



BSI Standards Publication

Railway applications — Rolling stock — Rules for installation of cabling

National foreword

This British Standard is the UK implementation of EN 50343:2024. It supersedes BS EN 50343:2014+A1:2017, which is withdraw.

The UK participation in its preparation was entrusted to Technical Committee GEL/9/2, Railway Electrotechnical Applications - Rolling stock.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Published by BSI Standards Limited 2024

ISBN 978 0 539 27732 6

ICS 45.060.01

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2024.

Amendments/corrigenda issued since publication

Date	Text affected
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English Version

Railway applications - Rolling stock - Rules for installation of cabling

Applications ferroviaires - Matériel roulant - Règles
d'installation du câblage

Bahnanwendungen - Fahrzeuge - Regeln für die Installation
von elektrischen Leitungen

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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Ref. No. EN 50343:2024 E

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European foreword

This document (EN 50343:2024) has been prepared by CLC/SC 9XB “Electromechanical material on board rolling stock”.

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2025-08-12
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2027-08-12

This document supersedes EN 50343:2014 and all of its amendments and corrigenda (if any).

EN 50343:2024 includes the following significant technical changes with respect to EN 50343:2014:

- references to EN standards updated and harmonized;
- modification based on IEC 62995;
- mechanical aspects detailed;
- cable lifetime considerations in accordance with Arrhenius.

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This document has been prepared under a standardization request addressed to CENELEC by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

1 Scope

This document specifies requirements for the installation of cabling on railway vehicles and within electrical enclosures on railway vehicles, including magnetic levitation trains and trolley buses.

NOTE With respect to trolley buses, this document applies to the whole electric traction system, including current collecting circuits, power converters and the respective control circuits. The installation of other circuits is covered by street vehicle standards for example those for combustion driven buses.

This document covers cabling for making electrical connections between items of electrical equipment, including cables, busbars, terminals and plug/socket devices. It does not cover special effect conductors like fibre optic cables or hollow conductors (waveguides).

The material selection criteria given here are applicable to cables with copper conductors.

This document is not applicable to the following:

- special purpose vehicles, such as track-laying machines, ballast cleaners and personnel carriers;
- vehicles used for entertainment on fairgrounds;
- vehicles used in mining;
- electric cars;
- funicular railways.

As the field of cabling in rolling stock is also dealt with in the cable makers' standard, references are made to EN 50264 series, EN 50306 series, EN 50382 series and EN 50355.

This document applies in conjunction with the relevant product and installation standards and describes minimum requirements.

2 Normative references

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

EN 45545 (all parts), *Railway applications — Fire protection on railway vehicles*

EN 45545-1, *Railway applications — Fire protection on railway vehicles — Part 1: General*

EN 45545-2, *Railway applications — Fire protection on railway vehicles — Part 2: Requirements for fire behaviour of materials and components*

EN 45545-5:2013+A1:2015, *Railway applications - Fire protection on railway vehicles — Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles*

EN 50121-3-1, *Railway applications — Electromagnetic compatibility — Part 3-1: Rolling stock — Train and complete vehicle*

EN 50121-3-2, *Railway applications — Electromagnetic compatibility — Part 3-2: Rolling stock — Apparatus*

EN 50124-1, *Railway applications — Insulation coordination — Part 1: Basic requirements — Clearances and creepage distances for all electrical and electronic equipment*

EN 50125-1, *Railway applications — Environmental conditions for equipment — Part 1: Rolling stock and on-board equipment*

EN 50153, *Railway applications — Rolling stock — Protective provisions relating to electrical hazards*

EN 50264 (all parts), *Railway applications — Railway rolling stock power and control cables having special fire performance*

EN 50306 (all parts), *Railway applications — Railway rolling stock cables having special fire performance — Thin wall*

EN 50355:2013, *Railway applications — Railway rolling stock cables having special fire performance — Guide to use*

EN 50382 (all parts), *Railway applications — Railway rolling stock high temperature power cables having special fire performance*

EN 50467:2011, *Railway applications — Rolling stock - Electrical connectors, requirements and test methods*

EN 50553, *Railway applications — Requirements for running capability in case of fire on board of rolling stock*

EN 60228, *Conductors of insulated cables (IEC 60228)*

EN 60423, *Conduit systems for cable management - Outside diameters of conduits for electrical installations and threads for conduits and fittings (IEC 60423)*

EN 60684-3-212, *Flexible insulating sleeving — Part 3: Specifications for individual types of sleeving — Sheet 212: Heat-shrinkable polyolefin sleeveings (IEC 60684-3-212)*

EN 60684-3-271, *Flexible insulating sleeving — Part 3: Specifications for individual types of sleeving — Sheet 271: Heat-shrinkable elastomer sleeveings, flame retarded, fluid resistant, shrink ratio 2:1 (IEC 60684-3-271)*

EN 61180, *High-voltage test techniques for low-voltage equipment — Definitions, test and procedure requirements, test equipment (IEC 61180)*

EN 61386-1, *Conduit systems for cable management — Part 1: General requirements (IEC 61386-1)*

EN IEC 60331-1, *Tests for electric cables under fire conditions - Circuit integrity - Part 1: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm (IEC 60331-1)*

EN IEC 60684-3-216, *Flexible insulating sleeving — Part 3: Specifications for individual types of sleeving — Sheet 216: Heat-shrinkable, flame- retarded, limited-fire-hazard sleeving (IEC 60684-3-216)*

IEC 60331-2, *Tests for electric cable under fire conditions — Circuit integrity — Part 2: Test method for fire with shock at a temperature of at least 830 °C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter not exceeding 20 mm*

HD 60364-5-54:2011¹, *Low-voltage electrical installations — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements and protective conductors (IEC 60364-5-54:2011)*

¹ As impacted by HD 60364-5-54:2011/A1:2022.

