Current collection systems – Technical criteria for the interaction between pantograph and overhead contact line (to achieve free access)

~~IEC 62497 (all parts), Railway applications – Insulation coordination~~

IEC 62497-1:2010, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*
IEC 62497-1:2010/AMD1:2013

IEC 62497-2, *Railway applications – Insulation coordination – Part 2: Overvoltages and related protection*

IEC 62498-2:2010, *Railway applications – Environmental conditions for equipment – Part 2: Fixed electrical installations*

~~IEC 62505 (all parts), Railway applications – Fixed installations – Particular requirements for a.c. switchgear~~

IEC 62505-2, *Railway applications – Fixed installations – Particular requirements for AC switchgear – Part 2: ~~Single-phase~~ Disconnectors, earthing switches and switches with ~~U_n~~ nominal voltage above 1 kV*

IEC 62621, *Railway applications – Fixed installations – Electric traction – Special requirements for composite insulators used for overhead contact line systems*

IEC 62641: 2022, *Conductors for overhead lines – Aluminium and aluminium alloy wires for concentric lay stranded conductors*

IEC 62724, *Railway applications – Fixed installations – Electric traction – Insulating synthetic rope assemblies for support of overhead contact lines*

IEC 62846:2016, *Railway applications – Current collection systems – Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line*

IEC 62848 (all parts), *Railway applications – DC surge arresters and voltage limiting devices*

IEC 62917, *Railway applications – Fixed installations – Electric traction – Copper and copper alloy grooved contact wires*

IEC 63190, *Railway applications – Fixed installations – Electric traction – Copper and copper alloy catenary wires for overhead contact line systems*

IEC 63248: 2022, *Conductors for overhead lines – Coated or clad metallic wire for concentric lay stranded conductors*

IEC 63438, *Railway applications – Fixed installations – Protection principles for AC and DC electric traction power supply systems*¹

IEC 63453, *Railway applications – Current collection systems – Validation of simulation of the dynamic interaction between pantograph and overhead contact line*²

ISO 630 (all parts), *Structural steels*

¹ Under preparation. Stage at the time of publication: IEC/AFDIS 63438:2023.

² Under preparation. Stage at the time of publication: IEC/CCDV 63453:2023.

ISO 898-1:2013, *Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs with specified property classes – Coarse thread and fine pitch thread*

ISO 898-2:2012, *Mechanical properties of fasteners made of carbon steel and alloy steel – Part 2: Nuts with specified property classes – Coarse thread and fine pitch thread*

ISO 1461:2022, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

ISO 2394, *General principles on reliability for structures*

ISO 2859 (all parts), *Sampling procedures for inspection by attributes*

~~ISO 3010:2001, *Basis for design of structures – Seismic actions on structures*~~

ISO 4354, *Wind actions on structures*

ISO 10721 (all parts), *Steel structures*

~~ISO/TR 11069:1995, *Aluminium structures – Material and design – Ultimate limit state under static loading*~~

~~ISO 14688-1, *Geotechnical investigation and testing – Identification and classification of soil – Part 1: Identification and description*~~

~~ISO 14688-2, *Geotechnical investigation and testing – Identification and classification of soil – Part 2: Principles for a classification*~~

~~ISO 14689-1, *Geotechnical investigation and testing – Identification and classification of rock – Part 1: Identification and description*~~

ISO 14713 (all parts), *Zinc coatings – Guidelines and recommendations for the protection against corrosion of iron and steel in structures*

~~ISO/TS 17892 (all parts), *Geotechnical investigation and testing – Laboratory testing of soil*~~

~~ISO 22475-1, *Geotechnical investigation and testing – Sampling methods and groundwater measurements – Part 1: Technical principles for execution*~~

~~ISO 22476-2, *Geotechnical investigation and testing – Field testing – Part 2: Dynamic probing*~~

~~ISO 22476-3, *Geotechnical investigation and testing – Field testing – Part 3: Standard penetration test*~~

~~ISO 23469:2005, *Bases for design of structures – Seismic actions for designing geotechnical works*~~

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definition **3**

For the purposes of this document, the following terms and definitions ~~given in IEC 60050-811 and the following~~ apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1.1 Systems

3.1.1.1

contact line system

~~support network for supplying electrical energy from substations to electrically powered traction units, which covers overhead contact line systems and conductor rail systems; the electrical limits of the system are the feeding point and the contact point to the current collector~~

support system and contact line supplying electric energy to vehicles through current-collecting equipment

Note 1 to entry: The mechanical system ~~may~~ can comprise

- the contact line,
- structures and foundations,
- supports and any components supporting or registering the conductors,
- head spans and cross-spans,
- ~~— tensioning devices,~~
- along-track feeders, negative feeders, reinforcing feeders, and other lines like earth wires and return conductors, including boosters, as far as they are supported from contact line system structures,
- cross-track feeders,
- overvoltage protection devices,
- conductors connected permanently to the contact line for supply of other electrical equipment such as lights, signal operation, point control and point heating, and
- any other equipment necessary for operating the contact line.

Note 2 to entry: The electrical limits of the contact line system are the feeding point and the contact point to the current collector.

[SOURCE: IEC 60050-811:2017, 811-33-59, modified – Note 1 to entry has been modified and Note 2 to entry has been added.]

3.1.1.2

contact line

conductor system for supplying traction units with electrical energy via current-~~collection~~ collecting equipment

Note 1 to entry: This includes all current-collecting conductors and conducting rails or bars, including the following:

- ~~— reinforcing feeders;~~
- ~~— cross-track feeders;~~
- ~~— disconnectors;~~
- ~~— section insulators;~~
- ~~— over-voltage protection devices;~~
- electrical connectors
- sectioning devices;
- tensioning devices;
- supports that are not insulated from the conductors;
- insulators connected to live parts;
- contact wires;
- catenary wires;
- auxiliary catenary wires;

- stitch wires;
- droppers.

~~but excluding other conductors, such as the following:~~

- ~~— along track feeders;~~
- ~~— earth wires and return conductors.~~

Note 2 to entry: Included are all components that affect the dynamic interaction.

[SOURCE: IEC 60050-811:2017, 811-33-01, modified – "Electric energy to vehicles through" has been replaced with "traction units with electrical energy via". In the Note 1 to entry "cross-track feeders; disconnectors; section insulators; overvoltage protection devices" have been removed and "electrical connectors, sectioning devices, tensioning devices, contact wires, catenary wires" have been added. The end of the Note 1 to entry has been removed. The Note 2 to entry has been added.]

3.1.1.3

overhead contact line system

contact line system using an overhead contact line to supply current for use by traction units

3.1.1.4

overhead contact line

OCL

contact line placed above or beside the upper limit of the vehicle gauge, supplying traction units with electrical energy through roof-mounted current collection equipment

Note 1 to entry: The overhead contact line can be of a flexible or rigid configuration.

[SOURCE: IEC 60050-811:2017, 811-33-02, modified – "Catenary" has been removed as synonym and replaced with the abbreviated term OCLS. In the definition, "electric" has been replaced with "electrical". The Note 1 to entry has been added.]

3.1.1.5

flexible overhead contact line

FOCL

overhead contact line using flexible tensioned conductors

Note 1 to entry: The flexible overhead contact line can be an overhead contact line with catenary suspension (IEC 60050-811:2017, 811-33-05) or a single tramway equipment (IEC 60050-811:2017, 811-33-03).

3.1.1.6

rigid overhead contact line

ROCL

overhead contact line using almost rigid not tensioned profiles

Note 1 to entry: In this document, rigid overhead contact line is used to define conductor rail (3.1.1.7) mounted in an overhead position.

3.1.1.7

conductor rail

~~contact line made of a rigid metallic section or rail, mounted on insulators located near the running rails~~

rigid metallic conductor mounted on insulators intended to interface with a vehicle mounted current collector

Note 1 to entry: The conductor rail can be of composite construction.

[SOURCE: IEC 60050-811:2017, 811-34-01, modified – Note 1 to entry has been removed.]

3.1.5**conductor rail system**

~~contact line system using a conductor rail for current collection~~

3.1.6**overhead conductor rail**

~~rigid overhead contact line, of simple or composite section, mounted above or beside the upper limit of the vehicle gauge, supplying traction units with electrical energy via roof mounted current collection equipment~~

3.1.1.8**inclined overhead contact line**

<system> overhead contact line in which one or more contact wires are suspended from the catenary wire by inclined droppers so the catenary wire and contact wire are not in a vertical plane in absence of a wind load

[SOURCE: IEC 60050-811:2017, 811-33-13, modified – In the term, the word "catenary" has been replaced with "overhead contact line" and the synonyms have been removed. The specific use has been added. The words "that the contact wire or wires follow a path corresponding approximately to the centre line of the track" have been replaced with "the catenary wire and contact wire are not in a vertical plane in absence of a wind load."]

