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| INSTYTUT KOLEJNICTWA | TECHNICAL STANDARDS<br>DETAILED TECHNICAL CONDITIONS FOR THE CONSTRUCTION OF THE RAILWAY INFRASTRUCTURE OF THE SOLIDARITY TRANSPORT HUB<br>– DESIGN GUIDELINES | CENTRALNY PORT KOMUNIKACYJNY<br>–<br>SOLIDARITY TRANSPORT HUB POLAND |
| **ul. J. Chłopickiego 50**<br>**04-275 Warsaw** | VOLUME II.2<br>3 KV DC OVERHEAD CATENARY AND TRACTION POWER SUPPLY | **Al. Jerozolimskie 134**<br>**02-305 Warsaw** |

# TECHNICAL STANDARDS

# DETAILED TECHNICAL CONDITIONS FOR THE CONSTRUCTION OF THE RAILWAY INFRASTRUCTURE OF THE SOLIDARITY TRANSPORT HUB – DESIGN GUIDELINES

# VOLUME II.2

# 3 KV DC OVERHEAD CATENARY AND TRACTION POWER SUPPLY

Version 1.3.0, closed on 05.08.2021

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The list of volumes constituting the detailed technical conditions for the construction of the railway infrastructure of the Solidarity Transport Hub:

| | |
|---|---|
| Volume A | Introduction to the STH railway standards |
| Volume I.1 | Railway track – layout geometry |
| Volume I.2 | Railway – design of civil structures |
| Volume I.3 | Railway track – drainage of track layout |
| Volume I.4 | Railway track – gauge |
| Volume I.5 | Railway track – geotechnical investigations and design |
| Volume II.1 | 2 x 25 kV 50 Hz AC overhead catenary system and traction power supply |
| Volume II.2 | **3 kV DC overhead catenary line and traction power supply**<br>Defines the principles of designing, construction and acceptance of power supply and overhead catenary systems of 3 kV power supply systems |
| Volume III.1 | Engineering structures |
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| Volume IV | Non-OCL power engineering |
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| Volume X | Conflicts with external networks |
| Volume XI | Electromagnetic compatibility (EMC) |
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| Volume XV | Survey control |
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Revisions of the document “Detailed technical conditions for the construction of railway infrastructure of the Solidarity Transport Hub; Volume II.2; 3 kV DC overhead catenary system and traction power supply”:

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**Table of contents**

# 1 Introduction

This volume II.2 of the Technical Standards – Design Guidelines is one of 30 volumes containing a description of detailed technical conditions for the construction of railway lines up to a speed of Vmax ≤ 250 km/h.

## 1.1. Technical scope

These guidelines apply to all categories of railway lines. They define the principles of designing, construction and acceptance of power supply and overhead catenary systems of 3 kV power supply systems. These guidelines contain technical requirements related to general parameters for the 3 kV power supply system, basic parameters of traction substations, design parameters of the 3 kV overhead catenary system, as well as electric shock protection and safety requirements. Compliance with the guidelines enables reliable operation of the 3 kV power supply system.

## 1.2. Links to other volumes

The links between this volume of Standards with other volumes are presented in Table 1.

Table 1.

| Volume No | Volume title | Relation content |
|---|---|---|
| Volume I.1 | Railway track – Layout geometry | Requirements for the track horizontal curve |
| Volume II.1 | 2 x 25 kV AC 50 Hz overhead catenary system and traction power supply | Requirements for separation sections of power supply systems and points of mutual influence of the AC and DC power supply systems |
| Volume III.2 | Tunnels | Requirements for overhead catenary system and traction power supply in a tunnel |
| Volume IV | Non-OCL power engineering solutions | Requirements for power supply systems for non-traction consumers |
| Volume X | Conflicts with external networks | Requirements concerning proximity for networks and systems not related to railway traffic |
| Volume XI | Electromagnetic compatibility (EMC) | Requirements concerning the resistance of the control command and signalling circuits to disturbances generated by power lines at proximities or crossings with railway lines |

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# 2 Essential, basic and general requirements for the STH railway infrastructure

The below-mentioned essential requirements for the rail system (general) and for the subsystems under Directive 797/2016 and the basic requirements under the Construction Law and the Act on construction products, as well as the general requirements supplementing them, defined in the context of the role of the STH infrastructure in the Polish transport system, constitute the basis for verification of the completeness of detailed technical conditions for the construction of the STH railway infrastructure. Therefore, each volume in chapter 2 contains the links between detailed technical conditions with these essential requirements for the STH railway infrastructure in the form of tables (with reference to the below-mentioned numbering).

Table 2 defines the link between the detailed technical conditions and the essential, basic and general requirements for railway lines.

Table 2.

| sub-chapter of this volume defining detailed technical conditions | essential requirements (Railway Interoperability Directive) | | | | | | basic requirements | general requirements for the STH railway infrastructure | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.1. security | 1.2. reliability and accessibility | 1.3. health | 1.4. environmental protection | 1.5. technical compliance | 1.6. accessibility | 2.1. mechanical resistance and stability<br>2.2. safety in case of fire<br>2.3. hygiene, health and the environment<br>2.4. safety and accessibility in use<br>2.5. protection against noise<br>2.6. energy economy and heat retention<br>2.7. sustainable use of natural resources | 3.1. focus on the needs of economy | 3.2. orientation towards the needs of passengers | 3.3. orientation towards the needs of carriers | 3.4. compatibility with the railway infrastructure connected with the STH railway infrastructure |
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| 3.2 | 1.1.1, 1.1.3, 1.1.7 | | | | 1.5.3 | | 2.4.1, 2.6.1 | | | | |
| 3.2.1 | | | | | 1.5.3 | | | | | | |
| 3.2.2 | | | | | 1.5.3 | | | | | | |
| 3.2.3 | | | | | 1.5.3 | | | | | | |
| 3.3 | 1.1.1, 1.1.3, 1.1.7 | | | 1.4.3 | 1.5.3, 1.5.1 | | 2.4.1, 2.6.1 | | | | |
| 3.3.1 | 1.1.1, 1.1.7 | | | 1.4.3 | 1.5.3,1.5.1 | | 2.4.1, 2.6.1 | | | | |
| 3.3.2 | 1.1.3 | | | 1.4.3 | 1.5.3 | | 2.4.1, 2.6.1 | | | | |
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| 3.3.2.2 | 1.1.3 | | | | 1.5.3 | | 2.4.1 | | | | |
| 3.3.2.3 | 1.1.3 | | | | 1.5.3 | | 2.4.1 | | | | |
| 3.3.2.4 | 1.1.3 | | | | 1.5.3 | | 2.4.1 | | | | |
| 3.3.2.5 | 1.1.3 | | | | 1.5.3 | | 2.4.1, 2.6.1 | | | | |
| 3.3.2.6 | 1.1.3 | | | 1.4.3 | 1.5.1 | | 2.4.1 | | | | |
| 3.3.2.7 | 1.1.3 | | | | 1.5.3 | | 2.4.1 | | | | |
| 3.3.2.8 | 1.1.3 | | | | 1.5.3 | | | | | | |
| 3.3.2.9 | 1.1.3 | | | | 1.5.3 | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.3.2.10 | 1.1.3 | | | | 1.5.1 | | | | | | | |
| 3.3.2.11 | 1.1.3 | | | 1.4.3 | 1.5.3 | | 2.4.1, 2.6.1 | | | | | |
| 3.3.2.12 | 1.1.3 | | | 1.4.3 | 1.5.3 | | 2.4.1, 2.6.1 | | | | | |
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| 3.4.2 | 1.1.1,1.1.7 | | | | 1.5.3 | | | | | | | |
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| 3.4.5.2 | 1.1.1, 1.1.5 | | | | | | 2.4.1 | | | | | |
| 3.4.5.3 | 1.1.1, 1.1.7 | | | | | | 2.4.1 | | | | | |
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**Cybersecurity**

Technical solutions which collect, store, process, make available or transmit data ensuring the compliance with essential safety requirements (requirements from 1.1.1. to 1.1.11. specified in Volume

A of the STH Railway Standards) and general requirements for the STH railway infrastructure concerning security (requirements 1.1.12. and 1.1.13 specified in Volume A of the STH Railway Standards) should be designed taking into account cybersecurity, i.e. "security of network and information systems", defined in the Directive concerning measures for a high common level of security of network and information systems across the Union, as follows:

> "security of network and information systems" means the ability of network and information systems to resist, at a given level of confidence, any action that compromises the availability, authenticity, integrity or confidentiality of stored or transmitted or processed data or the related services offered by, or accessible via, those network and information systems;
>
> *[as defined in Article 4 of Directive 2016/1148]*

Cybersecurity includes two types of threats resulting from unauthorised access to the systems/equipment/networks that collect, store, process, make available or transmit data:

1) physical security threats

   It is necessary to secure systems/equipment/networks against direct access which could enable causing (intentionally or unintentionally) threats to functional safety.

2) IT security threats

   It is necessary to secure systems/equipment/networks against logical access via IT systems/equipment/networks, which could enable causing (intentionally or unintentionally) threats to functional safety.

Cybersecurity defined this way applies both to information systems used for rail transport purposes and to operational systems used for rail transport purposes, but the STH railway standards do not include requirements for information systems, e.g. timetabling systems.

Physical security threats and IT security threats for operational systems for which requirements are defined in the STH railway standards should be addressed by railway operators as part of the risk assessment and by design engineers/manufacturers/contractors as part of threat control. Additionally, it is required for the applied protections to be documented and verified in accordance with the requirements included in Volume XVIII of the STH railway standards.

**Cybersecurity within the scope of this volume of the STH railway standards**

Currently, in the area covered by this volume of standards, there are no networks and information systems whose security could be endangered. However, it is possible that such networks and information systems or technical solutions that collect, store, process, make available or transmit data may arise. For example, a system of sensors may be used that, through wired or wireless, public or non-public networks, or directly, will connect to e.g. an infrastructure manager's system. Then, they should be protected against physical security and IT security threats in a manner compliant with the requirements of the Information Safety Management System (SZBI) implemented by Centralny Port Komunikacyjny spółka z o.o.

At the same time, it should be kept in mind that the ISMS will be subject to changes because maintaining the required level of cybersecurity is not possible by meeting requirements of the standards once since cybersecurity is a process rather than a state. In order to minimise the number and size of cyber threats, the requirements (obligations) included in the Act of 5 July 2018 on the national cybersecurity system in Chapter 3 for operators of key services, in Chapter 5 for public entities should be continuously observed in operational processes and only digital service providers fulfilling the obligations described in Chapter 4 of that Act should be used.

# 3 General requirements for the 3 kV DC power supply system

## 3.1. Formal arrangements

1) The traction power supply system, including the substations' capacity and the distance between them, should be designed and constructed in such a manner as to ensure, taking into account the overhead catenary system parameters, the required operating parameters assumed for the line, in particular:
a) railway line speed,
b) minimum permissible succession of trains,
c) maximum current consumed by a train,
d) timetable and scheduled maintenance activities,
e) average effective voltage.
2) The detailed EMC requirements for the 3 kV power supply system are included in Volume XI.
3) The requirements of this volume also apply to railway tunnels compliant with Volume III.2

## 3.2. General requirements for the 3 kV DC power supply system

### 3.2.1. Operating and short-circuit currents

1) The maximum current drawn by the train should be assumed at the following values:
a. 2800 V – on a line with v ≥ 200 km/h.
b. 4000 A – on a newly built line up to v < 250 km/h.
2) The main circuits of all power supply equipment and the overhead catenary system should be characterised by resistance to the flow of a short-circuit current of 50 kA.
3) The power supply system should be designed and constructed in such a manner as to ensure that the minimum short-circuit currents are cut off with the simultaneous uninterrupted flow of operating currents, taking into account the following conditions each time:
a) setpoint value of undervoltage protections,
b) bilateral or unilateral power supply,
c) dependence or non-dependence of the circuit breakers at bilateral power supply,
d) existence or absence of sectioning points,
e) power supply method under emergency conditions,
f) the use of microprocessor controllers of feeder cells with the function of triggering high-speed breakers.

### 3.2.2. Voltage in the overhead catenary system

1) The value of voltage in the overhead catenary system and its variations should be in accordance with the requirements of EN 50163 [6].
2) The value of the average effective voltage on the pantograph should be:
a) 2700 V – on a line with v ≥ 200 km/h.
b) 2800 V – on a line with v ≥ 200 km/h.

### 3.2.3. Stray currents

1) Earthing and protective connection to the rail systems used as protection against short-circuits in the DC network and protection against electric shock should be separated from each other and insulated. Open connection to the rail should be used for earthed or connected to the ground components.

