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NORME INTERNATIONALE

Railway applications – Supply voltages of traction systems

Applications ferroviaires – Tensions d'alimentation des réseaux de traction

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RAILWAY APPLICATIONS – SUPPLY VOLTAGES OF TRACTION SYSTEMS

FOREWORD

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International Standard IEC 60850 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

The text of this standard is based on the European Norm EN 50163 (2004).

This fourth edition cancels and replaces the third edition of IEC 60850 published in 2007. This edition constitutes a technical revision.

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

– clarification of some definitions in Clause 3,
– Subclause 4.1 completed,
– Table 1 modified,
– Annex B modified with new Table B.1.

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

FDIS	Report on voting
9/1978/FDIS	9/1996/RVD

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

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

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

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- withdrawn,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

RAILWAY APPLICATIONS – SUPPLY VOLTAGES OF TRACTION SYSTEMS

1 Scope

This International Standard specifies the main characteristics of the supply voltages of traction systems, such as traction fixed installations, including auxiliary devices fed by the contact line, and rolling stock, for use in the following applications:

– railways;
– guided mass transport systems such as tramways, light trains, elevated and underground railways and trolleybus systems;
– rail bound material transportation systems, e.g for coal or iron-ore.

This standard is also applicable for low speed maglev trains or linear motor transport systems.

This standard does not apply to:

– mine traction systems in underground mines;
– cranes, transportable platforms and similar transportation equipment on rails, temporary structures (e.g. exhibition structures) insofar as these are not supplied directly or via transformers from the contact line system and are not endangered by the traction power supply system;
– suspended cable cars;
– funicular railways.

This standard deals with long term overvoltages as shown in Annex A.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61133:2006, *Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service*[1]

IEC 62128-1:2013, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62128-1, as well as the following apply.

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1 A new edition is under development.

NOTE See bibliography and its reference to EN 50160 for clarification of some definitions.

3.1
electric traction system
railway electrical distribution network used to provide energy for rolling stock

Note 1 to entry: The system includes:

– contact line systems,

– return circuit of electric traction systems,

– running rails of non-electric traction systems, which are in the vicinity of, and conductively connected to the running rails of an electric traction system,

– electrical installations, which are supplied from contact lines either directly or via a transformer,

– electrical installations in substations, which are utilized solely for distribution of power directly to the contact line,

– electrical installations of switching stations.

[SOURCE: IEC 62128-1:2013, 3.4.1]

3.2
voltage
U
potential at the train's current collector or elsewhere on the contact line, measured between the contact line and the return circuit

Note 1 to entry: The values considered in this standard are the mean value of DC voltage or the r.m.s. value of the fundamental AC voltage.

3.3
nominal voltage
U_n
designated value for a system

3.4
highest permanent voltage
U_{max1}
maximum value of the voltage likely to be present indefinitely

3.5
highest non-permanent voltage
U_{max2}
maximum value of the voltage likely to be present for a limited period of time

3.6
overvoltage
any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

3.7
long-term overvoltage
overvoltage higher than U_{max2} lasting typically more than 20 ms, due to low impedance phenomena, for example a rise in substation primary voltage

Note 1 to entry: Such overvoltages are independent of line load and may be described by a voltage-time curve only. See Annex A for information on this curve.

3.8
highest long term overvoltage
U_{max3}
voltage defined as the highest value of the long-term overvoltage for t = 20 ms. This value is independent from frequency

3.9
lowest permanent voltage
U_{min1}
minimum value of the voltage likely to be present indefinitely

3.10
lowest non-permanent voltage
U_{min2}
minimum value of the voltage likely to be present for a limited period of time

3.11
voltage variation
increase or decrease of voltage normally due to variation of the total load of a distribution system or a part of it

3.12
rapid voltage change
single rapid variation of the r.m.s. value of a voltage between two consecutive levels which are sustained for definite but unspecified durations

3.13
supply voltage dip
sudden reduction of the supply voltage to a value of less than U_{min2}, followed by a voltage recovery after a short period of time

Note 1 to entry: Conventionally, the duration of a voltage dip is between 10 ms and 1 min. The depth of a voltage dip is defined as the difference between the minimum r.m.s. voltage during the voltage dip and the nominal voltage U_n. Voltage changes which do not reduce the supply voltage to less than U_{min2} are not considered to be dips.

3.14
supply interruption
condition in which the voltage at the supply-terminals is lower than 1 % of the nominal voltage U_n

Note 1 to entry: A supply interruption can be classified as:

– pre-arranged, when consumers are informed in advance, to allow the execution of scheduled works on the distribution systems, or

– accidental, caused by permanent or transient faults, mostly related to external events, equipment failures or interference. An accidental interruption is classified as:

  - a long interruption (longer than 3 min) caused by a permanent fault,
  - a short interruption (up to 3 min) caused by a transient fault .

