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Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 3: Mutual Interaction of AC and DC traction systems

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Bahnanwendungen - Ortsfeste Anlagen - Elektrische Sicherheit, Erdung und Rückleitung - Teil 3: Gegenseitige Beeinflussung von Wechselstrom- und Gleichstrombahnen

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Applications ferroviaires - Installations fixes - Sécurité électrique, mise à la terre et circuit de retour - Partie 3: Interactions mutuelles entre systèmes de traction en courant alternatif et en courant continu

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European foreword

This document (EN 50122-3:2022) has been prepared by CLC/SC 9XC “Electric supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations)”.

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2023-07-25
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2025-07-25

This document supersedes EN 50122-3:2010 and all of its amendments and corrigenda (if any).

EN 50122-3:2022 includes the following significant technical changes with respect to EN 50122-3:2010:

— harmonization with EN 50122-1:2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights

This document has been prepared under a Standardization Request given to CENELEC by the European Commission and the European Free Trade Association.

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1 Scope

This document specifies requirements for the protective provisions relating to electrical safety in fixed installations, when it is reasonably likely that hazardous voltages or currents will arise for people or equipment, as a result of the mutual interaction of AC and DC electric power supply traction systems.

It also applies to all aspects of fixed installations that are necessary to ensure electrical safety during maintenance work within electric power supply traction systems.

The mutual interaction can be of any of the following kinds:

— parallel running of AC and DC electric traction power supply systems;

— crossing of AC and DC electric traction power supply systems;

— shared use of tracks, buildings or other structures;

— system separation sections between AC and DC electric traction power supply systems.

The scope is limited to galvanic, inductive and capacitive coupling of the fundamental frequency voltages and currents and their superposition.

This document applies to all new lines, extensions and to all major revisions to existing lines for the following electric traction power supply systems:

a) railways;

b) guided mass transport systems such as:

   1) tramways,

   2) elevated and underground railways,

   3) mountain railways,

   4) magnetically levitated systems, which use a contact line system,

   5) trolleybus systems, and

   6) electric traction power supply systems for road vehicles, which use an overhead contact line system;

c) material transportation systems.

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The document does not apply to:

a) electric traction power supply systems in underground mines;

b) cranes, transportable platforms and similar transportation equipment on rails, temporary structures (e.g. exhibition structures) in so far as these are not supplied directly or via transformers from the contact line system and are not endangered by the electric traction power supply system for railways;

c) suspended cable cars;

d) funicular railways;

e) procedures or rules for maintenance.

The rules given in this document can also be applied to mutual interaction with non-electrified tracks, if hazardous voltages or currents can arise from AC or DC electric traction power supply systems.

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2 Normative references

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

EN 50122-1:2022, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

EN 50122-2:2022, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 2: Provisions against the effects of stray currents caused by DC traction systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 50122-1:2022 apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Hazards and adverse effects

4.1 General

The different requirements specified in EN 50122-1:2022 and EN 50122-2:2022, concerning connections to the return circuit of the AC railway, and connections to the return circuit of the DC railway, shall be taken into account in order to avoid risks of hazardous voltages and stray currents.

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Such hazards and risks shall be considered from the start of the planning of any installation which includes both AC and DC railways. Suitable measures shall be specified for limiting the voltages to the levels given in this document, while limiting the damaging effects of stray currents in accordance with EN 50122-2:2022.

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Additional adverse effects are possible, for example:

— thermal overload of conductors, screens and sheaths;

— thermal overload of transformers due to magnetic saturation of the cores;

— restriction of operation because of possible effects on the safety and correct functioning of signalling systems;

— restriction of operation because of malfunction of the communication system.

These effects are not considered in this Standard.

4.2 Electrical safety of persons

Where AC and DC voltages are present together the limits for touch voltage given in Clause 7 apply in addition to the limits given in EN 50122-1:2022, Clause 9.

5 Types of mutual interaction to be considered

5.1 General

Coupling describes the physical process of transmission of energy from a source to a susceptible device.

