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BSI Standards Publication

Railway applications — Electric traction — Short-primary type linear induction motors (LIM) fed by power converters

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This British Standard is the UK implementation of EN 62520:2011. It is identical to IEC 62520:2011.

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

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

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Railway applications - Electric traction - Short-primary type linear induction motors (LIM) fed by power converters
(IEC 62520:2011)

Applications ferroviaires -
Traction électrique -
Moteurs à induction linéaires (LIM) du type à primaire court alimentés par des convertisseurs de puissance
(CEI 62520:2011)

Elektrische Zugförderung -
Elektrische Maschinen für Schienen- und Straßenfahrzeuge -
Umrichtergespeiste Asynchron-Linearmotoren des Kurzstatortyps
(IEC 62520:2011)

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

The text of document (9/1531/FDIS), future edition 1 of IEC 62520, prepared by IEC TC 9, Electrical equipment and systems for railways, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62520 on 2011-06-29.

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

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-03-29
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-06-29

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62520:2011 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60034-5	NOTE Harmonized as EN 60034-5.
IEC 61672-1	NOTE Harmonized as EN 61672-1.
IEC 61260	NOTE Harmonized as EN 61260.
IEC 61287-1	NOTE Harmonized as EN 61287-1.
IEC 61377-1	NOTE Harmonized as EN 61377-1.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60034-8	-	Rotating electrical machines - Part 8: Terminal markings and direction of rotation	EN 60034-8	-
IEC 60050-131	-	International Electrotechnical Vocabulary (IEV) - Part 131: Circuit theory	-	-
IEC 60050-151	-	International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices	-	-
IEC 60050-411	-	International Electrotechnical Vocabulary (IEV) - Chapter 411: Rotating machinery	-	-
IEC 60050-811	-	International electrotechnical vocabulary (IEV) - Chapter 811: Electric traction	-	-
IEC 60085	-	Electrical insulation - Thermal evaluation and designation	EN 60085	-
IEC 60349-2	2010	Electric traction - Rotating electrical machines for rail and road vehicles - Part 2: Electronic converter-fed alternating current motors	EN 60349-2	2010
IEC 60850	-	Railway applications - Supply voltages of traction systems	-	-
IEC 61133	2006	Railway applications - Rolling stock - Testing of rolling stock on completion of construction and before entry into service	-	-
IEC 61373	-	Railway applications - Rolling stock equipment - Shock and vibration tests	EN 61373	-

CONTENTS

INTRODUCTION

This International Standard is introduced because there are significant differences between the rotary induction motor and the linear induction motor (LIM). These differences necessitate a different testing standard to ensure consistency, repeatability and dependability of the test results. For clarification, the significant differences are listed below:

a) The LIM has a power factor and an electric efficiency substantially lower than those of rotary motors, because its magnetic gap length is several times that of the rotary motors. As such, the assumption made for the rotary induction motor that the primary leakage reactance is significantly less than the mutual reactance is no longer valid.
b) The traction efficiency of a LIM does not include the mechanical transmission, typical of rotary motor propulsion.
c) LIMs produce direct thrust between the primary and secondary without the need for mechanical contact. Therefore, there are no adhesion limits due to the rail and wheels contact of the typical rotary drive. No spin/slide controls are needed with LIMs and thus there is no need for testing of this function.
d) LIMs produce not only thrust (which is in the longitudinal direction) but also normal and lateral forces which are effectively eliminated in the rotary induction motor, due to the symmetrical geometry of rotary motor. The normal force is either an attraction or a repulsion between the primary and secondary. The effect of these forces should be considered on deflection of primary and secondary and for their mechanical strength and rigidity, particularly as the deflection will affect the gap between primary and secondary and thereby change the LIM performance.
e) The normal force mentioned in d) has a direct effect on the design of magnetically levitated vehicles. Depending on whether the normal force is attractive or repulsive, this force will either assist the suspension of the vehicle or oppose it. Thus testing of the LIM must ensure that the force occurs in the appropriate part of the LIM operating range.
f) Information in Table 1 should be shared with subsystem component designers. Particular attention is drawn to the need for collaboration between the designers of the LIM and its associated converter as detailed in 5.1.

RAILWAY APPLICATIONS – ELECTRIC TRACTION – SHORT-PRIMARY TYPE LINEAR INDUCTION MOTORS (LIM) FED BY POWER CONVERTERS

1 Scope

This International standard applies to short-primary type linear induction motors (LIM) for propelling rail and road vehicles.

This standard applies to a specific configuration of LIM that has the primary mounted on either the vehicle body or trucks and a secondary that is fixed to the track and that is connected only by a magnetic field with the primary.

The object of this standard is to allow the performance of a LIM to be confirmed by tests and to provide a basis for assessment of its suitability for a specified duty.