3 Terms, definitions and abbreviations

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

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

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

3.1 Terms and definitions

3.1.1

cable

assembly consisting of

- one or more cores (screened or unscreened);
- their individual covering(s) (if any);
- assembly protection (if any);
- screen(s) (if any);
- sheath (if any)

[SOURCE: IEC 60050-461:2008, 461-06-01, modified - “insulated” has been removed from the term. “(screened or unscreened)”, “screen(s) (if any)” and “sheath (if any)” have been added, “protective covering(s) (if any)” has been removed. Note 1 to entry has been omitted.]

3.1.2

conductor

<of a cable> part of a cable which has the specific function of carrying current

[SOURCE: IEC 60050-461:2008, 461-01-01]

3.1.3

core

assembly comprising a conductor with its own insulation (and screens if any)

[SOURCE: IEC 60050-461:2008, 461-04-04, modified – Note 1 to entry has been omitted.]

3.1.4

solid conductor

conductor consisting of a single wire

[SOURCE: IEC 60050-461:2008, 461-01-06, modified – Note 1 to entry has been omitted.]

3.1.5

stranded conductor

conductor consisting of a number of individual wires or strands all or some of which generally have a helical form

[SOURCE: IEC 60050-461:2008, 461-01-07, modified – Notes 1 and 2 to entry have been omitted.]

3.1.6

busbar

<for connections> conductor consisting of a rigid metal profile

3.1.7

screen

<of a cable> conducting layer(s) having the function of control of the electro magnetic field within the cable and/or to protect the cable from external electro magnetic influences

[SOURCE: IEC 60050-461:2008, 461-03-01, modified – “or assembly of conducting layers” has been removed. “electric field within the insulation” has been replaced with “electromagnetic field within the cable and/or to protect the cable from external electromagnetic influences”. Note 1 to entry has been omitted.]

3.1.8

bundle

group of cables tied together

3.1.9

bolted connection

connection in which the pressure to the conductor is applied by bolting

[SOURCE: IEC 60050-461:2008, 461-19-05]

3.1.10

connector

device providing connection and disconnection to a suitable mating component

Note 1 to entry: A connector has one or more contact elements

Note 2 to entry: Connectors covered by this document are not intended to be connected and disconnected under electrical load

[SOURCE: IEC 60050-581:2008, 581-26-01, modified – Note 2 to entry has been added.]

3.1.11

crimp

cable termination in which a permanent connection is made by applying pressure, inducing the deformation or reshaping of a barrel part of the termination around the conductor

[SOURCE: IEC 60050-461:2008, 461-19-01, modified.]

3.1.12

spring-clamp connection

terminal connection in which the pressure between the conductor and terminal is applied by a spring

3.1.13

penetration

<connection> terminal connection in which the contact with the conductor is achieved by jaws which penetrate the insulation

3.1.14

plug

<for conductor or cable> connector intended to be coupled at the free end of an insulated conductor or cable, to be inserted into a matching socket, or readily removed when required

3.1.15

socket

connector intended to be mounted on a rigid surface and to hold a matching plug, such that the conductors contained within the socket make electrical contact individually with those in the plug

3.1.16

heat-shrinkable sleeve

tube that on exposure to heat during installation, will at a critical temperature, permanently reduce in diameter, while increasing in wall thickness

3.1.17**manufacturer**

organisation that has the responsibility for the supply of vehicle(s), equipment or groups of equipment to the purchaser

3.1.18**purchaser**

organisation that orders the vehicle or equipment or groups of equipment and has the responsibility for direct negotiations with the manufacturer

3.1.19**cable tie**

mechanical construction needed for either keeping cables or assemblies of cables together, or for attaching them in a defined place

3.1.20**short time current**

certain operation case where an electrical circuit carries a current that will introduce an amount of heat into the electrical circuit, which in general will increase its temperature

Note 1 to entry: "Short time" means that the heat exchange against the surrounding material is not significant.

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

CSA	cross sectional area
EMC	electromagnetic compatibility
IP	ingress protection
RMS	root mean square
UV	ultraviolet

4 Technical requirements**4.1 General requirements**

Cables and installation materials shall be type tested, selected for size and installed so as to be suitable for their function under their operating conditions. Size and installation of cables (including busbars and bare conductors) shall take into account the particular stresses to be expected in rolling stock. The materials used and methods of cabling shall be such as to prevent strain or chafing and excessive lengths of unsupported cable shall be avoided.

Cables on rolling stock shall not be used for any purpose other than for transmission, distribution and collection of electrical energy, electrical controls or monitoring systems. All components of cabling shall be selected, installed, protected, used and maintained so as to prevent danger (e.g. electrical or fire hazard, EMC problems).

The electrical connections shall be made in such a way that they cannot be unintentionally disconnected or interrupted during service.

Effects that have impact on electrical connections and should be considered are at least:

- the thermal effects;
- the dynamic loads, as shock, vibration, car-body motions; and
- the material creepage.