3.1.1.9**supporting assembly**

assembly of components attached to the main support structure that supports and registers the overhead contact line

3.1.9**static load gauge**

~~maximum cross-sectional profile of the vehicles using the railway line~~

3.1.10**kinematic load gauge**

~~static load gauge enlarged to allow for dynamic movements of the vehicle, e.g. suspension travel and bounce~~

3.1.11**kinematic envelope**

~~kinematic load gauge further enlarged to allow for possible tolerances in the position of the track~~

3.1.12**swept envelope**

~~kinematic envelope enlarged to allow for centre and end throw of the vehicles on horizontal and vertical curves~~

3.1.1.10**kinematic reference profile**

line specific to each gauge, representing the cross-section shape and used as a common basis to work out the sizing rules of the infrastructure and of the rolling stock

3.1.1.11**static reference profile**

kinematic reference profile without the dynamic uplift of the suspension and the vertical oscillations of the vehicles during operation

Note 1 to entry: See EN 15273-1 and EN 15273-3.

3.1.1.12

vertical superelevation

margin added to the reference profile to take into consideration the interconnection of two track gradient by vertical curves of radius

Note 1 to entry: See EN 15273-3.

3.1.1.13

tensioning device

device to maintain the tension of conductors within the system design parameters

[SOURCE: IEC 60050-811:2017, 811-33-45, modified – The preferred term "tensioner" has been removed.]

3.1.1.14

urban ~~mass transportation~~ rail system

light rail, ~~trolleybus and tramway system~~ (for example tramway, subways or suburban trains) and trolleybus system, operating in urban areas, excluding heavy rail systems

3.1.1.15

sectioning device

device used to divide the contact line into different sections or circuits

Note 1 to entry: Sectioning devices includes section insulators and neutral sections.

3.1.1.16

section insulator

sectioning point formed by insulators inserted in a continuous run of a contact line, with skids or similar devices to maintain continuous electrical contact with the current collector

[SOURCE: IEC 60050-811:2017, 811-36-15]

3.1.1.17

neutral section

section of a contact line provided with a sectioning point at each end to prevent successive electrical sections differing in voltage, phase or frequency from being connected together by the passage of current collectors

[SOURCE: IEC 60050-811:2017, 811-36-16, modified – The word "from" has been added for better understanding.]

3.1.1.18

disconnecter

switching device which provides, in the open position, a visible isolating distance in accordance with specified requirements

Note 1 to entry: A disconnecter can be a load or non-load breaking device.

Note 2 to entry: Switch-disconnectors and earthing switches are forms of disconnectors.

[SOURCE: IEC 60050-441:1984, 441-14-05, modified – Words "a mechanical" have been removed; "visible" has been added. The note 1 to entry has been modified. The notes 2 to entry has been added.]

3.1.1.19

span length

horizontal distance between the attachment points of the conductor on two consecutive supports

[SOURCE: IEC 60050-466:1990, 466-03-02]

**3.1.1.20
midpoint**

point in a tension length of the overhead contact line where the conductors are fixed in position to control the along track movement

**3.1.1.21
system height**

vertical distance between the main catenary wire and the contact wire measured at a support point

[SOURCE: IEC 60050-811:2017, 811-33-52]

3.1.2 Conductors

**3.1.2.1
along-track feeder**

overhead conductor mounted on the same structure as the overhead contact line to supply successive feeding points

Note 1 to entry: Along-track feeder is a generic term for all feeders mounted to OCL structures.

[SOURCE: IEC 60050-811:2017, 811-36-24, modified – Note 1 to entry has been added.]

**3.1.2.2
catenary wire
messenger wire**

longitudinal conductor supporting the contact wire or wires either directly or indirectly

Note 1 to entry: The term "messenger wire" is used in some countries instead of "catenary wire".

[SOURCE: IEC 60050-811:2017, 811-33-06, modified – "Cable" has been replaced by "conductor". – The Note 1 to entry has been added.]

**3.1.2.3
contact wire**

electric conductor of an overhead contact line with which the current collector makes contact and is characterized by two clamping grooves

[SOURCE: IEC 60050-811:2017, 811-33-15, modified – The second term "trolley wire" has been deleted and the words "and is characterized by two clamping grooves" have been added.]

**3.1.2.4
reinforcing feeder**

overhead conductor mounted adjacent to the overhead contact line, and directly connected to it at frequent intervals, ~~in order to increase the effective cross-sectional area of the overhead contact line~~

Note 1 to entry: The reinforcing feeder increases the effective cross-sectional area of the overhead contact line.

[SOURCE: IEC 60050-811:2017, 811-33-60]

**3.1.2.5
line feeder**

overhead conductor mounted parallel to, or in parallel with, the contact line either to supply successive feeding points or to increase the useful cross-sectional area

Note 1 to entry: Line feeder is not connected directly to the OCL. It can be a parallel feeding line from the substation or a bypass line to transfer energy over locations where OCL of a single-track line or of a station has to be switched off regularly to supply electric trains behind this location.

[SOURCE: IEC 60050-811:2017, 811-36-09, modified – Note 1 to entry has been added.]

3.1.2.6

negative feeder

overhead conductor mounted parallel to the contact line which has opposite (180° different) phase voltage to the contact line phase used in autotransformer system

3.1.2.7

jumper

short length of conductor(s) not under mechanical tension, making an electrical connection between two or more conductors or other electrical equipment

[SOURCE: IEC 60050-466:1990, 466-10-26, modified – "Conductor" has been replaced by "conductor(s)", "separate sections of an overhead line" has been replaced with "or more conductors or other electrical equipment".]

3.1.3 Return circuit

3.1.3.1

extended return circuit

part of the traction power supply circuit which leads the current back from the loads, such as vehicles or other equipment, to the source

Note 1 to entry: If contact is made between a live part and the return circuit, the circuit breaker should trip.

Note 2 to entry: The conductors can be

- running rails,
- return conductor rails,
- return conductors,
- return cables, or
- booster transformer return conductor.

3.1.3.2

return circuit

subset of the extended return circuit where the direct contact is permissible during both operational and fault conditions

Note 1 to entry: The earthed phase of a three-phase AC traction power supply system can be considered as a return circuit.

[SOURCE: IEC 60050-811:2017, 811-35-01, modified - Definition and Note 1 to entry have been completely changed.]

3.1.3.3

track return system

system in which the running rails of the track form a part of the return circuit for the traction current

[SOURCE: IEC 60050-811:2017, 811-35-02]

3.1.3.4

return conductor

conductor paralleling the track return system and connected to the running rails at periodic intervals

[SOURCE: IEC 60050-811:2017, 811-35-13]

3.1.3.5**return conductor rail**

conductor rail used instead of the running rails for the traction return currents

[SOURCE: IEC 60050-811:2017, 811-34-10]

3.1.3.6**booster transformer return conductor**

set of return conductors insulated from earth and necessary for the functionality of a booster transformer system

3.1.3.7**return cable**

conductor connecting the running rails or other parts of the return circuit to the substation

[SOURCE: IEC 60050-811:2017, 811-35-04, modified – "return current rail" has been replaced with "other parts of the return circuit".]

3.1.3.8**traction return current**

sum of the currents returning to the supply source, the substation or regenerative braking vehicles

Note 1 to entry: The traction return current can also include load fed from the traction systems, for example point heating, auxiliary supplies.

3.1.4 Electrical**3.1.4.1****nominal voltage**

~~voltage by which an installation or part of an installation is designated~~

<of an electrical installation> value of the voltage by which the electrical installation or part of the electrical installation is designated and identified

Note 1 to entry: The voltage of the contact line may differ from the nominal voltage by a quantity within permitted tolerances given in IEC 60850.

[SOURCE: IEC 60050-826:2022, 826-11-01, modified – Note 1 to entry has been added.]

3.1.4.2**feeding section**

electrical section of the route fed by individual track feeder circuit breakers within the area supplied by the substation

[SOURCE: IEC 60050-811:2017, 811-36-25, modified – The words "one or more substations" have been replaced with "the substation".]

3.1.4.3**functional-equipotential-bonding**

equipotential bonding for operational reasons other than safety

[SOURCE: IEC 60050-195:2021, 195-01-16, modified – The word "operational" has been added, and the word "electrical" deleted.]

3.3.3**fault current**

~~maximum current passed through the overhead contact line system under fault conditions between live equipment and earth, within a short defined time period~~

3.1.4.4**short-circuit**

accidental or intentional conductive path between two or more ~~points in a circuit~~ conductive parts forcing the ~~voltages between these points to be relatively low. Any such conductive path whether between conductors or between conductor and earth is regarded as a short-circuit~~ electric potential differences between these conductive parts to be equal to or close to zero

[SOURCE: IEC 60050-151:2001, 151-12-04]

3.3.5**short-circuit current**

~~electric current flowing through the short-circuit~~

3.3.6**continuous current rating**

~~permanent rated current carrying capacity of the overhead contact line within the system operating parameters~~

3.1.4.5**rated current-carrying capacity**

permanent maximum value of electric current which can be carried continuously by the overhead contact line within the system operating parameters

3.1.4.6**feeding point**

point at which the feeding system is connected to the contact line

[SOURCE: IEC 60050-811:2017, 811-36-26]

3.3.8**isolation**

~~disconnection of a section of overhead contact line from the source of electrical energy, either in an emergency or to facilitate maintenance~~

3.1.4.7**electrical clearance**

<of a contact line> minimum distance in air permitted between fixed structures and parts energized at contact line voltage

Note 1 to entry: The distance in air is used to provide functional insulation or basic insulation.

