IEC 62427

Edition 2.0 2024-12

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Railway applications – Compatibility between rolling stock and train detection systems

IEC 62427:2024-12(en)

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

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

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Railway applications – Compatibility between rolling stock and train detection systems

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 45.060.01

ISBN 978-2-8327-0024-2

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RAILWAY APPLICATIONS – COMPATIBILITY BETWEEN ROLLING STOCK AND TRAIN DETECTION SYSTEMS

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IEC 62427 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways. It is an International Standard.

This document is based on EN 50238-1:2019.

This second edition cancels and replaces the first edition published in 2007. This edition constitutes a technical revision.

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

a) generic compatibility process, which is broken into a two-stage process depending on whether there are established compatibility limits or not;
b) rules for characterization of train detection systems;

c) rules for characterization of rolling stock;

d) rules for characterization of the power system;

e) informative references are provided in notes to established CENELEC standards for compatibility;

f) terminology is updated.

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

Draft	Report on voting
9/3115/FDIS	9/3142A/RVD

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

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

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

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INTRODUCTION

This document defines a process to demonstrate compatibility between rolling stock operating on an area of use or network and train detection systems installed in this area of use or network.

Currently, general rules for the maximum levels of interference allowed, and maximum susceptibility levels (or minimum required immunity levels) are not established in every country. This is due to the great diversity of rolling stock, power supply and return current systems, and train detection systems installed in each country. This diversity leads to consideration of compatibility of rolling stock and train detection systems on a "route by route" or "network by network" basis, to avoid unnecessarily restrictive specifications.

The compatibility process described in this document is generic. The process refers to all types of train detection systems (TDS), which may be influenced by electromagnetic emissions of rolling stock or traction power supply systems, (e.g. axle counters, track circuits, wheel detectors, loops).

Compatibility is determined by both physical and electromagnetic considerations. With regard to the electromagnetic compatibility, the need is not for general values for maximum levels of interference permitted, and maximum susceptibility levels (or minimum required immunity levels) but for convenient methods by which to specify the level of interference allowed for operation on routes or a network.

Main interference sources are considered to be:

– rail currents and voltage sources;
– electromagnetic fields;
– differential voltage between adjacent axles of the train;

as shown in Figure 1.

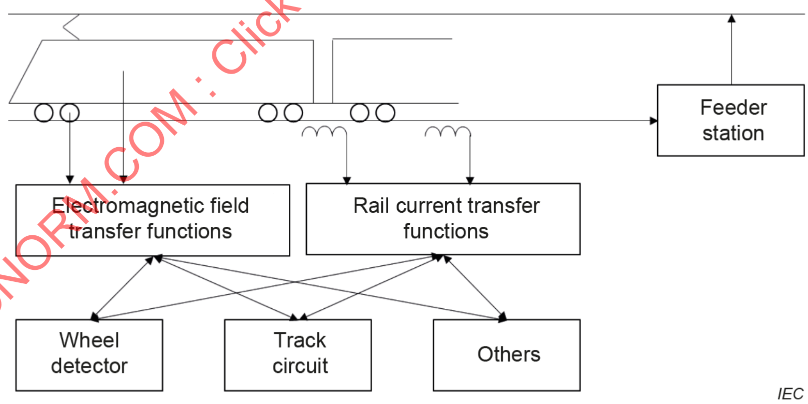

Figure 1 – Sources of electromagnetic interference

In practice, the susceptibility of the system is determined by:

– the sensitivity of individual components of the system and the type of interference it is susceptible to;
– the application of the components, i.e. the configuration of the system.

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Therefore the problems concerning TDS are considered separately for each type.

- National rules or standards, including agreements among stakeholders, define compatibility limits for track circuits;
- National rules or standards, including agreements among stakeholders, define compatibility limits for axle counters and wheel detectors;
- National rules or standards, including agreements among stakeholders, define the testing method of rolling stock for electromagnetic compatibility with axle counters;
- Compatibility with other types of wheel detectors (mechanical or magnetic) is described in 5.4;
- Compatibility with loops can be established following the guidance in 5.5;
- Compatibility with any other type of TDS not explicitly covered by this document can also be established following the generic process in this document.

NOTE 1 In Europe, CLC/TS 50238-2, CLC/TS 50238-3 and EN 50592 provide compatibility limits for track circuits, compatibility limits for axle counters and wheel detectors, and the testing method of rolling stock for electromagnetic compatibility with axle counters, respectively.

For determining the susceptibility of signalling systems, laboratory/simulation testing methods and in situ tests on the "real railway" are proposed. Modelling enables worst-case conditions to be simulated. In addition, particular test sites are selected because, from experience, they are expected to provide the test evidence required.

Then, taking account of the experience of the railways, it is possible to establish a general method for determining the susceptibility of train detection systems, described in this document.

NOTE 2 In Europe, general requirements on how to establish immunity have been defined in EN 50617-1 and EN 50617-2.

Before assessing the electromagnetic emissions of rolling stock, sufficient knowledge of the electric circuit diagram of the power equipment is important, including switching frequencies of on-board power converters, type of regulation used for power converters, resonant frequency of each filter, operating limits under high and low supply voltages, degraded modes of operation.

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RAILWAY APPLICATIONS – COMPATIBILITY BETWEEN ROLLING STOCK AND TRAIN DETECTION SYSTEMS

1 Scope

This document describes a process to demonstrate compatibility between rolling stock (RST) and train detection systems (TDS). It describes the characterization of train detection systems, rolling stock and traction power supply systems.

It is worth noting that the demonstration of technical compatibility between the rolling stock and infrastructure with respect to physical dimensions is not detailed in this document.

This document is not generally applicable to those combinations of rolling stock, traction power supply and train detection system which were accepted as compatible prior to the publication of this document. However, as far as is reasonably practicable, this document can be applied to modifications of rolling stock, traction power supply or train detection systems which can affect compatibility. The detailed process can be used where no rules and processes for compatibility are established.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

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3.1.1
competent body
body responsible for the independent evaluation of the compatibility case

Note 1 to entry: This can be an accredited conformity body or an independent safety assessor. This role is not limited to external parties, unless mandated under the applicable legislation.

3.1.2
compatibility case
set of documents which records the evidence demonstrating the degree of compatibility between rolling stock, traction power supplies and train detection systems for a specific route or specific railway network

[SOURCE: IEC 60050-821:2017, 821-03-47]

3.1.3
degraded modes, pl
modes of operation in the presence of faults which have been anticipated in the design of the signalling system or the rolling stock

[SOURCE: IEC 60050-821:2017, 821-01-52]

3.1.4
traction power supply system
part of the overall electricity energy supply system, not extending beyond the dedicated feeder stations on the rail network

Note 1 to entry: IEC 62313 applies at the interface to the national electricity supply network.

3.1.5
wheel detector
sensor which detects the passage of a wheel

Note 1 to entry: A wheel detector can be used as part of an axle counter or as a treadle.

[SOURCE: IEC 60050-821:2017, 821-03-53]

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3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

AC	Alternating current
DC	Direct current
IM	Infrastructure manager
MVA	Megavoltampere
NTR	National technical rule
RINF	Register of infrastructure
RST	Rolling stock
TDS	Train detection system
WSF	Wrong side failure

4 Compatibility process

4.1 Overview

The party which introduces a new element or introduces a change of an existing element or system is responsible for demonstrating compatibility between rolling stock, train detection, traction power supply systems and neighbouring infrastructure, if applicable. The party is responsible for initiating the compatibility process. The relevant data shall be made available to the party responsible for constructing and/or amending the compatibility case. If data are not available or not sufficient, alternative arrangements can be made by both the responsible party and the affected party to demonstrate compatibility, for example by carrying out specific compatibility tests. It is recommended that a competent body evaluates the compatibility case if the stakeholders consider the modification to be a significant change. In 4.2 to 4.8, the specific tasks to demonstrate compatibility are listed and explained.

4.2 Detailed compatibility process

The compatibility process is summarized in Figure 2.