2) The following measures limiting the flow of stray currents should be applied in the overhead catenary supply system and in the non-traction power supply system:

a) in traction substations, the negative rail should be insulated from substation earthing;

b) traction substations must be equipped with earth protection devices causing automatic earthing of the substation negative rail in emergency situations and enabling earthing of the negative rail for the duration of maintenance works;

c) the armours (shielding conductors) of feeder cables should be unilaterally connected to the earth electrode of the traction substation or sectioning point. In sectioning points operating in the connection to the rail system, this connection should be made to the bus connecting the sectioning point to the rail. These connections should be made using a Cu wire with a cross-section of at least 35 $mm^2$. It is not allowed to connect to the rail (earth) the cable armours from the overhead catenary system side directly or using a low-voltage limiter;

d) the shielding conductors of the MV cables supplying traction substations should be earthed unilaterally in the electrical substation (main power supply point or substation where the 110/15 (20) kV transformer is installed) and in the traction substation, they should be short-circuited between each other. If the public power companies do not consent to unilateral earthing of shielding conductors, they should be connected to the earthing in the traction substation by means of a low-voltage limiter; shielding conductors of non-traction line cables coming out of traction substations should be unilaterally earthed in the substation.

e) The other end of the shielding conductors of the cable line going to the overhead part should be insulated. In case the cable line supplies the transformer substation directly, the shielding conductors in this substation should be shorted with each other and isolated or connected to the substation earth electrode by means of a low-voltage limiter. At the section between the transformer and distribution substations, it is recommended to earth the shielding conductors from the side of the main power supply source. The shielding conductors of cable inserts of the non-traction line should be earthed unilaterally; shielding conductors of the MV cable lines between traction substations should be earthed unilaterally in traction substations, and should be insulated at the first cable box or transformer substation.

f) Shielding conductors of the central parts of the cable line should be earthed unilaterally or connected with the earth electrode by means of a low-voltage limiter;

g) shielding conductors of cable sections of medium voltage power lines led out from power supply points (traction substations) and metal casings of cable terminations should be earthed unilaterally from the power supply point side, while they should be insulated from the pole structure on which the cable is routed, regardless of its location;

h) elements of the overhead line which are not normally energised and which remain within the reach of contact of the operating personnel during operation activities should be earthed if they are located outside the influence zone of the overhead catenary system or if they are located within the overhead catenary system influence zone. If cable inserts are used, the cable shielding conductors and metal casings of cable terminations on terminal supports should be earthed or connected to the rail according to the following rules:

– if the terminal supports are located outside the overhead catenary system influence zone, the cable shielding conductors and metal casings of cable terminations should be earthed on one support and insulated from earthing on the other support,

– if one terminal support is located outside the overhead catenary system influence zone and the other inside the zone, cable shielding conductors and metal casings of cable terminations should be earthed on the support standing outside the zone, and insulated on the other support.

3) All civil structures, engineering structures, equipment and structural landscaping structures made of electrically conductive materials and located in the electrical traction influence zone should be connected to the rail by low-voltage limiters or connected to a group connection to the rail system.

## 3.3. Traction substations and sectioning points in the 3 kV DC system

### 3.3.1. Location of the traction substation and sectioning point

1) Traction substations should be separated by a distance ensuring the required level of minimum short-circuit currents and average effective voltage on the pantograph.
2) It is not recommended that the distance between adjacent traction substations is less than 15 km.
3) Traction substations should be located in places requiring the shortest possible feeders.
4) Sectioning points should be located near crossings or line branches so that feeder cables are as short as possible.
5) If it is necessary to reduce voltage drops in the overhead catenary system or increase the minimum short-circuit currents, a sectioning point or cross-connection point should be used as close as possible to half the distance between the traction substations.
6) The location of the traction substation or sectioning point should ensure:
a) the possibility of tractor access with a low-floor trailer or the possibility of constructing an access road with the required parameters;
b) routes of feeder lines and return cables as simple and short as possible;
c) distance between the earthing ring of the substation or the point and the extreme rail of the electrified line track of at least 20 m (in particularly difficult conditions, a distance of 16 m is allowed). In relation to non-electrified track rails, this distance may be smaller provided that insulating pads are installed in the track.

### 3.3.2. Requirements and basic parameters of instrumentation and equipment

#### 3.3.2.1. Substation external characteristics

1) The parameters of rectifier units and the traction substation power supply system should ensure obtaining the characteristics of an external double-unit traction substation, including the power supply system and feeders, corresponding to an equivalent substation internal resistance of $R_p \leq 0.1\Omega$.

#### 3.3.2.2. Traction substation supply and feeders

1) Traction substations should be supplied by HV lines with a voltage of 110 kV AC or MV lines with a voltage of 15 kV or 20 kV AC.
2) Each MV-supplied substation should have two connections: main and backup. They should be routed directly from two different main power supply point switching stations or from separate sections of the main power supply point switching station, preferably from separated HV/MV transformers.
3) It is allowed to supply the substation with one 110 kV line.
4) The 110 kV AC feeders should be connected to the commercial power generation system in the main power supply points, distribution power supply points or to the 110 kV line.
5) When calculating the feeders, the following should be taken into account: location of traction substation and main power supply point switching station, short circuit power at the outlet from this station, 15-min. and momentary power output of the traction substation and power reserve for non-traction purposes.
6) The line cross-section should be selected according to three criteria:
a) thermal-withstand capability;
b) permissible voltage drops;
c) short circuit withstand capability.

#### 3.3.2.3. HV AC switchgear

1) HV switchgear should have a single busbar system and should be equipped with transformer bays and feeder bays and possibly a coupler with circuit breakers. Detailed solutions must result from the Technical Conditions for Connection and the Connection Agreement concluded with a territorially competent distribution system operator. These documents should also specify the operational limits between the distribution system operator and the energy consumer, requirements for the protection instrumentation, remote control system and basic data (power and short-circuit currents at feeder points) necessary for calculations of the power supply system.
2) 110 kV HV switchgear should have the following parameters:
– rated voltage – 123 kV;
– insulation level – 550 kV;
– rated current – 1,600 A;
– breaking capacity – 40 kA.
3) All drives and control circuits should be suitable for a 220 V DC power supply.
4) It should be possible to earth the star point of the HV winding in the rectifier transformer by a motor-operated disconnector switch and it should be protected by a valve arrester.
5) Three-phase overhead circuit breakers with sulphur hexafluoride should be used as an insulating and extinguishing medium for electric arc and porcelain or composite insulation.
6) The disconnector switches should be overhead, three-pole, double-column, single-break units with one or two sets of earth blades. The insulation should be made of brown porcelain or composite.
7) Current transformers, voltage transformers and current and voltage transformers (combined) should be made as outdoor, standing, single-phase transformers with porcelain or composite casing. The casing should be hermetic, explosion-proof, preventing the rupture of the insulator during an internal short circuit by a controlled discharge of the insulating medium and its decomposition products in a direction safe for the personnel.

#### 3.3.2.4. MV AC switchgear

1) MV AC switchgear in traction substations supplied with MV voltage should have a single busbar system sectioned with a disconnector switch or circuit breaker with disconnector switches. Each section should consist of the following bays:
a) 1 feeder bay;
b) 1 rectifier transformer bay;
c) 1 auxiliary transformer bay;
d) half of the outgoing feeders.
2) The MV AC switchgear in the substation supplied with 110 kV voltage serves an auxiliary function and is mainly used to supply non-traction receivers and substation auxiliary needs. This switchgear should have a single busbar system sectioned with a disconnector switch or circuit breaker with disconnector switches. Each section should consist of the following bays:
a) 1 incoming feeder;
b) 1 balancing transformer bay (if necessary);
c) 1 auxiliary transformer bay;
d) half of the outgoing feeders.
3) It is recommended to use double-sectioned switchgears.
4) The circuit breakers should be equipped with electric, stored-energy remote control drives. MV disconnector switches should be provided with a manual drive, unless other conditions require the use of electric drives.
5) Required parameters of MV AC switchgear:
a) rated voltage – 17.5 (24) kV, 50 Hz;

b) rated continuous current for incoming feeders, coupler bay, busbars – resulting from the number and power output of rectifier units and other receivers;
c) rated continuous current for other bays – 630 A;
d) peak short-circuit current – 63 kA;
e) 1 sec. rated current – 25 kA.
6) Busbars and bus connections inside the switchgear should be selected taking into account the continuous current-carrying capacity and 1 sec. short circuit current rating.
7) The selection of voltage transformers should be based on the operating voltage value of the circuits in which they will be used.
8) For the selection of transformers, operating currents calculated for the target power output of the substation should be used as follows:
a) for incoming feeders and busbars – current calculated based on 15-min. substation power output;
b) for rectifier unit bays – continuous rated current of the unit in the overload capacity class III;
c) for non-traction needs bays – current resulting from the total power output of receivers supplied simultaneously from a given line;
d) for auxiliary needs bays – current calculated on the basis of the power output of the transformers of auxiliary needs.
9) MV switchgear should include vacuum circuit breakers with a withdrawable part.
10) All electrical instruments of the MV switchgear should be provided with auxiliary circuits supplied with 220 V DC voltage.

#### 3.3.2.5. Rectifier units

1) Traction substations should include rectifier units with 12-phase pulsation.
2) The units should be rated in the overload capacity class III with the following output voltages:
a) rated undulating voltage: $U_d \geq 3300$ V;
b) open-circuit voltage: $U_{d0} \leq 3600$ V.
3) Equivalent resistance of rectifier units: $Rz \leq 0.05\ \Omega$.
4) The power outputs of the transformer and rectifier windings should be adapted to the assumed traffic and rolling stock on the supplied lines and ensure an equivalent resistance of the double-unit substation of $Rp \leq 0.1\ \Omega$.
5) The rectifier transformer in substations supplied with a voltage of 15 kV or 20 kV should be made as an outdoor transformer and have three windings: one primary and two secondary with a voltage of 1.3 kV staggered by 30 electrical degrees (30 electrical °). The primary winding should be provided with outgoing taps enabling voltage control in the voltage-free condition within the range of +3 x 2.5% ÷ –1 x 2.5%.
6) Recommended parameters of rectifier’s transformers supplied with voltage of 15 or 20 kV:
a) rated power:
– primary HV winding: $P_{GN} = 6.3$ MVA;
– secondary LV1 and LV2 windings: $P_{DN1} = P_{DN2} = 3.15$ MVA
b) rated voltage of the HV winding: UGN = 15.75 kV or 21 kV;
c) arrangement of connections: Yy0d11;
d) no-load power losses: $P_0 \leq 5$ kW;
e) rated-load power losses: $P_{Cu} \leq 50$ kW;
f) short-circuit voltage in GN-DN1 and GN-DN2 configuration: $U_{z\%} \leq 5.2\%$.
7) The rectifier transformer in substations supplied with 110 kV voltage should be made as an outdoor transformer and have three windings: one primary, two secondary with a voltage of 1.3 kV staggered by 30 electrical degrees (30 electrical °). The HV transformer should be equipped with an on load tap changer interoperating with an appropriate voltage regulator within the range of ± 10%.

8) The rectifier transformer in substations supplied with 110 kV voltage can be equipped with a fourth winding with a voltage of 15 kV or 20 kV to supply the MV switchgear.
9) Recommended parameters of rectifier’s transformers supplied with voltage of 15 or 20 kV:
a) rated power:
– primary HV winding: $P_{GN}$ = 6.3 (7.3) MVA;
– MV winding: $P_{SN}$ = 1 MVA;
– secondary LV1 and LV2 windings: $P_{DN1} = P_{DN2}$ = 3.15 MVA;
b) rated voltage of the HV winding: UGN = 115 kV;
c) arrangement of connections: YN(d11)y0d11;
d) no-load power losses: $P_0 \leq 5$ kW;
e) rated-load power losses: $P_{Cu} \leq 50$ kW;
f) short-circuit voltage:
– in GN-DN1 and GN-DN2 configuration: $U_{z\%} \leq 10\%$;
– in GN-SN configuration: $U_{z\%} \leq 18\%$
10) The transformer should be equipped with the following factory protections:
a) I and II stage temperature protections,
b) I and II stage gas-flow protections,
c) oil level decrease signalling,
d) safety valve tripping.
11) The semiconductor rectifier should consist of sets of diodes connected in a double three-phase bridge system. The diode bridges should interoperate with each other in series. It is required that the diodes in the rectifier have natural cooling.
12) In substations supplied with 110 kV voltage, rectifier units with a rated rectified current of at least 1700 A should be used, and in substations supplied with 15 kV or 20 kV voltage – rectifier units with a rated rectified current of at least 1600 A.
13) The rectifiers should be rated in the overload capacity class III.
14) The number of diodes in the rectifier and its losses should be minimised while maintaining high reliability and susceptibility to damage (the rectifier can be operated if one diode is tripped).
15) The rectifier should be equipped with systems minimising commutation overvoltages, the values of which should not exceed 600 Vpp.
16) Recommended parameters of rectifiers for rectifier units supplied with a voltage of 15 (20) kV or 110 kV:
a) rated undulating voltage: $U_{dn} \geq 3300$ V;
b) rated rectified current: $I_{dn} \geq 1700$ A;
c) overload capacity class: III;
d) losses at $I_{dn}$: $P_s \leq 17$ kW;
e) reverse voltage distribution uniformity on diodes connected in series: ≥ 0.9;
f) commutation overvoltages within the load current range from 0 to 200% $I_{dn}$: up ≤ 600 Vpp;
g) short circuit withstand capability: $I_{zw} \geq 18.5$ kA.
17) At the “+” output of each rectifier, a smoothing inductor should be installed.
18) The rectifier unit should be connected to the AC busbars by means of a circuit breaker and disconnector switch, and to the +3 kV DC bus by means of a disconnector switch and a high-speed breaker.
19) The “–” connection of the rectifier with the minus cell should not contain any switching devices.
20) Smoothing inductors with an inductance of 4 mH (-0%, +10%) or 6 mH (-0%, +10%) should be used, depending on the smoothing device used.
21) The rated current of the smoothing inductor should be the same as the rectifier rated current. The current overload capacity of inductors should be class III.
22) Short circuit withstand capability: $I_{zw} \geq 18.5$ kA.
23) Each smoothing inductor should be equipped with an overvoltage protection system that activates when the 500 V voltage is exceeded and dissipates the energy accumulated in the inductor.