The following types of coupling shall be considered:

a) galvanic (conductive) coupling;

b) non-galvanic coupling,

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1) inductive coupling,

2) capacitive coupling.

Galvanic coupling dominates at low frequencies, when circuit impedances are low. The effects of galvanic coupling are conductive voltages and currents.

The effects of inductive coupling are induced voltages and hence currents. These voltages and currents depend *inter alia* on the distances, length, inducing current conductor arrangement and frequency.

The effects of capacitive coupling are influenced voltages into galvanically separated parts or conductors. The influenced voltages depend *inter alia* on the voltage of the influencing system and the distance. Currents resulting from capacitive coupling are also depending on the frequency.

NOTE As far as the capacitive and inductive coupling are concerned, general experience is that only the influence of the AC railway to the DC railway is significant.

5.2 Galvanic coupling

5.2.1 AC and DC return circuits not directly connected

A mutual interaction between the return circuits is possible by currents through earth caused by the rail potential of both AC and DC railways, for example return currents flowing through the return conductors, earthing installations of traction substations and cable screens.

In case a conductive parallel path to the return circuit exists in the influenced system, various effects are possible. In case a vehicle forms part of the parallel path, return current of the influencing railway system can flow through the propulsion system of the traction unit. The same effects are possible when the return current of the influencing system flows, for example, through the auto-transformer and substation transformer of an auto-transformer system or through booster transformers or other devices.

An electric shock with combined voltages can occur when parts of the return circuits or conductive parts which are connected to the return circuits by voltage limiting devices are located in the overhead contact line zone of the other railway system, see 8.2.2.

5.2.2 AC and DC return circuits directly connected or common

In addition to the effects described in 5.2.1 current exchange will be increased where AC and DC return circuits are directly connected or common.

EXAMPLE Direct connections can be railway level crossings, common tracks, system separation sections, etc.

Currents flowing between the AC railway and the DC railway can create mutual interaction between the return circuits.

Both return circuits are at the same potential at the location of the connection. A short-circuit within the AC system can cause a peak voltage on conductive structures connected to the return circuit of the DC railway. The same effects apply for conductive structures connected to it directly or via a voltage limiting device (VLD). The voltage across the voltage limiting device can trip the device without a fault on the DC side.

The connection of the return circuit of the DC railway to the earthed return circuit of the AC railway increases the danger of stray current corrosion.

For requirements for fixed installations see 8.3.

5.3 Non-galvanic coupling

5.3.1 Inductive coupling

An AC voltage can be induced on a DC contact line system and on the DC system’s return circuit. This effect needs to be considered in case the DC railway is within the zone of mutual interaction.

Consequently, an AC voltage can occur within the DC substation at the busbars versus earth (i.e. at the rectifier or in the feeder cubicles).

Interaction can occur in terms of impermissible touch voltages. See Clause 7.

Perpendicular crossings do not result in inductive effects in the DC system.

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5.3.2 Capacitive coupling

Within small distances an AC voltage can be influenced on a DC contact line system when it is isolated with a disconnector or circuit-breaker open. The possibility shall be considered that the flash-over voltage of the insulators or of the surge arrestors can be reached.

Distance depends *inter alia* on geometry and voltage.

An AC voltage can occur within the DC substation at the DC busbars versus earth, i.e. in the feeder cubicles.

Interaction can occur in terms of impermissible touch voltages. See Clause 7.

6 Zone of mutual interaction

6.1 General

The AC railway affects the DC railway and vice-versa by galvanic, inductive and/or capacitive coupling (see Clause 5). The zone of mutual interaction indicates a distance and a length of parallelism between an AC railway and a DC railway (see Annex A). The limits of zone of mutual interaction are based on the limits of the touch voltage given in Clause 7.

If a zone of mutual interaction exists the requirements given in this document shall be fulfilled.

In general no generic values can be given for the zone of mutual interference. An assessment based on local circumstances has to be made. However when the distance between AC and DC railways is less than 50 m a zone of mutual interaction is assumed. Distances in excess of 50 m are dealt with in 6.2 and 6.3.

