

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Railway applications – Fixed installations – Electric traction overhead contact lines

Applications ferroviaires – Installations fixes – Lignes aériennes de contact pour la traction électrique



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RAILWAY APPLICATIONS – FIXED INSTALLATIONS – ELECTRIC TRACTION OVERHEAD CONTACT LINES

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

This second edition cancels and replaces the first edition published in 1988. It constitutes a technical revision of the initial standard based on European standard EN 50119.

The main technical changes with regard to the previous edition deal with:

- fundamental design data,
- system requirements,
- structures,
- components requirements,
- testing

for overhead contact line design.

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

FDIS	Report on voting
9/1745/FDIS	9/1773/RVD

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

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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

RAILWAY APPLICATIONS – FIXED INSTALLATIONS – ELECTRIC TRACTION OVERHEAD CONTACT LINES

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 standard contains the requirements and tests for the design of overhead contact lines, 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.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 50119. 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 a.c. 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 a.c. 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 mainline 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 61245, *Artificial pollution tests on high-voltage insulators to be used on d.c. systems*

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

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 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*

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

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

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

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

IEC 62498-2, *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 a.c. switchgear – Part 2: Single-phase disconnectors, earthing switches and switches with U_n above 1 kV*

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

ISO 630 (all parts), *Structural steels*

ISO 898-1, *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, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

ISO 2394, *General principles on reliability for structures*

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/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 abbreviations

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

3.1 Systems

3.1.1

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

Note 1 to entry: The mechanical system may comprise

- the contact line,
- structures and foundations,
- supports and any components supporting or registering the conductors,
- head and cross-spans,
- tensioning devices,

- along-track feeders, reinforcing feeders, and other lines like earth wires and return conductors as far as they are supported from contact line system structures,
- any other equipment necessary for operating the contact line,
- conductors connected permanently to the contact line for supply of other electrical equipment such as lights, signal operation, point control and point heating.

3.1.2

contact line

conductor system for supplying traction units with electrical energy via current-collection 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;
- supports that are not insulated from the conductors;
- insulators connected to live parts;

but excluding other conductors, such as the following:

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

3.1.3

overhead contact line system

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

3.1.4

overhead contact line

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

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

3.1.7

conductor rail

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

3.1.8

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

3.1.13**tensioning device**

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

3.1.14**urban mass transportation system**

light rail, trolleybus and tramway system, operating in urban areas, excluding heavy rail systems

3.2 Conductors**3.2.1****along-track feeder**

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

3.2.2**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

3.3 Electrical**3.3.1****nominal voltage**

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

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.

3.3.2**feeding section**

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

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

3.3.4

short-circuit

accidental or intentional conductive path between two or more points in a circuit 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

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

3.3.7

feeding point

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

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

3.4 Geometrical

3.4.1

tension length

length of overhead contact line between two terminating points

3.4.2

gradient

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

3.4.3

contact wire height

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

3.4.4

minimum contact wire height

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

3.4.5

minimum design contact wire height

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

3.4.6

nominal contact wire height

nominal value of the contact wire height at a support in the normal conditions

3.4.7**maximum contact wire height**

maximum possible contact wire height which the pantograph is required to reach, in all conditions

3.4.8**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

3.4.9**contact wire uplift**

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

3.5 Foundations**3.5.1****gravity foundation**

shallow foundation installed by excavation and backfilling

3.5.2**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

3.5.3**sidebearing 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

3.6 Structures**3.6.1****drag factor****aerodynamic drag factor****force coefficient**

It is used to consider the shape of a object exposed to wind. The wind pressure is multiplied by this factor to determine the wind action

3.6.2**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 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 2 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.

3.7 Symbols and abbreviations

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
AACSR	Aluminium alloy conductor steel reinforced
ACSR	Aluminium conductor steel reinforced
a.c.	alternating current
C	compression amplitude for dropper test
C_C	drag factor of a conductor
C_{ins}	drag factor for insulators
C_{lat}	drag factor for lattice structures
C_{str}	drag factor of a structure
d.c.	direct current
E_d	total design value of actions
EMI	electromagnetic interference
EMC	electromagnetic compatibility
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
$F_{perm.op.}$	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
M_{dyy}, M_{dzz}	design bending moments
N_{dax}	internal axial force of an element
n	safety factor for calculating the permissible loading in wires
OCS	overhead contact line system
OCL	overhead contact line
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}	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_K	characteristic dynamic wind pressure
R_{dax}	axial resistance under tension or compression
R_{dyy}, R_{dzz}	design bending resistances
R_k	characteristic value of the foundation ultimate resistance
$R_{p\ 0,2\ min}$	0,2 % yield point
u	variation in elasticity (also named degree of non-uniformity)
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_F	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
ρ	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

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 this clause. In particular the integration of the overhead contact line design with the corresponding features of other interconnected systems, e.g. the power supply system and the traction system, shall be considered.

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

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 with the 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/traction units to be employed,
- the future performance capability to be anticipated and allowed for in the design, including any allowances for over speeding,
- the type and frequency of electrically hauled trains,
- the line speed for main and station tracks,
- track gradient profile and location of the route; including turnouts and transitions,
- type of turnouts.

4.3 Electrical power system design

The overhead contact line system design shall be based upon the consideration of the electrical characteristics of the power supply system design, including

- nominal voltage and frequency, in accordance with IEC 60850,
- short-circuit current details,
- required current rating,
- required impedance for a.c. systems where stated,
- required resistance for d.c. systems where stated,
- 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,
- requirements for over-voltage protection,
- insulation coordination.

For urban mass transportation 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 clearances for all vehicle types to be used on the line. In particular the following shall be determined:

- a) the static and kinematic load gauge, kinematic envelope and the swept envelope as well as any national or international requirements for structural clearances;
- b) the 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) mean contact force at maximum line speed,
- f) working width of the current collector head,
- g) working range and housed height,
- h) controlled height positions,
- i) mathematical model of dynamic characteristics,
- j) skew of current collector head,
- k) number, position on the train and separation of current collectors that may be used simultaneously.

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

4.6 Environmental conditions

For environmental conditions refer to 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 characteristics defined in 4.2 and 4.3. The design shall include the return circuit and feeder connections and shall consider short-circuit faults.

5.1.2 Temperature rise in conductors

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

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. 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 the mechanical and dimensional allowances 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 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

Material	Temperature °C		
	Up to 1 s (short-circuit current)	Up to 30 min (pantograph standstill)	Permanent (operating condition)
Normal and high strength copper with high conductivity	170	120	80
Silver copper alloy	200	150	100
Tin copper alloys	170	130	100
Magnesium copper alloys / bronze (0,2)	170	130	100
Magnesium copper alloys / bronze (0,5)	200	150	100
Aluminium alloys	130	-	80
ACSR / AACSR	160	-	80

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

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

NOTE There have been long satisfactory experiences in Japan that the highest permanent temperature of copper, aluminium and ACSR wires is 90 °C.

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

- the heating caused by the current;
- the heating caused by the environmental conditions;
- the radiant heat emitted from the conductor;
- the heat lost from the conductor by convection depending on the wind speed.