The working conditions of the connections, and especially electrical characteristics and maximum temperatures, shall be considered to define cables and their installation and usage (peak currents, etc.).

For consideration of environmental conditions, EN 50125-1 shall apply.

When considering operating conditions and environmental conditions, the locations as presented in Annex K (informative) should be taken into account.

Conductors and cables shall be installed in such way that any humidity or water flowing along them shall not be able to reach any cable entry (connector, cable gland, etc.) into the sealed cabinet.

For correct use of connectors, EN 50467:2011 shall apply.

For protection against electrical hazards, the cabling installed shall be in accordance with EN 50153.

4.2 Selection of type and size of cables

4.2.1 General

When selecting cables or busbars, the expected operating conditions should be taken into account. These should include, but are not limited to, the following parameters:

- voltage;
- current;
- higher harmonics by electronical converters (skin-effect);
- overload current;
- short time current;
- voltage drop;
- short-circuit current;
- shape and frequency of current;
- fusing characteristic of the protection device;
- grouping of cables;
- ambient temperature and temperature due to load current;
- methods of installation;
- predicted cable lifetime;
- presence of rain or steam or snow, or accumulation of condensing water;
- presence of corrosive, polluting or damaging substances;
- mechanical stresses;
- radiation such as sunlight.

Consideration should be given to the expected lifetime of the cabling compared with the expected lifetime of the vehicle.

The cable type (i.e. cable family) shall be selected in accordance with EN 50264 series, EN 50382 series or EN 50306 series, as applicable.

Once the cable type has been selected, the selection of conductor size for normal load shall be determined based on the methods specified in 4.2.2. up to 4.2.6. For cables intended for power distribution two methods are available: the selection of conductor size if the cable is intended for power distribution shall be based on either load current and current carrying capacity calculated in accordance with 4.2.3 or based on protection device size in accordance with 4.2.4.

The conductor size shall also be checked in relation to short-circuit conditions and overload conditions.

These should be checked with respect to the fusing characteristic of the protection device and the resistance of the chosen cable. See the example in Figure 1.

The switching level of the protection device shall be below the short time current carrying capacity of the cable (see 4.2.7).

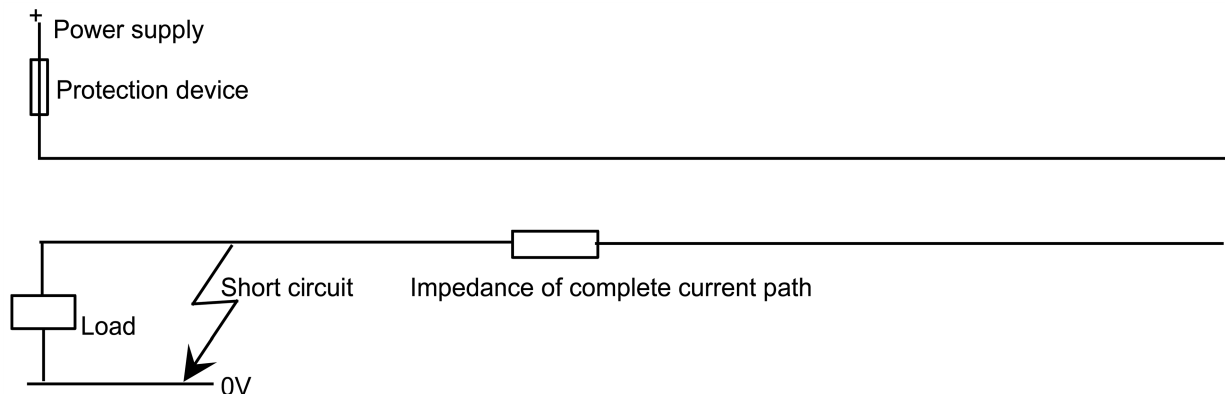


Figure 1 — Example of short-circuit condition where cable size will have influence on protection device behaviour

The cross-sectional area of any conductor shall be not less than the value specified in 4.5.

Cables and cabling shall be conform to the fire safety requirements specified in EN 45545-2.

The number of different types of cables installed on any one type of vehicle should be minimized for practical reasons.

4.2.2 Selection of cable size for control cables

Control cables, which are intended to carry control and data signals only, shall have a minimum conductor cross-sectional area as specified in 4.5. This is also valid if the load current would make a smaller cross-sectional area possible.

The cable sizes are selected on the general basis of a nominal current rating of 5 A/mm² of conductor; therefore it is not necessary for the conductor size of these cables to be selected according to 4.2.3.

4.2.3 Selection of cable size for cables for power distribution, on the basis of continuous load current

This subclause specifies a method for calculation of continuous maximum load current, of time duration longer than 5 s, of different cable sizes dependent on their method of installation and ambient temperature, to enable cables to be selected so as to ensure that the predicted lifetime is achieved.

For short time current, up to 5 s, see 4.2.7.

Correction factors from cable manufacturers should not be combined with correction factors given in this document, in order to avoid miscalculation or oversizing.