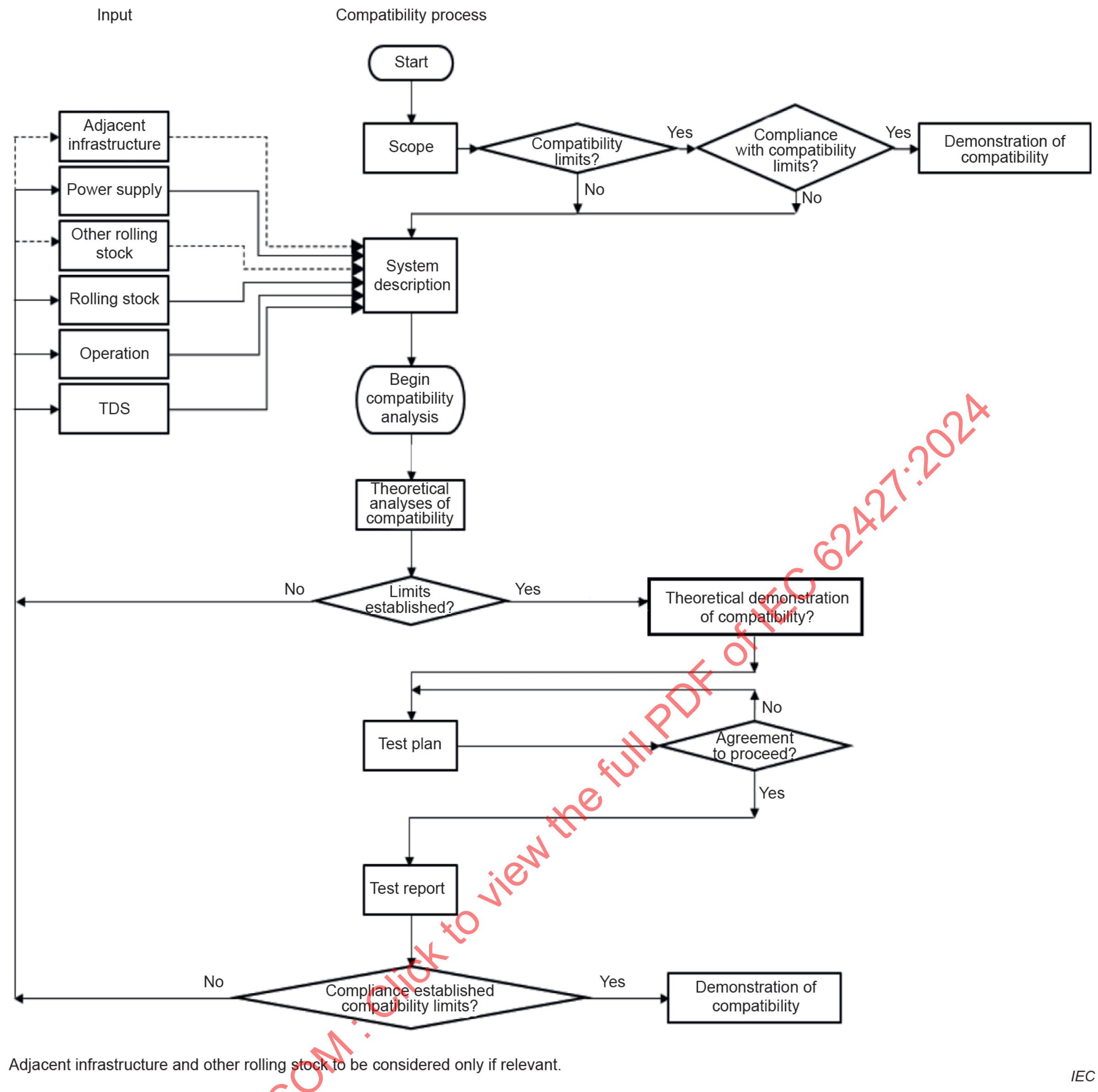

Figure 2 – The compatibility process

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4.3 Building the compatibility argument

A compatibility case in compatibility analysis shall be prepared, following the process depicted in Figure 2, including but not limited to the:

a) definition of the scope of the compatibility case, including:
   - new element to be introduced;
   - identification of the route or area of use (network) if applicable;
   - operational conditions;

b) description of the overall rail system including:
   - infrastructure:
     – train detection system (frequency-wide immunity limits if available);
     – track parameters relevant for the train detection system (e.g. earthing and bonding);
     – traction power supply and line parameters;

- rolling stock in any configuration, including degraded modes:
  – relevant operational conditions e.g. power limitations;
  – factors affecting rolling stock characteristics and compatibility as listed in Annex C, identification of disturbance sources, their behaviour and/or applicable summation rules;
- adjacent infrastructure and other rolling stock, if applicable;

c) theoretical analysis (e.g. simulation) against requirements of the scope including assumptions:
   - derive the permissible interference per on-board source using the analysis in 4.8;

d) test plan taking account of the results of the theoretical analysis;

e) test reports – see Clause 8;

f) assessment of theoretical analysis and test reports against requirements:
   - related compatibility cases;
   - check of validity of assumptions;
   - check if restrictions may be lifted or relaxed;

g) quality management plan and evidence.

If a competent body is appointed, then it is recommended to involve them at each step of the compatibility case.

It is recognized that characterization of interference generated and propagated by rolling stock can be a time consuming process, which may require a significant amount of testing during service operations in order to refine the characteristics. Therefore, provided that the risks to all parties can be demonstrated to be acceptable, temporary operational conditions may be imposed prior to full compatibility being established.

Hereunder specific aspects of the compatibility case will be further outlined.

4.4 Quality management

Quality management systems shall be in place. The importance of configuration management should be noted.

The configuration state of the relevant infrastructure and rolling stock (including maintenance processes and schedules) shall be recorded and referenced within the compatibility case. Any subsequent changes to these configurations shall lead to an examination of the continued validity of the compatibility case.

4.5 Route identification for introduction of RST (new or changed)

In order to accept a particular rolling stock in respect of a particular route or network, the different types and applications of train detection systems and traction power supply systems, if applicable, on the network or on the route and on adjacent routes which can be affected shall be identified. In addition to the intended operational route(s), alternative route(s), which may be required in the event of disruption to traffic shall also be considered.

4.6 Introduction of infrastructure elements (new or changed)

In order to accept a particular infrastructure change (e.g. TDS or traction power supply) in respect of a particular route or network, the different types of RST, TDS and traction power supply systems on the network or on the route and on adjacent routes, which may be affected, shall be identified.

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4.7 Characterization

The characteristics of the identified systems shall be obtained in accordance with the following clauses:

For train detection systems:	Clause 5;
For rolling stock:	Clause 6;
For power supply systems:	Clause 7.

4.8 Compatibility analyses

4.8.1 General terms

It shall be demonstrated that the rolling stock characteristics for generated and propagated interference comply with the train detection system limits, under defined operating conditions, including degraded modes.

NOTE 1 EN 50617-1, EN 50617-2, EN 50592 are available for operating conditions in Europe.

The relationship between rolling stock and infrastructure is shown in Figure 3. The information flow may be in either direction depending on which system is to be changed.

NOTE 2 Compatibility is now based on worst-case conditions. This results in very severe requirements for rolling stock interference limits, while in practice the tolerable interference level is much higher due to overall degradation of older systems and interference produced by the current collecting system. Despite this situation, the cases with hazards caused by interference are very rare. It is obvious that a perspective of risk calculation will ease the interference current requirement by probably a decade.

The safety margin is applicable for safety related tests, where train detection technology implies WSF. The availability margin is applicable for availability related tests.

NOTE 3 All applicable parameters for compatibility cases of track circuits and axle counters in Europe can be identified from EN 50617-1 and EN 50617-2 respectively.

The compatibility analysis is mandatory and shall explain the technical principles which ensure compatibility, including (or giving reference to) all supporting evidence, e.g., calculations, test plans and results.

The method of analysis of fault modes shall be agreed between the parties listed in 4.3.

The scenario for compatibility including the worst case shall be described with the following parameters:

– transfer function between interference sources (rolling stock and infrastructure) and sensitivity level of the used TDS in the specified frequency band;
– characteristics, operating modes and conditions of rolling stock (normal and degraded modes of RST and maximum torque, speed or other operating conditions);
– characteristics and operating conditions (normal and degraded modes) of traction power supply, including substation parameters and traction return path;
– safety and/or availability margin taking account of the above modes and conditions. Track circuit sequencing is considered when safety or availability margins are agreed.

NOTE 4 Testing during operation in service on one vehicle will establish a probability for generated interference, e.g. a level down to once per 1 000 h during several months of testing. This is only sufficient for the basic level of generated interference current.