[SOURCE: IEC 60050-811:2017, 811-09-05, modified – In the specific use, "a contact line" has been replaced with "an electrical installation".]

3.1.4.8**electrification clearance gauge**

contour which contains the various live parts of an overhead contact line, allowance being made for static electrical clearances, and from which all other fixed objects must be kept clear

[SOURCE: IEC 60050-811:2017, 811-09-04]

3.1.4.9**pantograph clearance gauge**

contour beyond which must be placed any fixed structure above vehicle roof level, to allow any pantograph in use to pass safely, making allowance for lateral displacement of the pantograph and for passing electrical clearances

[SOURCE: IEC 60050-811:2017, 811-09-03]

3.1.5 Geometrical

3.1.5.1

tension length

length of overhead contact line between two terminating points

[SOURCE: IEC 60050-811:2017, 811-33-61]

3.1.5.2

gradient

<of the overhead contact line> ratio of the difference in height of the overhead contact line above top of rail (or road surface for overhead contact line system for trolleybus applications) at two successive supports to the length of the span

3.1.5.3

contact wire height

distance from the top of the rail level ~~(~~ or road surface ~~for overhead contact line system for trolleybus applications)~~ to the lower face of the contact wire, ~~measured perpendicular to the track~~

Note 1 to entry: The contact wire height is measured perpendicular to the track or road surface.

[SOURCE: IEC 60050-811:2017, 811-33-62]

3.1.5.4

minimum contact wire height

minimum ~~value of the possible~~ contact wire height in the span in order to avoid ~~the arcing~~ flashover or contact between one or more contact wires and the vehicles in all conditions

[SOURCE: IEC 60050-811:2017, 811-33-64, modified – The definition has been completely modified in order to provide greater clarity about functional aspects.]

3.1.5.5

minimum design contact wire height

theoretical contact wire height including tolerances, designed to ensure that the minimum contact wire height is always ~~achieved~~ respected

3.1.5.6

nominal contact wire height

nominal value of the contact wire height above rail (or road surface for overhead contact line system for trolleybus applications) at a support in the normal conditions

Note 1 to entry: The nominal contact wire height is used preferentially when there is no constraint on the contact wire height, and is the height to which it returns after being adjusted to accommodate a constraint (e.g. level crossing or overbridge, etc).

Note 2 to entry: For normal conditions, refer to 6.2.7.

[SOURCE: IEC 60050-811:2017, 811-33-63, modified – The words "above rail level" have been replaced with "above rail (or road surface for overhead contact line system for trolleybus applications)". Notes 1 and 2 to entry have been added.]

3.1.5.7

maximum contact wire height

maximum possible contact wire height above rail (or road surface for overhead contact line system for trolleybus applications) which the pantograph is required to reach, in all conditions

[SOURCE: IEC 60050-811:2017, 811-33-65, modified – The definition has been completely modified in order to provide greater clarity about functional aspects.]

3.1.5.8

maximum design contact wire height

theoretical contact wire height taking account of tolerances, movements, etc., designed to ensure the maximum contact wire height is not exceeded

3.1.5.9

contact wire uplift

vertical upward displacement of the contact wire due to the force produced from the pantograph

3.1.5.10

stagger

lateral displacement of the contact wire to opposite sides of the track centre at successive supports

Note 1 to entry: Stagger avoids localized wear of the pantograph contact strips.

[SOURCE: IEC 60050-811:2017, 811-33-21]

3.1.5.11

dewirement

movement of the contact wire laterally beyond the ends of the pantograph head

Note 1 to entry: There are different causes of dewirement, including vandalism and wind-blown objects on the overhead equipment. Moreover, dewirement is not the only cause of pantograph head and overhead contact line incidents. Other phenomena can lead to incidents, without exceeding dewirement limits.

Note 2 to entry: Under worst conditions, contact inside the limits of dewirement can occur without damages with catastrophic consequences. In these cases, the contact point can be located outside the working range of pantograph head with arcing and current interruption without causing dewirement.

3.1.5.12

point of incipient dewirement

point on the pantograph head where, due to uplift force and pantograph shape, a dewirement is inevitable if the contact wire reaches this point

Note 1 to entry: The point of dewirement is determined by the point where the gradient of the profile exceeds for example 40° in CEN/CENELEC countries. Until this point and with this gradient, experience indicates that the contact wire is able to return successfully into the working zone.

3.1.6 Structures

3.1.6.1

drag factor

aerodynamic drag factor

force coefficient

~~It is~~ factor used to consider the shape of an object exposed to wind, the wind pressure ~~is~~ being multiplied by this factor to determine the wind action

3.1.6.2

partial factor

~~partial safety factor~~

~~It is a~~ factor to multiply characteristic loads to calculate design loads on the load side (load partial factor) of the equation for verifying adequate strength of components, or to divide the characteristic strength on the material side (material partial factor). ~~The partial factors should replace the safety factors applied in design approaches used before~~

Note 1 to entry: The partial factors should replace the safety factors applied in design approaches used before.

Note 2 to entry: The partial factor for an action is a factor, taking into account the possibility of unfavorable deviations from the characteristic value of actions, inaccurate modeling and uncertainties in the assessment of the effects of actions.

Note 3 to entry: The partial factor for a material property is a factor covering unfavorable deviations from the characteristic value of material properties, inaccuracies in applied conversion factors and uncertainties in the geometric properties and the resistance model.

3.1.6.3

lattice structure

structure formed from a regular arrangement of connected joints and has a solidity ratio of 0,6 or less

Note 1 to entry: The solidity ratio is the ratio of total area of all individual members to envelope area.

3.1.6.4

superstructure

upward extension of an existing structure above ground level

Note 1 to entry: The term "superstructure" is applied to various kinds of physical structures, such as OCL poles, retaining walls and bridges.

3.1.6.5

midpoint anchor structure

structure at the midpoint of tension length of the overhead contact line fulfilling the function of a midpoint anchor

3.1.7 Foundations

3.1.7.1

gravity foundation

~~shallow foundation installed by excavation and backfilling~~

form of spread foundation formed by rectangular, square, or sometimes circular concrete "pads" that support localized single-point loads such as overhead contact line structures

Note 1 to entry: Gravity foundations are usually shallow foundations installed by excavation and backfilling.

3.1.7.2

pile foundation

~~foundation which is flexible enough to show both rotation and deformations in the pile element itself subjected to horizontal loading or overturning moments. The cross-section may be circular or non-circular and it is installed by boring and/or ramming~~

long slender foundation installed without excavation

Note 1 to entry: The cross-section can be circular or non-circular and it is installed by boring, vibrating and/or hammering.

Note 2 to entry: The foundation is flexible enough to show both rotation and deformations in the pile element itself subjected to horizontal loading or overturning moments.

[SOURCE: IEC 60050-466:1990, 466-09-16, modified – Notes 1 and 2 to entry have been added.]

3.1.7.3

side bearing foundation

~~relatively short, rigid foundation installed by excavation or boring which is subjected to horizontal loading or overturning moments. The cross-section may be circular or rectangular~~

foundation normally consisting of a single block of concrete, into which the pole of an overhead contact line system structure or anchor bolts are embedded

Note 1 to entry: The surface area of the foundation provides the resistive force to counteract the overturn moments applied by the overhead contact line system.

3.1.8 Current collectors

3.1.8.1

current collector

equipment fitted to a vehicle and intended to collect current from a contact wire or conductor rail

[SOURCE: IEC 60050-811:2017, 811-32-01]

3.1.8.2

pantograph

apparatus for collecting current from one or more contact wires, formed of a hinged device designed to allow vertical movement of the pantograph head

[SOURCE: IEC 60050-811:2017, 811-32-02]

3.1.8.3

pantograph gauge

reference profile with its associated rules allowing verification that the pantograph head in a raised position remains within the allotted space

[SOURCE: EN 15273-1:2017, 3.23.1]

3.1.9 Current collection

3.1.9.1

static contact force

vertical force exerted upward by the collector head on the overhead contact line system at standstill

[SOURCE: IEC 62486:2017, 3.19, modified – “pantograph head” has been replaced with “collector head”. “, caused by the pantograph-raising device, whilst the pantograph is raised and the vehicle is stationary” has been replaced with “system at standstill”.]

3.1.9.2

contact loss

condition where the contact force is zero

Note 1 to entry: Contact loss surely induces arcing except in the case of coasting. However, if two or more pantographs are connected electrically each other, arc can disappear and then the condition will shift to current loss.

[SOURCE: IEC 62486:2017, 3.22, modified – In Note 1 to entry, “will immediately” was replaced by “can”.]