The rating of LIMs fed in parallel by a common converter should take into account the effect on load-sharing due to differences of gap length and of LIM characteristics. The user should be informed of the maximum permissible difference in gap length for the particular application.

The electrical input to LIMs covered by this standard should come from an electronic converter.

NOTE At the time of drafting, only the following combination of LIMs and converters had been used for traction applications, but it may also apply to other combinations which may be used in the future:

– LIMs fed by voltage source converters.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60034-8, *Rotating electrical machines – Part 8: Terminal markings and direction of rotation*

IEC 60050-131, *International Electrotechnical Vocabulary – Part 131: Circuit theory*

IEC 60050-151, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-411, *International Electrotechnical Vocabulary – Part 411: Rotating machinery*

IEC 60050-811, *International Electrotechnical Vocabulary – Part 811: Electric traction*

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60349-2:2010, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 2: Electronic convertor-fed alternating current motors*

IEC 60850, *Railway applications – Supply voltages of traction systems*

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

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-131, IEC 60050-151, IEC 60050-411 and IEC 60050-811, apply, as do the following.

3.1
LIM rating
combination of simultaneous values of electrical and mechanical quantities, with their duration and sequence assigned to the LIM by the manufacturer

3.2
rated value
numerical value of any quantity included in a rating

3.3
continuous rating
mechanical output that the LIM can deliver on the test bed for an unlimited time under the conditions specified in 8.1 without exceeding the limits of temperature rise given in Table 4, all other appropriate requirements in this part also being satisfied

NOTE Several continuous ratings may be specified.

3.4
short-time rating (for example, one hour)
mechanical output that the LIM can deliver on the test bed for the stated time without exceeding the limits of temperature rise given in Table 4

NOTE The test being carried out as specified in 8.1 starting with the LIM cold, all other appropriate requirements in this part being also satisfied.

3.5
intermittent duty rating
duty cycle in which the LIM may be operated without the temperature rises exceeding the limits given in Table 4 at any point

3.6
equivalent rating
continuous rating with constant values of voltage, current and speed that, as far as temperature rise is concerned, is equivalent to the intermittent duty cycle which the LIM has to withstand in service

NOTE This rating should be agreed between user and manufacturer.

3.7
guaranteed rating
rating assigned by the manufacturer for test purposes

NOTE Normally this is continuous rating but in special cases the user and manufacturer may agree that it be a short-time or intermittent rating.

3.8
rated voltage
root-mean-square value of the fundamental component of the line-to-line voltage applied to a LIM when it is operating at a guaranteed rating

NOTE For LIMs fed directly or indirectly from a contact system, it is normally the highest voltage (excluding transients) which can be applied to the LIM when it is drawing the rated current with the contact system at its nominal voltage as defined in Annex C.

3.9
rated speed
speed at a guaranteed rating

3.10
maximum voltage
highest root-mean-square value of the fundamental component of the line-to-line supply voltage which can be applied to the LIM in service

3.11
repetitive peak voltage
peak value of the waveform of the converter output voltage, any random transient peaks arising from line voltage transients or other causes being disregarded

3.12
maximum current
maximum current shown on the specified characteristic as defined in 5.3

3.13
maximum output
maximum value of output in an operation

3.14
thrust
longitudinal accelerating or decelerating force produced when a LIM is in operation

3.15
maximum thrust
maximum value of thrust in an operation

3.16
efficiency
ratio of measured/calculated output power to measured/calculated input power

3.17
linear induction motor
LIM
type of electrical machine which operates on the same principles as the classical rotary induction motor

NOTE Similar to the rotary motor, the LIM's primary and secondary are magnetically coupled and the magnetic field from the primary induces eddy current in the secondary. This magnetic interaction produces a thrust/braking force between the primary and the secondary.

3.18
single-sided linear induction motor
SLIM
LIM whose primary exists only on one side of the secondary side

3.19
end effect
performance deterioration and three-phase asymmetry which appear in high-speed operation of an LIM due to the finite longitudinal length of primary

NOTE The primary core has finite length. The travelling magnetic field at both longitudinal ends is zero. When there is motion between the primary and secondary there is a non-uniform distribution of the flux density in the air gap. This non-uniform magnetic flux density causes an asymmetry among three-phase currents and a reduction of thrust that increase with high speed.