### 3.3.2.6. Smoothing device

1) Smoothing devices should be used in the substations, including a smoothing inductor with a capacitor bank with an individual bleeder resistor and possibly LC branches. The smoothing device or devices should ensure that the psophometric interference voltage is limited to 0.5% of Ud, regardless of the substation load and taking into account the asymmetry of the voltage supplying the substation.
2) The smoothing device should be protected with a fuse connected from the side of the +3 kV busbar. The connection system of the smoothing device should ensure automatic discharge of the capacitors in case of an outage or loss of the DC voltage.
3) The smoothing device should contain elements limiting the discharge current of capacitors in case of a short circuit on the buses of the 3 kV switchgear or the overhead catenary system.
4) It is recommended to use aperiodic smoothing devices:

a) individual devices with a capacitor bank C = 0.8 mF interoperating with inductors with 6 mH inductance

or

b) central devices with a capacitor bank C = 0.8 mF and resonance branch for harmonics damping with the frequency of 600 Hz interoperating with inductors with 4 mH inductance.

5) Individual smoothing devices should be used for each single rectifier unit. One central smoothing device can interoperate with 1 to 3 rectifier units.

### 3.3.2.7. 3 kV DC switchgear

1) The 3 kV DC switchgear should be made as a prefabricated, indoor type, cell type switchgear with a high-speed breaker installed on a slide-out trolley.
2) The switchgear should be equipped with a double system of “plus” busbars (main bus and bypass bus), double-sectioned using two two-pole disconnector switches. During normal operation of the switchgear, both sectionalised disconnector switches should be closed. In the central section of the switchgear, there should be a spare circuit breaker bay and an undervoltage protection device.
3) The spatial arrangement of the switchgear and the applied automation system should enable the replacement of any feeder circuit breaker with a spare circuit breaker.
4) If a central smoothing device is used, it must be located in the central section of the switchgear.
5) If individual smoothing devices are used, they should be placed in the incoming feeders of the 3 kV switchgear, which are usually located in the terminal sections of the 3 kV switchgear.
6) The feeder bays should be distributed symmetrically in the extreme switchgear sections.
7) The operating voltages of the switchgear should be compliant with the PN-EN 50163 standard, and current parameters should be adapted to the power supply system.
8) The rated voltage of auxiliary circuits should be 220 V DC.
9) The location of feeder cells in the switchgear should correspond to the location of the supplied track sections in the field.
10) Each high-speed breaker in the 3 kV DC switchgear should be equipped with an automatic power restarting (reclosing) system and a line insulation condition test system.
11) Required parameters of the DC switchgear:

a) rated voltage – 3.3 kV;
b) highest operating voltage – 3.6 kV;
c) short circuit withstand capability – 50 kA, 0.25 s;
d) auxiliary circuit voltage – 220 V DC.
e) rated current of the main busbar and section disconnector switches:

– minimum 4 kA for a line with v < 200 km/h
– minimum 6 kA for new lines with v < 250 km/h;

f) rated current of the bypass busbar, feeder bays and spare circuit breaker and incoming feeders:

– minimum 2.5 kA for a line with v < 200 km/h;
– minimum 4 kA for new lines with v < 250 km/h.

#### 3.3.2.8. High-speed breakers

1) The type of the DC high-speed breaker used in the 3 kV DC switchgear must be provided with an approval certificate issued by the Office of Rail Transportation.
2) The high-speed breaker should be single-pole, designed for making of operating, overload and short-circuit currents, non-polarised, intended for operation in moderate climate conditions in rooms located at a height of up to 2000 m a.s.l.
3) The breaker should be equipped with an electromagnetic air-blast system.
4) The high-speed breaker should ensure the following parameters:
a) rated operating voltage – 3 kV DC;
b) rated operating current – in accordance with the rated feeder cell current or higher;
c) short-circuit current making capacity – 50 kA DC;
d) test voltage 50 Hz – 15 kV;
e) current setpoint range of the primary release ensuring correct breaking of minimum short-circuit currents and overloads of operational loads;
f) making durability – ≥ 1000 making operations;
g) mechanical durability – ≥ 20,000 switches;
h) opening time – ≤ 5 ms;
i) total breaking time – ≤ 20 ms;
j) arcing time when breaking critical currents – ≤ 500 ms;
k) arc chute – asbestos-free;
l) control circuit voltage – 220 V DC.
5) For the setpoints of primary releases of high-speed breakers smaller than 3000 A, the minimum short-circuit currents should be at least 300 A greater than the setpoints of the high-speed breaker releases supplying a given power supply section. For the setpoints of primary releases of high-speed breakers equal to or greater than 3000 A, the minimum short-circuit currents should be at least 10% greater than the setpoints of the high-speed breaker releases supplying a given power supply section.
6) The setpoint current of the primary release of the high-speed breaker should be 200 A greater than the maximum current flowing through the high-speed breaker resulting from momentary loads.
7) High-speed breakers should have the function of activation and deactivation with external signals.

#### 3.3.2.9. Minus cell, return cables and cables connecting to the rail

1) The traction substation should be equipped with one minus cell common for all rectifier units.
2) The minus busbar should be made as non-sectioned and insulated from the ground. The insulation level of the minus bus should be 1 kV. The connections of the minus bus with the negative pole of the rectifiers and with the return circuit should be made directly using cables. In the minus bus circuit, no connectors should be installed.
3) The minus cell should be fenced off. Ammeters should be installed in the circuits of the return cables coming out of the minus cell.
4) An integral part of the minus cell should be the earth protection device and the control tester of the return cables and earthing cables.
5) The cell should enable the connection of the following number of cables:
a) minimum cables from the rectifier unit – 5 x YAKY 1 x 240 (1 kV)/unit;
b) minus cables to switchgear 3 kV DC – 3 x YKY 1x50 (1 kV);
c) connection with earth protection device – YKY 1 x 120 (1 kV);

d) return cables – in accordance with the design documentation.
6) The currents should be discharged from the rails of the electrified track to the traction substation by return cables.
7) When designing the route of return cables and the place of their connection to the tracks, every effort should be made to ensure that their length is as short as possible and does not exceed 1000 m.
8) The return cable route should run within the area managed by the railway infrastructure manager. Passage through a non-railway area is allowed only if it significantly shortens the route and the area is not planned for development. Moreover, every effort should be made to avoid crossings and proximities with district heating pipelines, gas pipelines and control command and signalling cables.
9) The route should ensure easy access during the construction and operation of the return circuit.
10) The number of return screens in the bundle is selected on the basis of the 15-minute RMS substation current value, taking into account the reduced load capacity of the cables routed in the parallel bundle in accordance with the relevant standard. The number of cables resulting from the calculations should be increased by one reserve cable.

#### 3.3.2.10. 3 kV feeder lines

1) The feeders should be designed as cable lines with the shortest possible length.
2) The cross-section of cable feeders is selected on the basis of the 30-minute RMS current value, but not less than 185 mm$^2$.
3) For construction of railway feeders, cables with an aluminium live wire with a cross-section of 1x500 mm$^2$ with a rated insulation voltage of 6 kV, with insulation, sheath and polyvinyl shield, with a steel wire armour between the sheath and the shield should be used. The armour resistance should not exceed 1 Ω/km. It is allowed to use other types of cables, provided that the protective conductor of these cables is able to withstand short-circuit currents which may occur in case of damage to the feeder cable. The cross-section of the shielding conductor should ensure the possibility of breaking short-circuits at the end of the feeder. For calculations, the minimum short-circuit current of 150% of the setting current of the overcurrent relay of the earth protection of the traction substation should be assumed.
4) Indoor terminations of feeder cables should be made with indoor terminations that enable the armour to be routed to the earthing. On the side of the contact line, outdoor terminations should be used. Feeder cable armours earthed in the traction substation should not be connected to the rail directly or using a protective spark gap or a low-voltage limiter from the catenary side. The live wire on the termination should be protected with a lightning arrester without a protective spark gap.
5) It is recommended to use straight joints made of synthetic or thermosetting resins with a rated insulation voltage of at least 6 kV.

#### 3.3.2.11. Auxiliary power supply system

1) The auxiliary power supply system of the traction substation consists of the following equipment:
a) two MV/LV transformers;
b) 230/400 V AC switchgear;
c) 220 V DC switchgear;
d) maintenance-free battery bank;
e) 230/400 V AC installation switchgear;
f) inverter (optional).
2) The substation's auxiliary needs should be supplied from two MV/0.4 kV transformers installed in the MV switchgear bays. It is required to use indoor transformers.

3) The MV/LV transformers of auxiliary needs are designed to supply 230/400 V AC auxiliary needs switchgear in TN-C configuration and should provide power necessary to supply LV equipment necessary for the correct operation of the substation.
4) If a compensating reactor is used in the traction substation, it is allowed, instead of the transformers of auxiliary needs, to use an additional winding of reactor, independent of the compensating winding, dedicated for the auxiliary needs, as a voltage source for the 230/400 V AC auxiliary needs switchgear, provided that they meet the appropriate technical parameters for a specific structure.
5) Rated power of MV/LV transformers should be selected from the following series: 1; 3.6; 6.3; 16; 25; 40; 63; 100; 160; 250; 400; 630; 800; 1000; 1250; 1600 kVA.
6) Vector group of MV/LV transformers Yzn5 – up to the power of 160 kVA and Dyn5 – from the power of 250 kVA.
7) Short-circuit voltage: 4.5% ± 10% for transformers up to 400 kVA and 6.0% ± 10% for transformers above 400 kVA.
8) Transformers with a power output above 16 kVA should have a voltage regulation of ± 3 x 2.5%.
9) The 230/400 V AC switchgear should be made as a wall-mounted cabinet. The connections between the transformers and the switchgear should be made as cable connections. The switchgear should have an automatic transfer switch (automatic loss-of-voltage tripping) system. After shutdown of the automatic transfer switch (automatic loss-of-voltage tripping system), parallel operation of the auxiliary transformers should be possible, provided that the conditions of parallel operation of these transformers are met. If uninterrupted power supply of selected AC circuits (from the inverter) is necessary, these circuits should be separated.
10) The 220 V DC switchgear should operate with a maintenance-free battery bank. The following circuits are supplied from this switchgear:
a) drives of HV and MV AC and DC circuit breakers (separate circuits for each switchgear);
b) automation, protections and control (separate circuits for each switchgear);
c) signalling (common for the entire substation);
d) safety lighting;
e) locking;
f) inverter (if applicable).
11) The battery bank rectifier should be fed from the AC switchgear and connected to the battery in a buffer arrangement.
12) The rectifier connection system should enable periodic charging of batteries bypassing the DC switchgear.
13) The traction substation equipment should enable “point” operation of the substation which ensures active undervoltage and earth protection. The equipment used should enable “point” operation of the substation for a period not shorter than eight hours.
14) Individual auxiliary circuits should be protected with appropriate interference and overvoltage filters while maintaining appropriate grading of this protection.
15) All circuits not directly related to the substation technology should be fed from the 230/400 V AC installation switchgear. These include, among others: lighting, heating, sockets, ventilation, hydrophore, etc.

#### 3.3.2.12. Power supply of transformers of auxiliary needs and non-traction receivers

1) The MV switchgear of the substation from which the transformers of auxiliary needs are fed is supplied:
a) in substations supplied with 15 kV or 20 kV voltage by MV lines feeding the substation from the main power supply point,
b) in substations supplied with 110 kV voltage from:
– MV winding of the rectifier transformer,
– 110 kV/MV transformer intended for feeding non-traction receivers.

2) 110 kV/MV transformers intended for feeding non-traction receivers are constructed when the power of non-traction receivers exceeds the power of the MV winding of the rectifier transformer (1 MVA).
3) Non-traction receivers are fed by MV lines led out from the MV switchgear of the substation.
4) The requirements concerning power supply systems for non-traction receivers are presented in Volume IV.