3.1.9.3

current loss

condition where current flowing through a pantograph is zero under the condition of contact loss

Note 1 to entry: When a train is equipped with two or more pantographs electrically connected by a bus cable, necessary traction power can be supplied by other pantographs through the bus cable in case of contact loss. Therefore, current loss condition will generally not affect driving of the train.

[SOURCE: IEC 62486:2017, 3.23]

3.1.9.4

arcing

flow of current through an air gap between a contact strip and a contact wire or in case of contact force close to zero, usually indicated by the emission of intense light

[SOURCE: IEC 62486:2017, 3.1, modified – “or in case of contact force close to zero” added.]

3.1.10 Testing

3.1.10.1

sampling test

test on a sample

[SOURCE: IEC 60050-151:2001, 151-16-20]

3.1.10.2

type test

conformity test made on one or more items representative of the production

[SOURCE: IEC 60050-151:2001, 151-16-16]

3.1.10.3

routine test

conformity test made on each individual item during or after manufacture

[SOURCE: IEC 60050-151:2001, 151-16-17]

3.1.11 Miscellaneous

3.1.11.1

regulation

document providing binding legislative rules, which is adopted by an authority

[SOURCE: IEC 60050-901:2013, 901-02-10]

3.2 Symbols

A	local orography coefficient/altitude
A_{ins}	projected area of an insulator
A_K	characteristic value of accidental actions
A_{lat}	effective area of the elements of a lattice structure
A_{str}	projected area of a structure
~~a.c.~~	~~alternating current~~
a	length of conductor between specimen and centre of potential point; $a \cong 15d$
a_{mp}	amplitude
a_p	length of specimen
a_v	length of comparison conductor between centres of potential points; $a_v \cong 30 d + a$
b	length of potential points; $b \leq 2d$
C	compression amplitude for dropper test
C_C	drag factor of a conductor
c_f	force coefficient
C_{ins}	drag factor for insulators
C_{lat}	drag factor for lattice structures
C_{str}	drag factor of a structure
~~d.c.~~	~~direct current~~

D	diameter of conductor
d_{cant}	lateral deviation of contact wire position by vertical uplift at tracks with cant
d_{instl}	tolerance of installation of lateral deviation of contact wire
d_{instv}	tolerance of installation of vertical deviation of contact
d_{mess}	tolerance of measurement, measuring errors refer to horizontal position of contact wire
d_{pole}	lateral deviation of contact wire position issued on change of pole deflection under additional load due to wind speed for serviceability in nominal contact wire height d_{supp} lateral deviation of contact wire position issued on movement of cantilever for change wire temperature
d_{tens}	lateral deviation of contact wire position issued on reduced tension force of wires considering efficiency and tolerances of tension equipment, friction in cantilevers and resetting forces (cantilever drag) due to movement of cantilever for change wire temperature
e	elasticity of the overhead contact line
E_d	total design value of actions
EC_s	static electrical clearance between live parts and earth
EC_d	dynamic electrical clearance between live parts and earth
F_{Bmin}	minimum breaking load of stranded conductors and ropes
F_d	design value of an action
F_K	characteristic value of an action
F_L	internal force for dropper test
F_{max}	maximum or failure force for test specimens
F_{nom}	nominal force
$F_{\text{perm.op.}}$	permissible operating force
F_w	permissible tensile loading of stranded conductors and ropes
G_C	structural response factor for conductors
G_{ins}	structural resonance factor for insulator sets
G_K	characteristic value of permanent actions
G_{lat}	structural resonance factor for lattice structures
G_q	gust response factor
G_{str}	structural resonance factor for a structure
G_t	terrain factor
g_{IK}	specific characteristic ice loads
K_{clamp}	factor for termination fitting
K_{eff}	factor to the efficiency and accuracy of the tensioning device
K_{ice}	ice load factor
K_{icewind}	ice and wind load factor
K_{joint}	load factor for the effects of joints
K_{load}	factor for vertical loads acting on the catenary wire

K_{radius}	minimum bending radius factor
KRP	kinematic reference profile height
K_{wear}	allowable wear factor
K_{wind}	wind load factor
K_x	constant factors used to determine permissible tensile stress
l_1	minimum length between specimen and clamping piece and between specimens as per Table 20
l_2	minimum length of comparison conductor as per Table 20
L_1 / L_2	lengths of two adjacent spans
$M_{\text{dyy}}, M_{\text{dzz}}$	design bending moments
~~N_{dax}~~	~~internal axial force of an element~~
$\# N$	safety factor for calculating the permissible loading in wires
n_{cat}	number of catenary wires
n_{cont}	number of contact wires
T_{cat}	catenary wire tension, characteristic
T_{cont}	contact wire tension, characteristic
P_{prim}	externally applied heat
Q_{CK}	conductor tensile forces depending on the temperatures and climate related loads
Q_{IK}	characteristic ice load
Q_K	characteristic value of variable actions
Q_{PK}	characteristic value of construction and maintenance loads
Q_W	wind load
Q_{WC}	wind load on conductors
Q_{Wt}	wind load on lattice structures
Q_{Wstr}	wind load on structures
Q_{Wins}	wind load on insulators
~~q_k~~	~~characteristic dynamic wind pressure~~
$q_p(z)$	peak velocity pressure
~~R_{dax}~~	~~axial resistance under tension or compression~~
$R_{\text{dyy}}, R_{\text{dzz}}$	design bending resistances
R_k	characteristic value of the foundation ultimate resistance
$R_{p\ 0,2\ \text{min}}$	0,2 % yield point
SRP	static reference profile height
u	degree of non-uniformity/variation in elasticity
U_n	nominal voltage
U_{Ni}	rated impulse voltage
V_c	wave propagation velocity of the contact wire
V_R	reference wind velocity

v_w	wind speed
X_d	design value of a material property
X_K	characteristic value of a material property
α	heat transmission coefficient
Φ	angle of incidence of the critical wind direction
γ_A	partial factor for accidental loads
γ_C	partial factor for conductor tensile forces
γ_{CG}	partial factor for permanent conductor tensile forces
γ_{CV}	partial factor for variable conductor tensile forces
γ_E	partial factor for actions
γ_G	partial factor for permanent actions
γ_I	partial factor for ice loads
γ_M	partial factor for a material property
γ_P	partial factor for construction and maintenance loads
γ_W	partial factor for wind loads
μ_{tot}	coefficient of friction for bolt connections
P	density of air
ρ_I	unit weight force of ice
σ_{min}	minimum failing tensile stress of the contact wire
σ_w	maximum permissible working tensile stress of a contact wire
Σz	sum of working tensile loads of contact wire(s)
Σm	sum of linear masses of the contact wire(s)
ΣT_{OCL}	total of all tolerance of the overhead contact line (IEC 62486)
Δh_{RV}	vertical superelevation

3.3 Abbreviated terms

AC	alternating current
AACSR	aluminium alloy conductor steel reinforced
ACSR	aluminium conductor steel reinforced
ADD	automatic dropping device
DC	direct current
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ETA	European technical assessment
FOCL	flexible overhead contact line
OCL	overhead contact line
OCLS	overhead contact line system
OV	overvoltage
RAMS	reliability, availability, maintainability and safety
RMS	root mean square
ROCL	rigid overhead contact line

RTS rated tensile strength

4 Fundamental design data

4.1 General

The function of an overhead contact line system is not only to transmit energy from fixed installations, like substations to the vehicle, but also from vehicles back to substations and auxiliary consumers using regenerative braking. In order to fulfil this function, the principal features of the contact line system shall be designed in accordance with the requirements set out in Clause 4. In particular, the integration of the overhead contact line design with the corresponding features of other interconnected systems, for example the power supply system and the traction system, shall ~~be considered~~ ensure compatibility with the interconnected systems.

The requirements for overhead contact lines shall also apply to ~~masts~~ poles that are erected in connection with the overhead contact line system and used for line feeders.

The current collection system is a combination of overhead contact line and pantograph equipment, and the quality of the current collection system depends on the characteristics of both. Both sets of equipment shall be designed to appropriately fulfil their tasks. The design shall take cognisance of the compatibility between each other.

The data listed in 4.2 to 4.7 are normally specified by the purchaser.

4.2 Line characteristics

The train service characteristics and operational requirements to be considered in the design shall include:

- the speed and performance capability of the train/ or traction units ~~to be employed~~ powered from the contact line,
- the future performance capability to be anticipated and allowed for in the design, including any allowances for over speeding and increasing of mechanical and electrical load,
- the type and frequency of electrically hauled trains,
- the line speed for ~~main and station~~ all tracks,
- the track gradient profile and location of the route, including turnouts and transitions,
- the type of turnouts, and
- the track gauge.