Both on-board systems and/or infra-side systems can be used to monitor the probability of occurrence of high levels of interference currents, provided they remain compatible with the various immunity levels of the propagation and detection systems.

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4.8.2 Transfer function

The "transfer function" expresses the relation between the received interference signal at the train detection system equipment and the total interference signal generated by rolling stock.

Let the transfer function be denoted by F.

Let the interference signal at the train detection system equipment caused by a single train and/or multiple trains at the electric section be denoted by I_{TDS}.

Let the interference signal generated by the rolling stock be denoted by I_{RS}.

The interference signal is then:

$$I_{\text{TDS}} = F \times I_{\text{RS}}$$

The maximum permissible interference signal at the train detection system equipment I_{TDSmax} is determined by the sensitivity of the train detection system equipment. Let the total permissible interference generated by rolling stock be denoted by I_{RStot}. Then:

$$I_{\text{RStot}} = I_{\text{TDSmax}} / F$$

Where multiple sources (rolling stock and substations) may contribute to the total interference signal, the permissible interference per source shall take this into account.

NOTE 1 Line resonances and phase sensitive receivers can be part of the evaluation of compatibility.

NOTE 2 In Europe, CLC/TS 50238-2 provides possible guidance on the application of the transfer function considering multiple sources.

Note that the permissible interference signal will have two values determined by the following criteria:

– the signal which may cause the train detection system to show clear when it is in fact occupied (a wrong side failure, i.e. a matter of safety);
– the signal which may cause the train detection system to show occupied when it is in fact clear (a right side failure, i.e. a matter of availability). The effect on interlocking logic shall however be considered.

The process of application of the summation rules can be applied in both directions as depicted in Figure 3.

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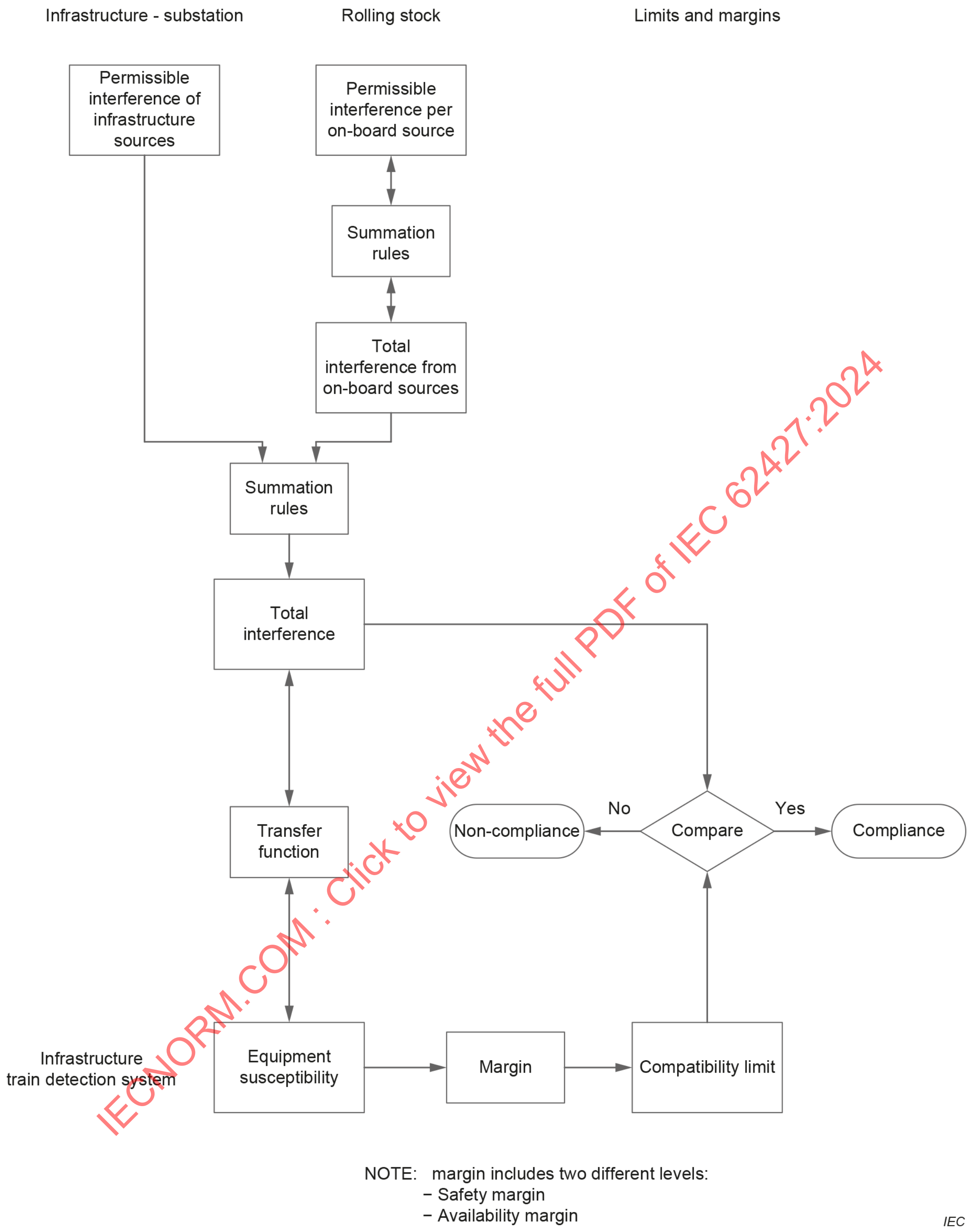

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Figure 3 – Relationship between compatibility limits and permissible interference

5 Characterization of train detection systems

5.1 Objective of procedure

To ensure the correct operation of axle counter systems, wheel detectors and track circuit systems, their physical and electromagnetic properties are defined in the detailed standards and regulations (see 5.2, 5.3 and 5.4 for details) as well as the measurement methodology and how to report the compatibility with these standards.

For other train detection systems not covered by standards, their relevant properties shall be defined by the infrastructure manager in collaboration with the manufacturers. Relevant information shall be described by the manufacturers in the product documentation.

5.2 Track circuit systems – Standards, regulations and technical specifications

Parameters for track circuits are provided by national rules or standards, including agreements among stakeholders. All requirements to be fulfilled by a track circuit system are listed and defined there in detail.

NOTE 1 In Europe, EN 50617-1 directly includes the requirements for physical and electrical aspects (e.g. axle resistance, ballast resistance, broken rail behaviour) as well as the electromagnetic parameters (e.g. behaviour to interferences and immunity limits), the measurements to be executed and the reporting to show the compatibility with this document.

NOTE 2 The methodology defined in Europe in EN 50617-1 can be used where practically applicable.

NOTE 3 Guidance to establish compatibility limits is contained in Annex A. Some known track circuit compatibility limits in Europe are published in CLC/TS 50238-2.

5.3 Axle counter systems – Standards, regulations and technical specifications

An axle counter system is the whole system including the axle counter detector with its sensor, and the evaluation unit.

If the characterization is to be performed on the axle counter (wheel detector) alone, rather than on the axle counter system, refer to 5.4.

Parameters for axle counter systems are provided by national rules or standards, including agreements among stakeholders. All requirements to be fulfilled by an axle counter system are listed and defined there in detail.

NOTE 1 In Europe, EN 50617-2 directly includes the requirements in accordance with physical and electrical aspects (e.g. axle distances, fastenings to the rail, environmental conditions) as well as the electromagnetic parameters (e.g. behaviour to interferences and immunity limits), the measurements to be executed and the reporting to show the compatibility with this document.

NOTE 2 The methodology defined in Europe in EN 50617-2 can be used where practically applicable.

NOTE 3 Some known axle counter compatibility limits are published in Europe in CLC/TS 50238-3.

5.4 Wheel detectors (treadle applications)

5.4.1 General

Treadle applications are mainly switch on/off functionalities, direction detection or speed measurement.

NOTE Requirements for wheel detectors applied as treadles in Europe are not explicitly described in EN 50617-2 because they are not used for axle counter systems.

5.4.2 Wheel detectors based on inductive technology

Owing to the principle of discrete detection of wheels passing a wheel detector, transient and continuous interference limits may be considered as equivalent to the limits defined for axle counter detectors or axle counter sensors.