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.

5.1.3 Clearances between live parts of contact lines and earth

The recommended air clearances between earth and the live parts of the overhead contact line system are stated in Table 2.

Table 2 – Electrical clearances

Nominal voltage	Recommended minimum clearances mm	
	Static	Dynamic
d.c. 600 V (720 V) ^a	100	50
d.c. 750 V (900 V)	100	50
d.c. 1,5 kV (1,8 kV)	100	50
d.c. 3,0 kV (3,6 kV)	150	50
a.c. 15 kV (17,25 kV)	150	100
a.c. 20 kV (24 kV)	250	150
a.c. 25 kV (27,5 kV)	270	150
a.c. 25 kV (30 kV)	300	150 ^b
^a Only for existing systems. ^b The value is 300 mm in Japan. Values in brackets are highest permanent voltage.		

Different clearances for “static” and “dynamic” cases are justifiable by probabilistic determinations (probability or time for example). For example, it is improbable that an over-voltage surge will occur at the same moment that a pantograph passes a narrow part of a tunnel. For this “dynamic” or temporary case, the use of a dynamic clearance is justified.

For section insulators, it is allowed to reduce the static values of recommended clearance in Table 2 to ensure acceptable dynamic performance of the pantograph and overhead contact line system.

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 values for section insulators may be specified by National 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 arrestors or other means should be used if the electrical clearances to earthed structures are not sufficient to avoid flashovers.

5.1.4 Clearances between adjacent live a.c. 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 feeder line and all live parts connected to the overhead contact line.

For single phase a.c. 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 a.c. contact line system of differing phases.

Table 3 – Clearance between differing phases

Nominal voltage kV	Phase difference degrees	Relative voltage kV	Recommended minimum clearance	
			Static mm	Dynamic 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.

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 current collection systems

5.2.1 General

The design of both the overhead contact line system and pantograph shall take into account the required relevant 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.

For a train with multiple pantographs, 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.

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 :

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

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.

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

The elasticity should normally be calculated 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 D.

5.2.3 Vertical movement of contact point

The contact point is the point of the mechanical contact between a 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 the purchaser.

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.

5.2.4 Wave propagation velocity

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

$$V_c = \sqrt{\frac{\sum z}{\sum m}} \quad (2)$$

where

V_c is in m/s;

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

$\sum m$ is the sum of the linear mass of the contact wire(s) 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

Pantographs and overhead contact lines 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

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

5.2.5.2 Contact forces

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

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

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

Force values vary with different combinations of pantographs and overhead contact systems. The simulated or measured values of contact forces between the contact wire and contact strip shall not exceed the range given in Table 4.

Where contact forces are used to define the current collection, the mean value and standard deviation of contact force shall be the criteria for current collection quality.

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.

Table 4 – Contact force

System	Speed km/h	Contact force	
		Maximum N	Minimum N
a.c.	≤ 200	300	> 0
a.c.	> 200	350	> 0
d.c.	≤ 200	300	> 0
d.c.	> 200	400	> 0

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 systems the dynamic behaviour needs not be considered. In this case the static contact force shall be at least 60 N. For trolleybus systems the values are specified in 5.13.5.

NOTE Requirements for contact forces for interoperable lines are given in IEC 62486.

5.2.5.3 Loss of contact

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.

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

NOTE Requirements for interoperable lines are given in IEC 62486.

5.2.5.4 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 overhead contact line design, consideration can be given to the bending stress of contact wire.

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 5.3.7. All of these parameters shall be weighted with an individual factor. The minimum tensile failing stress σ_{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 the following equation:

$$\sigma_w = \sigma_{\min} \times n \times K_{\text{temp}} \times K_{\text{wear}} \times K_{\text{icewind}} \times K_{\text{eff}} \times K_{\text{clamp}} \times K_{\text{joint}} \quad (3)$$

This formula 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 given in Table 5.

Table 5 – Factor K_{temp} for contact wires

Contact wire material	K_{temp}	
	For max. temperature ≤ 80 °C	For max. temperature = 100 °C
Cu	1,0	0,8
Cu-Ag 0,1	1,0	1,0
Cu-Sn	1,0	1,0
Cu-Mg	1,0	1,0

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

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.

Notwithstanding 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.

5.3.4 Wind and ice loads K_{icewind}

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

Table 6 – Factor K_{icewind} for contact wires

Type of overhead contact line	Wind and ice load	Wind load
Contact and catenary wire automatically tensioned	0,95	1,00
Contact wire automatically tensioned and catenary wire fixed termination	0,90	0,95
Single contact wire automatically tensioned	0,90	0,95

Contact and catenary wire fixed termination	0,70	0,80
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5.3.5 Efficiency of tensioning devices K_{eff}

The efficiency of tensioning devices is considered by the factor K_{eff} . For the normal design and installation of tensioning devices, K_{eff} is assumed to be equal to the efficiency specified and proven by the supplier.

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

5.3.6 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.

5.3.7 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.

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 from:

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

This formula gives the minimum requirements which can 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 the values in Table 1. At higher working temperatures, the factor shall be reduced in accordance with the possible reduction in percent of the tensile strength.

Table 7 – Factor K_{temp} for stranded conductors

Stranded wire type	K_{temp}	
	For max. temperature $\leq 80\text{ °C}$	For max. temperature = 100 °C
Cu	1,0	0,8
Al-alloy	1,0	0,8
Cu Ag	1,0	1,0
Cu-Sn 0,4	1,0	1,0

Cu-Mg / Steel	1,0	1,0
ACSR / AACSR	1,0	0,8

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

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 7.

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.

Table 8 – Factor K_{wind} for stranded conductors

Type of termination	K_{wind}	
	Wind speed ≤ 100 km/h	Wind speed > 100 km/h
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 Table 9.

Table 9 – Factor K_{ice} for stranded conductors

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

5.4.5 Automatic tensioning accuracy and efficiency K_{eff}

Automatic tensioning accuracy and efficiency is considered by the factor K_{eff} . For the normal design and installation of tensioning devices, 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.

5.4.6 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 more than 95 % of the calculated rated tensile strength (RTS). Otherwise K_{clamp} shall be equal to the ratio of the clamping force to RTS.

5.4.7 Additional vertical load K_{load}

The effect of vertical loads acting on catenaries is considered by the factor K_{load} equal to 0,8. For catenary wires without loads acting the factor K_{load} shall be equal to 1,0.

Dropper loads are not included in consideration of the factor K_{load} .

5.5 Mechanical design of other stranded conductors

For stranded conductors, other than catenary wires, the requirements of 5.4.1 to 5.4.7 shall only apply if the working load exceeds 40 % of the calculated breaking load of the stranded conductor.

For calculation of the working loads the load cases according clause 6.3.1 should be considered.

5.6 Mechanical design of solid wires

Solid wires in overhead contact line systems other than contact wires shall not be loaded over 40 % of the minimum breaking load.