NOTE For information on analysis and assessment of the zone of mutual interaction, see Annex C.

6.2 Effects of AC railway systems on DC railway systems

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In case of an AC railway influencing a DC railway the zone of mutual interaction is based on voltages coupled galvanically and inductively into the affected system. In this Subclause effects of capacitive coupling are negligible.

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For planning purposes the zone of mutual interaction has to be investigated either by calculation or by the following procedure.

For a system having the characteristics as described below the maximum distance to be considered between AC and DC railway is 1 000 m:

— double track line, where only the four running rails of the AC railway are used for the return circuit;

— the inducing current is 500 A per overhead contact line (1 000 A in total);

— the length of parallelism between AC and DC railway is 4 km;

— the soil resistivity is 100 Ωm;

— the rated frequency is 50 Hz;

— the affected system is insulated versus earth along its entire length and connected to earth at one end only;

— screening effects of other parallel metallic objects have not been taken into account.

Where other preconditions apply the dimension of the zone of mutual interaction shall be calculated.

A method for the calculation is given in Annex A.

NOTE The example above is based on a 35 V limit for AC with a time duration longer than 300 s.

In case a DC railway is within the zone of mutual interaction of an AC railway, the level of voltages or currents coupled into the DC system is not necessarily too high; in this case further analysis of the situation shall be carried out.

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6.3 Effects of DC railway systems on AC railway systems

For the effects of DC railway systems on AC railway systems the dimension of the zone of mutual interaction can be neglected due to the steep voltage gradient in the soil, caused by the insulated rails.

If the possibility of a galvanic transfer exists, whether temporary or permanent, between conductive parts, then the zone of mutual interaction is given by the dimensions of those parts. This does not necessarily mean that the voltages or currents coupled into the AC system are too high, but it does mean that further analysis shall be carried out to quantify the effects of the coupling

7 Touch voltage limits for the combination of alternating and direct voltages

7.1 General

The limits given in 7.2 to 7.6 are based on touch voltage only and shall not be exceeded. Where an alternating or a direct voltage is present the touch voltage limits given in EN 50122-1:2022 apply. Other effects with respect to electrical installations are not taken into account.

The direct and the alternating components of a combined voltage $u(t)$ for time duration in excess of 1 s are calculated as follows:

$$U_{\mathrm{DC}} = \frac{1}{T}\int_{t_0}^{t_0+T} u(t)\,\mathrm{d}t \quad (1)$$

$$U_{\mathrm{AC}} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} (u(t) - U_{\mathrm{DC}})^2\,\mathrm{d}t} \quad (2)$$

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where

- T = 1 s;
- t is the time in seconds (s);
- t_0 is the starting time of the time interval ($t_0 + T$);
- $u(t)$ is the combined voltage;
- U_{DC} is the direct component of combined voltage;
- U_{AC} is the alternating component of combined voltage.

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NOTE 1 Formula (1) gives the moving average value of the direct component, and Formula (2) gives the moving RMS value of the alternating component.

For short-duration phenomena ≤ 1 s the following definitions for alternating voltage and direct voltage are used:

— U_{DC} is defined as that part of the combined voltage that is caused by the DC system;

— U_{AC} is defined as that part of the combined voltage that is caused by the AC system.

NOTE 2 Further information on combined voltages is given in Annex B.

NOTE 3 Long-term conditions are associated with operation conditions and short-term conditions are associated with fault conditions or for example switching operations.

7.2 Touch voltage limits for long-term conditions

The following approach shall be used to check whether the combined voltage is permissible:

1) the alternating part of the combined voltage shall not exceed the maximum permissible alternating body voltage as given in EN 50122-1:2022, Table 7 for the applicable duration;

2) the direct part of the combined voltage shall not exceed the maximum permissible direct body voltage as given in EN 50122-1:2022, Table 9 for the applicable duration;

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3) the combined voltage is permissible if it is within the envelope as given for the applicable duration in Figure 1;

4) for time durations in excess of 1 s the combined peak value (see explanation in Annex B) shall be less than 2 × √2 times the maximum permissible alternating body voltage as given in EN 50122-1:2022, Table 7 for the applicable duration irrespective of frequency content.