NOTE 1 In Europe, EN 50617-2 can be taken into account where applicable for wheel detectors based on inductive technology with respect to the physical, electromechanical and electromagnetic interface.

Owing to the inherent difficulties of designing a sufficiently complete electrical equivalent circuit for an inductive wheel detector, field testing or alternatively laboratory tests injecting interference currents into the rail and applying external electromagnetic fields shall be used for measuring the susceptibility of wheel detectors.

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To allow for uncertainties in the accuracy of measurements and simulations, the susceptibility of the train detection system as determined above shall be increased by a factor of safety (margin). The uncertainties shall be estimated and the factor of safety shall be sufficient to allow for them.

It is possible that it will be necessary to take into account interference due to DC substation ripple (e.g. harmonics of the substation voltage source) in the factor of safety.

NOTE 2 Wheel detectors based on other technology (e.g. mechanical or optical) are not described in detail in this document.

5.5 Loops

5.5.1 General aspects

Loops are mainly used for level crossing applications, to command the lowering or raising of barriers. A loop application based on the principle of continuous detection of a large metal mass has a different influencing mechanism compared to axle counter sensors and track circuits which shall be taken into account.

Loops have a greater area to be influenced by trains than wheel sensors, on the other hand the sensitivity of a loop against rail currents is not directly linked because the loops are not connected to the rails. Because of this, induction is the main interference mechanism. Loops for communication tasks and/or automatic train protection applications are not within the scope of this document.

For reliable train detection with loops, the definition of compatibility requirements with the train shall be taken into account as shown in the example in Annex E, for a specific type of loops. Loops are usually used as one component of an applicable solution. The necessary level of reliability shall be documented within the application the loops are used for.

5.5.2 Interfering mechanisms

The variation of the loop inductance is caused by the generation of eddy currents and mutual induction with conductive elements interacting with the magnetic field of the loop.

Loops can be influenced by magnetic fields and by the metal construction of the vehicles. At the time of writing of this document, magnetic fields have shown no negative effect on the operation of the loops. Specific strong radiating sources on board the RST, for example track circuit shunt assisting devices can affect the operation of loops.

Railway vehicles' metal construction can vary the inductance by the following influencing factors:

a) metal construction (bogies, metal parts of the vehicle, metal vehicle floor) above the loop within a defined distance to the rail and within a defined conductivity;

b) electrical short circuit rings (electrical conducting loops) made from construction elements of a vehicle e.g. frame beams with cross connections or electrically connected and conducting construction parts below the vehicle floor within a defined distance to the rail. These parts are electrically connected in a suitable way to form electrically conducting short circuit rings with defined dimensions and defined electrical resistances;

c) electrical short circuit rings formed by the wheels, axles and rails, with a sufficiently low impedance between wheels as well as between the wheels and rails.

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5.5.3 Characterization

Compatibility requirements can be established in different ways (e.g. lab tests, safety assessment, field tests).

Lab tests and field tests shall be performed to prove compatibility between newly developed loops and trains in accordance with the level of availability for the infrastructure function. It shall be proven that no detection will be lost while the train is inside the loop area and no occupation will occur in the absence of a train.

6 Characterization of rolling stock

6.1 Objective

Tests shall be made on rolling stock to verify that the generated interferences comply with the train detection system's compatibility limits.

The procedure used for the tests depends on the applicable scope of use. The described compatibility tests for rolling stock with train detection systems are derived from the general procedure described in 6.2.

6.2 General procedure

Clause 4 defines the generic compatibility process. Tests shall be based on analysis of the potential sources of interferences. The compatibility analysis of 4.8 shall be used to define the tests.

European Standards or national standards can be used as far as applicable.

Compatibility cases may be established by adherence to existing rules if available. The generic procedure defined in this document applies to cases where compatibility limits do not exist.

The general procedure for rolling stock characteristics is described in Annex B.

Compatibility limits, test procedures and post-processing for demonstrating compatibility with track circuits and axle counters are provided by national rules or standards, including agreements among stakeholders.

NOTE In Europe, CLC/TS 50238-2, CLC/TS 50238-3 and EN 50592 provide compatibility limits for track circuits, compatibility limits for axle counters and wheel detectors, and the test procedure and post-processing for demonstrating compatibility with axle counters, respectively.

The compatibility with loops, if applicable, shall be demonstrated by checking compliance with construction requirements (e.g. Annex E) or by train testing following functional requirements (for example the variation of the inductance of the loop explained in 5.5.2).

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7 Characterization of traction power supply systems

7.1 Objective

The objective is to determine the influence of the traction power supply system on the generation and transmission of interference.

Relevant factors include but are not limited to the following:

- nominal voltage characteristics (AC or DC);
- voltage tolerance;
- frequency tolerance;
- harmonic content;
- transients;
- MVA rating;
- impedance of substation;
- impedance of catenary or conductor rail(s);
- impedance of return system;
- normal and degraded modes of operation;
- protective elements – e.g. overvoltage protection.

Information about power supply characteristics is defined in IEC 60850 (nominal values and tolerances) and IEC 62313 (impedances, resonances) or is provided by the IM, national rules or standards, including agreements among stakeholders.

Certain interference frequencies may be generated by both the substation and rolling stock. The superposition rules applicable to the corresponding interference generation mechanisms shall be considered. In order to limit the influence of interference generated by the substation at the location of rolling stock, minimum impedance requirements for rolling stock may be formulated.

Resonances and oscillations shall also be considered when defining a test location for characterization purposes. The rolling stock's interaction with the electric traction system should be included in the considerations due to the fact that resonances and oscillations are mainly provoked by rolling stock interaction with the electric traction system.

7.2 DC traction power supplies

DC traction power supplies are, due to their rectifiers, particularly likely to produce interference currents which can affect track circuits or axle counters. The voltage ripple is mainly due to the rectifier bridge and to phase unbalance in the high voltage supply. Annex D briefly describes the interaction of interference currents between the rolling stock and the DC traction power supply.

7.3 AC traction power supplies

In AC traction power supply systems, the following effects shall be considered:

– Feeding of the lines by static converters. In this case, the converter (substation) can create harmonics, which have similar effects as the harmonics created by the substation in DC traction power supply systems.

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- Harmonics created by other rolling stock. AC rolling stock can create significant magnitudes of harmonic currents, which produce harmonics in the line voltage due to voltage drop over the line impedance. Emissions of different rolling stock in the section may be mixed by this effect. Emissions of rolling stock under regenerative braking conditions shall also be considered.
- In the audio frequency range, local resonance effects between capacitive input impedances of rolling stock (e.g. shielded high voltage cables) and the traction power supply shall be taken into account. This can both amplify the interference of the rolling stock under test as well as make it more susceptible to interference created by other rolling stock operated in the same feeding section.

NOTE Line-vehicle resonances can lead to both a high line voltage, and to high line current harmonics.

7.4 Test procedures

As a possible approach, the voltage spectrum of the line voltage without the rolling stock under test shall be measured. Together with the line impedance and the input impedance of the rolling stock, this allows an estimation of the influence of the power supply on the measurements if the rolling stock is in operation, however it is not a precise quantification.

Resistive loads connected to the line voltage may help to identify the influence of the power supply.

Local resonances can be identified when operating the rolling stock over feeding sections of several kilometres or more.

8 Test report

8.1 General

The tests and the context in which they were performed shall be presented in a report, the main text and appendices of which should include the information given in 8.2 to 8.9.

8.2 Introduction to the report

A general presentation of the systems under test (rolling stock, traction power supply system and train detection system) shall be included.

8.3 Test organization

A statement concerning who performed the tests and their contact address shall be provided.

8.4 Configuration

A definition of the design status of the rolling stock and/or infrastructure, including the status of hardware and software listed in the documentation of the factors affecting the characteristics of rolling stock and the TDS shall be presented.

8.5 Reference documents

This includes the test plan, the description of the rolling stock or TDS and the document listing the factors affecting the characteristics of the RST or TDS.

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8.6 Application of the test plan

With specific reference to compromises or amendments to the test plan which were found to be necessary, including:

- Test conditions – technical characteristics of the test site including the TDS, traction power supply system and the tested RST;
- Instrumentation – a block diagram of the equipment used, the location of the measuring transducer, the interconnections between instruments, their accuracy, response characteristics, sensitivity, signal scaling;
- Test procedure – calibration, verification of environmental noise, number of test runs, operational conditions of the system under investigation during tests.