5.7 Mechanical design of ropes of non-conducting materials

5.7.1 General

Ropes formed from non-conducting materials may be used only up to their calculated working load. Particular attention shall be given to shearing loads, bending radius, termination arrangement and elongation. These requirements apply to ropes which are made from synthetic fibres and have an external synthetic sheath to protect the fibres. Refer to EN 50345 in Europe for further details.

5.7.2 Permissible tensile loading F_w

The permissible tensile load of a rope shall be weighted with an individual factor (refer to 5.7.3 to 5.7.7). The minimum breaking load F_{Bmin} of the combined fibres shall be multiplied by the product of these factors and a factor n not greater than 0,45 to get the maximum permissible working tensile load.

The maximum permissible working tensile load shall be determined from

$$F_w = F_{Bmin} \times n \times K_{wind} \times K_{ice} \times K_{clamp} \times K_{load} \times K_{radius} \quad (6)$$

This formula gives the minimum requirements which can be increased by national regulations.

5.7.3 Wind loads K_{wind}

Wind load is considered by the factor K_{wind} depending on the wind speed:

$$K_{wind} = 1,00 \text{ for wind speed } \leq 100 \text{ km/h;}$$

$$K_{wind} = 0,90 \text{ for wind speed } > 100 \text{ km/h.}$$

5.7.4 Ice loads K_{ice}

The effects of ice loads shall be taken into consideration:

$$K_{ice} = 0,95.$$

5.7.5 Termination clamps K_{clamp}

The effect of termination fittings shall be considered by the factor K_{clamp} :

$$K_{clamp} = 1,00 \text{ for cone end termination fittings;}$$

$$K_{clamp} = 0,80 \text{ for other kinds.}$$

5.7.6 Vertical loads K_{load}

The effect of vertical loading shall be considered using the factor K_{load} :

$K_{load} = 0,7$ when vertical loads attached;

$K_{load} = 1,0$ without loads attached.

Examples of vertical loads to be considered are direction indicators or feeding cables for traffic lights or for the overhead contact line.

5.7.7 Minimum bending radius K_{radius}

The effect of the radius on the ropes shall be considered by the factor K_{radius} according to Table 10.

Table 10 – Factor K_{radius} for ropes of non-conducting materials

Bending radius r m	K_{radius}
$r \geq 1$	1
$0,5 \leq r < 1$	0,9
$0,2 \leq r < 0,5$	0,8
$0,1 \leq r < 0,2$	0,7
$r < 0,1$	0,5

5.8 Suspension systems

Automatically tensioned equipment shall be suspended from supports which allow longitudinal movement. Fixed termination equipment may be supported from fixed supports. Where line speeds are greater than 100 km/h or where high operational currents demand it, a catenary wire type suspension should be used. When overhead contact rails are used, no catenary suspensions are necessary.

5.9 Tensioning systems

The tensions in the contact and catenary wires shall be maintained within the system design parameters. To ensure satisfactory current collection for speeds above 100 km/h, the contact wires shall be automatically tensioned. The catenary wires shall also be automatically tensioned when the system parameters demand it.

For speeds above 225 km/h both catenary and contact wires shall be automatically tensioned separately.

According to special conditions in Japan there it is possible to use for more than 225 km/h only one tensioning equipment for all wires if tension of each wire can be kept properly.

For automatically tensioned equipment, local tension in the overhead contact line can vary, due to the effect of along track movement of registration arms or cantilever frames. The maximum acceptable variation of tension in the overhead contact line shall be considered.

5.10 Geometry of overhead equipment

5.10.1 Horizontal deflection of contact wire

Under defined environmental conditions and mechanical tolerances, the horizontal deflection of the contact wire and the pantograph shall be such that it is not possible for the contact wire to slide off the pantograph head unless specifically designed to do so at contact wire takeover.

points. A minimum stagger value shall be specified for each project, in order to maintain adequate mechanical clearances and to minimise wear of contact wire and pantograph strip. Under normal operational conditions, the contact wire shall be contained within the pantograph working width.

Wind force on conductors shall be assessed and the resulting maximum across track deflection determined in either direction. Assessment of the wind force on individual conductors shall be in accordance with the serviceability requirements of 6.2.4.1, and the maximum wind speed in operational conditions for individual spans, or applying special national conditions where applicable.

For calculation of deflection of the contact wire, wind forces shall be applied to the contact and catenary wires. Dropper wires may also be considered.

The resulting contact wire movement, together with the structure deflection, shall result in contact wire deviation within the maximum values permitted by the system design when added to the contact wire stagger in still air at any point along track.

Mechanical and electrical clearances of conductors to other parts of the railway infrastructure, when subject to wind, shall similarly be verified.

5.10.2 Uplift

The design uplift of the contact wire at the support, for the maximum span length under normal operating conditions, shall be determined or evaluated by calculation, simulation or measurement. The space for free and unrestricted uplift of the contact wire at the support shall be a minimum of twice the design uplift. If restrictions to uplift of the contact wire are included in the design, a figure not lower than 1,5 shall be used.

5.10.3 Variation in contact wire height

If, due to local conditions, e.g. bridges, a variation in contact wire height is necessary, this shall be achieved with as small a gradient as possible. Design values for gradient and changes of gradient shall not exceed the values set out in Table 11 as a function of speed.

Table 11 – Contact wire gradients

Speed up to km/h	Maximum gradient		Maximum change of gradient	
		‰		‰
50	1/40	25	1/40	25
60	1/50	20	1/100	10
100	1/167	6	1/333	3
120	1/250	4	1/500	2
160	1/300	3,3	1/600	1,7
200	1/500	2	1/1 000	1
250	1/1 000	1	1/2 000	0,5
> 250	0	0	0	0

5.10.4 Minimum contact wire height

The minimum contact wire height shall always be greater than the swept envelope, also taking into consideration the electrical clearance in air and the minimum working height of the pantograph, to avoid arcing between the contact wire and the earthed parts of vehicles.

See Figure 1 for the relationship between contact wire heights and pantograph working heights.

5.10.5 Minimum design contact wire height

The minimum design contact wire height shall be calculated by adding all downwards movements of the contact wire to the minimum height. Consideration shall be given to

- vertical tolerance on the track position,
- downwards installation tolerance for the contact wire,
- downwards dynamic movements of the contact wire,
- effects of ice load and temperature on the conductors.