3.15
contact line
conductor system for supplying traction units with electrical energy via current-collection equipment

Note 1 to entry: This includes all current-collecting conductors and conducting rails or bars, including the following:

– reinforcing feeders;

– cross-track feeders;

– disconnectors;

– section insulators;

– over-voltage protection devices;

– supports that are not insulated from the conductors;

– insulators connected to live parts;

but excluding other conductors, such as the following:

– along-track feeders;

– earth wires and return conductors.

[SOURCE: IEC 60913:2013, 3.1.2]

3.16
substation
traction substation
installation, the main function of which is to supply a contact line system, at which the voltage of a primary supply system, and in certain cases the frequency, is converted to the voltage and frequency of the contact line

3.17
normal operating conditions
traffic operating to the design timetable and train formation used for power supply fixed installation design. Power supply equipment is operated according to standard rules.

Note 1 to entry: Standard rules may vary depending on the infrastructure manager's policy.

3.18
abnormal operating conditions
either higher traffic loads or outage of power supply equipment outside the standard rules

Note 1 to entry: Under these conditions, traffic may not operate to the design timetable.

4 Voltages and frequencies of traction systems

4.1 Voltages

The characteristics of the generic voltages of traction power supply systems (overvoltages excluded) are specified in Table 1 below.

"Generic", means that these voltages of the traction power supply systems are to be used in projects which have common/classical operating parameters and allow the use of other generic international standards. These traction power supply systems are implemented in many countries over the world and their efficiency is proven.

However, some countries have studied and implemented variations of the values based from these generic voltages of traction power supply systems, They have been made to solve difficulties or particular conditions such as very heavy power demand. These conditions may be:

- Need of high amount of energy avoiding voltage drops in the rails / contact line loop.
- Lack of insulation distance (narrow gauge under bridges or tunnels).
- Difficulties to find the appropriate power supply connection to the grid.
- Long tunnel necessitating very long distance between substations.

- Particular RAMS (Reliability, Availability, Maintainability, Safety) requirement (e.g. extended supply zone).
- Any other particular local condition.

These alternatives are presented in Annex B, Table B.1. It is suggested, during engineering studies to read this Annex B in order to consider it.

The choice of using these alternatives shall be made taking into account interoperability requirements if connection with another railway system is foreseen.

Table 1 – Nominal voltages and their permissible limits in values and duration

Electrification system	Lowest non-permanent voltage U_{min2} V	Lowest permanent voltage U_{min1} V	Nominal voltage U_n V	Highest permanent voltage U_{max1} V	Highest non-permanent voltage U_{max2} V
DC (mean values)	500	500	750	900	1 000
	1 000	1 000	1 500	1 800	1 950
	2 000	2 000	3 000	3 600	3 900
AC (r.m.s. values)	11 000	12 000	15 000 [a]	17 250	18 000
	17 500	19 000	25 000 [b]	27 500	29 000
[a] 16,7 Hz.					
[b] 50 Hz and 60 Hz.					

The following requirements shall be fulfilled:

a) the duration of voltages between U_{min1} and U_{min2} shall not exceed 2 min;

   the duration of voltages between U_{max1} and U_{max2} shall not exceed 5 min;

b) the voltage of the busbar at the substation at no load condition shall be less than or equal to U_{max1}. For DC substations, it is acceptable to have this voltage at no load condition less than or equal to U_{max2}, provided that when a train is present, the voltage at this train's pantograph (s) is in accordance with Table 1 and its requirements;

c) under normal operating conditions, voltages shall lie within the range $U_{min1} \leq U \leq U_{max2}$;

d) under abnormal operating conditions the voltages in the range $U_{min2} \leq U \leq U_{min1}$ in Table 1 shall not cause any damages or failures;

   NOTE The use of train power limitation devices on board may limit the presence of low voltage on the contact line (see IEC 62313).

e) if voltages between U_{max1} and U_{max2} are reached, they shall be followed by a level below or equal to U_{max1}, for an unspecified period;

f) Voltages between U_{max1} and U_{max2} shall only be reached for non-permanent conditions such as

   - regenerative braking,
   - move of voltage regulation systems such as mechanical tap changer;

g) lowest operational voltage: under abnormal operating conditions U_{min2} is the lowest limit of the contact line voltage for which the rolling stock is intended to operate.

   Recommended set values for undervoltage tripping relays in fixed installations or on board rolling stock are from 85 % to 95 % of U_{min2}.

4.2 Frequency

The frequency of the 50 Hz and 60 Hz electric traction systems is imposed by the three phase grid.

NOTE 1 Therefore, the values stated in EN 50160 are applicable in Europe.