### 3.3.3. Local automation and protection devices

#### 3.3.3.1. General requirements

1) Local automation and protection devices should be made on the basis of microcomputer digital devices.
2) One type of data transmission protocol bus should be used in all power supply facilities. If protection devices using other buses and transmission protocols are used, they must be used provided that a module converting signals from a non-standard bus to a selected standard is ensured.
3) Substations and sectioning points should be fully prepared for remote operation as standard.
4) The automation system of traction substations should be able to operate in the following modes:
a) remote operation mode – equipment operation is controlled from the Central Control Room;
b) local operation mode – equipment operation is controlled directly from the traction substation;
c) partially local operation mode – equipment operation is controlled from the Central Control Room and selected bays of the switching station or equipment from the traction substation.
5) Control operations should be allowed only from the place specified in the selected operation mode (Central Control Room for remote operation or traction substation for local operation), except for shutdown operations for selected equipment, which should be allowed from each place, regardless of the selected operation mode.
6) The remote control system should be compatible with the control system of the adjacent power supply facility operated by another operator.
7) Automation and control equipment operating in the substation should be able to operate in the following modes (regardless of the operating mode of the traction substation):
a) automatic operation – equipment operation is controlled via the transmission link; commands sent via the transmission link are received by controllers performing control operations of power equipment (from the computer terminal to the substation or remotely),
b) manual operation – equipment operation is controlled by means of push-buttons or levers co-operating directly with the equipment controller (while maintaining protections),
c) overhaul – equipment does not operate normally (main circuits disconnected); the control of electric instrumentation in this mode is used to control the correctness of their operation.
8) The controllers should be provided with displays ensuring unambiguous visualisation of the status of the controlled instruments and a menu in Polish.
9) Controller design and software should provide protection against improper or unintentional control, also in case of controller failure.
10) The controllers should have the function of event recording with the record of date and time with event-specific accuracy (10 ms on average). The controller should enable the review of events and their resetting.

#### 3.3.3.2. HV switching station

1) it is required to use digital protection terminals and station automation systems in the HV switching station. All devices should be delivered with software for configuration, data reading and for setting and configuration changes.
2) The devices should be equipped with communication interfaces for:

a) joint operation with the control and monitoring system for communication with the Distribution Operator;
b) joint operation with the substation operator's control and monitoring system;
c) construction of the engineering channel;
d) local communication with the device.

3) All station protections and automation systems should be equipped with event and disturbance recorders.
4) Primary and back-up protections using different short-circuit detection criteria should be used. These protections should operate jointly with separate current and voltage circuits. Off pulsing should take place in both breaking circuits.
5) The protections should include at least two setpoint banks. The selection of the setpoint bank should be possible locally and remotely.
6) One of the applied protections should function as a bay controller. Such protection should be equipped with a graphic display representing the meter states in the bay and should enable control of all meters equipped with electric drives.
7) There should be local signalling of activation of protection functions in the form of signal lights (LEDs).
8) Each protection should have its own test terminal for safe testing.
9) The protections should send pulses to both circuit breaker coils from two independent outputs of the device, using two independent control voltages. In the breaking and actuating circuits, it is recommended to use interfacing relays.
10) The protections should have an automatic supervision function and programmable logic. They should be supplied with 220 V DC voltage.
11) The HV line bays should be equipped with the following protections:

a) primary – distance or sectional. For cable or overhead lines with a length of up to 2 km, sectional protection should be used;
b) back-up – distance or earth fault, current protection for radial feeders;
c) automatic power restarting (reclosing) implemented in the distance protection.

12) Differential and distance protections operating concurrently should communicate using appropriately selected fibre optic interfaces through separate fibre optic fibres.
13) HV bus coupler bays equipped with a circuit breaker should be equipped with overcurrent protection or, in justified cases, distance protection.
14) Depending on the needs, the HV switching-station should be equipped with an automatic transfer switch (automatic loss-of-voltage tripping). Automatic loss-of-voltage tripping should be implemented by means of a dedicated device. It should be possible to switch off the automatic transfer switch (automatic loss-of-voltage tripping).
15) The automatic loss-of-voltage tripping system should be automatically interlocked after activation of protections in the HV bays, protection of the HV busbars, HV breaker failure protection.
16) In stations in the H configuration, it is allowed to use breaker failure protection and busbar protection as a single device.
17) The breaker failure protection should be activated by all installed protections of individual bays.
18) The operation of the breaker failure protection should be based on the current and circuit-breaker criteria.
19) Busbar protection should be equipped with the function of dead zone recognition.
20) The breaker failure protection should operate in two stages:

a) pulsing to deactivate the circuit breaker in the bay in which a retrip has occurred;
b) pulsing to deactivate all circuit breakers of the respective section or busbar system.

21) The breaker failure protection and bus bar protection should automatically adjust the operating zones to the current configuration of the HV switching station.
22) The automatic breaker failure protection and busbar protection systems should allow for extension with another bay without the need to alter the entire system.

23) The automatic breaker failure protection and busbar protection systems should be provided with two redundant feeders, at least one of which should be fed with 220 V DC voltage.
24) It should be possible in each bay to shut down the excitation and tripping of the breaker failure protection of a given bay. Signalling from the translators should be introduced to the master system.
25) Automatic power restarting (reclosing) should be used in outdoor and outdoor/cable lines.
26) The automatic power restarting system should be three-phase, single-shot, activated by the primary and back-up protections.
27) The automatic power restarting system should lock during operational switching of the line and disconnection of the circuit-breaker drive.
28) It should be possible to locally and remotely interlock the automatic power restarting system.

#### 3.3.3.3. MV switching station

1) it is required to use digital protection terminals and station automation systems in the HV switching station. All devices should be delivered with software for configuration, data reading and for setting and configuration changes.
2) The MV switchgear automation should be supplied with 220 V DC voltage. It is allowed to introduce 230V AC voltage for the lighting of cabinets and service sockets.
3) The protections should have an automatic supervision function and programmable logic.
4) The devices should have the following data transmission channels:
a) primary channel;
b) backup channel;
c) engineer channel;
d) additional communication interfaces (if necessary).
5) The protections should send pulses to both breaking coils of the circuit breaker from two independent outputs of the device, using two independent control voltages.
6) The protections should have at least two setpoint banks. The selection of the setpoint bank should be possible locally and remotely.
7) The bay protection device should act as a bay controller, be equipped with a graphic display mapping the switch states in the bay and enable control of all switches equipped with electric drives.
8) The devices should locally signal the activation of protection functions on protection panels.
9) In order to ensure effectiveness and selectivity of protection activation, the protection devices of the MV switchgear should provide automatic protection of the busbars and the breaker failure protection. Activation of the busbar protection and the breaker failure protection should be performed by all installed protections of individual bays except for the bays in which the protection is only a receiver of this signal. The automatic busbar protection and breaker failure protection systems should enable individual shutdown for individual protections.
10) The feeder bay should be equipped with the following protection and automatic control devices:
a) short-circuit protection;
b) independent overcurrent protection, min. 3 stages;
c) earth fault protection with directional function;
d) undervoltage and overvoltage protection;
e) frequency protection;
f) inputs of the breaker failure protection, busbar protection and automatic loss-of-voltage tripping (automatic transfer switch).
11) The outgoing line bay should include the following protection and automation solutions:
a) short-circuit protection;
b) independent overcurrent protection, min. 3 stages;
c) non-directional earth fault overcurrent protections, min. 2 stages (line with neutral point earthing via resistor);

d) directional earth fault overcurrent protection;
e) admittance protections with directional function;
f) automatic power restarting (reclosing) for overhead and overhead and cable lines, activated by any protection device;
g) automation solutions for accelerating protection activation when the line experiences a short circuit;
h) automation solutions for breaker failure protection, busbar protection and automatic loss-of-voltage tripping (automatic transfer switch).

12) All protection devices trip the respective circuit breaker.
13) The bay of the rectifier unit transformer should include the following protection and automation solutions:

a) short-circuit protection;
b) independent overcurrent protection, min. 3 stages;
c) dependent overcurrent protection;
d) earth fault overcurrent protection;
e) transformer factory protections:
- temperature protection I° and II°;
- gas-flow protection I° and II°;
- low oil level;
- safety valve actuation;

f) frequency protection;
g) inputs of the breaker failure protection and busbar protection automation system;
h) power overrun monitoring system automation system.

14) Activation of temperature protections I°, gas-flow protection I° and low oil level protection cause activation of the signalling system. Other protections cause deactivation of the bay circuit breaker.
15) Additionally, the protection and automation systems should trip the bay circuit breaker in case of:

a) traction rectifier failure;
b) activation of the 3 kV DC switchgear protection.

16) The bay of the (earthing) transformer of auxiliary needs should have the following protection and automation solutions:

a) two-stage independent overcurrent protection (I and II);
b) earth fault overcurrent protection for the criterion of current measurement from the reactor (for a compensated network);
c) transformer factory protections;
d) factory protections of the reactor and active component forcing resistor (for a compensated network);
e) directional earth fault protection (for an isolated network);
f) forced active component automation (for a compensated network);
g) breaker failure protection and busbar protection automation.

17) Activation of the circuit breaker in the bay should take place in case of operation of the following protections:

a) overcurrent protection;
b) II stage earth fault protection;
c) 2nd stage transformer factory protection.

18) The activation of other protections mentioned in point 16 should trigger signalling.
19) The bus coupler bay should include the automation system of breaker failure protection and busbar protections as well as protections tripping the circuit breaker:

a) short-circuit protection;
b) independent overcurrent protection, min. 2 stages;
c) earth fault overcurrent protection (in a network earthed using a resistor);

20) The MV switchgear should be equipped with voltage measurement with undervoltage and overvoltage protections.
21) The MV switchgear should be equipped with an automatic transfer switch unit (automatic loss-of-voltage tripping system).
22) The automatic transfer switch unit should include:
a) voltage measurement system with adjustable overvoltage and undervoltage stages and time settings;
b) automation system with a possibility of selecting the backup type;
c) external signalling system with a possibility of generating alarm states;
d) internal signalling and automatic supervision system with a possibility of monitoring switch states and internal damage to the controller;
e) event recording system;
f) remote and local control command and signalling system.
23) Activation of short-circuit and overcurrent protections in feeder bays, incoming transformer bays, bus coupler bays and activation of some protections in the auxiliary bays should interlock the automatic loss-of-voltage tripping.
24) The automatic loss-of-voltage tripping should enable remote and local interlocking and unlocking as well as should have the possibility of local (manual) shutdown.
25) It is recommended that the MV switchgear, with air insulation, be equipped with arc protection, operating with light and voltage criteria.
26) Arc protection should activate tripping of feeder bay circuit breakers and bus coupler bays.
27) Arc protection devices should detect an arc fault within less than 10 ms and switch it off within up to 50 ms.

#### 3.3.3.4. 3 kV DC switching station

1) The automation and control systems of the 3 kV DC switchgear should be supplied with 220 V DC voltage.
2) The equipment should be equipped with primary, backup and engineering data transmission channels. If necessary, they can be equipped with additional communication interfaces.
3) Feeder bays should be equipped with high speed breakers with an overcurrent trip device.
4) The overcurrent trip devices of high speed breakers should ensure an appropriate setting range of current values. The maximum setting values of the high speed breaker overcurrent trip devices must not be greater than the minimum short-circuit current reduced by 10%, but not less than 300 A.
5) The automation system of the feeders should ensure an automatic catenary isolation test before the switch-on of the circuit breaker. The limit value of the permissible load occurring during the catenary isolation test should be adjusted.
6) High speed breakers feeding jointly one section of a line with circuit breakers of the neighbouring substation should be connected with a dependency system.
7) The +3 kV DC busbar should be equipped with undervoltage protection.
8) The 3 kV circuit breaker cell controller should ensure control and supervision over the 3 kV high speed breaker and other cell instrumentation. Control of the circuit breaker operation should be possible both from the manual control level and via the CAN-Bus/RS485 bus (issuing commands from the substation terminal or from the Central Control Room). The controller should also ensure compatibility with dependency support.
9) For 3 kV DC switching-station with controlled disconnector switches of bypass bus or bypass and main bus, the controller should not support the control of these disconnector switches for the supervised high speed breaker. These functions may be performed by the back-up circuit breaker controller or other dedicated controllers.