3.20
transverse edge effect
phenomena caused by the finite lateral width of the primary and secondary sides

3.21
primary
the primary comprises three parts; a three-phase winding, a slotted laminated ferromagnetic core and a mechanical support structure

3.22
short primary type
short primary type has the primary installed on board the vehicle and the secondary fixed to the track or guideway; the secondary is essentially almost continuous along the track

3.23
secondary
reaction plate, reaction rail
conductor and ferromagnetic iron core distanced more than several millimetres from the primary

3.24
cladding reaction plate
method of bonding or securing the conductive reaction plate to the surface of the secondary core

3.25
secondary conductor
non-magnetic conductive reaction plate secured to the surface of the secondary ferromagnetic iron core

3.26
secondary overhangs
additional width of secondary reaction plate in comparison with primary core width

3.27
secondary supporting structure
steel fabricated structure which secures the conductive reaction plate and secondary ferromagnetic iron core to the guideway surface and provides for any adjustment

3.28
mechanical gap
physical vertical separation between the bottom surface of the primary and the top surface of the secondary

3.29
nominal gap length
mechanical gap applicable to LIM-rated performance design

3.30
magnetic gap
gap length in a magnetic circuit; the physical distance between the primary and the secondary ferro-magnetic cores

3.31
travelling magnetic field
magnetic field produced by primary windings of a LIM, which corresponds to the rotating field in a rotary AC-machine

3.32
pole pitch
τ
longitudinal distance between two adjacent poles of the magnetic field

3.33
synchronous speed
speed of the fundamental wave of travelling magnetic field of LIMs

$$v_s = 2f\tau \quad \text{(m/s)}$$

where

f is the frequency of a power supply, i.e., primary frequency (Hz);

τ is the pole pitch (m).

3.34
slip
difference between the synchronous speed and speed of the primary divided by the synchronous speed:

$$s = \frac{v_s - v_p}{v_s}$$

where

v_p is the primary speed (m/s).

3.35
slip frequency
frequency of the secondary currents :

$$f_s = s\,f$$

3.36
normal force
vertical force between primary and secondary and which is perpendicular to the direction of motion and to the surface of the primary

3.37
electric braking
means of decelerating the vehicle by means of electric energy transfer

NOTE There are two different methods as described below.

3.38
regenerative braking
braking force caused by converting mechanical power to electrical power that is returned to the electric power supply system used to power onboard vehicle electrical systems or dissipated in a braking resistor

3.39
reversing-phase braking
electric braking method produced by reversing the longitudinal direction of the magnetic field in the air-gap thereby creating a slip greater than 1 and dissipating the power in the secondary conductor as eddy currents

3.40
electromagnetic suspension
magnetic levitation method achieved by using attractive magnetic force between electromagnets onboard and ferromagnetic rails

3.41
magnetic levitation force
net vertical repulsive or attractive reactive forces generated between the LIM primary on the vehicle and the LIM secondary

3.42
magnetic lateral guidance force
net horizontal repulsive reactive forces generated between the LIM primary on the vehicle and the LIM secondary

3.43
space-harmonic analysis
electromagnetic analysis method for calculating the characteristics of a LIM

NOTE The method uses the space harmonic spectrum derived by a Fourier series representation of the current sheets produced by a periodic sequence of virtual primaries.

3.44
user
agency responsible for defining the operational requirements of the LIM and for signing the acceptance certificate

3.45
manufacturer
company responsible for validating that the LIM meets the user's performance requirements

NOTE It is possible that a number of different companies may be involved in the design, manufacture and test of the components of the LIM.

4 Environmental conditions

Unless otherwise specified by the user, the following environmental conditions apply:

a) altitude: height above sea level not exceeding 1 200 m;
b) temperature: air temperature in the shade not exceeding 40 °C.

Whenever LIMs are intended to operate where one or both of these limits will be exceeded, special requirements may be agreed between user and manufacturer.

Furthermore, the user shall inform the manufacturer of any particularly severe environmental condition such as dust, humidity, temperature, snow, dynamic effects, etc. to which the LIMs will be subjected.

5 Characteristics

5.1 Exchange of information

The LIM and converter designers shall collaborate to produce all the technical information necessary to ensure that the combined unit will meet the requirements of this standard.

To fulfil this requirement, the LIM designer shall provide the converter designer with all information necessary to fully evaluate the interaction between the LIM and the converter.

The converter designer shall also provide the LIM designer with the characteristics showing, for example, the converter line-to-line output voltage (including the repetitive voltage peaks), current, fundamental frequency, harmonics and power over the whole range of the application, including operation at the maximum and minimum values of the contact-system voltage.

The documents recording this exchange of information shall form an integral part of the specification of the LIM and of the converter.

NOTE 1 This requirement for the exchange of information is also included in IEC 61287-1.

NOTE 2 The length of cable run between LIM and converter and the effect on peak voltages seen at the LIM terminals should be considered.

In addition, the designer of the primary of a LIM, the designer of the secondary, the fastening device of the secondary, and the system integrator should coordinate all the necessary technical items so that the LIM fulfills the requests described in this standard.

The designer of the primary of the LIM shall supply necessary technical information to the designer of the secondary and fastening devices of the secondary, the system integrator, for sufficient investigation on interaction between the primary and the secondary.

Also the designer of the secondary shall supply all the necessary technical information to the primary and the fastening devices of the secondary and the system integrator.