The continuous maximum conductor temperature for the cable types defined in the various parts of the EN 50264 series, the EN 50306 series and the EN 50382 series is 90 °C, 105 °C, 120 °C or 150 °C. This is based either on proven experience and reliability over many years or, in the case of newer, less well defined insulations, upon an acceptance test, using long-term thermal endurance ageing to demonstrate a lifetime of at least 20 000 h at 110 °C, 125 °C, 140 °C or 170 °C respectively (i.e. 20 °C above the

continuous rating). Data from this thermal testing can, with care, be extrapolated to the conductor temperature to provide a predicted lifetime of the cable when continuously loaded. This predicted lifetime may be used in conjunction with the known duty cycle of the vehicle, and its predicted time out of service, to estimate the ability of the cable to function reliably for the predicted lifetime of the whole vehicle.

NOTE 1 Because the cable standards allow a variety of solutions for insulation type, it is important to confirm lifetime extrapolations with the cable manufacturer.

NOTE 2 A predicted lifetime of cable of 100 000 h is used as a theoretical basis value for cables according to the EN 50264 series, the EN 50306 series or the EN 50382 series and their specific maximum conductor temperature at continuous operation.

This subclause only deals with thermal degradation of insulation material and it should be noted that mechanical stresses (bending, wear, etc.) and other environmental factors (for example the presence of fluids such as cleaning detergents or aggressive atmosphere) may be the limiting factor determining predicted cable lifetime.

For cables intended for power distribution, the cable size shall be selected on the basis of the load current and the current carrying capacity in accordance with the following procedure (i.e. the three steps a), b) and c)).

a) The load current

The load current I_{load} , in amperes (A), which a cable has to carry for sustained periods during normal service, shall be a basic value for cable sizing.

When the circuit(s) being supplied by the cable is in continuous or sustained cyclic operation, I_{load} shall be calculated according to the following formula:

$$I_{load} = \sqrt{\frac{1}{t_1} \int i^2 dt}$$

where

t_1 is the duration of a typical duty cycle during service, in minutes (min);

i is the instantaneous current, including overload, if any, in amperes (A).

NOTE 3 For continuous direct current operation, the above formula has the simple form $I_{load} = i$.

When operation is not continuous or sustained cyclic, I_{load} shall be calculated according to Annex A.

b) The current carrying capacity

The permissible continuous current carrying capacity I_{cable} in amperes (A) of a single-core cable or a single core within a multi-core cable being operated in free air shall be another basic value for cable sizing. A particular value of I_{cable} is valid for a particular reference ambient temperature T_{ref} and for a particular maximum conductor temperature in service, $T_c(max)$.

I_{cable} within the reference values T_{ref} and $T_c(max)$, shall be those provided by the cable manufacturer.

Examples for I_{cable} for single-core cables are presented in Annex B.

I_{cable} for maximum conductor temperatures other than $T_c(max) = 90\text{ °C}$ shall be calculated according to Annex C.

The current carrying capacity of the cable in service, I_{corr} , in amperes (A), shall be calculated from I_{cable} using correction factors k_1, k_2, k_3, k_4, k_5 , in accordance with the following formula:

$$I_{corr} = I_{cable} \times k_1 \times k_2 \times k_3 \times k_4 \times k_5$$

where

k_1 is a correction factor for the expected ambient temperature. It shall be calculated according to the following formula:

$$k_1 = \sqrt{\frac{T_{c(max)} - T}{T_{c(max)} - T_{ref}}}$$

where

- $T_{c(max)}$ is the maximum conductor temperature, in degrees Celsius (°C), in service, which will allow the predicted lifetime of the cable to be achieved;
- T is the estimated value of the actual ambient temperature, in degrees Celsius (°C) during operation, on the outside of the bundle or of the tube – if any. T is an average value;
- T_{ref} is the reference ambient temperature, in degrees Celsius (°C), for which the I_{cable} value is valid.

Examples of k_1 values are given in Table D.1.

k_2 is a correction factor for installation type (grouping and installation conditions).

Values for k_2 given in Table 2 shall be used. Interpolation between the different number of cables in Table 2 is allowed.

k_3 is a correction factor to allow for a decrease in predicted cable lifetime, calculated according to the formula in Annex E. In all cases where the standard predicted cable lifetime shall be used, the value of k_3 shall be 1,0.

k_4 is a correction factor to take into account short time current when operation is not continuous, calculated according to the procedure in Annex A. When operation is continuous, the value of k_4 shall be 1,0.

k_5 is a correction factor for multi-core cables; the correction factor k_5 is applicable for each individual core within a multi-core cable. Values for k_5 are given in Table 1. Interpolation between the different number of loaded cores in Table 1 is allowed. When single-core cables are used, the value of k_5 shall be 1,0. If single-core cables and multi-core cables are lying together on the same cable tray, open or close, by the correction factor k_5 , different values for I_{corr} are obtained for single-core cables and multi-core cables.

Table 1 — Modification factor k_5 for individual cores within a multi-core cable; number of cores are simultaneously loaded

Number of loaded cores	2	3	4	5	7	9	12	19
Correction factor k_5	0,91	0,78	0,63	0,59	0,51	0,46	0,41	0,38
NOTE Extrapolation to higher number of loaded cores could be negotiated with the cable manufacturer.								

c) Selection of cable size

The cable size shall be selected such that the current carrying capacity of the cable in service, calculated in accordance with item b) above, is greater than or equal to the predicted load current, calculated in accordance with item a), i.e.:

$$I_{load} \leq I_{corr}$$

The minimum cross-sectional area of the conductor shall be as specified in 4.5.