5.10.6 Nominal contact wire height

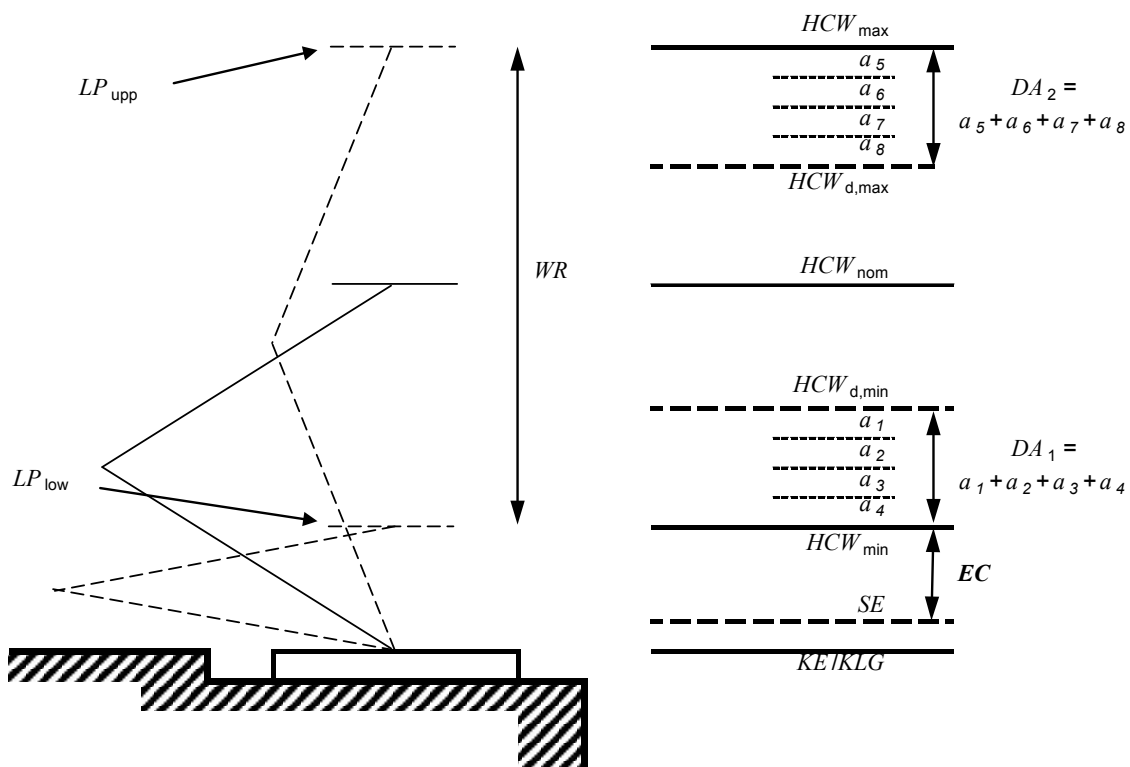
It is permissible to set the nominal height for an overhead contact line in the range between the minimum and the maximum design heights of the contact wire.

NOTE Specific requirements for contact wire heights for interoperable lines are given in IEC 62486.

5.10.7 Maximum design contact wire height

The maximum design contact wire height shall be obtained by deducting from the maximum working height of the pantograph the possible upwards movements of the contact wire. Consideration shall be given to

- vertical tolerance of the track,
- uplift of the contact wire by the pantograph,
- upwards dynamic movement of the contact wire,
- upwards installation tolerance,
- uplift of the contact wire due to wear,
- uplift of the contact wire due to any effect of temperature changes in the conductors.



Key

IEC 256/13

LP_{upp}	upper operating position of pantograph or collector (see IEC 60494-1)
LP_{low}	lower operating position of pantograph or collector (see IEC 60494-1)
WR	working range of pantograph or collector (see IEC 60494-1)
KE/KLG	kinematic envelope / kinematic load gauge height
SE	swept envelope height
EC	electrical clearances
HCW_{min}	minimum contact wire height
HCW_{max}	maximum contact wire height
$HCW_{d,min}$	minimum design contact wire height
$HCW_{d,max}$	maximum design contact wire height
HCW_{nom}	nominal contact wire height
DA_1	design allowances above HCW_{min}
	a_1 vertical tolerance of the track (if not included in envelope / gauge)
	a_2 downwards installation tolerance for the contact wire
	a_3 downwards dynamic movements of the contact wire
	a_4 effects of ice load and temperature on conductors
DA_2	design allowances below HCW_{max}
	a_5 vertical tolerance of the track
	a_6 uplift of the contact wire by the pantograph and dynamic movement of the contact wire
	a_7 upwards installation tolerance for the contact wire
	a_8 uplift of the contact wire due to wear and any temperature changes in the conductors

Figure 1 – Relationship between contact wire heights and pantograph operating position

5.11 Contact line arrangement above turnouts and crossings

Contact lines above turnouts and track crossings shall be designed such that they can be traversed in all planned directions at the planned speeds whilst still meeting the requirements of the permissible range of contact forces (Table 4).

The design of crossing points and the configuration and geometry of tangential contact lines shall ensure that no contact wire is able to slip below the pantograph contact strips. The sway and skew of the pantograph shall be considered as well as contact wire uplift and lateral deflection due to wind. At the point where the incoming contact wire touches the pantograph head, both contact wires shall be placed on the same side of the pantograph head related to its central axis.

Suitable remedies, e.g. cross contact bars and cross droppers, shall be employed to guarantee that both contact wires are lifted when being traversed by a pantograph. The temperature-related longitudinal expansions of contact wires shall be considered when adopting such remedies.

To avoid the use of cross-contacts alternative equipment arrangements may be used to prevent the effects of a significant dynamic uplift of the pantograph.

5.12 Overlap arrangements

Overlaps shall enable the pantograph to pass from one tension length to the next without speed reduction or interruption of the power supply to the traction unit. The number and lengths of spans including the differences in the length of adjacent spans and the contact wire gradients within overlaps shall be designed such that the permissible range of contact forces and the permissible differences in elasticity are met. The maximum running speeds and track radii need to be taken into account.

For overlaps in automatically tensioned equipment, the supports of both contact line equipments shall enable the unrestricted movement of the contact line due to the temperature related longitudinal expansion.

For insulated overlaps the minimum dynamic electrical clearance of parallel conductors shall, under the specified environmental conditions, be maintained. The required static electric clearance in air shall be met.

Uninsulated overlaps should be permanently connected by a jumper. Insulated overlaps should be connected, during operational conditions, by a disconnector or via a substation.

5.13 Specific requirements for overhead contact lines for trolleybus systems

5.13.1 General

The typical characteristic of an overhead contact line system for trolleybus applications is twin contact wires that are electrically separate.

The function of an overhead contact line for trolleybus applications is to transmit energy from electric substations to the trolleybus units and return it, all under the necessary protection conditions. In order to fulfil this function, the electrical system, made of cable and feeding/return wire, shall be designed in accordance with the requirements set out in 5.13.2 to 5.13.6.

5.13.2 Line characteristics

The trolleybus service characteristics and operational requirements should be taken from National Standards.

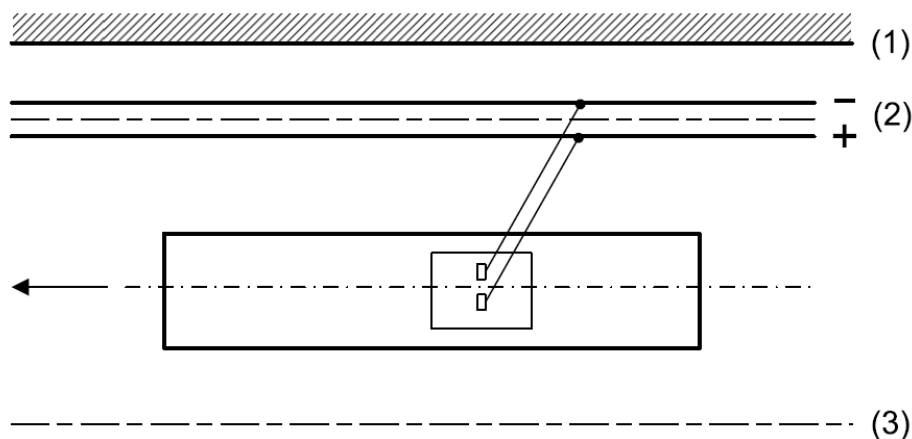
Consideration also shall be given to the environmental operating conditions and the urban area in which the overhead contact line will be installed, with particular attention being given to any national requirements for structural clearances.