Technical items transferred and requested between the manufacturer of the primary and his counterparts are shown in Table 1. The documents recording this exchange of information shall form an integral part of the specification of the LIM.

Table 1 – Technical items transferred and requested between the manufacturer of the primary and his counterparts

Items		Manufacturer of primary	Manufacturer of secondary	Manufacturer of secondary fastening device	System integrator[a]
Nominal gap length		O	O		■
LIM type Technical data on primary		■	O		O
Technical data on secondary (type and form including its base)		O	■	O	O
Dimension and material of conductor Dimension and material of core		■	O		O
Maximum thrust		■	O	O	O
Maximum normal force		■	O	O	O
Distribution of the normal force		■	O	O	O
Maximum deflection	Primary	■			O
	Secondary		■		O
	Secondary fastening device			■	O
Strength	Primary	■			O
	Secondary		■		O
	Secondary fastening device			■	O
Stress of support by secondary fastening device			O	O	■

■ Primary information supplier.

O Information sharer.

[a] System integrator may be either a system supplier or a transport authority.

5.2 Reference temperature

All characteristics, irrespective of the class of insulation used on the LIM to which they apply, shall be drawn for a winding reference temperature of 150 °C which shall be stated in the characteristics.

5.3 Specified characteristics

LIM specifications shall, as a general rule, include characteristic curves in accordance with the relevant clauses of this standard. These curves, defined as the “specified characteristics”, shall be plotted to the designed operating limits of each variable. Unless otherwise agreed between user and manufacturer, the characteristics shall show the LIM performance at the nominal voltage of the supply system as defined in Annex C, and shall be submitted to the user before the order for the LIMs is placed.

5.4 Declared characteristics

Declared characteristics are derived from the results of type tests carried out in accordance with 8.2.1 and shall meet the requirements of 8.2.2.

Unless previously agreed, the declared characteristics of LIMs electromagnetically identical with any previously manufactured for the same user or application shall be those of the existing LIMs, in which case, the compliance with the characteristics shall be demonstrated by routine tests only.

5.5 Efficiency characteristics

Efficiency characteristics shall take into account losses arising from the harmonics in the supply from the converter.

5.6 Traction motor characteristics

The specified and declared characteristics of a traction motor shall be for the converter-supplied variable frequency characteristics, which show LIM line-to-line voltage, current, frequency, slip frequency, mean thrust and efficiency as a function of speed over the whole range of application of the LIM at the nominal gap length. Voltage curves shall show the root-mean-square value of the fundamental component. Current curves shall show the root-mean-square value of the fundamental component and the total root-mean-square value. For LIMs used in the braking mode, similar characteristics shall be produced showing the thrust input and the electrical output as a function of motor speed.

NOTE 1 The system integrator determines the nominal gap length considering tolerance of the attachment of primary and secondary, abrasion of wheel and rail, the deflection of gap length according to vibration and shocks in running.

NOTE 2 Subclause 5.1 refers to the need for the exchange of information between the designers of the LIM and of the converter.

6 Marking

6.1 Primary nameplate

All LIM primaries covered by this standard shall carry a nameplate. The nameplate will include at least the following information:

a) manufacturer’s name;
b) primary type designation;
c) primary serial number;
d) year of manufacture.

Furthermore, a serial number shall be punched on the primary of every LIM. Those LIMs designed for unidirectional motion shall carry an arrow indicating the direction of motion.

NOTE 1 The primary serial number and direction arrow should be easily readable when the primary is installed in the vehicle.

Terminal and lead markings shall be in accordance with IEC 60034-8 unless otherwise agreed.

If the standard direction is not easily determined by the appearance of the LIM, it shall be indicated by the manufacturer.

NOTE 2 Example of marking for windings having 6 terminals:

– U1; U2; V1; V2; W1; W2.

6.2 Secondary marking

All LIM secondaries shall be permanently marked with an identification serial number. The marking will be placed on both sides of the support frame and have the following information:

a) secondary type;

b) length;
c) manufacturer sequence number;
d) special features.

7 Test categories

7.1 Test categories

7.1.1 General

There are three categories of tests:

a) type tests;
b) routine tests;
c) investigation tests.

7.1.2 Type tests

7.1.2.1 General

Type tests are intended to prove the ratings, characteristics and performance of new types of LIM. They shall be carried out as specified in Clause 8 and on one primary of the LIM of every new design. Unless otherwise agreed, the LIM shall be one of the first ten manufactured. Where there is a change in place and/or method of manufacture, requirements of 7.1.2.3 apply.

Before testing commences, the manufacturer shall provide the user with a test specification outlining the tests to be undertaken to demonstrate compliance with this standard. Following completion of the type tests, the manufacturer shall supply the user with a full test report.

7.1.2.2 Type tests on converter supply

If each LIM is fed by its own converter, the type test shall preferably be carried out using the converter to be employed in service, but, as an alternative, a supply which closely resembles the supply from the vehicle converter in the magnitude and harmonics may be employed.