NOTE 4 Combining the formulae from 4.2.3 a) and b) and c), would lead to the following formula:

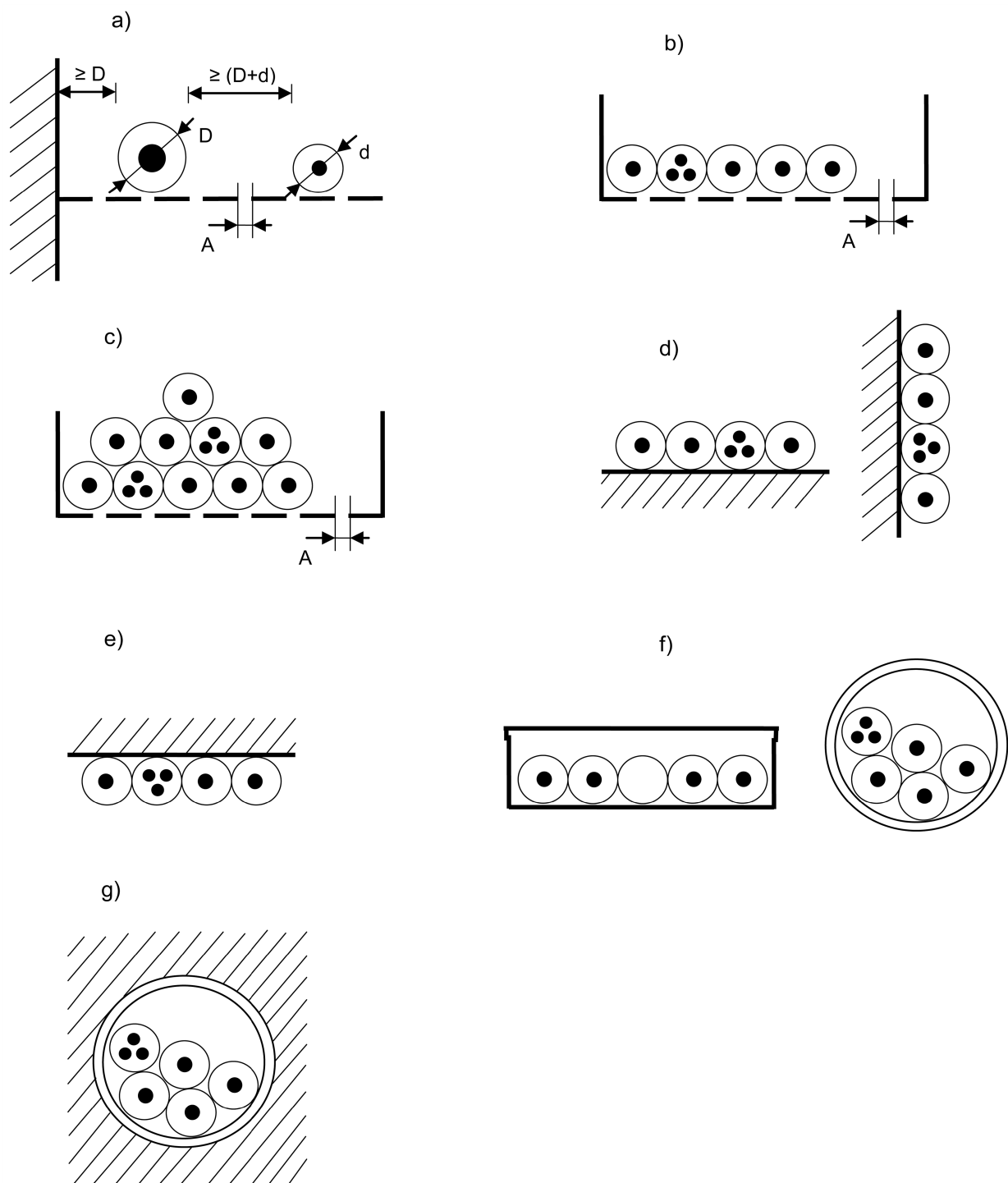
$$I_{cable} \geq \frac{I_{load}}{k_1 \times k_2 \times k_3 \times k_4 \times k_5}$$

This formula will in practice be easier to use, because in cases with defined cable type and defined load conditions, the last term is constant and so it is easy to find the right cable size via I_{cable} in the current ratings table (see examples in Table B.1).

For a calculation example, refer to Annex F.

Table 2 — Modification factor k_2 for installation type (grouping and installation conditions)