The trolleybus characteristics and operational requirements include:

- right-of-way types: the types of road or rail alignments (e.g., street, reserved, grade-separated, etc.) commonly used for each different mode,
- average speed: the average origin-to-destination speed for each mode in revenue service. This includes time spent at station stops, in traffic and due to other delays,
- maximum speed: the top speed the vehicle is capable of reaching on a straight, level right-of-way way with no curves, gradients, stops, traffic signals or other delays,
- right-of-way dimensions: the width and height of right-of-way needed to accommodate the vehicle in dynamic mode according to modern standards of safe operation,
- minimum curves: the tightest curves that may be used for a given transit mode, measured as the radius of the curve to the centre line of the transit vehicle,
- road surface gradients: the steepest gradients that may be used for a given transit mode without compromising reliability or safety of operations.

The distance between the feeding and return contact wires shall be either 0,60 m or 0,70 m, with a maximum tolerance of ± 15 mm.

If one pole of the d.c. system is earthed or connected to the return circuit of a tram or light rail system the contact wire of this pole shall be mounted on the outside of the right-of-way (see Figure 2).



IEC 257/13

Key

- 1 limit of the carriageway
- 2 overhead contact line: (–) return wire
(+) feeding wire
- 3 axis of right of way

Figure 2 – Position of return wire in relation to right-of-way

The assemblies of an overhead contact line (wires, suspension, switches and crossing) shall be so positioned as to allow

- a regular vehicle circulation along the route,
- a correct approach to platform stops,
- overtaking of another vehicle of the maximum admissible dimensions for road vehicles.

5.13.3 Vehicle characteristics

The following characteristics shall be determined and incorporated into the system design:

- nominal voltage of the overhead contact line;
- type of trolleybus and road characteristics;
- maximum and minimum road gradient of the route;
- maximum and permanent current of the vehicle;
- type of traction (by resistance, chopper, inverter, etc.);
- type of braking (by resistance, energy saving, etc.);
- environmental characteristics of the vehicle;
- trolleybus horizontal displacement from overhead contact line.

5.13.4 Current collector system

In particular, the following information shall be considered for the current collector:

- current collector dimension and type;
- construction characteristics of the current collector and all equipment that comprises the overhead contact line, such as switching and crossing points;
- static contact force between the current collector and contact wire;
- range of the contact forces related to the dynamic movement of the vehicle and variation of the height of the overhead contact line;
- type of contact line.

NOTE CLC/TS 50502 provides information regarding safety requirements and connection systems for electric equipment in trolley buses in Europe.

5.13.5 Static contact forces

The range of static contact force applied to feeding and return wires shall be between 70 N and 120 N for each wire.

5.13.6 Trolleybus in the vicinity of tramways

It is typical, especially for an urban area, that trolleybus and trams run under the same supporting system. In this case, the overhead contact lines for both systems are supported by the same suspension.

The distance between the contact wires for trolleybus and tramways shall not be less than the distance between the feeding and return wires.

In any case the following shall be determined and incorporated into the system design:

- the static and kinematic load gauge of the trolleybus and tram;
- the distance between the return wire and the tramways overhead contact line is at least the distance between the feeder and return contact wires of the trolleybus overhead contact line.

Overhead contact lines for trolleybuses and tramways are generally supplied by separate feeding sections to facilitate maintenance activities.

5.14 Tolerances and limits

Parameters which are capable of being influenced by construction shall be limited by tolerances and limits. Tolerances and limits depend on the type of contact line and shall be defined in accordance with the requirements on safety, quality of current collection, compatibility to interfaces and aesthetic aspects. The interdependencies between the individual values shall be considered as well as the relationship between the tolerances and limits and external effects like climate, pantograph design and power supply.

For parameters which are capable of changing during operation, and so influence the system performance, e.g. due to the shift of track position, operational limits shall be additionally defined. The relationship between the tolerances and limits for construction and the limits for operation shall consider the possible changes of parameters over time between inspection and maintenance periods.

The tolerances and limits shall be implemented in the design (see e.g. 6.4.5) and kept during construction and operation.

Table 12 shows examples of the parameters for which tolerances and limits should be defined. The types of parameters are divided in four main groups in the order of their importance to the system. In each main group, examples of parameters for tolerances and limits are given in relation to construction and/or operation. The specific values shall be defined by the system designer.

Table 12 – Important parameters to assist in the definition of tolerances and limits

Type of parameter	Tolerances	Limits	To be defined for:	
			Construction	Operation
Type A, safety related				
dimension of foundations, position of foundations perpendicular to track, rotation angle of masts, contact wire stagger	X		X	
safety clearance, electrical clearances, contact wire height (minimum/maximum), maximum deviation of contact wire due to wind, maximum contact wire wear		X	X	X
Type B, related to quality of current collection				
system height, distance between droppers, position of foundations along the track	X		X	
inclination of droppers along the track, maximum/minimum contact forces, variation of elasticity (u)		X	X	X
contact wire gradient, change of gradients, inclination of droppers perpendicular to track		X	X	
Type C, compatibility related				
geometrical tolerances of component interfaces	X		X	
Type D, aesthetics related				
mast height	X		X	
inclination of poles, inclination of horizontal cantilever tubes		X	X	

Refer to Annex E for special national conditions requirements.

6 Structures

6.1 Basis of design

6.1.1 General

Structures for overhead contact lines may be designed in accordance with the general principles contained in 6.1.2 to 6.1.6, or refer to the international standards or national standards or as described in EN 1990:2002 for Europe.

6.1.2 Basic requirements

Structures for overhead contact line shall be designed and constructed in such a way that during their intended life

- they will perform their purpose under a defined set of conditions with acceptable levels of reliability and in an economic manner. This refers to aspects of reliability requirements,
- they will not be liable to progressive collapse if a failure is triggered in a defined component. This refers to aspects of security requirements,
- they will not be liable to cause human injuries or loss of life during construction, operation, and maintenance. This refers to aspects of safety requirements.

An overhead contact line shall also be designed, constructed and maintained in such a way that due regard is given to safety of the public, durability, robustness, maintainability and environmental considerations.

The above requirements shall be met by the choice of suitable materials, by appropriate design and detailing, and by specifying control procedures for design, production, construction and use relevant to the particular project.

6.1.3 Design with regard to structural limits

Generally, a distinction is made between ultimate limit state and serviceability limit.