8.7 Test results

An analysis and summary of the measurements made with typical examples of recordings.

8.8 Comments

An evaluation of the results, their validity and comparison with the expected results.

8.9 Archive of test results

Measurements often require the collection of large quantities of recordings. It is not always practical for these to be reproduced and circulated with a report, but provision shall be made for their archive and reference made in the test report as to how authorized access to this documentation may be achieved.

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Annex A
(informative)

Guidelines for the determination of susceptibility of train detection systems

A.1 Examples of system configurations

Some examples of train detection system configurations are shown in Clause A.2 to Clause A.11. They are simplified and do not show, for example, structures bonded to the traction return rail. It is emphasized that these are not the only possible configurations; they are included as examples of the type of situation that should be considered.

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A.2 "Normal" configuration

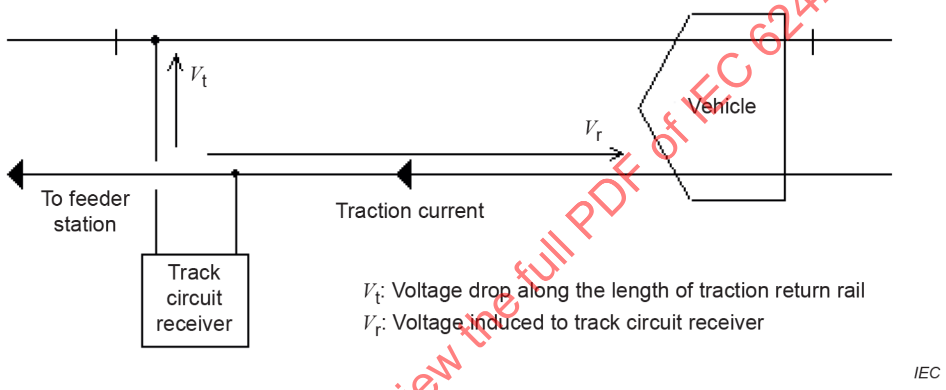

Figure A.1 – Interference mechanism with rails intact

Figure A.1 shows an interference mechanism with rails intact. The voltage drop along the length of traction return rail included within the track circuit length appears across the track circuit receiver when the track circuit is occupied.

A.3 Interference mechanism with broken signal rail

Figure A.2 shows an interference mechanism with self-revealing broken rail. This interference mechanism applies to single rail track circuits which uses only one rail to detect the presence of the train. This rail is known as a signal rail and is sectionalized by insulated block joints, therefore it is not used for return currents. With a break in the signal rail the track circuit will normally show as being occupied (a "self-revealing" fault). The circuit is as shown in Figure A.2.

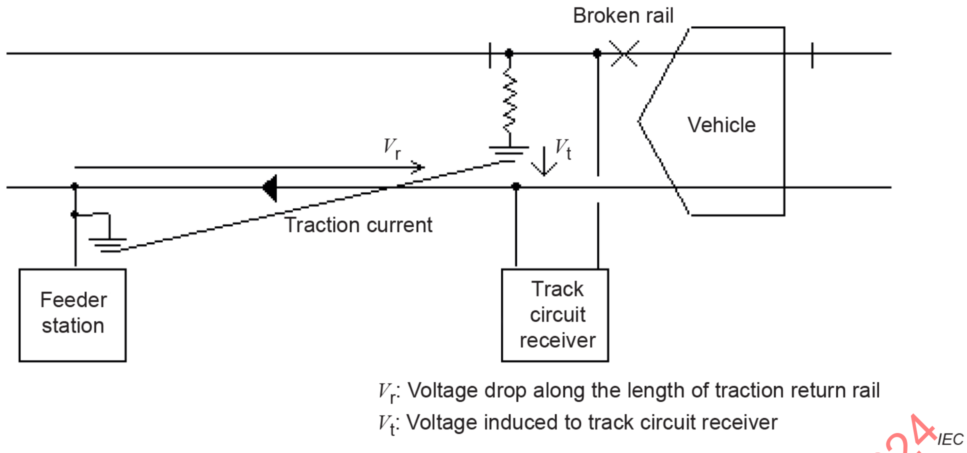

Figure A.2 – Interference mechanism with self-revealing broken rail

The voltage appearing at the receiver is now determined by the voltage drop between the vehicle and the feeder station, although the ballast resistance of the broken rail is in series with the input of the track circuit receiver. Since the broken rail causes the track circuit to show as being occupied, this situation should arise very infrequently.

A.4 Interference mechanism with broken return rail

In the case of an unrevealed break in a traction return rail, the circuit is as described in Figure A.3.

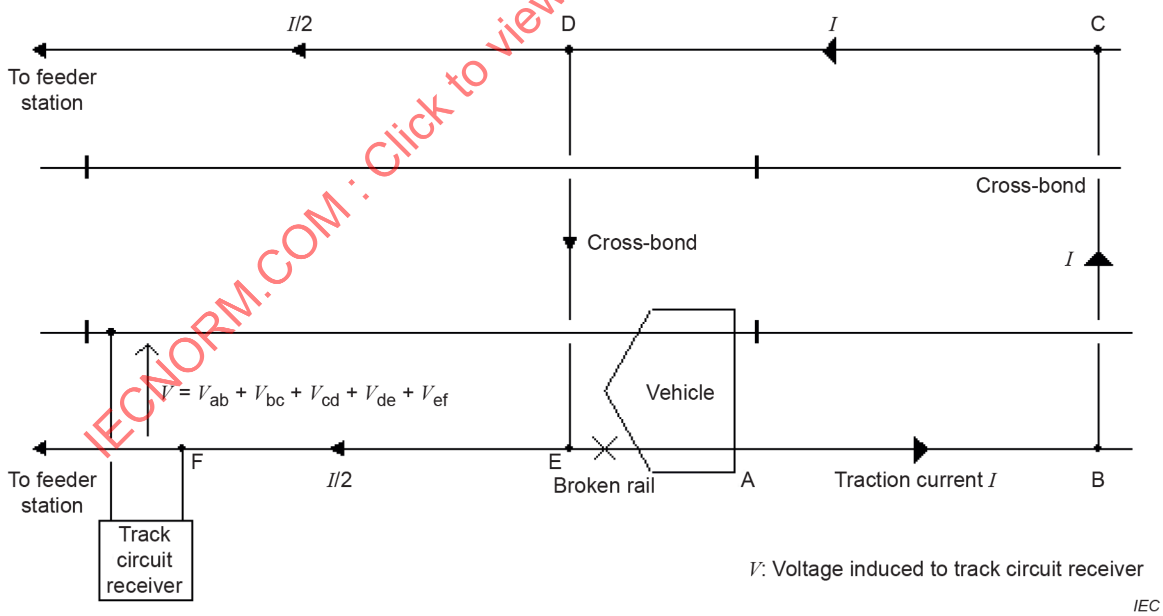

Figure A.3 – Interference mechanism with unrevealed broken rail

Since the traction current now has to take a longer return path to the feeder station (although a proportion will flow in the earth), the interference voltage at the receiver will be increased. The length of the return path depends on the spacing of the cross-bonds and the length of the track circuit.

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A.5 Double rail track circuits

A typical configuration for a double rail track circuit is shown in Figure A.4.

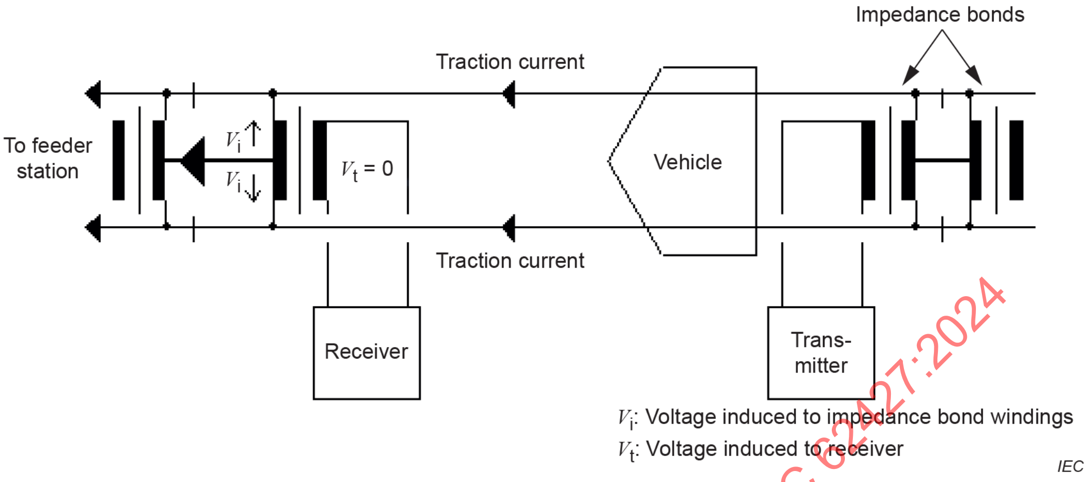

Figure A.4 – Double rail track circuit

In normal operation the traction return current in each rail is approximately the same and little voltage is developed at the track circuit equipment terminals. However in the case of a broken rail or impedance bond, the return current will be totally unbalanced resulting in a transverse voltage, as is shown in Figure A.5.