Number of cables being simultaneously loaded	Installation type							
	Cable in free air	Cables on trays, in one layer	Cables on trays, in two layers	Cables on trays, in several layers	Cables on the floor or on a wall	Cables on a ceiling or under floor	Cables in a closed tube, conduit or tray	Cables in a closed tube or conduit, thermally insulated
	Type a)	Type b)		Type c)	Type d)	Type e)	Type f)	Type g)
1 single cable	1,0	1,0	1,0	1,0	1,0	0,95	0,95	0,76
2 cables together	-	0,87			0,85	0,81	0,80	0,61
3 cables together	-	0,83	0,83		0,79	0,72	0,70	0,53
4 cables together	-	0,78	0,71	0,71	0,75	0,68	0,65	0,49
8 cables together	-	0,74	0,59	0,52	0,75	0,62	0,52	0,40
12 cables together	-	0,73	0,54	0,45	0,75	0,61	0,45	0,34
16 cables together	-	0,72	0,51	0,41	0,75	0,61	0,41	0,31
20 cables and more together	-	0,71	0,47	0,38	0,75	0,61	0,38	0,29
Details of installation types are as follows: Type a): One single cable in free air with heat dissipation into the surrounding air ensured by all the following measures: – distance between the cable and adjacent walls over, under or beside: at least equal to the cable diameter; – distance between the cable and any other cable lying beside it in any direction: at least equal to the sum of its own cable diameter and the adjacent cable diameters; – cable lying in an open tray or ladder support with perforations, the total area A in Figure 2 of the perforations being at least 15 % of the total supporting area in case of metallic tray or support with good thermal contact to car-body (otherwise at least 30 %), and without any cover. Type b): Cables lying in one layer, touching each other, on an open tray or ladder support, with perforations as for type a). Type c): As for type b) but cables in several layers over each other. Type f): Cables lying in bundles in closed tubes, closed trays or boxes without significant air flow. Type g): As for type f), but for thermally completely insulated closed tubes, closed trays or boxes. Current flowing through the screen (e.g. motor cables and brake resistors) should be calculated as an additional conductor.								
NOTE Installation types a), b), c), d), e), f) and g) are illustrated in Figure 2.								



- Key**
- a) cable in free air
 - b) cables on trays, in one layer
 - c) cables on trays, in several layers
 - d) cables on the floor or on a wall
 - e) cables on a ceiling or under floor
 - f) cables in a closed tube, conduit or tray
 - g) cables in a closed tube or conduit, thermally insulated

Figure 2 — Cable grouping and installation conditions

4.2.4 Selection of cable size for cables for power distribution, on the basis of rating of protection device

In cases where the load current I_{load} is not exactly defined, the rating of the protection device may be chosen according to the maximum load current that can be expected. The conductor size shall then be selected according to the rating of protection device in accordance with Table 3. This applies to all cable types with $T_c(max)$ of at least 90 °C, at an ambient temperature of maximum 45 °C.

NOTE This method is simple but has disadvantages (weight, required space and costs of cables can increase).

Table 3 — Selection of cable conductor size on the basis of rating of protection device

Rating of protection device A	Nominal cross-sectional area of conductor mm ²	
	Up to 4-core cables, or bundles of max. 4 cables, on open trays or in free air	Up to 4 cables in a closed tube
6	1,0	1,0
10	1,0	1,5
16	1,5	2,5
20	2,5	4,0
25	4,0	6,0

4.2.5 Motor cables

Traction motor cables shall be sized according to the procedure specified in 4.2.3. For cables in motion during operation, higher flexibility of cables should be considered when selecting cable type (i.e. class 6 in accordance with EN 60228).

4.2.6 Cables for protective bonding

Cables for protective bonding shall be sized and installed according to the rules described in HD 60364-5-54:2011, Clause 543. This standard deals with general rules for electrical equipment. The requirements of EN 50153 shall be fulfilled.

In HD 60364-5-54:2011, 543.1.2, a formula for minimum cross-sectional areas of protective conductors applicable for disconnecting times not exceeding 5 s is given.

4.2.7 Cables used under short time current (below 5 s)

For cables loaded with a short time current (below 5 s), CSA shall be sized such that the end temperature does not exceed a temperature of 20 °C over the conductor operating temperature of the insulation as defined in EN 50355. Lifetime, in this case, is reduced to at least 20 000 h of cumulated operation.

For dimensioning of cables for short time current within the scope of this document, the formula given in HD 60364-5-54:2011, 543.1.2, should also be used.

EXAMPLE Conductors for thermal engine starters.

k factors for bare conductors are given in HD 60364-5-54:2011, Table A.54.6.

k factors and short-circuit ratings for rolling stock cables are given in EN 50355.

For any other material of the conductor, the insulation and other parts, and the initial and final temperatures, the k factor shall be calculated or be given by the cable manufacturer.

For calculation of k , see Annex A in HD 60364-5-54:2011.

NOTE The k factor referred to in the formula in HD 60364-5-54:2011, 543.1.2, and in EN 50355 have a different meaning than k factors used in EN 50343.

For a calculation example in EN 50343, refer to Annex F.

4.3 Bundling of cables

If several cables are to be laid together as a bundle, the following factors shall at least be taken into consideration:

- thermal requirements (see 4.2.3);
- EMC requirements (see 5.2);
- rated voltages (see 4.11);
- mechanical aspects, such as strength of bundle, weight of bundle, available space, relative movement and tension forces;
- fixing points (see 4.15).

If cables with different cross-sectional area are to be bundled together, the mechanical stresses should be considered.

4.4 Flexibility of cables

If high flexibility is required, stranded conductors of class 6 in accordance with EN 60228 should be used. In all other cases, stranded conductors of class 5 in accordance with EN 60228 shall be used (see also 4.7).

High flexibility is required in case of car-to-car or car-to-bogie cabling, i.e. locations 5, 6 and 7 in Annex K and for equipment which may have relative cabling movements between internal parts, for example doors, shoe gears.

Internal connections of, for example, electronic devices, may use single solid conductors of class 1 in accordance with EN 60228 (e.g. for wire wrap connections) if there is no risk of fatigue failure or if precautions have been taken to avoid this risk.

When higher flexibility of a bundle is required, the nominal cross-sectional area of each individual cable should be selected with respect to its individual load current. In many cases, the smaller the cross-section of a conductor, the more flexible the cable is.