Ultimate limit states are those associated with collapse or with other similar types of structural failure due to excessive deformation, loss of stability, overturning, rupture, buckling, etc. Ultimate limit states concern the reliability and security of supports, foundations, conductors and equipment as well as the safety of people.

Serviceability limit states correspond to certain defined conditions beyond which specified service requirements for an overhead contact line are no longer met. Serviceability requirements concern the mechanical functioning of supports, foundations, conductors and equipment and the unrestricted transmission of electric energy to the vehicles.

Therefore, serviceability limits require consideration of deformations and displacements which affect the use of the overhead contact line and any damage which is likely to affect the durability or function of the supports and equipment adversely.

Serviceability limits may be given in the purchaser specification.

Design with reference to ultimate limit state and serviceability limit states shall be carried out by:

- setting up structural and load models for relevant ultimate and serviceability limits to be considered in the various design conditions and load cases,
- design values which are generally obtained by using characteristic values as defined in this Standard in conjunction with partial factors as defined
 - in this Standard,
 - in ISO 10721 (all parts) and ISO 23469:2005,
 - in EN 1992 (all parts), EN 1993 (all parts), EN 1995 (all parts), EN 1997 (all parts), EN 1998 (all parts) and EN 1999 (all parts) for Europe,
 - in purchaser specifications,
- verifying that the limits are not exceeded when design values for actions, material properties and geometrical data are used in the model,
- reference to Eurocodes, alternative standards or experimental data for materials not covered by this standard.

6.1.4 Classification of actions

Actions can be classified by their variation in time or by their nature and/or structural response:

NOTE For the definition of an 'action', reference can be made to EN 1990:2002 in Europe, 1.5.3.1.

- Permanent actions (G) are self-weight of supports including foundations, fittings and fixed equipment, self-weight of conductors and the effects of conductor tensile loads at the reference temperature without ice and/or wind action. The characteristic value of permanent actions can normally be determined as one value G_K since the variability of G is small.
- Variable actions (Q) comprise wind loads, ice loads, or other imposed loads. Wind and ice loads as well as applicable temperatures are climatic conditions which can be assessed by probabilistic methods or on a deterministic basis or from applicable standards such as IEC 62498-2. Conductor tensile load effects due to wind and ice and temperature deviations are variable actions as well. For variable actions, the characteristic value Q_K corresponds to a nominal value used for deterministic based actions or an upper value of an intended probability not to be exceeded or a lower value with an intended probability not to be lower during a reference period.

- Accidental actions (A) are loads related to failure containment, etc. The representative value is generally a characteristic value A_K corresponding to a specified value. The dynamic actions after the operation of the fall arresting device of an automatic tensioning device or the failure of a contact or catenary wire may be considered by the use of an equivalent static action.
- Construction and maintenance loads (Q_{PK}) take into account working procedures, temporary guying, lifting arrangements, etc. The characteristic values Q_{PK} for construction and maintenance loads are deterministic values stipulated to guarantee the safety of structures and people.

6.1.5 Reliability levels

In principle, overhead contact lines shall be designed using a certain design working life and adequate reliability requirements. For civil structures of overhead contact lines, except temporary installations, a design working life of 50 years should be considered. The provisions shall comply with ISO 2394. Design application rules are defined in EN 1990 for Europe.

6.1.6 Models for structural analysis and resistance

Calculations shall be performed using appropriate design models involving relevant variables. The models shall be appropriate to predict the structural behaviour and the serviceability and failure limits. They should be based on an established engineering theory and practice, verified experimentally if necessary.

Concerning the interaction between foundation and soil, special attention should be paid to the loads derived from the supports, loads resulting from active soil pressure and permanent weight of foundation and soil and buoyancy effects of groundwater on soil and foundation. Together with the reaction forces of the soil strata, these effects shall be taken into account when calculating the foundations. In addition, the criteria for acceptable settlements of the foundations, imposed deformations on supports and the contact lines and inclinations of the supports should be defined and taken into consideration.

6.1.7 Design values and verification methods

In this standard, reliability is achieved by the application of partial factors and appropriate return periods for climatic actions based on statistical approach and partial factors for deterministic actions and for material properties. The partial factor method verifies that the effects of design actions do not exceed the design resistance at the failure limit and that design complies with the performance requirements concerning the serviceability limit.

The design value F_d of an action is expressed in general terms as:

$$F_d = \gamma_F \times F_K \quad (7)$$

where

γ_F is the partial factor for actions;

F_K is the characteristic value of an action.

In general, the partial factor for actions γ_F takes account of the possibility of unfavourable deviations of the actions, inaccurate modelling and uncertainties in the assessment of the effects of actions. For deterministic calculations including accidental loads, the partial factor may be applied to the effect of the characteristic values of action, i.e. on the conductor tensile load including the effects of wind, temperature and ice.

The design value X_d of a material property is generally defined as:

$$X_d = \frac{X_K}{\gamma_M} \quad (8)$$

The partial factor γ_M for material property covers unfavourable deviations from the characteristic value X_K of the material property, inaccuracies in applied conversion factors, and uncertainties in the geometric properties and the resistance model.

In the design of any component or their connection it shall be verified that

$$E_d \leq R_d, \quad (9)$$

where

E_d is the total design value of effects of action such as internal forces or moments or their combination.

E_d is a function of the actions in a certain design situation:

$$E_d = f(\gamma_G G_K; \gamma_W Q_{WK}; \gamma_I Q_{IK}; \gamma_P Q_{PK}; \gamma_C Q_{CK}; \gamma_A A_K) \quad (10)$$

where

G_K self-weight of supports, conductors fittings and conductor tensile forces depending on self weight considering reference temperature;

Q_{WK} characteristic wind load;

Q_{IK} characteristic ice load;

Q_{PK} construction and maintenance load;

Q_{CK} conductor tensile forces depending on the temperatures and climate related loads;

A_K actions induced by accidental loads and special actions;

$\gamma_G, \gamma_W, \gamma_I, \gamma_P, \gamma_C, \gamma_A$ associated partial factors.

R_d is the corresponding structural design resistance associating all structural properties with the respective design value X_{nd} according to:

$$R_d = f\{X_{1d}; X_{2d} \dots\} \quad (11)$$

For more details refer to EN 50341-1 in Europe. For urban mass transportation systems the calculations described in this subclause are not required.

6.2 Actions on overhead contact lines

6.2.1 General

Characteristic values for actions on lines concerning climatic data can be derived from probabilistic or deterministic approaches based on long periods of successful experience. The climatic data may be taken from relevant standards such as IEC 62498-2 or ISO 4354 or EN 1991-1-4 in Europe and may be given in the purchaser specification. The total of actions constitutes a complete design system especially taking the established load cases into consideration.

Actions on overhead contact lines are be considered as quasi-static actions, which do not require the verification of fatigue strength.

In case of essential vibration of structure e.g. bridges under earthquake conditions, effects of the vibration on overhead contact line should be considered.

Dynamic actions due to pantograph/contact line interaction caused by running trains are small and need not be considered. Aerodynamic action by running trains should be considered additionally, if required. The aerodynamic action in railway tunnel should be taken in consideration according to IEC 62498-2. Any detailed requirements should be stated by the purchaser specification.