If several LIMs are fed in parallel from a single converter, the type test shall be carried out on a single primary of the LIM using a supply closely resembling the supply from the vehicle converter in magnitude and harmonic content of the waveform.

7.1.2.3 Type tests on sinusoidal supply

This test is to provide a reference for the characteristics of a LIM.

The test shall include a temperature rise test at a rating determined by the manufacturer.

Voltage, frequency, thrust, ventilation and test duration can be at the manufacturer's discretion, but the duration of the test shall be at least 1 h and at values that do not over-stress the LIM above those normally seen in service.

The test parameters shall be retained for any subsequent test on that design of LIM.

The temperature-rise measurements shall be carried out as detailed in 8.1.

7.1.2.4 Repeat type test

Subject to agreement, and to the results of both the type test on sinusoidal supply (refer to 7.1.2.3), and the routine test for the new LIM being within the tolerances established on the previous LIM's, a full type test is not required for the new LIM provided that the manufacturer has produced a full type test report for a previous LIM of the same electromagnetic design at the same or higher rating. This also applies to repeat orders, and where there is a change of place and/or method of manufacture.

7.1.3 Routine tests

Routine tests are intended to demonstrate that the primary of a LIM has been assembled correctly, is able to withstand the appropriate dielectric tests and is in sound working order both mechanically and electrically. The tests listed in Table 2 shall be carried out on all LIM primaries.

The routine test on the secondary will demonstrate that the secondary conforms to the design configuration, meets the dimensional tolerances and other specific requirements agreed in advance by the user and manufacturer. The routine tests for the secondary are listed in Table 3. The test quantities for the secondary may be agreed between the user and manufacturer.

The routine tests specified in Clause 9 shall normally be carried out on all LIMs but, before placing an order, the user and manufacturer may agree to adopt an alternative test procedure (e.g. in the case of LIMs produced in large quantities under a strict quality assurance procedure). This may permit reduced routine testing of all LIMs or may require the full tests on a proportion of LIMs chosen at random from those produced on the order. Any such agreement shall require the dielectric tests specified in 9.1.3 to be carried out on all LIMs.

7.1.4 Investigation tests

Investigation tests are optional special tests performed to obtain additional information. They shall be carried out only if agreement between user and manufacturer has been reached before placing the order for manufacture of the LIMs. The results of these tests shall not influence acceptance of LIMs.

7.2 Summary of tests

Tables 2 and 3 list the tests required for compliance with this standard.

Table 2 – Summary of tests for the primary[a]

	Test category		
	Type	**Routine**	**Investigation**
Temperature rise	8.1	—	—
Short-time thermal test /heat run	7.1.2.3	9.1.1[b]	—
Characteristics	8.2	9.1.2	—
Dielectric	—	9.1.3	—
Shock and vibration	8.3	—	—
Structural tests	—	9.1.4	—
Noise	—	—	10.2

[a] All primaries, including those type tested, shall be routine tested.

[b] Optional tests are subject to agreement between user and manufacturer.

Table 3 – Summary of tests for secondary

Test item	Type test	Routine test	Investigation test
Dimension test	—	9.2.1	—
Chemical composition test	—	9.2.2	—
Tension test	—	9.2.3	—
Bending test	—	9.2.4	—
Shear test	—	9.2.5	—
Ultrasonic flaw detection	—	9.2.6	—
Friction test	—	9.2.7	—
Electrical conductivity test	—	9.2.8	—

8 Type tests

8.1 Temperature-rise tests

8.1.1 General

The tests shall be carried out at the guaranteed ratings of the primary.

In the case of continuous rating tests of primary current and frequency, the time to reach a steady temperature may be shortened by commencing the test at an increased load or reduced ventilation, provided that the rated conditions are subsequently maintained for at least 2 h or until it is demonstrated by appropriate means that steady temperatures have been reached.

The tests may be carried out without using the secondary.

NOTE Steady temperature is defined as a change in temperature of less than 2 K during the final hour of the test

8.1.2 Ventilation during temperature-rise tests

If cooling is by forced ventilation, the static pressure and the airflow specified by the manufacturer shall be used for testing.

In general, no cooling corresponding to that produced by the movement of the vehicle shall be provided but, where this cooling is particularly important, it may be provided subject to agreement between user and manufacturer.

8.1.3 Measurement of temperature

The temperature shall be measured in accordance with Annex A.

8.1.4 Judgement of results

The temperature rises of the windings at the “commencement of cooling” as defined in Annex A, and shall not exceed the values given in Table 4.

8.1.5 Limits of temperature rise

The different thermal classes of insulation systems are defined in IEC 60085.

Table 4 gives the permissible limits of temperature rise above the temperature of the cooling air, measured on the test bed, for windings and other parts insulated with materials of the thermal classes presently used in the construction of LIMs to which this part applies.