4.5 Minimum cross-sectional area of conductors

Single-core cables laid separately, or cables laid side by side, connecting electrical components in different locations inside rolling stock vehicles (e.g. for connections between locations A, B and C as shown in Figure 3) shall have a nominal conductor cross-sectional area of at least 1,0 mm².

Higher minimum cross-sections may be necessary due to, for example:

- voltage drop;
- load current; and
- mechanical strength.

Special care should be taken on minimum cross-sectional area in order to achieve the necessary mechanical strength for car-to-car or car-to-bogie cabling, i.e. locations 5, 6 and 7 in Annex K.

It is permitted to use smaller cross-sectional areas under the following conditions:

- for internal wiring in racks or assemblies, or in electronic equipment or precabled devices, if the circuit is protected against overload and if the mechanical strength is given (e.g. inside A or B or C as shown in Figure 3);
- for multi-core cables, bundled cables, databus connections, etc., if the mechanical strength is provided and if the load current in all operational cases allows this;
- for devices specified and tested as a complete unit for use in rolling stock.

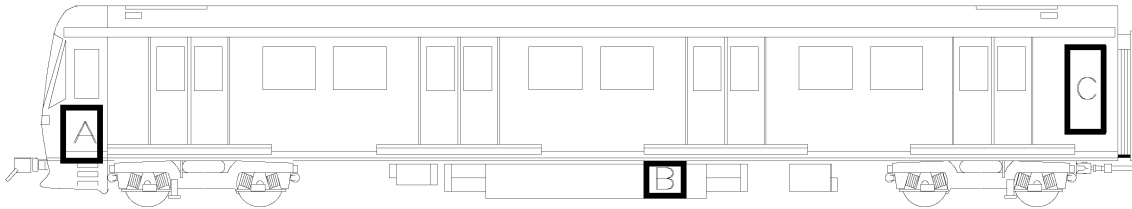


Figure 3 — Locations in rolling stock, concerning use of minimum cross-sectional areas for conductors

4.6 Use of green and yellow colour

Conductors of a protective equipotential bonding system whether insulated or bare, shall be readily distinguishable by shape, location, marking or colour. If identification by colour is used, it shall be the bicolour combination green-and-yellow.

If the use of a conductor for protective equipotential bonding is obvious, for example at bogies, it is allowed to identify protective equipotential bonding by other means than colour.

The green/yellow core of a multi-core cable, if any, shall not be used for purposes other than protective equipotential bonding.

Individual cores in multi-core cables not used for protective equipotential bonding may be either green or yellow.

The bicolour combination green and yellow shall not be used in cabling or cables for any purpose other than to indicate protective equipotential bonding.

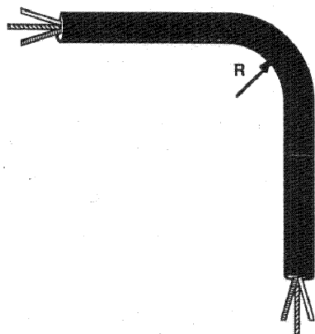
4.7 Bending radii and other mechanical requirements

Cables shall be installed so that the minimum bending radii for fixed-installation cables and cables which are flexing during service are not less than those given in the relevant product information or cable standard.

In a bundle, for example consisting of cables having different diameters, the minimum bending radii for the bundle shall be that of the cable having the highest bending radii.

Examples for minimum internal bending radii are given in Table 4.

The definition of the internal bending radius is as given in Figure 4.



Key
R internal bending radius

Figure 4 — Definition of internal bending radius

Table 4 — Minimum internal bending radii R for static applications

Cable diameter mm	≤ 12	> 12
Unscreened cables	4D	5D
Screened cables	10D	10D
Minimum bending radii given by the cable manufacturer shall prevail.		
NOTE 1 D is the overall cable diameter.		
NOTE 2 If the bending radius of screened cables is not respected this can influence their EMC behaviour.		
NOTE 3 Values based on EN 50355:2013, Table 16.		

The cable material should be considered carefully with respect to its ability to resist the effects of dynamic movement. Excessive forces on the installation devices used – for example fastening clamps and termination points – should be avoided as far as possible, for example by using extra fixing means or more flexible cables.

In high vibration environmental conditions (e.g. in the diesel engine compartment or location 6 and 7 in Annex K) thin wall cables according to EN 50306-2 should not be used inside a non-metallic flexible conduit if they are not additional mechanically protected by sleeves, braided hoses, etc. The abrasion protection sleeve should be able to protect the thin wall cables not only during installation inside the conduit but also throughout the life on the vehicle.

NOTE Mechanical stresses are detailed in EN 50355.

All cabling mechanical fixing elements shall be free of any kind of sharp edges to avoid possible damage of the cables during installation by penetrating the insulation or due to chafing and vibrations in service conditions.

Sharp edges which are able to cause damages on cable insulation shall be covered by edge protectors.

See the example in Figure 5. Cabling mechanical fixing elements may be shaped according to the cabling installation curvature. Fixings should be added in the proximity of the edge.