During construction, the loads due to the wheels running on the tracks should be considered where required, e.g. for foundation excavation.

NOTE EN 1991-2 gives the general requirements in Europe.

6.2.2 Permanent loads

Self-weight of supports and their equipment such as cantilevers, tensioning equipment, insulators and span wires act as permanent loads. Conductor tensile forces of automatically tensioned wires and stagger loads can be considered as permanent loads. The characteristic value is G_K .

6.2.3 Variable loads

The variation in tension of fixed termination equipment shall be determined according to each individual load case such as:

- conductor under the action of ice load,
- conductor at both the design temperature and the minimum temperature,
- conductor under the action of maximum wind load,
- conductor under the combined action of wind and ice load.

The characteristic value is Q_{CK} and for other components are Q_{WK} , Q_{IK} , Q_{PK} .

6.2.4 Wind loads

6.2.4.1 General

Design of overhead contact lines in view of wind loads shall be based on the meteorological wind velocity measured 10 m above ground over an average period of 10 min in a relatively open terrain designated with terrain category II in ISO 4354, in national standards or in EN 1991-1-4 in Europe. For the structural design of the supports, the wind velocity having a return period of 50 years shall be used whilst for the verification of the serviceability the return period for wind velocity shall be given in the purchaser specification. Wind velocities have been recorded by meteorological services for many years. In most countries, information on the statistical wind data is available depending on the region. Values for the 50 years wind velocities are given in IEC 62498-2, in national standards or shall be given in the purchaser specification.

If the site concerned is located on high viaducts or bridges, the wind velocities to be used shall consider the relevant height above ground.

Design of wind loads on overhead contact lines may be undertaken in accordance with standard methods, for example in ISO 4354, in national standards, or in EN 1991-1-4 in Europe or alternatively in accordance with the method described in 6.2.4.2 to 6.2.4.7.

6.2.4.2 Dynamic wind pressure

The dynamic wind pressure q_K measured in N/m^2 acting on elements of overhead contact lines shall be determined by:

$$q_K = \frac{1}{2} G_q \times G_r \times \rho \times V_R^2$$

where

G_q is the gust response factor as defined in EN 50341-1:2001 in Europe or in national standards. For overhead contact lines with heights of approximately 10 m, G_q should be 2,05;

G_t is the terrain factor taking into account the protection of lines, e. g. in cuts, cities or forests. In open terrain G_t shall be 1,0; for other sites or protected sites factors G_t may be defined in national standards or by the purchaser specification;

V_R is the reference wind velocity in m/s at a height of 10 m above ground averaged over 10 min having a return period in accordance with 6.2.4.1;

ρ is the air density equal to 1,225 kg/m³ at 15 °C and 600 m altitude. For other values of temperature and altitude, the relevant air densities can be calculated with Equation (13):

$$\rho = 1,225 \times \left(\frac{288}{T} \right) \cdot e^{-1,2 \cdot 10^{-4} \cdot H} \quad (13)$$

where

T is the absolute temperature in K;

H is the altitude in m.

For line elements more than 10 m above the reference ground level the wind speed increases according to an appropriate logarithmic or power law.

In many countries stipulations for the dynamic wind pressures q_K exist which take into consideration the gust response factor and the given wind conditions. These data can be used for the design of contact lines in addition.

The dynamic wind pressure for different return periods can be derived from the 50 year dynamic wind pressure using the procedures given in national standards, such as EN 50341-1:2001 in Europe.

6.2.4.3 Wind forces on conductors

Wind pressure on conductors causes forces transverse to the direction of the line. From two adjacent spans the wind force on a support shall be determined by:

$$Q_{WC} = q_K \times G_C \times d \times C_C \times \frac{L_1 + L_2}{2} \times \cos^2 \phi \quad (14)$$

where

q_K is the characteristic dynamic wind pressure (refer to 6.2.4.2);

G_C is the structural response factor for conductors taking into account the response of moveable conductors to wind load. The factor G_C should be determined according to national experience. A widely accepted value would be $G_C = 0,75$;

d is the diameter of the conductor;

C_C is the drag factor of the conductor. A value of 1,0 is recommended; other values may be given in the purchaser specification;

L_1, L_2 are the lengths of the two adjacent spans;

ϕ is the angle of incidence of the critical wind direction in respect to the perpendicular to the conductor. In general ϕ is assumed to be zero.

Where twin conductors are run in parallel a reduction in the wind load may be taken on the leeward conductor, as 80 % of the windward conductor if the spacing between the axes is less than five times the diameter.

6.2.4.4 Wind forces on insulators and other line fittings

The wind force on an insulator acts at the attachment point to the support in wind direction and shall be determined by:

$$Q_{W\ ins} = q_K \times G_{ins} \times C_{ins} \times A_{ins} \quad (15)$$

where

- q_K is the characteristic dynamic wind pressure (refer to 6.2.4.2);
- G_{ins} is the structural resonance factor for insulator sets. A value of 1,05 is recommended; other values may be given in the purchaser specification;
- C_{ins} is the drag factor for insulators. A value of 1,2 is recommended; other values may be given in the purchaser specification;
- A_{ins} is the area of the insulator projected horizontally on a vertical plane perpendicular to the axis of wind action.

The wind force on other components shall be calculated from formula (15) with due consideration of appropriate drag factors. In many cases wind loads on insulators or line fittings will be very low in proportion to that from other sources.

6.2.4.5 Wind forces on cross-spans and cantilevers

The wind forces acting on cross-beams, head spans and cross-spans as well as cantilevers shall be determined by summing up the wind actions on the individual elements. The wind actions on the individual elements can be determined by the formulae specified in 6.2.4.3 for conductors, 6.2.4.4 for insulators and 6.2.4.7 for other structural components.

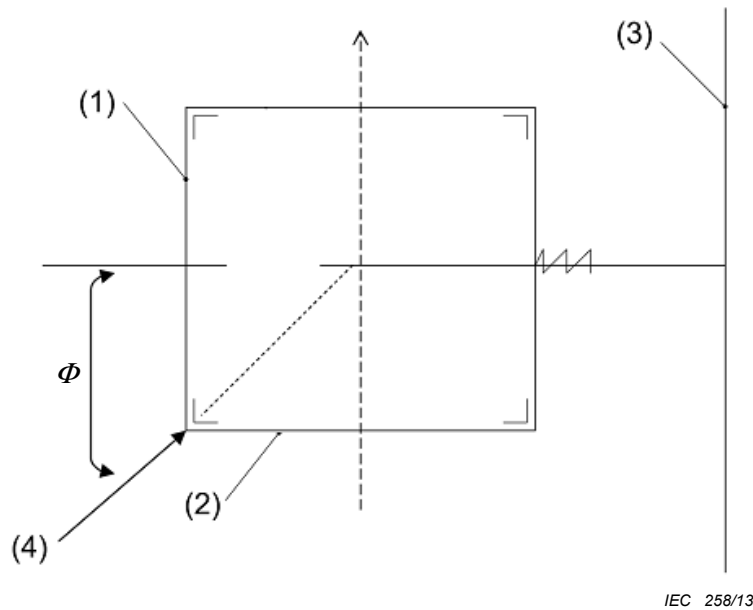
6.2.4.6 Wind forces on lattice structures