4.3 Electrical power system design

The overhead contact line system design shall be ~~based upon the consideration of~~ compatible with the electrical characteristics of the power supply system design, including the following:

- ~~nominal~~ voltage range and frequency range and their limit values, in accordance with IEC 60850, corresponding to the nominal system voltage;
- mean useful voltage at the pantograph for the zone and train in accordance with IEC 62313;
- short-circuit current details, in accordance with IEC 62313;
- short circuit duration, in accordance with the protection design documented in accordance with IEC 63438; where the protection system employs backup protection, for example, as the method of protection reliability, the protection operating time shall be that of the backup protection; 4
- required current rating and the corresponding parameters (continuous, fault and short circuit condition);

~~— required impedance for a.c. systems where stated,~~

~~— required resistance for d.c. systems where stated,~~

- required impedance limit values (AC) or resistance limit values (DC), for reasons such as respecting voltage limitations and profile at pantographs, ensuring correct electrical protection system performance, and respecting the effective touch voltage limit values to comply with safety limits;
- proposed feeding system;
- proposed return system;
- earthing and stray current protection in accordance with IEC 62128-1 and IEC 62128-2;
- requirements to mitigate EMI and facilitate EMC in accordance with IEC 62236-2;
- when relevant, requirements for overvoltage protection, in accordance with IEC 62497-2;
- insulation coordination in accordance with the IEC 62497 series.

For urban ~~mass transportation~~ rail systems, the short-circuit current details are not required.

~~Overhead contact lines shall be separated in electrical sections and switching groups by insulators, sectioning devices, insulated overlaps, neutral sections, disconnectors for maintenance, emergency repair, planned directional operation, railway tunnel safety and phase breaking.~~

4.4 Vehicle characteristics

The overhead contact line system design shall ~~consider~~ provide clearances for all vehicle types to be used on the line. In particular, the following shall be determined:

- a) static and ~~kinematic load gauge, kinematic envelope and the swept envelope~~ kinematic reference profile as well as any national or international requirements for structural clearances;
- a) number of pantographs in service, their spacing, and whether they are electrically linked or independent.

4.5 Current collectors

The characteristics of the current collectors to be used on the line shall be determined. These characteristics include:

- a) current collector head width, length and profile as defined in IEC 60494-1 and IEC 60494-2;
- b) number of contact strips, the type of material and the spacing;
- c) ~~mean~~ static contact force of current collector, depending on its working height;
- d) details of the lateral movement of the current collector head;
- e) maximum load current of the collector head when the vehicle is at standstill; 5
- f) mean contact force at maximum line speed;
- g) working width of the current collector head;
- h) working range and housed height;
- i) controlled height positions for current collectors with height limiting device;
- j) mathematical model of dynamic characteristics;
- k) ~~skew~~ inclination of current collector head;
- l) number, position on the train and separation of current collectors that may be used simultaneously;
- m) ADD, whether fitted, and its type (damaged carbons or overheight, or both).

~~NOTE Specific requirements for pantographs for interoperable lines are given in IEC 62486.~~

For interoperable lines ~~are given~~, the characteristics set out in IEC 62486 shall be used

4.6 Environmental conditions

~~For environmental conditions refer to IEC 62498-2.~~

The overhead contact line system shall be designed according to the environmental characteristics selected from the conditions and classes set out in IEC 62498-2.

4.7 Design life

The purchaser may state the required design life of the system. Consumable components such as contact wire are not included in the design life of the system. Specific requirements for the design life of these components may also be specified by the purchaser.

5 System requirements

5.1 Design of electrical system

5.1.1 General

The overhead contact line system shall be designed ~~to allow for the electrical~~ based on the characteristics defined in 4.2 and 4.3. The design shall ~~include~~ take into account the return circuit system, feeder connections and ~~shall consider~~ short-circuit ~~faults~~.

Overhead contact lines should normally be electrically separated into sections and sub-sections by use of insulators, sectioning devices, insulated overlaps, neutral sections, etc. This provides operational flexibility for maintenance, emergency repair, planned directional operation, railway tunnel safety and neutral section.

The electrical characteristics and ratings relating to insulation coordination for the overhead contact line system, its products, assemblies, components, and its interfaces with other systems should be determined in accordance with the requirements set out in IEC 62497-1:2010, 8.4.1.3. In accordance with 5.1, 5.1.3 provides clearance dimensions for values of impulse voltages (U_{Ni}) of 95 kV and above.

Functional-equipotential-bonding shall be provided across mechanical bearings within the overhead contact line system where the efficiency of mechanical bearings would otherwise be adversely affected by the flow of load current or fault current. **6**

5.1.2 Temperature rise in conductors

The overhead contact line system, including return circuit and feeder connections, shall be designed ~~to allow for~~ based on the electrical load defined by the system design, ~~including return circuit and feeder connections~~, under ~~all~~ environmental operating conditions for the relevant classes defined in IEC 62498-2.

The overhead contact line shall be designed for the full temperature range taking in account the specified minimum environmental temperature and the maximum temperature rise in the conductors. For this temperature range, the proper work of tensioning devices and hinged cantilever is required. Furthermore, the minimum electrical clearances and all functional requirements have to be respected in any case.

~~The maximum temperature rise in the conductors, due to load currents, shall not lead to conductor temperatures at which the mechanical properties of the material are unduly impaired.~~ The maximum temperature rise in the conductors, due to load or short-circuit currents, should not lead to conductor temperatures above the values given in Table 1. See also 7.3 and 7.4.

The temperature rise ~~caused by current heating shall be used in addition to the ambient temperature and solar gain in determining~~ affects the mechanical and dimensional properties

to be made for the maximum expansion of the conductor system, and geometrical allowances for electrical clearance and contact wire height.

The design shall accommodate the ~~pantograph current~~ maximum load current of the current collector when the vehicle is at standstill.

The temperatures above which the mechanical properties might be impaired are given in Table 1 for material compositions of tensile stressed conductors used in contact line systems.

Table 1 – Temperature limits for material mechanical properties 7

Material	Temperature		
	°C		
	Up to 1 s short-circuit current	Up to 30 min (e.g. pantograph standstill) ^a	Permanent (e.g. operating condition)
Normal and high strength copper with high conductivity	170	120	80
Silver copper alloy	200	150	100
Tin copper alloys (0,1 to 0,4)	~~170~~ 200	~~130~~ 150	100
~~Magnesium copper alloys / bronze (0,2)~~	~~170~~	~~130~~	~~100~~
~~Magnesium copper alloys / bronze (0,5)~~	~~200~~	~~150~~	~~100~~
Magnesium copper alloys (0,1 to 0,7)	200	150	100
Aluminium alloys	130	-	80
ACSR/AACSR	160	-	80
^a These values are applicable for exceptional operational cases and should not happen too often in the same position.			

~~For new products it can be necessary to lower the values until enough operational experiences are collected.~~

NOTE 1 For novel products it can be necessary to reduce the limits until sufficient operational experience has been gained.

For temperatures higher than those in Table 1, the possible reduction in conductor strength according to the duration of the raised temperature ~~shall~~ should be checked and, if necessary, the dimensions of the conductor shall be increased and/or the working load shall be reduced.

NOTE 2 There have been long satisfactory experiences in Japan that the highest permanent temperature of pure copper, aluminium and ACSR wires for catenary wires and feeder wires is ~~90~~ 100 °C.

When calculating the temperature rise in a conductor, the following contributions should be considered:

- heating caused by the current and its duration;
- heating caused by the environmental conditions, for example ambient temperature and solar radiation;
- radiant heat emitted from the conductor;
- heat lost from the conductor by convection depending on the wind speed and direction.

NOTE 3 A wind speed of 1 m/s is often used for this calculation as per IEC 62498-2:2010, category SW 2.

The values of the environmental parameters (ambient temperature, wind speed and temperature rise caused by solar gain) shall be given in the purchaser specification.

The temperature of the contact wire at the interface with the contact strips shall not exceed the appropriate value given in Table 1. Nominally, the "up to 30 min" value should be used for when assessing pantographs at standstill; however, in some cases, it may be appropriate to use the "permanent" value.

For longer than 30 min pantograph standstill and also for pantograph standstill repeatedly at the same place, the temperature limits for permanent operational conditions shall be used.

The rated current-carrying capacity of the overhead contact line based on the permanent rated current-carrying capacity of their conductors and the current distribution in these conductors should be calculated and provided by the power supply system design for the adjustment in the protection relays.

5.1.3 Clearances between live parts of contact lines and earth

The air clearances between the live parts of the overhead contact line system or pantograph head and earthed parts of the fixed installations, and those of vehicles, shall be defined to achieve acceptable availability of service and to limit damage to these assets. The safety clearances identified in IEC 62128-1 shall apply for protective provision against direct contact.

NOTE For the purpose of 5.1.3, "earth" in the context of DC includes equipment connected to the traction return system as well as parts in contact with earth.

For technical and economic reasons, ~~The recommended~~ typical air clearances between earth and the live parts of the overhead contact line system are stated in Table 2. These values are based on operational experience and have provided a proven acceptable level of performance and reliability.

The clearance values given in Table 2 may be reduced or increased depending on various parameters, for example highest permanent voltage, transient voltage conditions, switching and thunderstorm conditions, overvoltage protection, absolute humidity, the ambient temperature range, air pressure, pollution, relative air density, measures to avoid short circuits with birds, shape and material for both energised and earthed structures (refer to IEC 62498-2 and IEC 62497-1). Each case, however, shall be considered individually.