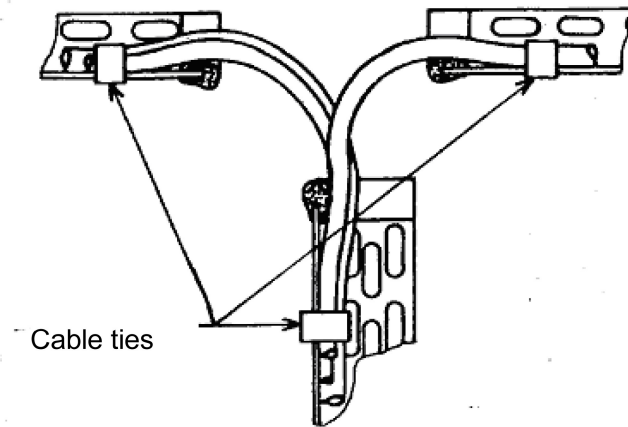


Figure 5 — Examples of mechanical protection of cabling

When slight relative movement is expected, then the cabling installation should be designed to withstand all possible movements. In this case, forces imposed to the terminations and frictions caused by these movements should be avoided by adequate fixing.

In addition, when considerable relative movement is expected, the ends of cabling installation should be vertical or present a minimum angle to the vertical, reducing the bending effect of gravity.

Adequate protection against impact of objects, for example ballast stones, at under car-body locations should be considered (e.g. locations 4, 5, 6 and 7 according to Annex K).

4.8 Re-termination

Single- and multi-core cables with a nominal conductor cross-sectional area of 16 mm² or less installed on rolling stock should have sufficient spare length at each termination to allow for at least 3 re-terminations. Cables above 16 mm² should have sufficient spare length at each termination to allow for at least 1 re-termination. When cables are terminated by a plug it may be impracticable to provide spare lengths within the enclosure or housing of the plug, spare lengths can then be provided behind the plug.

For requirements regarding refurbishment and repair, refer to 4.12.

4.9 Busbars

Busbars should be made of copper, brass or aluminium. On contact surfaces, precautions shall be taken to prevent contact resistance values from increasing with time in particular due to corrosion effects or material creepage.

Corrosion caused by the difference of electrochemical potentials between bars, terminals and/or bolts shall be taken into account. Refer to Table J.1 for examples.

The selection of the type and dimensions of busbars shall be at the discretion of the vehicle manufacturer. The sizing procedure shall include the influence of ambient temperature.

4.10 Connections to busbars

Electrical connections between busbars and equipment, or between different bar sections, or between different devices shall be flexible if relative movement can be expected.

If bolted connections are used, they shall have suitable locking arrangement, which will retain their mechanical forces nearly constant over the lifetime of the equipment, including any material creepage.

4.11 Separation of cables with different voltage levels and for safety reasons

Measures in order to prevent electrical hazards to persons shall be according to EN 50153.

EN 50153 specifies the use of measures such as equipotential connection for protective purposes, insulation, prevention of access, automatic disconnection of power supply in hazardous cases, car

protective bonding, warning labels with respect to different voltage bands and possible occurrence of direct and indirect contact.

As methods of cabling are not mentioned in EN 50153, this will be detailed in the following.

When grouping cables, cables carrying different voltage levels shall be separated as far as practicable.

Separation shall be by distance, insulating barriers or earthed metallic barriers (see Figure 6 and Figure 7).

Separation barriers or screens or sleeves shall have at minimum the same mechanical strength and resistance to fire and insulation properties as the insulation of the cables in the higher category.

If cables, for example on the roof, are touched by a broken overhead line, the dangerous voltage shall lead to short-circuit detection in the trackside power substation before endangering any person, see EN 50153.

Further requirements for separating cables for safety reasons may be:

- regarding running capability in case of fire according to EN 50553;
- power supply train line (e.g. 800 A 1 kV/1,5 kV/3 kV), which has the ability to start a fire in case of failure of insulation;
- in EN 50124-1 clearances and creepage distances for all electrical and electronic equipment.

EMC guidance is given in Clause 5 and may require a larger distance than that shown in Figure 6.

NOTE The separation is necessary for safety reasons, in order to minimize, in case of accidents, fire, chafing of cables, etc., the probability of introducing higher voltages or higher power into cables intended for carrying lower voltages/power.

Where separation by distance cannot be achieved, for example because of restricted space available, the cables shall be separated by a partition (see Figure 7). Where separation by a partition cannot be achieved, separation by insulation is allowed by exception. Exceptions shall be limited to cases where no practical solutions are possible (close to terminal strips, at crossings, etc.). Solutions shall at minimum adhere to the requirements of EN 50124-1.

When possible, the individual return cables should be treated in the same way as their matching forward supply cables in all categories.

The unprotected parts of circuits shall be as short as possible. This shall be achieved by ensuring that protective devices and transducers for protective devices are installed as close as possible to the source of supply.

If high voltage cables (circuits within voltage level IV according to EN 50153) have to be laid in a passenger compartment or driver's cab, they shall be installed in closed earthed metallic tubes or behind earthed metallic enclosures.

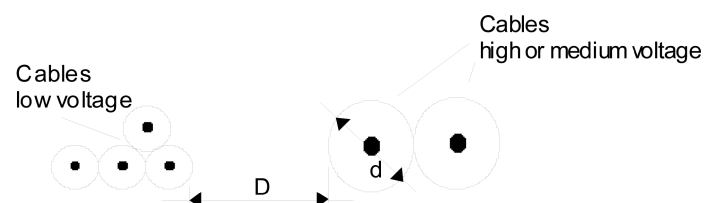


Figure 6 — Separation of cables by required distance: $D > 2d$ and $D > 0,1\text{ m}$