10) The 3 kV switching-station cell controller together with co-operating equipment should be adapted to install a circuit breaker in the cell in a manner ensuring safe and convenient access to control elements and information provided by the controller.
11) The measuring accuracy of 3 kV DC voltages and currents flowing through 3 kV high speed breakers executed by cell controllers should not be lower than:
a) 2% for voltages within the range of rated values ± 30%,
b) 10% for currents in the range from 10,000 A to 4,000 A,
c) 5 % for currents in the range from 4000 A to 2000 A,
d) 2 % for currents in the range from 2000 A to 1000 A,
e) 5 % for currents in the range from 1000 A to 500 A,
f) 10% for currents in the range from 500 A to 200 A.
12) Currents should be measured in both directions.
13) The current and voltage measuring transducer should be supplied with 3 kV DC measured voltage and ensure galvanic isolation.
14) The controller structure and software should ensure protection against incorrect and unintentional control both during normal operation of the controller and in case of its fault.
15) The controller should ensure compatibility with the dependent circuit breaker in the neighbouring structure, communicating via the communication bus and an additional controller supporting the dependency transmission.
16) Descriptions of control elements should be clear, unambiguous and permanent. Information provided by the controller should be clear and unambiguous. This information should illustrate the condition of the monitored circuit breaker and other instruments in the cell, the condition and operation mode of the dependent circuit breaker, the voltage supplied to the catenary and the current consumed.
17) The main function of the 3 kV circuit breaker cell controller in the traction substation is to provide control of the 3 kV high speed breaker operation. The controller should enable:
a) operational (intended) switch-on of the circuit breaker,
b) operational (intended) switch-off of the circuit breaker,
c) dependent switch-on of the circuit breaker,
d) dependent switch-off of the circuit breaker,
e) automatic switch-on of the circuit breaker after an overcurrent or dependent circuit breaker switch off,
f) switch-off of the circuit breaker by overcurrent protection,
g) switch off of the circuit breaker by other protections not implemented directly by the controller (e.g. activation of undervoltage or earth protection in the substation).
18) Any circuit breaker switch-on, except for overhaul switch on, must be preceded by a catenary isolation test, the result of which determines whether the circuit breaker is to be switched on (if the test result is positive) or not (if the result of one or more subsequent tests is negative). The maximum number of catenary isolation tests performed before switch-on of the circuit breaker should be specified as 2 or 3. A negative result of all permissible catenary isolation tests should block the circuit breaker switch-on until the operational (intended) switch-on is performed.
19) An automatic switch-on of the circuit breaker should take place after an overcurrent switch-off. In the case of an overcurrent switch-off occurring within 10 seconds after the circuit breaker is automatically switched on, a subsequent automatic switch-on should not be possible until an operational (intended) switch on is performed.
20) It should be possible to switch on the circuit breaker only after a time depending on the maximum current value read during the last switch-off. The controller software should enable determination of the relation between the time to initiate the switch-on and the current value at which the last switch-off took place based on the data of the high speed breaker manufacturer.
21) Operational switch-on and switch-off of the circuit breaker must be possible both by means of control elements (e.g. a button or a lever) and by means of commands sent to the controller via the communication bus (e.g. from the terminal or the Central Control Room).

22) If more than one circuit breaker is switched off at the same time, the cell controllers of the 3 kV switching station should ensure time detuning between switching on of the subsequent circuit breakers.
23) In order to perform a catenary isolation test, the controller must enable control of the catenary isolation test contactor(s) and read the test result by measuring the voltage value supplying the catenary. The course of the circuit breaker switch-on procedure with a catenary isolation test should be as follows:
a) waiting before the catenary isolation test (min. 5 s),
b) activation of the catenary isolation test contactor(s),
c) waiting for a specified period to determine the catenary isolation test result (0.5 ÷ 2 s),
d) reading the catenary isolation test result by voltage measurement,
e) deactivation of the catenary isolation test contactor(s),
f) if the test result is negative, then after a period not shorter than two seconds, the catenary isolation test should be reinitiated,
g) if the test result is positive, the circuit breaker switch-on should be initiated.
24) In the case of a 3 kV DC switching station with controlled disconnector switches of bypass bus (or bypass and main bus), the automation system of the 3 kV switching-station of traction substation should enable control of these disconnector switches.
25) The bypass bus disconnector switch allows to reserve the relevant high speed breaker with a back-up circuit breaker. This ensures the possibility of energising the catenary in case of fault of the appropriate high speed breaker or its control circuits.
26) Control of the bypass bus disconnector switch should be possible only if:
a) circuit breaker is switched off,
b) the disconnector switches of the reserve bus in the remaining switching station cells are open,
c) the back-up circuit breaker is switched off.
27) The control should enable opening and closing of the reserve bus disconnector switch provided that the above requirements are met, and it should be possible both by means of actuators (buttons or levers) co-operating with the controller and by means of a command sent via the communication bus.
28) Control of the main bus disconnector switch should be possible only if:
a) circuit breaker is switched off,
b) the reserve bus disconnector switch is open.
29) Both the bypass and main bus disconnector switch should not be controlled by the automation system (controller) of the cell in which these devices operate. These functions should be performed by the back-up circuit breaker controller or by another dedicated controller.
30) The cell controller of the 3 kV circuit breaker should ensure recording of at least 200 recent control operations of the circuit breaker with the recording of the following data:
a) date and time with an accuracy of 10 milliseconds,
b) cause (command, automatic change, etc.),
c) maximum current at switch-off time.
31) In the case of automatic switching off of the circuit breaker or switch-off by dependencies, recording in the sequence of events should also be provided, i.e. whether the automatic switch-off took place first, followed by a command to switch off the circuit breaker by the dependencies or vice versa.
32) The controller should also record the number of switch-offs performed by the circuit breaker divided into at least six groups (counters) depending on the current at which the switch-off occurred. Current threshold values for individual counters should be set by the user.
33) The user should be able to reset and view switch off counters and view recorded events.
34) The controllers should enable remote reading of recorded events (e.g. by the substation terminal or from the Central Control Room).

#### 3.3.3.5. Minus cell

1) The negative busbar should be equipped with an earth protection device shorting the negative bar with earthing when the potential of the negative bus rises above the set threshold. This protection should also be provided in an overcurrent relay switching off the 3 kV switching station and rectifier units.
2) Ammeters should be installed in the return cable circuits to enable the measurement of current distribution to individual cable groups. The signalling of the earth protection activation, earth fault of the negative bus and the presence of supply voltages should also be ensured.
3) It is recommended that the minus cell be equipped with devices for controlling earthing and return cables.

#### 3.3.3.6. Auxiliary needs

1) Low voltage AC circuits should be protected with automatic circuit breakers and, in justified cases, thermal fuses.
2) DC circuits should be protected with thermal fuses or automatic circuit breakers intended for use in DC circuits.
3) Power supply rectifiers should be protected in accordance with the manufacturer’s instructions.
4) Battery banks should be protected with thermal fuses.
5) The switching station should ensure remote and local measurement of battery voltage and detect irregularities such as battery earth fault. It is also recommended to perform AC low voltage measurements, if possible.

#### 3.3.3.7. Substation terminal

1) The basic functions of the substation terminal are to inform about the condition of monitored equipment and to ensure control of such equipment.
2) The information to be provided by the terminal is mainly:
a) full information on the substation main circuit equipment (circuit breakers, disconnector switches, earth protection, undervoltage protection, etc.),
b) information on the equipment in the power supply facilities co-operating with the substation (co-operating high speed breakers in neighbouring substations),
c) information on the operation of the substation auxiliary power supply switchgear,
d) information on the operation of battery banks together with the charging system,
e) information on the operation of external equipment controlled from the substation (e.g. catenary disconnector switches and non-traction line),
f) information on the operation of auxiliary equipment in the substation (such as air-conditioning controllers, burglar alarm system, fire alarm system, etc.).
3) Additionally, the terminal should enable the display of the values of measurements performed by individual pieces of equipment, in particular:
a) voltage values on feeders and non-traction lines,
b) voltage at traction substation 3 kV busbars,
c) values of currents flowing through individual high speed breakers in the 3 kV switching station,
d) values of auxiliary voltages and battery banks.
4) The terminal display should also include the name of the substation and, if necessary, the names of adjacent traction substations.
5) Control of equipment operation should be possible only after switching the substation to local operation mode and it should be executed in a manner ensuring control unambiguity (the function of re-confirming the control operation requested by the operator).
6) In all operation modes, equipment operation information should be correctly provided on the substation terminal display and in the Remote Control Centre.

#### 3.3.3.8. Dependency system of high speed breakers

1) High speed breakers together with circuit breakers of the neighbouring substation (point) supplying one section of the line should be equipped with a dependency system.
2) The dependency system should guarantee appropriate voltage isolation of transmission lines. Dependencies regardless of the transmission means should use the transmission protocol for dependencies used in adjacent power supply sections, regardless of the power supply system operator.
3) The response time of dependencies on the occurrence of an automatic switch-off signal from the circuit breaker to initiate the switch-off of the dependent circuit breaker should not be longer than 100 ms.
4) Dependencies should also ensure, in case of switch-on of the back-up circuit breaker, automatic switching of dependencies from the circuit breaker being replaced to the back-up circuit breaker.
5) Information on the operation of the dependent circuit breaker should include:
a) circuit breaker status (on/off),
b) reason for circuit breaker switching off (overcurrent switch-off, use of emergency stop button, activation of undervoltage or earth protection).

#### 3.3.3.9. Metering and settlement equipment

1) The power consumption monitoring and energy consumption settlement system should form a system independent of the remote control system. However, this does not mean that there are no links between the systems. It is essential to strive for the common use of data transmission equipment.
2) Power consumption monitoring and energy consumption settlement systems should ensure the possibility of collecting information through remote control and making it available in the Central Control Room. The collection of information on the current power consumption (for 15-minute power monitoring) should be performed in real time (delay of 2-6 seconds).
3) For longer delay times, it is not possible to respond quickly enough to reduce power consumption. Selected information from the energy consumption monitoring and settlement system should be made available to the power supply dispatcher. This requires an appropriate connection between the systems.
4) Power overrun monitoring automation devices should be used in transformer bays of rectifier units in traction substations fed with MV voltage.
5) The task of the power overrun monitoring automation devices is to switch off the rectifier unit after exceeding the 15-minute power of the substation and to signal it to the Central Control Room.
6) The source of activation of the power overrun automation devices are the energy meters connected with the measurement of feeders. After exceeding the settable 15-minute power threshold, the signal is fed to the inputs of controllers (protections) of the rectifier unit bays.
7) The switch-off of individual rectifier units should depend on the coupler circuit breaker condition. For systems with an open coupler, only units within the section where power has been overrun are switched off. For systems with a closed coupler, the power overrun signal switches off all rectifier units.
8) After the power overrun signal ceases, the circuit breaker of the rectifier unit should be automatically switched on once the following conditions are met:
a) the reason for the switch-off was the power overrun;
b) the input to which the overrun signal was fed has been de-excited;
c) no operation lock of the power overrun monitoring automation.
9) There should be a possibility of remote and local locking and unlocking of the power overrun monitoring automation.

#### 3.3.3.10. Burglar alarm and fire alarm systems

1) Traction substations and sectioning points should be equipped with burglar and fire alarm systems.
2) High-quality components should be used in the construction of the systems to guarantee no false alarms.
3) These systems should be equipped with their own batteries allowing at least an 8 hours of unpowered operation.
4) Both systems should ensure co-operation with the remote control system and have the necessary certificates.
5) Burglar alarm system should cover all rooms.
6) The fire alarm system outside the rooms should be equipped with detectors also in major cable tunnels.

#### 3.3.3.11. Communication and data transmission equipment

1) Each traction substation and sectioning point should be equipped with a telephone connected to the general operational communication network.
2) For the substation or point, a spare means of communication should also be provided. Depending on local conditions, this means may be selector communication, radio communication in the railway band, a telephone of another operator and GSM-R.
3) In cases where modern communication solutions based on digital equipment are used on the railway line, the selector should not be considered as a back-up communication as all communication is defined as traditional wired communication over the same transmission paths and exchanges.

## 3.4. Overhead catenary system in the 3 kV DC system

### 3.4.1. Contact line parameters

#### 3.4.1.1. General recommendations

1) On railway lines of category I railway infrastructure, when designing supporting structures, the infrastructure gauge determined on the basis of the kinematic outline given in the EN 15273-2:2013 standard (first column of Annex A.3.12)[1], as described in the TSI “Rolling stock” — locomotives and passenger rolling stock' subsystem of the rail system in the European Union” Commission Regulation (EU) No 1302/2014[2] and/or the kinematic parameters and structure gauge GC, should be taken into account.
2) In track sections laid in curves, the horizontal distances to trackside structures above the rail head should be increased by the size specified in the relevant documents. .
3) In all cases, deflection of supporting structures should be taken into account at the highest characteristic load also with wind load.
4) The provisions on the distance of the supporting structures from the centre line of the nearest track should also apply to the outages of these structures and to all auxiliary structures and accessories mounted on the supporting structures.
5) The performance parameters to be met by P2, M2, P3/P4, M3 contact lines are as follows:
   a) maximum line speed,
   b) the minimum permissible time interval between trains,
   c) train power consumption at the collection point,
   d) maximum current consumed by a train,
   e) average effective voltage,

f) timetable and scheduled maintenance.