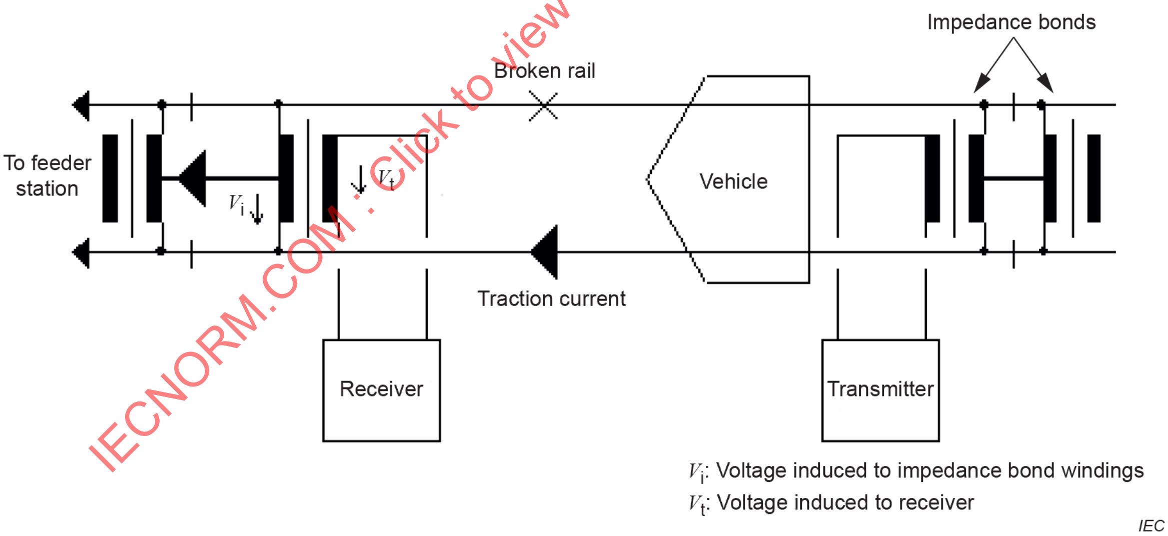

Figure A.5 – Double rail track circuit with broken rail

Such a break will normally cause the track circuit to show as being occupied (self-revealing) but depending on the type of track circuit it could be possible for the receiver to be falsely energized by interference before the train enters the track circuit, thereby permitting the train to proceed. The track circuit could then continue to show clear when it is occupied by the train.

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A.6 Voltage between axles of rolling stock

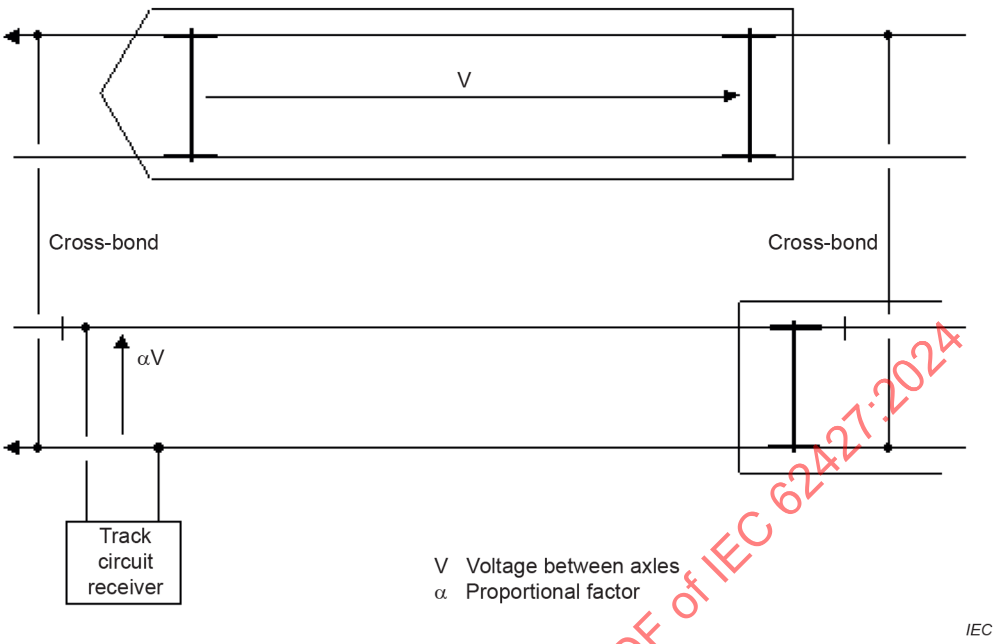

Figure A.6 – Interference mechanism due to voltage between axles – Case 1

Figure A.6 shows an interference mechanism due to voltage between axles when only one train contributes to the interference. If a voltage is generated between the axles of the train, a proportion α of this voltage may appear across the track circuit receiver. If the train length is similar to the track circuit length and to the cross-bond spacing, α may approach unity.

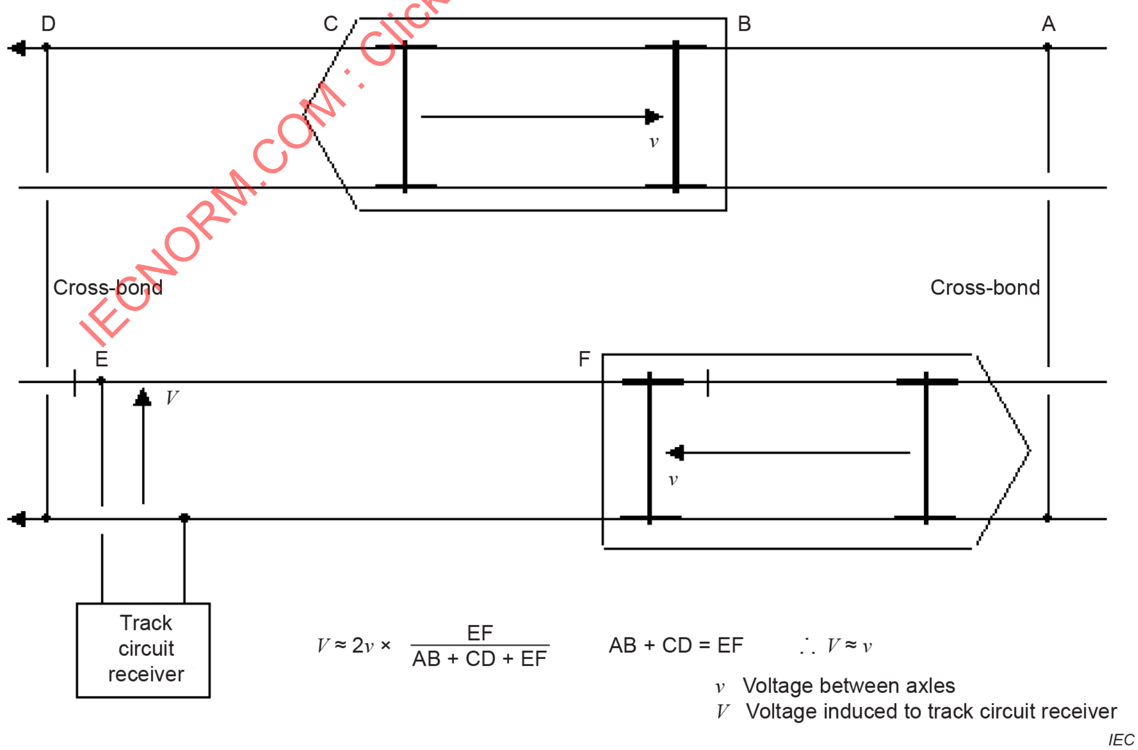

Figure A.7 – Interference mechanism due to voltage between axles – Case 2

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If two trains contribute to the interference, the combined effect is similar to that for one train, as is shown in Figure A.7.