In areas where overvoltage can occur very often due to lightning or where reduced air clearances occur, surge arrestors, supplementary insulation or other means may be used in accordance with IEC 62497-1, if the electrical clearances to earthed structures are not sufficient.

The following provides an example of reduced clearances by the application of surge arresters:

- for overhead contact line systems with nominal voltage $U_n = 25$ kV (overvoltage category OV4, impulse voltage $U_{Ni} = 200$ kV from IEC 62497-1:2010 and IEC 62497-1:2010/AMD1:2013, Table A.2) according to Table 2, the static clearance is given as $EC_s = 270$ mm and dynamic clearance as $EC_d = 150$ mm;
- in the same case, the prospective overvoltage at a bridge or structure can be reduced by fitment of a surge arrester with a lower impulse value than the U_{Ni} 200 kV rating for OV4. Fitment of a surge arrester with a $U_{10\text{ kA}}$ rating of ≤ 90 kV allows the effective clearance to be aligned with that applicable to 15 kV systems, namely a static clearance of 150 mm and a dynamic clearance of 100 mm (OV4 impulse voltage $U_{Ni} = 125$ kV).

The clearance values given in Table 2 should also be applied for clearances between adjacent live parts of contact line systems for different electrical sections of the same voltage and phase.

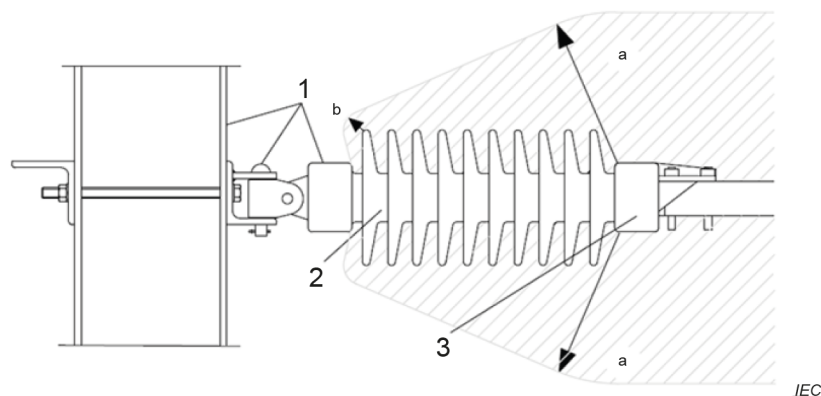
Table 2 – Typical electrical clearances

Nominal voltage	~~Recommended minimum~~ Typical clearances	
	mm	
	Static (EC_s)	Dynamic (EC_d)
DC 600 V (720 V) ^a	100	50
DC 750 V (900 V)	100	50
DC 1,5 kV (1,8 kV)	100	50
DC 3,0 kV (3,6 kV)	150	50
AC 15 kV (17,25 kV)	150	100
AC 20 kV (24 kV)	250	150
AC 25 kV (27,5 kV)	270	150
AC 25 kV (30 kV)	300	150 ^b
Values in brackets are the highest permanent voltages in accordance to IEC 60850.		
^a Only for existing systems.		
^b ~~The value is 300 mm in Japan.~~		

The value for the static case is a value to be applied to the electrification clearance gauge as a minimum air clearance between the live parts of an overhead contact line to fixed objects. The value for the dynamic case is a value to be applied to a temporary case, for example the pantograph clearance gauge or the live parts of an overhead contact line during uplift by pantographs or the designed wind speed flow. **8**

Different clearances for "static" and "dynamic" cases are justifiable by probabilistic determinations ~~(probability or time for example)~~ taking in account duration. For example, it is improbable that an overvoltage surge will occur at the same moment when a pantograph passes a narrow part of a tunnel. For this "dynamic" or temporary case, the use of a dynamic clearance, also called "passing" clearance, is justified. A usual train stop at a railway line, for example in a station, can be considered as a temporary case due to the limited duration. It is almost improbable that a train stops with the pantograph at the closed point to a fixed earthed structure with the dynamic clearance between and at the same moment an overvoltage surge will occur. For this temporary case, the pantograph clearance gauge with the dynamical (passing) clearances may be applied also.

Electrical clearances in air for insulators may be designed and measured according to Figure 2. The measurement approach in Figure 2 shall not be used for safety clearances. For safety clearances, the approach set out in IEC 62128-1 shall apply.

**Key**

- 1 earthed equipment
- 2 insulator sheds
- 3 live equipment
- a value of static clearance (EC_s) given in Table 2
- b 10 mm

Figure 2 – Static electrical clearance in air between live parts of an insulator and earthed equipment 9

For section insulators, it is allowed to reduce the static values of ~~recommended~~ typical clearance in Table 2 ~~to ensure acceptable~~ for dynamic performance of the pantograph and overhead contact line system, where necessary and where the intended operation and maintenance regime is compatible. The reduced static values for section insulators shall not be less than the dynamic clearances in Table 2.

~~The lower static values for section insulators shall be not less than;~~

- ~~— 50 mm up to 3 kV,~~
- ~~— 100 mm for 15 kV,~~
- ~~— 150 mm for 25 kV.~~

Higher minimum values for section insulators may be specified by national rules and regulations.

~~The clearance values given in Table 2 may be reduced or increased depending on various parameters, e.g. highest permanent voltage, thunderstorm conditions, absolute humidity, the ambient temperature range, air pressure, pollution, relative air density, shape and material for both energised and earthed structures (refer to IEC 62498-2). Each case, however, shall be considered individually.~~

~~The clearance values given in Table 2 should also be applied for clearances between adjacent live parts of contact lines of different electrical sections of the same voltage and phase.~~

~~In areas where over voltage can occur very often due to lightning, surge arresters or other means should be used if the electrical clearances to earthed structures are not sufficient to avoid flashovers.~~

For urban rail systems, static values for section insulators shall not be less than

- 25 mm for 750 V, and
- 35 mm for 1,5 kV.

The primary function of section insulators is to provide operational sectioning of the overhead contact line system. To meet this functionality, the required electrical performance characteristic is to maintain integrity during switching and shall provide a minimum rated impulse voltage at least equal to the switching impulse voltage (U_{90re}). The electrical performance characteristics of section insulators for other functions can be subject to compliance with national rules and regulations. **10**

5.1.4 Clearances between adjacent live AC contact lines of differing voltage phases

For an overhead contact line system, there may be a phase difference between different parts of the system, resulting in a phase-to-phase voltage higher than the nominal voltage. For 15 kV and 25 kV autotransformer systems, there is a phase difference of 180° between all live parts connected to the line feeder and all live parts connected to the overhead contact line.

For single phase AC systems, the phase difference between 90° and 180° at neutral section locations results in a similar effect.

Table 3 provides recommendations for the air clearance which should be achieved between live parts of an AC contact line system of differing phases.

Table 3 – ~~Clearance between differing phases~~ Typical clearances between adjacent live AC contact line systems of differing voltage phase

Nominal voltage kV	Phase difference degrees	Relative Highest permanent RMS voltage between phases kV	Recommended minimum clearance	
			Static (EC_s) mm	Dynamic (EC_d) mm
15 (17,25)	120	26	260	175
15 (17,25)	180	30	300	200
20 (24)	90	28,2	300	200
20 (24)	120	34,6	300	200
25 (27,5)	120	43,3	400	230
25 (27,5)	180	50	540	300
25 (30)	90	35,3	500	350
25 (30)	120	43,3	500	350

Values in brackets are highest permanent voltage in accordance with IEC 60850.

When a pantograph passes the overlap of a phase separation section, a phase to phase voltage acts between both contact lines for a short period. Therefore, the clearances between both contact lines shall be selected in accordance with the dynamic clearances set out in Table 3. These clearances shall be maintained at all times.

5.2 Design of overhead contact line for current collection systems

5.2.1 General

The design of both the overhead contact line system and used pantographs shall take into account the required ~~relevant~~ line speed.

~~The performance of the overhead contact line and pantograph should consider geometric and static characteristics. Dynamic behaviour can be predicted in the design phase by computer simulation and verified on the installed overhead contact line system with measurements. In Europe, the simulation programs shall be validated in accordance with EN 50318 and the measurements shall be undertaken in accordance with EN 50317. For non-European countries~~

~~EN 50317 and EN 50318 are informative and should be used unless certain national standards are determined by the purchaser in priority.~~

The performance of the overhead contact line, when interacting with a pantograph, shall be assessed in static and dynamic conditions. For new types of OCL or new types of pantographs, dynamic behaviour shall be predicted in the design phase by computer simulations. These simulations shall later on be verified on the installed overhead contact line system with measurements. For existing OCL and pantograph designs which have already been used in operation, at least measurements shall be performed to confirm design and installation quality. For overhead contact lines with line speeds of up to 100 km/h, computer simulations and measurements at line speed need not to be performed. **11**

The simulation programs shall be validated in accordance with IEC 63453 and the measurements shall be undertaken in accordance with IEC 62846.