6) When calculating the overhead catenary system, the maximum driving speed should be assumed as follows:
   a) 250 km/h for P2, M2 railway lines,
   b) 200 km/h for P3/P4, M3 railway lines.
7) For calculations, the design horizontal curve radius of the track should be assumed, as specified in point 5 entitled: Geometric parameters in the horizontal plane of Volume I.1 Railway track – Layout geometry.
8) The calculations should take into account the minimum permissible horizontal curve radius of the track equal to 600 m for railway lines from P2 to P4 and M2 to M3.
9) The following characteristic temperatures should be adopted during calculations:
   a) minimum temperature: -30°C,
   b) rime ice temperature: -30°C,
   c) normal temperature: +10°C,
   d) temperature at wind: +10°C,
   e) maximum temperature: +40ºC,
   f) the following operating stress values should be used:
   – contact wires – at least 200 MPa,
   – messenger wires – 150 MPa.
10) The largest span on a straight line is determined from the wind-out condition. The maximum deviation of the contact wire from the track centre line given in the TSI “Energy” [3] – point 4.2.9.2 should not be exceeded as long as the proper dynamic joint operation of the contact line with current collectors is ensured.
11) For travel speeds of 250 km/h and above, it is not allowed to profile the height of the contact wire. For lower speeds, the permissible inclination values of the contact wire are specified in PN-EN 50119:2020 [4] – point 5.10.3.
12) Detailed requirements concerning exposures for networks and systems not related to railway traffic are provided in Volume X.

#### 3.4.1.2. Mechanical wave propagation velocity

1) The mechanical wave propagation velocity should be selected so that the maximum travel speed on a given line does not exceed 70% of the wave propagation velocity.

#### 3.4.1.3. Contact line geometry

1) The contact line for the 3 kV DC power supply system should be designed for pantographs with a head length of 1950 mm.
2) In accordance with the requirements of point 4.2.9.1 of the TSI “Energy” [3] and point 5.1 of PN-EN 50367:2012 [5], the rated height of the contact line for driving speeds exceeding 250 km/h should be between 5080 and 5300 mm. The minimum height of contact wire suspension is 5080 mm and the maximum height is 5300 mm.
3) The level of any contact line wire should not be lower than the level of the contact wire of the track to which the wire belongs under the most unfavourable design atmospheric conditions
4) Contact wire stagger should amount to:

a) along a straight line ± 200 mm,
b) on bends with a radius of R < 4000 m, the contact wire should be routed in the middle of the span tangentially to the track centre line, the stagger should be increased in the suspension area, and should not exceed 360 mm,
c) basically, the full contact wire stagger cycle should be completed within two directly following spans, the stagger between the messenger wire and the contact wire should be the same and in the same direction.

5) The maximum lateral deviation of the contact wire relative to the track centre line in crosswind is 550 mm for a 1950 mm long pantograph. The values should be adjusted taking into account the movement of the pantograph and track tolerances according to Appendix D.1.4 of TSI “Energy”.
6) Wind loads should be calculated in accordance with the requirements specified in point 4.3. ab. 2 of the PN-E-50341-2-22:2016 [6] standard for a height of <300 m (a.s.l.). The K factor of the overhead catenary system should be calculated according to the rules given in point 6.2.4 of the EN 50119:2009 [7] standard taking into account the impact of hangers and hanger brackets.

#### 3.4.1.4. Distance of the contact line from earthed structures

1) In the most unfavourable design atmospheric conditions, the distance between the components of a contact line or a live current collector and earthed structures should amount to at least 150 mm, unless otherwise specified below.
2) The distance of the overhead catenary system or its live parts from parts of the visual signalling equipment and from parts of the external lighting equipment supplied by a cable should be at least:
a) 1,500 mm from the signal pole and from the edge of the lighting fitting. With reference to lighting equipment, this distance should be measured in the horizontal plane,
b) 1000 mm from the edge of the light signal luminaire and other visual signalling elements.
3) These distances should be maintained in all operating positions of the elements of signalling devices and external lighting at the most unfavourable design weather conditions.
4) Distances between the live contact line or its components and the areas intended for human occupancy are specified in PN-EN 50122-1:2011 [8] – point 5.1.2.
5) The distances referred to in point 3.4.1.4 4) may be reduced provided that barriers meeting the requirements specified in PN-EN 50122-1:2011 [8] – point 5.1.3. are used.
6) In the insulated overlap span, when calculating the maximum span, the following should be assumed:
a) at the section where the wires of two lines are routed in parallel, the contact wires on the wind side protrude from the track centre line by the value generated by wind pressure, and the contact wires of the other line by half of this value,
b) the horizontal distance between the line wires of different tension sections routed in parallel should be at least 200 mm in windless conditions and at least 75 mm in wind conditions (distances measured between the axes of the nearest wires),
c) the vertical distance between the line wires of different tension sections routed in parallel should, at the point of their crossing, be at least 200 mm for bare wires, and at least 150 mm for wires from which the wires crossing on top are in an insulating sheath (distances measured between the axes of the nearest wires),
d) the distance between the accessories of different tension sections belonging to different electrical circuits should be 200 mm, under the most unfavourable atmospheric conditions (wind).
7) The distance of the overhead catenary system or its live parts from parts of the visual signalling equipment and from parts of the external lighting equipment supplied by a cable should be at least:
a) 1,500 mm from the signal pole and from the edge of the lighting fitting. With reference to lighting equipment, this distance should be measured in the horizontal plane,
b) 1000 mm from the edge of the light signal luminaire and other visual signalling elements.
8) These distances should be maintained in all operating positions of the elements of signalling devices and external lighting at the most unfavourable design weather conditions.
9) Distances between the live contact line or its components and the areas intended for human occupancy are specified in PN-EN 50122-1:2011 [8] – point 5.1.2. These distances may be reduced provided that barriers meeting the requirements specified in PN-EN 50122-1:2011[8] – point 5.1.3. are used.

#### 3.4.1.5. Pantograph static contact force

1) For the 3000 V system, the static contact force is defined in point 7.2 of EN 50367 [5] and is exerted by the pantograph on the contact wire. The overhead catenary system should be designed for a static contact force of 90 to 120 N in accordance with point 7.2 of PN-EN 50367:2012 [5].

#### 3.4.1.6. Cross-sections and materials of contact line components

1) The overhead catenary system should be constructed in accordance with the requirements specified in point 4.2 of the TSI "Energy" [3] and points 5 and 6 of PN-EN 50119:2009 [7] – points: 5 and 6 and UIC 799-1 [9]
2) It is recommended to use tension-regulated insulator string networks consisting of the following depending on the electricity demand: one messenger wire and one contact wire, one messenger wire and two wires or two messenger wires and two wires.
3) It is recommended to use the following construction heights for new types of contact lines:
a) 1.70 m for open line contact lines and main straight tracks of stations,
b) 1.30 m for station siding track networks.
4) For the (upper) overhead catenary system of the 25 kV power supply system in the pantograph area, in accordance with point 4.2.10 of the TSI "Energy"[3], no part of the energy sub-system should enter the mechanical kinematic pantograph gauge (GC) except for the contact wire and steady arm. A description of the procedure for calculating the mechanical gauge is given in Appendix D to the TSI "Energy" [3]. The pantograph gauge is maintained if the mechanical and electrical gauge is maintained at the same time.
5) For the 3000 kV power supply system, the minimum insulation clearances should be used between the energised overhead catenary system components and the earthed components in accordance with point 5.1.3 of PN-EN 50119:2009 [7], amounting to 150 mm in static conditions and 50 mm in dynamic conditions.
6) The contact wire should meet the requirements of PN-EN 50149:2012 [10] – tables 1, 3, 4 and 5. Materials approved for use in contact wires are copper and copper alloys. It is recommended to use materials marked in the above-mentioned standard with the following symbols: Cu-ETP CuAg0.10, CuMg0.02.
7) The recommended contact wire diameter is 100 $mm^2$ and 150 $mm^2$.
8) Stresses in the maximum wire wear condition must not exceed the permissible values in accordance with PN-EN 50119:2009 [7] – point 5.3.1.
9) The messenger wire should be made of copper or copper alloy and meet the requirements of PN-E-90081:1974 [11].
10) The recommended messenger wire diameter should be from 100 $mm^2$ to 150 $mm^2$.
11) Stresses calculated in the maximum wire wear condition according to point 5.4.1 of PN-EN 50119:2009 [7] may not exceed the permissible values.
12) Wire mechanical permanent and momentary loads. Permanent forces should be taken into account, i.e. weight of the wire and accessories of the contact line, tension of the wires. Momentary loads should also be taken into account, i.e. weight of rime ice, wind pressure, current collector contact force, loads during line installation, loads during the breaking of wires.
13) The rime ice loads of the contact line wires should be determined in accordance with point 4.5 of table 4 of PN-E-50341-2-22:2016 [6].
14) Catastrophic rime ice is not taken into account. The weight of rime ice on hangers and overhead catenary system accessories should not be taken into account.
15) In overhead catenary systems of the 3000 kV system, smooth-surface supporting structures made of steel or of pre-tensioned concrete reinforced from the bottom with steel bars should be used.
16) Steel supporting structures should be hot-dip galvanised in accordance with the requirements

of PN-93/E-04500 [12], and then painted twice with paints of the colour and type determined by the overhead catenary system administrator. The thickness of the zinc coating should be at least 60 µm.

17)It is recommended to build foundations using the piling technique. Pile foundations should be constructed as follows:

a) They should be driven with a suitable pile driver, which will allow them to be sunk to the planned depth without damage,

b) When striking the top of the pile head with the hammer, it shall be ensured that the hammer and pile are concentric and that the impact is perpendicular to the top of the head,

c) The impact velocity should be adjusted to the pile type and soil conditions.

d) It is allowed to build foundations as block and cast foundations. Foundation heads should be made of concrete of a class not lower than B-30.

e) The head of the prefabricated concrete pile foundation, which is hit during driving, should be protected with a washer ensuring reduction and uniform distribution of stresses on the top of the pile head.

18)The load-carrying and conductive accessories (connectors, holders, etc.) should be made of copper alloys in the forging technology.

19) Requirements for supporting structures

a) When constructing the overhead catenary system, the primary solution is to use individual supporting structures of the contact line in the form of individual galvanised, painted, smooth-surface steel poles fastened to pile foundations with bolts. Supporting structures of a different design are allowed.

b) In special cases, it is allowed to use cast foundations for prefabricated moulds sunk in the ground.

c) It is allowed to use portal structures, especially at stations. The recommended structure consists of one-span portals with a span of up to 34.5 m.

d) Static calculations and designing of steel supporting structures should be performed on the basis of ZN-87/MTŻiŁ-CBP-11 and PN-B-03200.

e) Static calculations and designing of reinforced concrete supporting structures should be performed on the basis of PN-B-03264:2002 and ZN-89/M ŻiŁ-CBP-10.

f) Supporting structures should be isolated from foundations. This also applies to the stays of supporting structures.

g) The structures of the contract line of each track of a double-track route should be arranged symmetrically, opposite each other.

h) The placement of individual contact line supporting constructions at stations should be avoided.

i) The supporting structures of the contact line should be spaced so as to maintain the visibility of light signals.

20) Requirements for accessories

a) The accessories mounted on contact wires should be of sufficient strength and light weight to ensure the most favourable conditions of contact line flexibility.

b) Terminals and connectors should be designed so that during current flow they do not show a voltage drop higher than the wire section of the same length, whereas the temperature of this accessory should not be higher than the wire temperature.

c) The mechanical tensile strength of holders and connectors should be at least equal to the breaking force of the wire. The mechanical strength of holders adapted to fix two or more wires should be at least equal to the sum of forces breaking individual wires.

d) It is not recommended to use bolts with a dimension of less than M12 for connecting the accessory elements, unless it is permitted by structural considerations of a given element.

e) Conductive load-carrying accessories should be made of copper alloys by pressing.

f) The load-carrying and conductive accessories (connectors, holders, etc.) should be made of copper alloys using forging technology.

g) The safety factor for slipping and tearing for heavy-tensile accessories should be 1.54.

21) Contact wire connectors

a) In new contact lines of open lines and main straight tracks of stations, it is not allowed to use contact wire connectors.

b) The cross-section of electrical connection cables of contract lines should be at least 50% of the larger of the total cross-sections (messenger wire and contact wire) of the connected contact lines.

22) Hangers

a) The design should ensure permanent (non-sliding) location of the hanger in the place of installation on the messenger wire, auxiliary wire or contact wire.

b) The design of hangers should ensure conductivity. Depending on the type of line, hangers should be made of copper wire (Cu) or copper alloy wire (BzII) with a cross-section of 10-16 $mm^2$.

c) The length of a single hanger should not be smaller than 250 mm.

### 3.4.2. Isolation of the contact line

1) Isolation – an electrical division of the contact line should ensure:

a) process requirements concerning train traffic in normal conditions, taking into account traffic operation in special conditions – emergency or scheduled exclusion of (a) track(s),

b) the reliable power supply of the line during a failure, with guaranteed minimum voltage drops,

c) possibility of performing repairs and maintenance works.

2) For OHS reasons, the electrical division of the contact line should not be excessively extended.

3) The contact line should be isolated by:

a) longitudinal isolation – an electrical division of the contact line of the same track,

b) transverse isolation – an electrical division of the contact line between adjacent tracks.

4) Longitudinal and transverse isolation of the line should be performed by using:

a) insulated overlap spans,

b) section insulators,

c) insulating inserts.

5) As line isolation connecting elements, section power disconnectors and disconnector switches should be used.