A.7 Effect of resistance between coupled vehicles

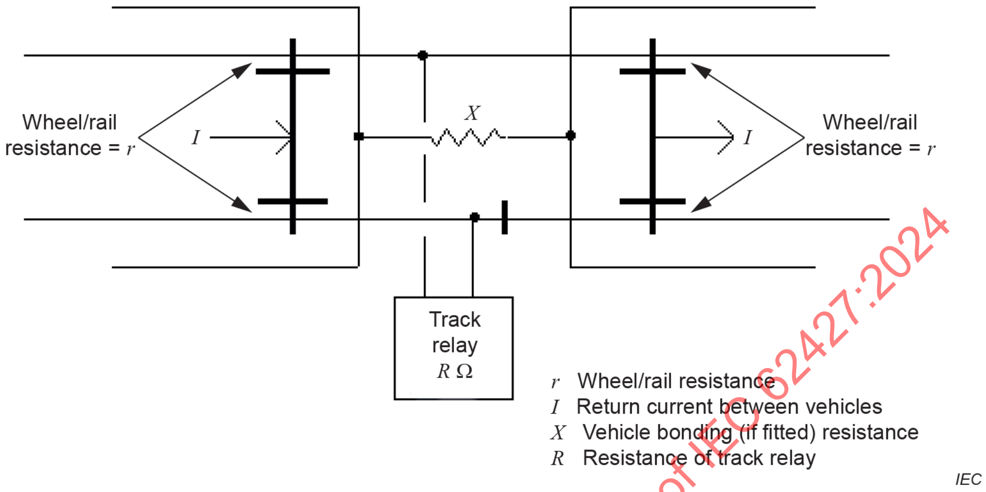

Figure A.8 – Effect of inter-vehicle current

Figure A.8 shows an effect of inter-vehicle current. This can be re-drawn (ignoring rail resistance) as is shown in Figure A.9.

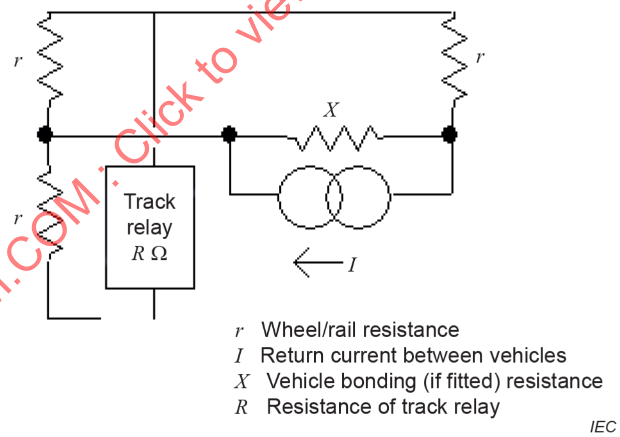

Figure A.9 – Equivalent circuit for Figure A.8

If all r are equal

and $R \gg r$

and $X \rightarrow \infty$ (either disconnected or not fitted)

then $V_R \rightarrow I \times r$

If X approximates to r

then $V_R \rightarrow (I \times r) / 3$

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If the maximum tolerable V_R is 200 mV and I is 120 A then

$$R_{max} = 1{,}7\ \text{m}\Omega \text{ if } X \rightarrow \infty$$

or

$$r_{max} = 5\ \text{m}\Omega \text{ if } X \text{ approximates to } r$$

These values are quite low.

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A.8 Radiated interference

Figure A.10 shows some examples of radiated interference.

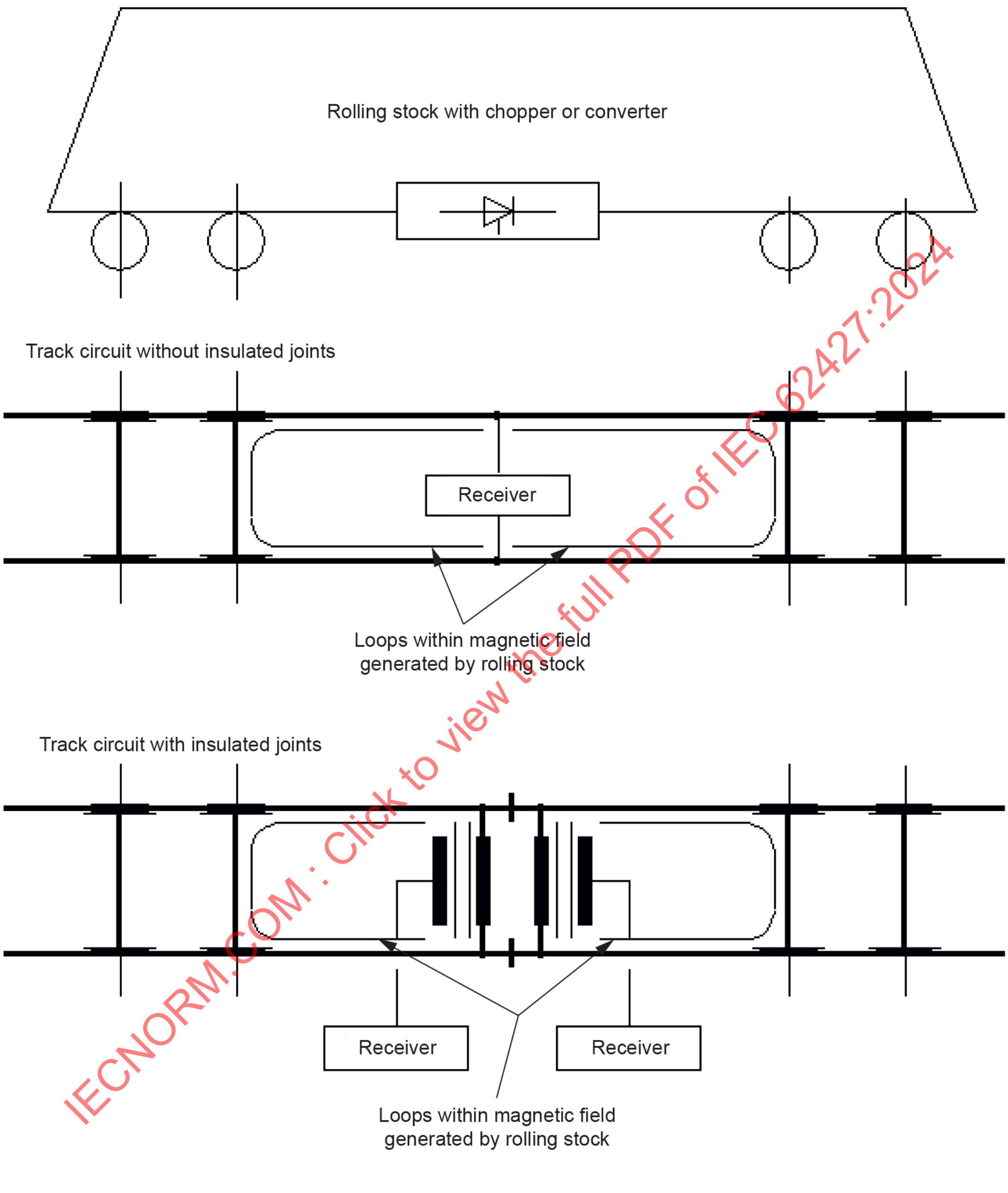

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Figure A.10 – Example of radiated interference

A.9 Sensitive zone of wheel detector

The sensitive zone of the wheel detector is described in national rules or standards, including in agreements among stakeholders.

NOTE EN 50617-2 provides a sensitive zone for European wheel detectors.

A.10 Factor of safety

Factor of safety is described in national rules or standards, including in agreements among stakeholders.

NOTE EN 50617-1 and EN 50617-2 provide factor of safety for European TDS.

A.11 Multiple interference sources

The maximum number of interference sources that could affect a given train detection system at any one time should be determined from operational considerations. Summation rules should take into consideration the interdependence among all equipment and among multiple sources within the equipment.