~~For a train~~ The assessment of the overhead contact line shall take into account trains with multiple pantographs, and the performance of each pantograph both separately and with the pantographs used collectively shall be assessed.

~~For systems with speeds under 100 km/h, the dynamic behaviour need not be considered.~~

~~NOTE~~ Technical criteria for the interaction between pantograph and overhead contact line to achieve free access to rail infrastructure are given in IEC 62486:2017, Clause 7.

5.2.2 Elasticity and its variation

The overhead contact line should be designed in such a way that there is a small variation, u , of the elasticity, e . The elasticity e , expressed in millimetres by Newton (mm/N), is the uplift divided by the force measured at the contact wire. In every span, there is a maximum and a minimum elasticity. The elasticity values are static values. These values describe the variation u :

$$u = \frac{e_{\max} - e_{\min}}{e_{\max} + e_{\min}} \times 100 \quad [\%] \quad (1)$$

NOTE 1 The value u is also named "degree of non-uniformity".

NOTE 2 Low values of elasticity do not always give a small variation.

The elasticity and its variation depend upon the configuration of the overhead contact line. For the overhead contact system, the following main factors shall be taken into account:

- ~~— number of contact and catenary wires;~~
- ~~— tension of contact and catenary wires;~~
- ~~— span length;~~
- ~~— use of stitch wires;~~
- ~~— type of support;~~
- ~~— type, number and the position of droppers.~~
- for FOCL: number, mass and tension of contact and catenary wires, system height, use of stitch wires, type, number and position of droppers;
- for ROCL: mass, profile and type of their fixation;
- for both: span length, type of support (e.g. cantilever type) and registration;

~~If dynamic simulations are not undertaken,~~ Elasticity and variation may be specified by the purchaser.

The elasticity should normally be calculated and measured with a value of force equal to either the mean contact force at maximum speed or double the static contact force. Information about reasonable values is given in the informative Annex F.

5.2.3 Vertical movement of contact point

The contact point is the point of the mechanical contact between a collector head's contact strip and a contact wire.

The overhead contact line shall be designed in such a way that the vertical height of the contact point above the track is as uniform as possible along the span length; this is essential for high-quality current collection.

The maximum permissible difference between the highest and the lowest dynamic contact point height within one span shall be ~~as specified by~~ in accordance with the limit set out in the purchaser specification.

This shall be verified by measurements or simulations. The verification shall include the maximum line speed allowed by the overhead contact line, considering the mean contact force and the longest span length.

~~This needs not be verified for overlap spans or for spans over. Considerations should be taken to the contact wire uplift above switches and overlaps.~~

This does not need to be verified for overlap spans or for spans over turnouts and crossings.

5.2.4 Calculated wave propagation velocity

Waves caused by pantograph forces on the tensioned contact wire(s) have a propagation velocity. The flexible overhead contact line ~~should~~ can be designed to ~~ensure that~~ limit the maximum operational speed ~~of the line is~~ to less than 70 % of the wave propagation velocity, V_c of the contact wire.

~~$$V_c = \sqrt{\frac{\sum z}{\sum m}}$$~~

$$V_c = \sqrt{\frac{\sum z}{\sum m}} \quad [\text{m/s}] \quad (2)$$

where

V_c is the wave propagation velocity of the contact wire, expressed in m/s;

$\sum z$ is the sum of the working tensile loads of contact wire(s), expressed in N;

$\sum m$ is the sum of the linear mass of the contact wire(s), expressed in kg/m.

~~For urban mass transportation systems the calculation of the wave propagation velocity may be omitted.~~

5.2.5 Quality of current collection

5.2.5.1 General

Overhead contact lines and pantographs shall be designed and installed to ensure acceptable current collection performance at all operating speeds and whilst at standstill.

The life cycle of the contact strips and contact wires essentially depends on the following:

- dynamic behaviour of the overhead contact line and the pantograph;
- current flow across the interface between contact strips and contact wire;
- contact areas and the number of contact strips;
- material of contact strips and contact-wire elements of the overhead contact line;
- speed of the train, the number of pantographs in operation and the distances between them;
- environmental conditions;
- geometry of the contact line;
- elasticity and their uniformity;
- contact wire tensile load;
- pantograph design and contact force.

5.2.5.2 Contact forces 12

The overhead contact line-equipment system shall be designed to-accept withstand the maximum permissible contact forces between the pantograph and the overhead contact-wire line. The aerodynamic effects which occur at the maximum permissible speed of the vehicle shall be taken into account.

The-minimum contact force overhead contact line system shall be-positive to ensure that there is-no loss of contact designed to minimize contact loss between the pantograph and the overhead contact line.

NOTE 1 Contact loss can occur during testing and operation caused by the statistical behaviour of the interaction and external factors, for example track quality, vehicle suspension, etc.

In the case of using multiple pantographs connected by bus line, it is allowed to have the short-term contact loss. Assessment of conformity shall be decided between-client purchaser and supplier.

Contact force values vary with different combinations of pantographs and overhead contact line systems. The simulated or measured instantaneous values of contact forces-between the contact wire and contact strip shall not exceed the range given in Table 4 are usually below the value of the mean force (F_m) plus three standard deviations (3σ). Higher values may occur at particular locations; however, they shall not exceed the maximum contact force limit value given in Table 4.

NOTE 2 $F_m \pm 3\sigma$ represents 99,73 % of values for a normal distribution of force.

Where-contact force values are-used to define the current collection, the mean value and standard deviation of contact force shall be the criteria for current collection quality not a normal distribution, i.e. ROCL, then at least 99,73 % of the resulting values shall be within the range defined in Table 4.

The mean contact force plus three standard deviations shall be equal to or smaller than the maximum value in Table 4. The mean contact force minus three standard deviations shall be positive.

The minimum contact force values in Table 4 are limits that shall be applied in the statistical analysis of both simulations in accordance with IEC 63453 and testing in accordance with IEC 62846. The evaluation of the results shall be undertaken using a representative section of the overhead contact line, including overlap.

During simulations and testing, it may be accepted that instantaneous contact loss occurs, but this contact loss should be random. See 5.2.5.3 for details of measurement of contact loss.

Where contact forces are used to define the current collection quality, the mean value and standard deviation of contact force shall be the main assessment criteria. When assessing the dynamic behaviour and current collection quality, the limits for mean contact force (F_m) and maximum standard deviation (σ_{max}) that shall be applied are defined in IEC 62486.

Table 4 – Contact force limits

System	Speed km/h	Contact force limits	
		Maximum N	Minimum (statistical) N
AC	≤ 200	300 ^a	> 0
AC	$> 200 < 320$	350	> 0
AC	> 320	400	> 0
DC	≤ 200	300 ^a	> 0
DC	> 200	400	> 0

^a 350 N for short single rigid components, such as section insulators, or transition between FOCL and ROCL systems in overhead contact line systems up to 200 km/h.

~~For rigid components such as section insulators in overhead contact line systems up to 200 km/h the contact force can increase up to a maximum of 350 N.~~

For urban ~~mass transportation~~ rail systems, ~~the dynamic behaviour needs not be considered. In this case~~ the static contact force ~~shall~~ is recommended to be at least 60 N. If lower values are used, it should be demonstrated, that the dynamic behaviour of current collection is acceptable and the temperature limits for the contact wire according to Table 1 are followed. For trolleybus systems, the static force values are specified in 5.13.5.

~~NOTE~~ Additional requirements for contact forces for interoperable lines are given in IEC 62486.

5.2.5.3 Contact loss

A high quality of current collection is achieved through continuous mechanical contact between the contact wire and contact strip. ~~If this contact is interrupted, arcing occurs which increases wear on the contact wire and contact strip.~~ Contact loss leads to arcs that may cause many negative effects such as shortening of the lives of contact strips or contact wires by increasing wear, faults due to melting of components and inadmissible acoustic and electrical noises.

Where contact loss is used to define the current collection quality, the frequency and duration of arcing shall be the criteria for the current collection quality. Where these criteria are used, parameters and ~~assessment~~ conditions of tests shall be selected in accordance with ~~the purchaser specification~~ IEC 62846. This is applicable in case of using multiple pantographs connected by bus line also.

~~NOTE~~ Additional requirements for interoperable lines are given in IEC 62486.

5.2.6 Fatigue of contact wire

When pantograph slides on contact wire, bending stress grows in the wire. As train speed becomes higher and more pantographs passing by, bending stress would be larger, and life of the wire by fatigue in special cases can become shorter than the life of wear. In flexible overhead contact line design, consideration can be given to the bending stress of contact wire.

NOTE Test procedures are described in IEC 62846:2016, Annex B.

5.3 Mechanical design of contact wire loads

5.3.1 Permissible tensile stress σ_w

The maximum permissible working tensile stress σ_w of a contact wire depends on the parameters defined in 5.3.2 to 5.3.8. All of these parameters shall be weighted with an individual factor. The minimum tensile failing stress $\sigma_{\min}$ of the contact wire shall be multiplied by the product of these factors and a safety factor n not greater than 0,65 to get the maximum permissible working tensile stress.