The frequency of the 16,7 Hz electric traction system (except for synchronous-synchronous converters) is not imposed by the three phase grid.

NOTE 2 Concerning the 16,7 Hz electric traction system, strictly considered, the frequency corresponds to 16⅔ Hz. In order to simplify the denomination of the system, it is agreed to state the frequency as 16,7 Hz. This denomination is used in this standard.

The frequencies on AC railway power systems and their permissible limits are shown hereinafter.

Under normal operating conditions, the mean value of the fundamental frequency measured over 10 s shall be within a range of the HV supply network.

- For systems with synchronous connection to an interconnected system:

  50 Hz ± 1 % (i.e. 49,5 Hz to 50,5 Hz) for 99,5 % of a year

  50 Hz + 4 %/–6 % (i.e. 47 Hz to 52 Hz) for 100 % of the time

- For systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands):

  50 Hz ± 2 % (i.e. 49 Hz to 51 Hz) for 95 % of a week

  50 Hz ± 15 % (i.e. 42,5 Hz to 57,5 Hz) for 100 % of the time

For 60 Hz electric traction systems, the limit values for frequency variations are from 59 Hz to 61 Hz.

NOTE 3 Special national conditions for China, see Annex B.

For 16,7 Hz electric traction systems, the value are:

- for systems with synchronous connection to an interconnected system:

  16,7 Hz ± 1 % (i.e. 16,5 Hz to 16,83 Hz) for 99,5 % of a year

  16,7 Hz + 4 %/–6 % (i.e. 15,67 Hz to 17,33 Hz) for 100 % of the time

- for systems with no synchronous connection to an interconnected system (e.g. supply systems on certain islands):

  16,7 Hz ± 2 % (i.e. 16,33 Hz to 17 Hz) during 95 % of a week

  16,7 Hz ± 15 % (i.e. 14,16 Hz to 19,16 Hz) during 100 % of the time

- For systems connected to the railway 16,7 Hz interconnected grid:

  16,7 Hz + 2 %/–3 % (i.e. 16,17 Hz to 17 Hz) during 100 % of the time

NOTE 4 In practice, the variation of frequency is more closely controlled in some countries and regions such as in Europe and in Japan than stated above. Vehicles will operate only within the frequency tolerances for 15 000 V/16,7 Hz from 16,17 Hz to 17 Hz and for 25 000 V/50 Hz range from 49 Hz to 51 Hz. If the frequency is out of this range, the vehicles performance may be reduced or the vehicle drives may be disconnected.

The effects of the frequency variations may be examined by the railway operators to ensure the absence of harmful consequences on the train signalling.

For other traction frequencies, national regulations apply.

5 Testing

The tests specified in Table 2 are applicable, depending on the type of the line and on the need.

Table 2 – Tests

Title	Technical requirement	Test methodology	Kind of test
Voltage on the line	4.1	6.1.1 Rolling stock	Measurement
		6.1.2 Fixed installations	Measurement
Frequency	4.2	6.2 16,7 Hz only [a]	Continuous monitoring test
[a] The test is only necessary for 16,7 Hz systems which are not fed by at least one synchronous–synchronous rotating converter (= synchronous connection to an interconnected system).			

NOTE Annex C describes the tests related to voltage changes.

6 Test methodology

6.1 Measurement of the voltage on the line

6.1.1 Rolling stock

Rolling stock shall be tested as described in Clause 9 of IEC 61133:2006.

6.1.2 Fixed installations (see Table 3)

Table 3 – Measurement of the voltage on the line

Where	When	How	Acceptance condition
Substation Busbar, line circuit breakers open, normal operating conditions. For DC substations, it may be necessary to add a small resistive load.	At commissioning	• Voltage recorder for the fundamental frequency or • Digital data loggers with a frequency range greater than or equal to 2 kHz averaging over 1 s • Measurement period 1 min	See 4.1 item c)
If a voltage conditioning device is installed along the line Measure on either side of the device under no load and normal operating condition	At commissioning and operating	No load ⇒ see substation When in operation ⇒ see ad hoc measurement	No load ⇒ see substation When in operation ⇒ see ad hoc measurement
Ad hoc measurement at the site, where problems are situated.	In response to problems	• Voltage recorder devices for the fundamental frequency or • Digital data loggers with a frequency range greater than or equal to 2 kHz averaging over 1 s • Measurement period minimum 1 h maximum 1 week	• All voltage values are greater than or equal to U_{min2}. • All durations of voltages below U_{min1} are less than or equal to the duration stated in 4.1 item a). • Average value of the voltage is between U_{min1} and U_{max1}. • All durations of voltages above U_{max1} are less than or equal to the duration stated in 4.1, item b). • Il voltage values are less than or equal to U_{max2}.