NOTE ORE B108 reported rules for the distribution of interference current from the traction equipment and from auxiliary converters depending on the position of the train in relation to the track circuit. These general rules are superseded by the specific transfer function established under this procedure.

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Annex B
(informative)

General characterization of rolling stock

B.1 Objective of procedure

Tests should be made on rolling stock to verify the electromagnetic emissions generated and also for the following reasons:

– to acquire additional information concerning the characterization of the train power system;
– to compare measured levels of electromagnetic emissions with those predicted, to confirm the understanding of the train power system.

Although tests are usually carried out with reference to the specific routes on which the rolling stock will operate, tests should be defined, carried out and the results documented without ambiguity to avoid unnecessary repetition of testing in the event that a future new route comes under consideration.

The acceptance of previously accepted rolling stock on new routes may skip further testing if the characteristics of the new route are similar to an existing route, e.g. an extension of an existing line with similar train detection and traction supply systems.

Electric multiple-unit trains should be tested complete as a fixed formation; locomotives should be tested separately from the coaches they haul. The testing of each type of hauled passenger coach can be subject to national technical rules.

NOTE The European technical specification CLC/TS 50238-2:2015, B.8.2 can be used for summation rules for harmonic currents.

B.2 Description of rolling stock and factors affecting its characteristics

The factors on which the rolling stock and/or signalling compatibility depend should be defined and documented by the manufacturer or operator and should include all relevant modifications to the rolling stock. Safety critical components should be clearly identified.

Annex C, Annex D and Annex E list known factors which can affect the rolling stock and/or signalling compatibility.

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B.3 Configuration (design status)

Measurements should be carried out on a representative sample or samples of the rolling stock for which acceptance is to be obtained. The equipment should be in a fully developed and defined operating state; the status of hardware and software which are factors affecting rolling stock and/or signalling compatibility, should be known and fully documented.

B.4 Test plan

B.4.1 General

The test plan is a document which should provide the appropriate means of measuring the rolling stock characteristics. It should make reference to the criteria in B.4.2, B.4.3 and B.4.4.

B.4.2 Test site

Measurements should be carried out with the rolling stock operating on sections of track which are as representative as possible of those of the intended routes. The extent to which a non-totally representative test site may be used to explore the range of tests listed in Clause B.1 should be evaluated.

Rolling stock should be tested on lines electrified with the different types of traction power supply with which the rolling stock can operate.

To avoid ambiguity of results, attention should be paid to the contribution of measured levels of interference resulting from the traction power supply characteristics and those actually generated by the rolling stock under test. All the electrical characteristics of the traction power supply (minimum source impedance, power supply filters characteristics) should be traced and included in the test report in order to evaluate the influence of the traction infrastructure on the interferences sourced by the RST under test.

B.4.3 Instrumentation

Measurement and testing equipment should be specified and agreed (in particular, transducers, spectrum analysers, selective voltmeters).

The choice of instruments used and their set-up should be such that measurements made can be interpreted with respect to the reference limit(s). Specifically, consideration should be given to

– location of measuring transducer;
– accuracy;
– bandwidth;
– dynamic range;
– quantification of systematic errors, e.g. noise, intermodulation effects;
– system response to evaluate signals within both frequency and time domains;
– recording of speed, location, traction power supply parameters and other factors which may have an influence on the level of interference generated;
– procedural calibration checks.

B.4.4 Test procedure

Tests should be conducted over the range of conditions which may occur with a sufficient number of tests being performed to enable the true rolling stock characteristics to become apparent. The worst cases should be examined in the closest detail. If tests are not defined in national regulations and standards, tests should be conducted in the following operational conditions:

– at standstill – raising or lowering a pantograph;
– the full extent of the effort-speed characteristics in motoring and braking (including regenerative braking):
  • with an acceleration or deceleration of the train that is low enough to allow the observation of change in frequencies generated by rolling stock in the frequency bands of track circuits,
  • up to the maximum operating frequency of traction converters (which can perform at overspeed tests, particularly when the train under test is equipped with new wheels).
– constant speeds (regulated by speed control or the driver);
– operational conditions (speed and tractive effort) associated with the worst case emissions;

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- operation at reduced tractive efforts as determined by the position of the driver's power controller;
- sequences of motoring, coasting and braking;
- normal and degraded modes of operation;
- typical variations or disturbances in the supply voltage (e.g. due to other trainsets on the system, a substation cut out, line gaps, poor contact of current collection equipment);
- environmental conditions which can affect the rolling stock equipment operation (e.g. wheelslip, wheelslide);
- regular known transients (e.g. circuit breaker opening and/or closing, particular rolling stock equipment starting and/or stopping) if explicitly required for demonstration of compatibility.

NOTE 1 In Europe, the test procedure for axle counters is defined in EN 50592 and for track circuits, in national specifications. Attention is drawn to the fact that axle counters specific tests required for "typical variations or disturbances in the supply voltage" or for "environmental conditions" or "regular known transients" are not specified in EN 50592. Instead, theoretical assessment of their impact on operations is included for the demonstration of compatibility

NOTE 2 For track circuits, only some of these tests are performed. Theoretical assessment of all known phenomena that affect compatibility is included for the demonstration of compatibility.

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Annex C
(informative)

Factors affecting rolling stock characteristics and compatibility

The factors which are known historically to be relevant are as follows:

– individual vehicle and overall train lengths;
– spacing between the individual wheelsets of each vehicle and between the outermost wheelset and the vehicle extremity;
– the construction of wheelsets and the method of train braking;
– input vehicle impedances, including their argument, for all modes of operation (normal and degraded modes);
– characteristics of electromagnetic interference sources;
– tractive effort diagram, including speed ranges;
– equipment that affects the wheel – rail interface (vehicle axle load, impedance between wheels, characteristics of sanding equipment and on-board flange lubricators);
– wheel characteristics;
– metal and inductive components entering the sensitive area of wheel sensors;
– characteristics of vehicle metal construction;
– braking methods and their characteristics (regenerative braking, magnetic track brakes and eddy current track brakes, for example);
– characteristics of shunt assisting devices;
– the electrical bonding between the running surface of wheels and the vehicle bodyshell, also the electrical bonding between vehicles. It would be a good idea to provide a copper connection to be used (e.g. axle grounding) in the rake of coaches or rail vehicle, which would convert the passing currents from one rail to another one by way of less resistance, see Figure C.1.

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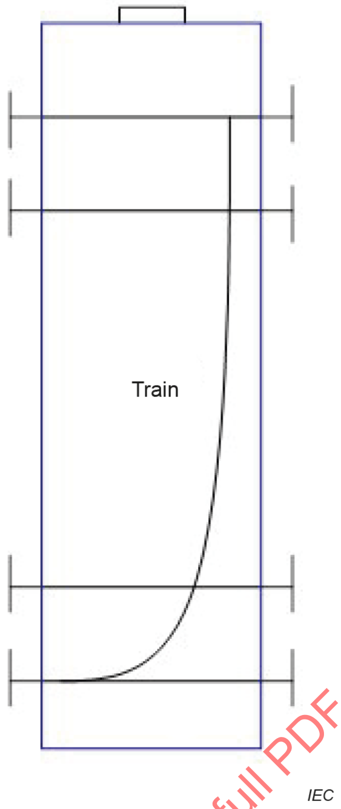

Figure C.1 – Electrical bonding

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Electrical bonding can also be done by grounding the car body on the left front wheel and right rear wheel.

The electrical bonding of any active or passive vehicle (locomotive, wagon) should be symmetrical and as close as possible mirroring the balanced flow of the track circuit currents.

If it is not symmetrical, there is a resultant current on the axles that unnecessarily disturbs all the track circuits and their lightning protection or alternatively the automatic train protection (ATP) signal if sent through the rails:

– the traction and auxiliary power circuits (including the train line return current); the filter values, return current paths, interaction between power circuit elements;
– the traction and auxiliary control packages; chopping frequencies, hardware and software control techniques, feedback transducers, fault detection;
– current collection equipment, distance between line contact points;
– interference current monitoring units and other equipment that may be used to monitor signalling interference related parameters;
– magnetic fields produced by vehicles;
– minimum maintenance requirements;
– different operating conditions and degraded modes of operation where the other factors listed may change.