The values in Table 5 ~~and Table 7~~ may be interpolated.

The maximum permissible working tensile stress to be applied to unworn contact wire shall be determined using Formula (3):

~~$$\sigma_w = \sigma_{\min} \times n \times K_{\text{temp}} \times K_{\text{wear}} \times K_{\text{icewind}} \times K_{\text{eff}} \times K_{\text{clamp}} \times K_{\text{joint}}$$~~

$$\sigma_w = \sigma_{\min} \times n \times K_{\text{temp}} \times K_{\text{wear}} \times K_{\text{wind}} \times K_{\text{ice}} \times K_{\text{eff}} \times K_{\text{clamp}} \times K_{\text{joint}} \text{ [N/m}^2\text{]} \quad (3) \quad 13$$

Formula (3) gives the minimum requirements which can be increased by national regulations.

5.3.2 Maximum temperature K_{temp}

The tensile strength and creep behaviour of contact wires depend on the maximum working temperature. The factor K_{temp} expresses the relationship between the permissible tensile stress and the maximum working temperature of a contact wire and ~~is~~ shall be selected from the values given in Table 5.

Table 5 – Factor K_{temp} for contact wires

Contact wire material	K_{temp}	
	For max. temperature $\leq 80 \text{ }^{\circ}\text{C}$	For max. temperature ~~$\leq 100 \text{ }^{\circ}\text{C}$~~
Cu	1,0	0,8
Cu-Ag 0,1	1,0	1,0
Cu-Sn (0,1 to 0,4)	1,0	1,0
Cu-Mg (0,1 to 0,7)	1,0	1,0

For new products, it ~~can~~ should be ~~necessary~~ considered to use lower values until sufficient operational experiences ~~are collected~~ has been gained.

For maximum working temperatures above $100 \text{ }^{\circ}\text{C}$, the reduction of conductor strength over the lifetime of the wire shall be determined by type tests. The factor K_{temp} shall be adjusted according to the residual strength of the wire shown in Table 5.

In addition to the requirements of the permitted tensile stress, consideration should also be given to the properties of the contact wire material with respect to resistance to creep. To achieve this resistance to creep, a lower permissible tensile stress and/or working temperature should be adopted.

5.3.3 Allowable wear K_{wear}

Provision shall be made for allowable wear by applying a factor appropriate to the permissible wear.

$$K_{\text{wear}} = 1 - x \quad (4)$$

where

x is the permissible wear ~~in percent / 100~~ expressed as a proportion of the total cross-sectional area.

5.3.4 Wind ~~and ice~~ loads ~~K_{icewind}~~ K_{wind}

The effect of wind ~~and ice loads~~ load on maximum contact wire tensile strength depends on the design of overhead contact lines. The factor ~~K_{icewind}~~ K_{wind} depends on the wind ~~and ice loads~~ load and the type of the overhead contact line and ~~is~~ provision shall made as set out in Table 6.

Table 6 – Factor ~~K_{icewind}~~ K_{wind} for contact wires

Type of overhead contact line	~~Wind and ice load~~	~~Wind load~~	K_{wind}
Contact and catenary wire automatically tensioned	~~0,95~~	~~1,00~~	1,00
Contact wire automatically tensioned and catenary wire fixed termination	~~0,90~~	~~0,95~~	0,95
Single contact wire automatically tensioned	~~0,90~~	~~0,95~~	0,95
Contact and catenary wire fixed termination	~~0,70~~	~~0,80~~	0,80

5.3.5 Ice loads K_{ice}

The effect of ice loads on maximum contact wire tensile strength depends on the design of overhead contact lines. The factor K_{ice} depends on the ice loads and the type of the overhead contact line and provision shall be made as set out in Table 7. In some tropical zone and temperate zone areas where ice does not appear on wires, K_{ice} may be 1,0 in any condition of Table 7.

Table 7 – Factor K_{ice} for contact wires

Type of overhead contact line	K_{ice}
Contact and catenary wire automatically tensioned	0,95
Contact wire automatically tensioned and catenary wire fixed termination	0,95
Single contact wire automatically tensioned	0,95
Contact and catenary wire fixed termination	0,88

5.3.6 Efficiency of tensioning devices K_{eff}

The efficiency and accuracy of tensioning devices is considered by the factor K_{eff} . ~~For the normal design and installation of tensioning devices, K_{eff} is assumed to~~ When the tensioning device is installed in accordance with the supplier's instructions, K_{eff} shall be equal to the efficiency specified and proven by the supplier.

Where fixed terminations are used, K_{eff} shall be equal to 1,0.

5.3.7 Termination fittings K_{clamp}

The effect of termination fittings is considered by the factor K_{clamp} which shall be equal to 1,00 if the clamping force is equal to or greater than 95 % of the contact wire tensile strength. Otherwise, K_{clamp} shall be equal to the ratio of the clamping force to the tensile strength.

5.3.8 Joints K_{joint}

The effect of joints is considered by the factor K_{joint} . This shall be equal to 1,00 if no joints are adopted or if the values of tensile strength and the percentage elongation after fracture at a joint area are in accordance with the specified values of the wire material. Otherwise, K_{joint} shall be equal to the ratio of the tensile strength of joints to the higher calculated rated tensile strength of contact wire. The minimum tensile strength of the joint shall be in accordance with ~~EN 50149 in Europe~~ IEC 62917.

5.4 Mechanical design of catenary wire loads

5.4.1 Permissible tensile loading F_w

The maximum permissible working tensile load of catenary wire depends on the parameters defined in 5.4.2 to 5.4.7. All of these parameters shall be weighted with an individual factor. The minimum breaking load F_{Bmin} of the catenary wire shall be multiplied by the product of these factors and a factor n not greater than 0,65 to get the maximum permissible working tensile load.

The maximum permissible working tensile load shall be determined using Formula:

$$\frac{F_w}{F_{\text{Bmin}}} = n \times K_{\text{temp}} \times K_{\text{wind}} \times K_{\text{ice}} \times K_{\text{eff}} \times K_{\text{clamp}} \times K_{\text{load}}$$

$$F_w = F_{\text{Bmin}} \times n \times K_{\text{temp}} \times K_{\text{wind}} \times K_{\text{ice}} \times K_{\text{eff}} \times K_{\text{clamp}} \times K_{\text{load}} \quad [\text{N}] \quad (5)$$

Formula (5) gives the minimum requirements which ~~can~~ may be increased by national regulations.

5.4.2 Maximum temperature K_{temp}

The factor K_{temp} ~~is assumed to 1,0 as long as the maximum working temperature does not exceed~~ shall be selected from the values in ~~Table 1~~ Table 8. At higher working temperatures, the factor shall be reduced in accordance with the possible reduction in percent of the tensile strength.

Table 8 – Factor K_{temp} for stranded conductors

Examples of stranded wire-type material	K_{temp}	
	For max. temperature $\leq 80\text{ °C}$	For max. temperature $\leq 100\text{ °C}$
Cu ^a	1,0	0,8
Al-alloy	1,0	0,8
Cu Ag0,1 ^b	1,0	1,0
Cu-Sn (0,1 to 0,4) ^b	1,0	1,0
Cu-Mg ~~Steel~~ (0,1 to 0,7) ^b	1,0	1,0
Steel	1,0	1,0
ACSR/AACSR	1,0	0,8
^a C0 according IEC 63190.		
^b C1 to C7 according IEC 63190.		

For new products, it ~~can~~ should be ~~necessary~~ considered to use lower values until sufficient operational experiences ~~are collected~~ has been gained.

For maximum working temperatures above 100 °C, the reduction of conductor strength over the life of the wire shall be determined by type tests. The factor K_{temp} shall be adjusted according to the residual strength of the wire as shown in Table 8.

5.4.3 Wind loads K_{wind}

Wind load is defined by a factor K_{wind} ~~which depends on the wind speed as defined in Table 8.~~ This factor shall be selected from Table 9 according to the corresponding wind velocity and type of termination.

Table 9 – Factor K_{wind} for stranded conductors

Type of termination	K_{wind}	
	~~Wind speed~~ Mean wind velocity $\leq 100\text{ km/h (27,7 m/s)}$	~~Wind speed~~ Mean wind velocity $> 100\text{ km/h (27,7 m/s)}$
Automatically tensioned	1,00	0,95
Fixed termination	0,95	0,90

5.4.4 Ice loads K_{ice}

The effect of ice loads shall be considered when determining the maximum working load of the stranded wire. The factor K_{ice} depends on the type of termination ~~as specified in~~ and shall be selected from Table 10. In some tropical zone and temperate zone areas where ice does not appear on wires, K_{ice} may be 1,0 in any condition of Table 10.

Table 10 – Factor K_{ice} for stranded conductors

Type of termination	K_{ice}
Automatically tensioned	1,00
Fixed termination	0,95