6) It is recommended to use power disconnectors (enabling switching off of operating currents) in the following locations:

a) power supply division of the contact line (substations, sectioning points),

b) station electric boundaries,

c) overhead catenary system power supply points.

7) In places not listed in point “6)”, it is recommended to use section disconnector switches as connecting elements.

8) The design of section power disconnectors and disconnector switches should ensure a current flow not lower than the permissible load current of the contact line.

9) The contact line of the main tracks on an open line should be isolated from the lines belonging to the station in such a way that it is possible to operate train traffic in the entry and exit ramifications of the station in accordance with the set process requirements of the operating control point. Such isolation should also ensure that it is possible to de-energise a section of an open line contact line or tracks at the station for repair or maintenance purposes in such a way that the train can travel:

a) from a correct open line to an incorrect main straight track of the station with the main straight track of the station de-energised,

b) from a correct main straight track of the station to the track of an incorrect open line, with the appropriate open line de-energised.

10) The insulated overlap spans should function as station electric boundaries. If it is necessary to use a section insulator as a station electric boundary, it should be located near the middle

anchorage or permanent anchorage of the contact line. The (permanent) middle anchorage should be located between the section insulator and the open line contact line.

11) The insulated overlap spans constituting the boundaries of different power supply circuits should be located taking into account the location of traction substations, sectioning points and semaphores, so as to maintain the possibility of passage of electric vehicles with the main circuits switched off.
12) Longitudinal isolation elements located within the station should be placed behind the semaphores when looking in the travel direction.
13) On double- or more track lines, the contact lines of tracks on an open line and main straight track networks within the area of the station should be separated from each other.
14) Within the station, it is also necessary to isolate from each other the contact lines of tracks with different functional purposes, in particular:

a) overhead catenary systems of main secondary tracks from the main straight track network,
b) overhead catenary systems of siding tracks from the main secondary track network,
c) single-purpose overhead catenary systems of siding fans from other-purpose siding track networks (e.g. a network of an arrival siding fan from a network of a departure siding fan or a network of cargo tracks from a network of other tracks).

15) The number of main secondary track networks constituting an electrically integrated whole should not exceed two and the number of siding track networks should not exceed four.
16) Each siding fan, which is important in terms of traffic, should have at least two independent power supply directions.
17) The placement of section power disconnectors and disconnector switches should be avoided on the anchoring poles of a contact line, especially when the anchoring of the messenger wires and contact wires is separated and when two tension sections are anchored on one pole.
18) Section power disconnectors or disconnector switches of a contact line and power disconnectors of a power supply points should not be placed on one pole.
19) It should be avoided to use in series more than two section disconnectors, i.e. one isolating the network of the whole sifing fan and one of further subdivision. This rule does not apply to track networks through which emergency power supply is planned and to networks of communication tracks.
20) Manually operated disconnector switches within a substation should be grouped, if possible, so that they are as close as possible to the point from which they are to be operated.
21) A contact line supplied by a disconnector switch with a contact connecting to the rail may be supplied only through this one disconnector switch, except for the arrangements specified in points 23 and 25.
22) A contact line running over tracks such as terminal load tracks, stabling sidings for minor repairs of rolling stock should be isolated from the remaining part of the live line and equipped with a disconnector switch with a contact causing its connection to the rail after disconnection.
23) A contact line running over the tracks of stations for electric vehicle sanding, inspection channels, platforms for current collector adjustment, washing of rolling stock should be isolated from the remaining part of the live line and should be equipped with a disconnector switch with a contact causing the connection of this section to the rail after its disconnection. The other side of the line section should be provided with a second disconnector switch (connected unilaterally to the line of the disconnected section, without the possibility of energising) with a contact causing its connection to the rail only after it has been connected to the rail by the first disconnector switch. Both disconnector switches should be coupled in a manner ensuring appropriate interlocking of their mutual position and signalling of voltage condition. If a contact line terminates at a close distance outside the discussed stations and it is not possible to supply the section on the other side, the second disconnector switch is redundant.
24) A contact line entering a building (e.g. an electric locomotive shed) should be isolated from the remaining line and equipped with a disconnector switch with a contact causing the line to be connected to the rail inside the building after de-energising. The disconnector switch should be

provided with position signalling (open, closed) visible from the outside and inside the building, from each place where works may be performed in the vicinity of the line.

25) A contact line running in tunnels should provide a possibility of isolating it on both sides from the remaining part of the line (at its terminations) through disconnector switches with a contact allowing for connection to the rail. Both disconnector switches should be coupled in a manner ensuring simultaneous connection to the rail.
26) Requirements for separation sections of power supply systems specified in Volume II.1
27) Requirements for tension section:

a) The maximum length of a tension section should not exceed 1260 m.
b) For tension sections of a contact line tensioned on both sides, line middle anchorages should be used. The maximum length of a contact line section between the balance weight termination and middle anchorage is 630 m.
c) The lengths of contact line tension sections should be determined so that the overlap spans located near the entry and exit semaphore of a station ensure maximum visibility of these semaphores.
d) The lengths of contact line tension sections should be determined so that the location of the overlap span is possible at a distance of not less than 10 m before a passenger stop platform in accordance with the relevant direction of travel.

28) Marking of section power disconnectors and disconnector switches should be distinguished by a graphic symbol.
29) Power disconnectors or disconnector switches installed on longitudinal isolation elements, for connection of contact lines of normally mutually isolated tracks, for disconnection of feeders from the contact line should be marked with one, two or three-digit numbers.
30) Power disconnectors mounted on longitudinal isolation elements at traction substations and sectioning points should be marked only with three-digit numbers ending with 1 or 2. The last digit of the number is used to define the track (odd, even) on which the contact line is longitudinally isolated.
31) Power disconnectors installed to disconnect feeders from traction substations or sectioning points from the contact line should be marked with two or three-digit numbers, in which the last digit is zero. The odd or even number should specify the track (odd and even) over which the contact line is supplied.
32) The disconnector switches cutting off the contact lines of individual tracks in the electric locomotive shed hall should be marked with the number of the main disconnector switch cutting off the network of the fan of sidings introduced into the hall slashed by the track number in the electric locomotive shed.
33) The disconnector switches of the switching stations cutting off the power supply of subsequent tracks in the fan of sidings supplied with a separate feeder should be marked with the number of the main disconnector switch of the feeder with the addition of a capital letter of the alphabet.
34) The last digit of the number or one-digit number should be characterised by the operating purpose of the power disconnector or disconnector switch. The other digits are used to distinguish between power disconnectors or disconnector switches whose characteristic digits are the same. In the area of a given station, each power disconnector or disconnector switch should be marked with a different number.
35) The numbers of power disconnectors or disconnector switches should be marked as follows:

a) 1; 11...91 – power disconnector or disconnector switch installed on the longitudinal isolation element separating the track network of the odd open line from the main straight track network of the station – on the side of the entry to the station,
b) 2; 12...92 – power disconnector or disconnector switch installed on the longitudinal isolation element separating the track network of an even open line from the main straight track network of the station – on the side of the entry to the station,
c) 3; 13...93 – power disconnector or disconnector switch installed on the longitudinal isolation element separating the track network of an odd open line from the main straight track network of the station – on the side of the exit from the station,

d) 4; 14...94 – power disconnector or disconnector switch installed on the longitudinal isolation element separating an even track network of the open line from the main straight track network of the station – on the side of the exit from the station.
e) 5; 15...95 – power disconnector or disconnector switch used for direct connection of an odd track network of the open line or main straight track of the station to an even track network of the open line or main straight track of the station,
f) 6; 16...96; 206...306... – disconnector switch with a contact connecting to the rail used to disconnect and connect the contact line to the rail,
g) 106; 116...196 – disconnector switch with a contact connecting to the rail used to disconnect and connect the network of fan of sidings introduced to the hall to the rail (e.g. electric locomotive shed),
h) 106/1; 106/2... – disconnector switch with a contact connecting to the rail used to disconnect and connect the network of individual subsequent tracks introduced into the hall to the rail (e.g. electric locomotive shed),
i) 7; 17...97 – disconnector switch installed on the longitudinal isolation element dividing an odd main straight track network into electrically independent parts,
j) 107; 117...197 – disconnector switch used to disconnect the network of odd main secondary or siding tracks from the network of an odd main straight track,
k) 8; 18...98 – disconnector switch installed on the longitudinal isolation element dividing an even main straight track network into electrically independent parts,
l) 108; 118...198 – disconnector switch used to disconnect the network of even main secondary or siding tracks from the network of an even main straight track,
m) 9; 19...99; 109... – disconnector switch used to connect networks of tracks or fan of sidings located in the area of the station, which are not covered by the above-mentioned definitions, with each other.

36) For disconnector switches with the same last digit characterising the operating purpose of series 7; 107 or 8; 108 installed on longitudinal or transverse isolation elements of the line, the numbering should be increasing in accordance with the direction of travel of the primary reference track (odd or even main straight track). In case of difficulties in determining the main direction of travel, for series 5; 15 and 6; 16 disconnector switches or series 9; 19 fan of sidings, the numbering should be increasing according to the direction of the main line chainage:

a) 101; 111...191 – power disconnector located in the network of an odd main track on the longitudinal isolation element belonging to the traction substation or sectioning point,
b) 102; 112...192 – power disconnector located in the network of an even main track on the longitudinal isolation element belonging to the traction substation or sectioning point,
c) 10; 110...910 – power disconnector disconnecting the feeder from the contact line of an open line odd track, located on the side of the entry to the station or power disconnector at the traction substation or sectioning point disconnecting the feeder from the contact line of the odd track, located in front of the longitudinal isolation element, looking in the direction of travel,
d) 20; 120...920 – power disconnector disconnecting the feeder from the contact line of an open line even track, located on the side of the entry to the station or power disconnector at the traction substation or sectioning point disconnecting the feeder from the even track contact line, located in front of the longitudinal isolation element, looking in the direction of travel,
e) 30; 130...930 – power disconnector disconnecting the feeder from the contact line of an open line odd track, located on the side of the exit from the station or power disconnector at the traction substation or the sectioning point disconnecting the feeder from the odd track contact line, located behind the longitudinal isolation element, looking in the direction of travel,
f) 40; 140...940 – power disconnector disconnecting the feeder from the contact line of an open line even track, located on the side of the exit from the station or power disconnector at the traction substation or sectioning point disconnecting the feeder from the contact line of the even track, located behind the longitudinal isolation element, looking in the direction of travel.

37) The power disconnectors numbered 10; 20; 30; 40 together with their derivatives should have a similar numbering as the power disconnectors located nearby on longitudinal isolation elements in accordance with the following principle:

a) in front of power disconnector No. 1 or 101 on the longitudinal isolation element, looking in the direction of travel, power disconnector No. 10 of the feeder should be placed,
b) in front of power disconnector No. 11 or 111, power disconnector No. 110 of the feeder should be placed,
c) behind power disconnector No. 3 or 103 on the longitudinal isolation element, looking in the direction of travel; power disconnector No. 30 of the feeder should be placed,
d) behind power disconnector No. 13 or 113, power disconnector No. 130 of the feeder should be placed.
e) 60 – power disconnector disconnecting the feeder from the contact lines of the fan of sidings introduced to the hall (e.g. electric locomotive shed),
f) 70 – power disconnector disconnecting the feeder from the contact lines of the odd side of the station,
g) 80 – power disconnector disconnecting the feeder from the contact lines on the even side of the station,
h) 90; ...190 – power disconnector disconnecting the feeder from the contact lines of the separated fan of sidings within the station.

38) The number of the power disconnector should be preceded by the letter “R”, such as R1, R101.
39) In case of construction of a switching station enabling disconnection of the line of individual tracks or a fan of sidings directly behind the power disconnector 70; 80; 90; ...190; individual further power disconnectors should be numbered with the base number with the addition of a dash and a next capital letter of the alphabet, e.g. 70-A; 70-B etc. except that letters I, J, Ł, O, Q, R, V, X and Y should not be used.

### 3.4.3. Contact line crossings

1) The overhead crossing design should ensure passage on the main track (straight) at the maximum speed for a given contact line type. When driving on the turnout tracks, the speeds depend on the type of track turnout used, characterised by two parameters: crossing angle and curve radius.
2) For a driving speed exceeding 160 km/h, the overhead crossings installed in the open lines and main straight tracks of the stations should be constructed as a spatial arrangement of messenger wires and contact wires without mechanical connections between both lines of the contact line. These structures should ensure smooth passage of the pantograph head in all directions for which driving is planned.
3) For a travel speed of 160 km/h and less, the crossings should be designed with a crossing of contact wires and should ensure smooth passage of the current collector head in all directions for which a crossing passage is planned.

### 3.4.4. Return circuit

1) The traction current returns to the substation via a return circuit, which consists of running rails and return wires.
2) Under normal conditions, the permissible touch voltage present in the return circuit depends on the duration and is specified in point 6.2.2 and table 6 of PN-EN 50122-1:2011 [8].
3) Making direct transverse interconnections of earthing conductors or earthing and return conductors of the return circuit and their direct connection to rail sections is allowed only in cases where the operating conditions of the control command and signalling system circuits allow it.
4) The Detailed Design of the overhead catenary system should include, in addition to a diagram

of the contact line, also a diagram of the electric return circuit.