For lattice structures of rectangular cross-sections the wind forces shall be calculated from:

$$Q_{Wl} = q_K \times G_{lat} (1 + 0,2 \sin^2 2\phi) (C_{lat1} \times A_{lat1} \cos^2 \phi + C_{lat2} \times A_{lat2} \sin^2 \phi) \quad (16)$$

where

- q_K is the dynamic wind pressure (refer to 6.2.4.2);
- G_{lat} is the structural resonance factor. For lattice structures this should be taken as 1,05;
- C_{lat1} is the drag factor for the lattice structure face 1 in a wind perpendicular to this face;
- C_{lat2} is the drag factor for the lattice structure face 2 in a wind perpendicular to this face;
- A_{lat1} is the effective area of the elements of the lattice structure face 1;
- A_{lat2} is the effective area of the elements of the lattice structure face 2;
- ϕ is the angle between wind direction and the perpendicular to structure face 1 (see Figure 3).



Key

- (1) face 1
- (2) face 2
- (3) overhead contact line
- (4) wind direction

Figure 3 – Wind action on lattice steel structures

Alternatively the wind force may be calculated in accordance with Eurocodes or purchaser specifications.

The drag factors C_{lat} depend on the solidity ratio as described in ISO 4354 and EN 1991-1-4:2005, 7.11 for Europe. An appropriate value is $C_{lat} = 2,8$ for lattice structures with square or rectangular cross-section made of angle sections.

6.2.4.7 Wind forces on other structures

Wind force on other structures is equal to:

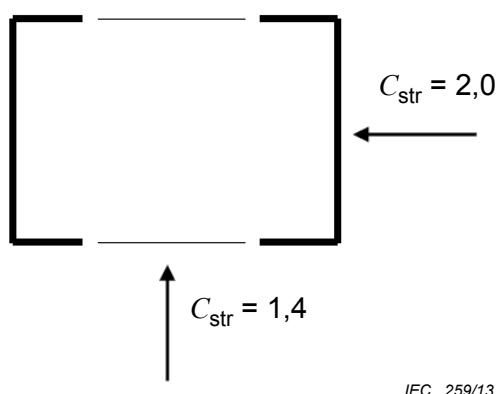
$$Q_{Wstr} = q_K \times G_{str} \times C_{str} \times A_{str} \quad (17)$$

where

- q_K is the dynamic wind pressure (refer to 6.2.4.2);
- G_{str} is the structural resonance factor for a structure. For self-supporting steel and concrete structures typically used for overhead contact lines G_{str} shall be 1,0. Other values may be used if determined from approved standards or methods;
- C_{str} is the drag factor depending on the shape and surface roughness of the structure. The values in Table 13 are recommended; other values may be given in the purchaser specification;
- A_{str} is the projected area of the structure.

Table 13 – Recommended values for factor C_{str} for different structure types

Structure type	C_{str}
Tubular steel and concrete structures with circular cross-section	0,7
Tubular steel structures with dodecanal cross-section	0,85
Tubular steel and concrete structures with hexagonal or octagonal cross-section	1,0
Tubular steel and concrete structures with square or rectangular cross-section	1,4
Double channel with square or rectangular cross-section	See Figure 4
H profiles	1,4



IEC 259/13

Figure 4 – Definition of drag factors for double channel structure

6.2.5 Ice loads

Ice loads are created by accretion due to hoar frost, precipitation icing or wet snow at the conductors of overhead contact lines. The characteristic ice loads g_{IK} depend on the climate and the local conditions, e.g. the height above ground, the proximity to lakes and the exposure to wind. Definitions for ice loads are given in IEC 62498-2. The ice loads should be given in the purchaser specification.

If specified in the purchaser specification ice on structures shall be considered.

6.2.6 Combined wind and ice loads

Where the combined actions of wind and ice load are considered for the design of overhead contact line installations and structures, 50 % of the wind load according to 6.2.4 may be assumed as acting on structures and equipment without ice and on conductors with ice diameter. The ice loads shall be used according to 6.2.5 taking consideration of D_1 as following. An alternative value may be given in the purchaser specification. This is a simplified method of the common cases of considering independent variable actions by additional combination factors. The unit weight force ρ_1 of the ice may be taken from appropriate standards and the aerodynamic drag factor as 1,0.

An increase in the diameter of the ice accretion should be considered if given in the purchaser specification. The equivalent diameter D_1 in metre of the ice accretion shall be calculated from:

$$D_1 = \sqrt{d^2 + \frac{4 \times g_{IK}}{\pi \times \rho_1}} \quad (18)$$

where

d is the conductor diameter without ice measured in metres;

g_{IK} is the characteristic ice load measured in N/m.

6.2.7 Temperature effects

The temperature effects shall be considered in common with the other existing climatic actions. The following parameters should be defined by the purchaser specification, based on IEC 62498-2:

- the minimum temperature to be considered with no other climatic action;
- the ambient reference temperature for the extreme wind load condition;
- the temperature to be assumed with ice loads and combined wind and ice load, where relevant;
- the reference temperature for the calculation of tensile forces as a permanent action.

The following temperatures are used in many European countries: minimum temperature $-20\text{ }^{\circ}\text{C}$; ambient reference temperature $+5\text{ }^{\circ}\text{C}$; temperature with ice loads (and combined wind and ice load where relevant) $-5\text{ }^{\circ}\text{C}$; reference temperature for calculation of tensile force as a constant action is $+15\text{ }^{\circ}\text{C}$. The temperatures can be used when considering the tensile load of the conductors.

6.2.8 Construction and maintenance loads

Loads due to construction and maintenance activities shall be considered, taking into account working procedures, temporary guying, lifting arrangements, etc. Recommended values of at least 1,0 kN shall be assumed for the horizontal cross-beams of portal structures and at least 2,0 kN for other types of structures, acting vertically. These forces shall act at the individually most unfavourable nodes of the cross-beams or at the attachment points of supports or conductors to the structures.

Structural elements need not be designed for such loads where appropriate working practices are adopted. Details should be given in the purchaser specification.

6.2.9 Accidental loads

Accidental loads are specified to take care of failure containment and emergency situations. In general, at any conductor attachment point to a structure the relevant residual static load resulting from the release of the tension of a contact wire, catenary wire or feeder line shall be applied. In general, it is sufficient to consider accidental loads for structures at the end of tensioning sections or for anchor structures of mid-span anchors. Details should be given in the purchaser specification together with a definition of associated load cases.

6.2.10 Special actions

Consideration should be given to special actions that might be relevant, such as forces imposed on the overhead contact line system after very high short-circuit currents..

Requirements on special actions may be given by national regulations.

When overhead contact lines are to be constructed in seismically active regions, consideration can also be given to forces on installations due to earthquakes and/or seismic tremors.

NOTE Informations are given in ISO 3010 respectively EN 1998 for Europe and EN 50341-1:2001, Annex C for Europe.