If different parts of the same primary have different thermal classes of insulation, the temperature-rise limit of each part shall be that of its individual thermal class.

Table 4 – Limits of temperature rise for continuous and other ratings

Part	Method of measurement	Thermal class of insulation system					
		130(B)	155(F)	180(H)	200	220	250
Primary windings	Resistance	130 K	155 K	180 K	200 K	220 K	250 K

Where the primaries are directly or indirectly exposed to the heat from an engine or from any other source, the adoption of temperature rises lower than those specified in Table 4 may be agreed between user and manufacturer.

8.2 Characteristic tests and tolerances

8.2.1 General

8.2.1.1 Test methods for LIMs

As it is more difficult to perform characteristic tests on LIMs than for a rotary induction machine, characteristics shall be checked by one of following special methods.

a) rotary test facility of a LIM;

b) electromagnetic force analysis method;

c) dynamic thrust test with vehicle;

d) vehicle dynamic test.

In the case of c) and d), the system integrator shall provide vehicles.

8.2.1.2 Rotary test facility of LIM

For verifying the design of a LIM, running tests may be requested, but it is difficult to execute dynamic testing of a LIM itself. For such cases, a special rotary test machine, whose primary length is approximately same as the investigated LIM, is often used. General technical information and examples are described in Annex B.

8.2.1.3 Electromagnetic force analysis method

8.2.1.3.1 Standstill test

The primary and secondary are fixed by keeping the nominal gap length between them. Then, a sinusoidal nominal voltage with nominal frequency is applied to the primary windings. The thrust and normal force are measured. The supporting structure shall be designed so that the interference from the deflection of this structure to the force measurements can be minimized. The surface temperature of the secondary conductor shall be measured and recorded. A manufacturer shall determine the nominal voltage, frequency, thrust, normal force and their margins, and shall inform the user before the type test. This test of the first machine for a specific new design is recommended, but the availability of the test depends on agreement between user and manufacturer.

8.2.1.3.2 Electromagnetic force analysis

If a test run of a LIM unit is not feasible, measurement of speed characteristics, which is normally carried out on rotating machines, may be replaced by the results of calculation by a program for electromagnetic characteristics.

It shall be confirmed that the results of calculation of characteristics as in 8.2.1 shall not vary by more than10 % in the range up to the rated speed, i.e. the area of V/F-constant operation by comparison with the test values of speed characteristics in relation to the speed and thrust of at least one utility-scale LIM, e.g., a rotary test facility described in 8.2.1.1.

NOTE The program for calculating electromagnetic characteristics should be on the basis of Maxwell's equations, taking longitudinal end-effects into account with correction of secondary conductivity concerning transverse edge effects.

The tests described in 8.2.1.3.1 and 8.2.1.3.2 are both required.

8.2.1.4 Dynamic thrust test with vehicle

The LIM primary is installed on a vehicle and dynamically tested on a track with the appropriate secondary.

Dynamic thrust is determined directly by instrumentation or observed from the acceleration measurements. Corrections are made for vehicle weight, grade, rolling resistance and line voltage.

The dynamic thrust test may be replaced by an acceleration test.

8.2.1.5 Vehicle dynamic test

Refer to 9.2.1 of IEC 61133:2006.

The test shall be conducted at the nominal gap length within measurement tolerance. The nominal gap length shall be confirmed by measurement prior to starting dynamic tests.

8.2.2 Tolerances

The thrust at the breakpoint shall be between –5 % and +15 % of the specified value for the rated conditions.

The manufacturer shall present confirmation data to the user.

The temperature rise from the sinusoidal supply type test (see 7.1.2.3) where applicable, shall not vary by more than ±12 % or ±15 K, whichever is the highest, from the original type test.

8.3 Shock and vibration tests

Shock and vibration tests are subject to IEC 61373. This test can be omitted or the conditions of the test can be amended by agreement between user and manufacturer.

NOTE For a Maglev, which is free from rolling motion of wheels, reduced conditions of these tests may be used.

9 Routine tests

9.1 Routine tests of primary

9.1.1 General

Routine tests shall be carried out using a sinusoidal supply at power frequency or at a frequency used in service.

The frequencies used for different tests need not be the same but, once established, they shall not be changed. The declared values for the test points shall be the average of the tests on four primaries, one of which shall be the primary which has been type-tested. In order to reduce the effect of temperature variations, the tests shall be carried out in the same sequence on all primaries. Efficiency measurements are not required nor are tests in the braking mode.

To confirm consistency within a series, the sinusoidal temperature rise type test (see 7.1.2.3) may be undertaken at intervals throughout the series, either randomly or at set intervals with agreement between user and manufacturer. The tolerances are as defined in 8.2.2.