5) The following electrical connections are present in the return circuit:
a) longitudinal busbar couplers,
b) transverse inter-rail busbar couplers,
c) transverse inter-track busbar couplers,
d) lateral equipotential bonding between the return or earthing conductors of each of the tracks,
e) bypass connections,
f) return cable connections.
6) Return line conductors and electrical connections conducting operating currents in normal operating conditions should have cross-sections suitable for the maximum equivalent 30-minute operating current flow. The cross-section of the return cables should include a reserve. Moreover, the thermal strength of these conductors and earth conductors should be checked for loads with maximum short-circuit currents.
7) The transverse (equipotential) bondings of the rail return circuits on the lines with the track circuits using buses for transmission of signals of the control command and signalling system should be made with the use of impedance switches. The arrangement of transverse connections between the tracks should be determined taking into account the values of touch and available voltages, operating conditions of the track circuits and should be coordinated with the general design of the power supply system. It is recommended to install transverse connections in the area of every other track circuit.
8) lateral equipotential bonding and bypass connections should be made by means of connectors with a cross-section of at least 50 mm² Cu or equivalent.
9) The equipotential bonding between the tracks and the equipotential bonding between the earthing and return wires on double track lines should be made as cable connections so as to avoid routing the wires above the contact line.
10) If the operating conditions of the control command and signalling circuits do not allow direct connections to the return wire running rails, such connections should be made as group connections by means of impedance switches.

### 3.4.5. Electric shock protection and safety

#### 3.4.5.1. General recommendations

1) Meeting the requirements of electric shock protection is superior to other technical and environmental requirements. For the application of safety measures and electric shock protection against direct and indirect contact, the requirements of the following standards should apply: PN-EN 50122-1 [8], PN-EN 50119 [7].
2) The PN-EN 50122-1: 2011 standard includes the requirements and guidelines concerning:
a) areas to be occupied by passengers,
b) areas to be occupied by persons performing works,
c) minimum contact wire height at crossings,
d) height of the power supply cable suspension above the loading routes,
e) distance between the upper contact line and trees,
f) use of barriers,
g) means of protection against climbing the structures in the vicinity of the overhead catenary system,
h) warning signs,
i) minimum insulation clearances.
3) In emergency conditions, the potential of the busbar against ground determines the value of touch voltages or voltages available in operating conditions. PN-EN 50122-1:2011 [8] specifies the admissible values of touch and available voltages and their durations.
4) Items and components with longitudinal dimensions (measured along the track) not exceeding 2 m and not equipped with any electrical systems present in the impact zone of the upper contact line do not need to be earthed – in accordance with the requirements of PN-EN 50122-1 [8].

5) The basic means of protection against indirect contact in the return circuit is to connect the conductive parts located in the impact zone of an overhead catenary system and current collectors to the rail.
6) It is not allowed to use any manoeuvring or short-circuit switches in the current circuits of the return circuit.
7) In exposed places (footbridges above tracks, overpasses, bridges, tunnels, shelters, etc.), basic protection measures should be applied against direct contact with live parts of the contact line under normal operating conditions. The basic protection measures include: insulating shields, screens, insulating inserts, partitions – in accordance with the recommendations of PN-EN 50122-1:2011.
8) The value of the design rail potential (PN-EN 50122-1:2011) should be determined for the maximum values of the operating current and short-circuit current flowing in the running rail (taking into account the initial value of short-circuit current). If the design values of touch or available voltages exceed the permissible values (taking into account their duration), the measures recommended in PN-EN 50122-1:2011 [8] should be applied.
9) Additional protection measures and requirements for power supply systems, telecommunication systems and other LV systems are specified in PN-EN 50122-1:2011 [8].

#### 3.4.5.2. Guards

1) Bridges, flyovers, pedestrian overpasses and, if necessary, other structures under which the contact line runs should be equipped with vertical guards protecting people that may be present on these structures against accidental touching of live parts of the contact line and the contact line against damage as a result of accidental touching or falling of objects onto the contact line.
2) All planes (e.g. platforms) for an unrestricted stay of persons located above the contact line (road overpasses and pedestrian overpasses, etc.) should be equipped with vertical or horizontal guards (protective nets) compliant with the requirements of PN-EN 50122-1:2011. They should be installed above each electrified track on both sides of the structure, symmetrically in the track centre line. The width of the guards must be not smaller than the width of the pantograph zone adopted in TCS (3400 mm), including the angle of the crossing of the track axis and the edge of the engineering structure. This condition applies to structures that are new and already used regardless of the owner.

#### 3.4.5.3. Group connection to the rail

1) As the basic electric shock protection measure, group connection to the rail with the use of low voltage limiters should be used. These devices have a rated tripping voltage of $U_{Tn}$ – 120 V. Some structures of these devices have a short-circuit current of up to 20 kA for 40 ms or 12 kA for 100 ms.
2) In the normal condition, these devices have high resistance, but if, for example, the contact line rhomb insulator is damaged and the voltage value at the contacts of this device increases above 120 V, the overhead catenary system will be connected to the rails, which will turn off the voltage in the substation.
3) As a group connection lead or cable, a 120 $mm^2$ lead (ALFe120) made of aluminium with a steel core should be used.

#### 3.4.5.4. Lightning protection of the contact line

1) The contact line should be protected against the effects of lightning surges by means of horn, valve or semiconductor lightning arresters.

2) When determining the arrangement of lightning surge protections along the contact line, apart from the specified zone of operation, areas with increased storm activity should be taken into account. It is recommended to install two protections on one section of the contact line tension

in normal conditions.

3) The contact line should be protected against the effects of lightning surges by means of horn, valve or semiconductor lightning arresters.
4) When determining the arrangement of lightning surge protections along the contact line, apart from the specified zone of operation, areas with increased storm activity should be taken into account. It is recommended to install two protections on one section of the contact line tension in normal conditions.

### 3.4.6. Interaction of the overhead catenary system with the pantograph

1) In order to ensure proper quality of current collection without undue arcing and to reduce wear and hazards to contact strips, the mean contact force $F_m$ exerted by the pantograph on the contact wire in a function of the train driving speed should comply with the relationship described in EN 50367 [5]:
2) The maximum force ($F_{max}$) on the open line should be within the range $F_m$ plus three standard deviations σ; in other places, higher values may occur. Upper values $F_{max}$ are presented in point 5.2.5. of EN 50119:2020 [4]
3) For railway lines, the conformity assessment should be carried out in accordance with the provisions of point 6 of PN-EN 50317 [13].

#### 3.4.6.1. Dynamic characteristics and quality of current collection

1) Definitions, values and methods of tests or simulations are given in PN-EN 50317 [13] and PN-EN 50318 [14].
2) The overhead catenary system must reach the values of the dynamic properties and the contact wire uplift. The requirements for dynamic behaviour and quality of current collection are presented in Table 4.2.12 of the TSI “Energy” [3]. The uplift space of the steady arm is marked with 2 $S_0$, and $S_0$ is the calculated, simulated or measured contact wire uplift at the steady arm under normal operating conditions for one or more pantographs having a maximum force equal to the upper limit of the Fm at the maximum line speed.
3) The values of the average contact force in a function of speed for the DC power supply system are specified in point A10 of PN-EN 50367 [5].
4) The overhead catenary system must be designed to withstand the upper threshold limit of the contact force $F_m$ given in table 6 of PN-EN 50367 [5].
5) The standard deviation at the maximum line speed $\sigma_{max}$ [N] must not exceed 0.3 Fm, σ max ≤ 0.3 F max .
6) The overhead catenary system must be designed so as to enable interaction of at least two pantographs with the system. The spacing between the pantograph head centre lines of pantographs operating adjacently should be in accordance with point 4.2.13 of the TSI “Energy” [3].
7) As required by point 4.2.12 of the TSI “Energy” [3], the contact wire uplift for the designed maximum line speed should be $S_o$ maximum.
8) The geometry and interpretation profiles of 1,600 mm and 1,950 mm current-collector bow are specified in point A.2 of EN 50367:2012 [5].

#### 3.4.6.2. Pantograph spacing

1) In accordance with the requirements of point 4.2.13 of the TSI “Energy” [3], the pantograph spacing

should be assessed on the basis of the contact wire uplift affected by at least two pantographs located at a distance specified in Table 4.2.13 of the TSI “Energy” [3]. Pantographs should be certified to comply with the “Rolling stock and passenger rolling stock” TSI in the trans-European conventional rail system 1302/2014 [2].

2) For the AC power supply system and the driving speed:
   a) up to 80 km/h inclusive, for subsequent types of lines of types A, B, C, the distance between pantographs is 8 m, 8 m, 8 m respectively,
   b) from 80 to 120 km/h inclusive, for subsequent types of lines of types A, B, C, the distance between pantographs is 20 m, 15 m, 15 m respectively,
   c) from 120 to 160 km/h inclusive, for subsequent types of lines of types A, B, C, the distance between pantographs is 85 m, 85 m, 35 m respectively,
   d) 160 to 250 inclusive for subsequent types of lines of types A, B, C, the distance between pantographs is 200 m, 85 m, 35 m respectively,
3) Contact wire suspension height according to point 4.2.9 of the TSI “Energy” [3] for speeds:
   a) equal to 250 km/h should be between 5080 mm and 5300 mm,
   b) lower than 250 km/h should be between 5,000 mm and 5750 mm,
   c) for speeds of 250 km/h and higher, it is not allowed to profile the level of the contact wire,
   d) permissible changes in the contact wire profiling within the speed range of up to 250 km/h are specified in point 5.10.3. of PN-EN 50119 [7].
4) The maximum lateral deviation of the wire under action of crosswind, calculated from the track centre line, should be in accordance with the values given in table 4.2.9.2. TSI “Energy” [3].
5) The maximum lateral deviation according to point 4.2.9.2 of the TSI “Energy” is 550 mm for heads with a length of 1950 mm.
6) The new structures of the upper contact line should be assessed by simulation carried out in accordance with the provisions of PN-EN 50318 [14] and by measuring the test section of the new structure in accordance with PN-EN 50317 [15].

# 4. Reference documents

The following reference documents were used to prepare Volume II.2:

## 4.1. Normative documents


1. CENELEC. EN 15273-2:2013+A1:2016 Railway applications. Gauges. Rolling stock gauge: EN 15273-2:2013+A1:2016. CENELEC, 2013.
2. COMMISSION REGULATION (EU) No 1302/2014 of 18 November 2014 concerning a technical specification for interoperability relating to the 'rolling stock — locomotives and passenger rolling stock' subsystem of the rail system in the European Union.
3. COMMISSION REGULATION (EU) No 1301/2014 of 18 November 2014 on the technical specifications for interoperability relating to the 'energy' subsystem of the rail system in the Union (TSI Energy). 2014.
4. CENELEC. EN 50119:2020 Railway applications - Fixed installations - Electric traction overhead contact lines: EN 50119:2020. CENELEC, 03-Apr-2020. 109 p.
5. CENELEC. EN 50367 Railway applications - Current collection systems - Technical criteria for the interaction between pantograph and overhead line: EN 50367. CENELEC, 2012. 42 p.
6. CENELEC. PN-EN 50341-2-22 – Elektroenergetyczne linie napowietrzne prądu przemiennego powyżej 1 kV. Część 2-22: Zbiór normatywnych warunków krajowych. Normatywne warunki krajowe Polski: PN-EN 50341-2-22. PKN, 2016. 70 p.
7. CENELEC. EN 50119:2009 Railway applications - Fixed installations - Electric traction overhead contact lines. 2009. 94 p.
8. CENELEC. EN 50122-1 2011 Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock. CENELEC, 2011. 92 p.
9. UIC. UIC 799-1 Characteristics of direct-current overhead contact systems for lines worked at speeds of over 160 km/h and up to 250 km/h. 2000.
10. PN-EN 50149:2012 Zastosowania kolejowe - Urządzenia stacjonarne - Trakcja elektryczna - Profilowane przewody jezdne z miedzi i jej stopów: PN-EN 50149:2012-wersja angielska. 2012. 35 p.
11. PN-E-90081:1974 Elektroenergetyczne przewody gołe -- Przewody miedziane: PN-E-90081:1974. 2 p.
12. PN-93/E-04500 "Elektroenergetyczne stalowe konstrukcje wsporcze. Powłoki ochronne cynkowe zanurzeniowe."
13. CENELEC. EN50317 Railway applications - Current collection systems - Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line: EN50317. CENELEC, 2012. 14 p.
14. CENELEC. EN 50318. Railway applications. Current collection systems. Validation of simulation of the dynamic interaction between pantograph and overhead contact line: EN 50318. CENELEC, 2018. 87 p.
15. PN-EN 50317:2012 Zastosowania kolejowe -- Systemy odbioru prądu -- Wymagania dotyczące walidacji wyników pomiarów oddziaływania dynamicznego pomiędzy pantografem a siecią jezdną górną: EN 50317:2012. 18 p.


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