EXAMPLE Assuming the maximum permissible direct touch voltage of 120 V being present in the DC system the alternating voltage limit is 35 V, see Figure 1. Assuming the maximum permissible alternating touch voltage of 60 V being present in the AC system the direct voltage limit is 85 V, see Figure 1.

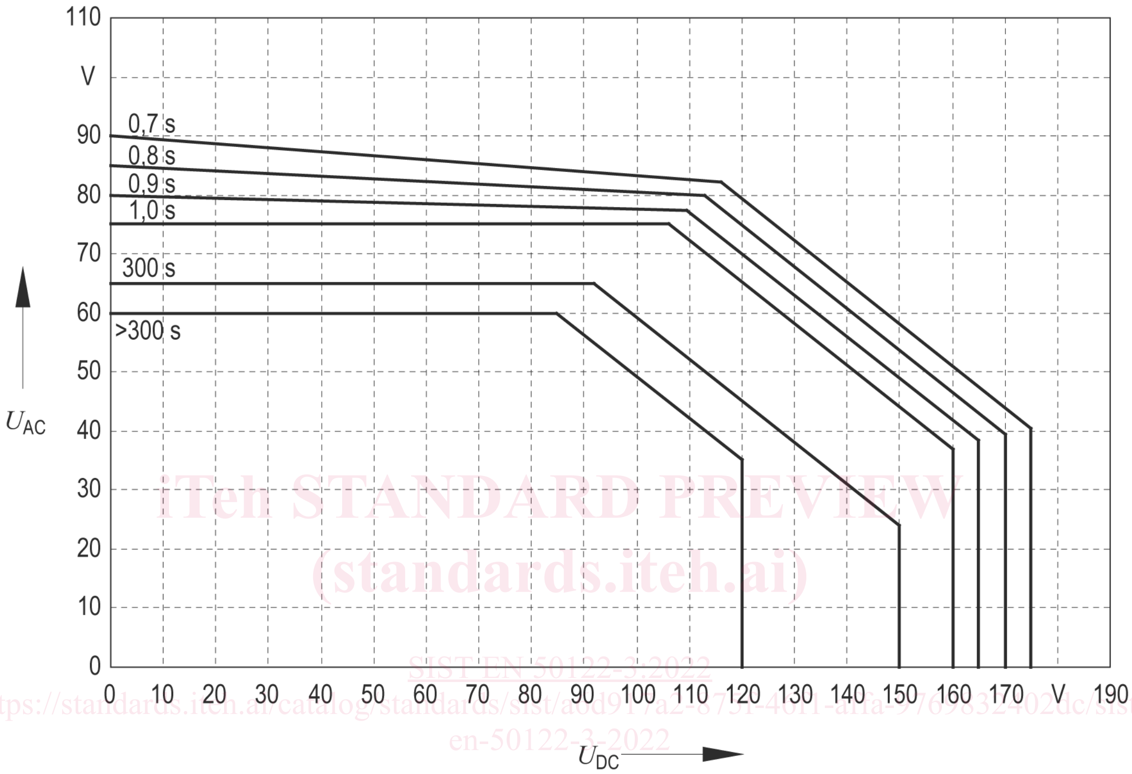

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Figure 1 — Maximum permissible combined effective touch voltages (excluding workshops and similar locations) for long-term conditions

7.3 AC system short-term conditions and DC system long-term conditions

The following approach shall be used to check whether the combined voltage is permissible:

1) the short-duration alternating part of the combined voltage shall not exceed the maximum permissible alternating touch voltage as given in EN 50122-1:2022, Table 8 for the applicable duration;

2) the direct part of the combined voltage shall not exceed the maximum permissible direct touch voltage as given in EN 50122-1:2022, Table 10 for the applicable duration;

3) the combined voltage is permissible if it is within the envelope as given for the applicable durations in Figure 2.