9.1.2 Characteristic tests and tolerance

9.1.2.1 General

If a test run of a primary unit is not feasible, routine characteristic tests may be replaced by the following measurements.

9.1.2.2 Resistance measurement of primary winding

The resistance of the primary winding is calculated from the resistance values measured between each terminals of a LIM at arbitrary ambient temperature by the following formula:

$$r_1 = \frac{R_1}{2} \times \frac{235 + 150}{235 + t}$$

where

r_1 is the esistance per phase of the primary winding at 150 °C;

R_1 is the mean value of the resistance values measured between each terminals of the primary winding;

t is the ambient temperature at the time of resistance measurement.

When R_1 is measured with the current fall-of-potential method, the current for measurement shall be 10 % to 20 % of continuous rating current.

The standard value of resistance of the primary winding shall be the mean value of four LIMs, one of which has been type-tested.

NOTE For materials other than copper, the value 235 in the above formula should be replaced with the reciprocal of the temperature coefficient of resistance at 0 °C for the material.

9.1.2.2.1 Tolerances

Resistance of the primary winding shall not exceed the standard value obtained from the measurements in 9.1.2.2 by more than ± 5 %.

9.1.2.3 Measurement of impedance

With the secondary not fitted, impedance shall be calculated from the current, voltage and power factor measured with a sinusoidal current applied to the primary terminals at the commercial frequency or the frequency to be used in service. The frequency and number of phases, once used ,shall not be changed.

The standard value of impedance shall be the mean value of four primaries, one of which has been type tested.

9.1.3 Dielectric tests

The tests shall normally be carried out using a.c. of near sinusoidal waveform and a frequency between 25 Hz and 100 Hz, but d.c. testing may be employed if agreed between user and manufacturer before placing an order.

The test voltage shall be applied in turn between the windings and the frame (primary iron core). The full value of the voltage shall be applied only to new LIMs with all their parts in place as under normal working conditions. The test shall be carried out with the hot LIM immediately after completion of the routine tests specified in the preceding clauses.

The test voltage shall be the highest of the values listed in Table 5 for the chosen test method and shall be applied gradually, commencing at not more than one-third of the final value. When reached, this final value shall be maintained for 60 s.

Table 5 – Dielectric test voltages

<table>
<tr><th>Winding</th><th colspan="2">Test voltage
V</th></tr>
<tr><td rowspan="2">All windings</td><td>AC tests</td><td>$2 \times U_{dc} + 1\ 000$
or
$2 \times U_{rp} / \sqrt{2} + 1\ 000$
or
$U_{rpb} / \sqrt{2} + 1\ 000$</td></tr>
<tr><td>DC tests</td><td>$3,4 \times U_{dc} + 1\ 700$
or
$2,4 \times U_{rp} + 1\ 700$
or
$1,2 \times U_{rpb} + 1\ 700$</td></tr>
<tr><td colspan="3">U_{dc} is the highest mean voltage to earth which can be applied to the d.c. link when the contact system is at its maximum voltage and the machine is motoring.
U_{rp} is the maximum repetitive peak voltage to earth which can be applied to the machine winding when the contact system is at its maximum voltage and the machine is motoring. (Repetitive peak voltage is defined in 3.11.)
U_{rpb} is the maximum repetitive peak voltage to earth which can appear on the winding when the machine is braking.</td></tr>
</table>

If neither the d.c. link nor the motor windings are normally earth referenced, then U_{dc} and U_{rp} shall be taken as the highest voltages to earth that can appear on their respective circuits, should any point on them become connected to earth.

9.1.4 Structural tests

9.1.4.1 Dimensions and appearance

Structural checks shall be performed by dimensions measurements using the drawing agreed between user and manufacturer. The acceptance criteria shall be based on agreement between user and manufacturer.

9.1.4.2 Flatness measurement

Flatness of the surface of the primary core, facing the secondary conductor, of the LIM shall be measured. This may be replaced by measurement of geometric tolerance based on the drawing agreed between user and manufacturer.

9.2 Routine tests of secondary

9.2.1 Dimension test

The thickness of the secondary conductor, thickness and width of secondary core, the height, the length, the longitudinal level, maximum camber, width, flatness, planarity of the complete reaction plate in combination of the secondary conductor and core shall be measured. They can be substituted by the measurement of geometrical tolerance based on drawings agreed between user and manufacturer.

9.2.2 Chemical composition test

Tests of chemical composition for the secondary conductor and secondary iron shall be executed. In addition, the material strength analysis shall be completed on the secondary supporting structure and fastener systems to ensure acceptable deflection and fatigue resistance characteristics. The tests can be substituted by the submission of material certification documents. These procedures shall be the confirmation that the materials of the secondary side fulfil the requests from the supplier of the primary side.

9.2.3 Tension test

The tensile strength of the ferromagnetic and conductive materials for the secondary side shall be measured. The test can be substituted by the submission of the material certification document or by analysis.

9.2.4 Bending test

The bending strength of the ferromagnetic and base materials for the secondary reaction plate shall be measured. The test can be substituted by the submission of the material certification document or by analysis.

9.2.5 Shear test

Strength in shear of the secondary conductor and the secondary core shall be measured if the reaction plate consists of clad material in conductor and ferromagnetic materials. Fastener strength shall be measured if the reaction plate is mechanically connected. This test can be substituted by analysis.

9.2.6 Ultrasonic flaw detection

The joint condition between the secondary conductor and the core shall be checked by an ultrasonic flaw detector. This test is applied to clad-type reaction plates.

9.2.7 Friction test

The dash friction force is measured by the force needed to draw the secondary conductor plate over the secondary iron, where the secondary core or the base is fixed, and the joint strength between the secondary conductor and the core is checked. This test is applied to mechanically jointed reaction plates. The acceptable friction force can also be determined by analysis.

9.2.8 Electrical conductivity test

Electrical conductivity of the secondary conductor shall be measured and the result shall be within the range agreed by the system integrator and the primary designer, if appropriate.

10 Investigation tests

10.1 General

Investigation tests are optional special tests performed to obtain additional information, as defined in detail in 7.1.4.

10.2 Noise test

Fundamentally, a noise test for the LIM primary is not necessary. If there are specific technical reasons for the necessity of a noise test, the methods of measurement shall be determined in agreement between user and manufacturer. The detailed informative description for rotary traction motors as well as the fundamental philosophy is set out in Annex C of IEC 60349-2:2010. The fundamental philosophy of the system noise test is described in 8.19 of IEC 61133:2006.

Annex A
(normative)

Measurement of temperature

A.1 Temperature of LIM parts

The temperature of insulated windings shall be measured by the resistance method.

No correction shall be made to the measured temperature rises if the temperature or the cooling air is between 10 °C and 40 °C during the test.

If the cooling air temperature is outside these limits during a type test, a correction to the measured temperature rises may be agreed between user and manufacturer.

Before starting a short-time test, it shall be confirmed, by either thermometer or resistance measurements that the temperatures of the windings are within 4 K of the temperature of the cooling air. When calculating the winding temperature rises, any such difference in initial temperature up to 4 K shall be subtracted from the result if the winding is the hotter or added to it if it is the cooler.

Resistance method

In this method, the temperature rise of a winding is determined by its increase in resistance during the test.

For copper windings, the temperature rise at the end of a test is determined by the following formula:

$$\text{temperature rise} = t_2 - t_a = \frac{R_2}{R_1}(235 + t_1) - (235 + t_a)$$

where

t_1 is the initial temperature of the winding in Celsius;

R_1 is the resistance of the winding at temperature t_1;

t_2 is the temperature of the winding at the end of the test in Celsius;

R_2 is the resistance of the winding at the end of the test;

t_a is the temperature of the cooling air at the end of the test in Celsius.

NOTE For materials other than copper, the value 235 in the above formula should be replaced with the reciprocal of the temperature coefficient of resistance at 0 °C for the material.

A.2 Cooling air temperature

For forced ventilation, the temperature of the cooling air shall be as measured at its entry to the LIM and, in the case of more than one entry point, this temperature shall be the average of the measurements at each of the points.

The thermometers shall be protected from radiated heat and draughts so that they record the true temperature or the air entering the LIM and around it. In order to avoid errors due to variations in the temperature of the cooling air, all reasonable precautions shall be taken to keep such variations to a minimum.

The temperature of the cooling air at the end of a test shall be the average of the measurements taken at approximately 15 min intervals during the last hour of a continuous rating test or throughout the duration or short-time test.

A.3 Measurement of resistance

A.3.1 Initial cold resistance

The initial cold resistance measurement shall be carried out using the same instruments as for subsequent hot measurements but the measurement need not be repeated at the beginning of each test. The temperatures of the windings shall be taken as their surface temperature as recorded by thermometer at the time of the resistance measurement and shall not differ from the temperature of the ambient air at that time by more than 4 K.

A.3.2 Hot resistance

Hot resistance shall be measured as soon as possible after stopping the LIM at the end of the test. Measurement may be made using the voltmeter and ammeter method (volt-ampere method), by means of a bridge or other suitable means. The same method shall be employed for all readings on a given winding, including the initial cold one.

If the voltmeter and ammeter method is used the current shall be high enough to give the necessary accuracy, without itself influencing the temperature rise. (In general, a value not exceeding 10 % of the rated current will meet the latter requirement.)

A.4 Estimation of primary temperature

A.4.1 "Commencement of cooling" time

At the end of a test, the main circuits are opened immediately, any separate ventilation being cut off at this instant.

A.4.2 Hot resistance measurement and extrapolation of the cooling and heating curves time

Resistance measurements of each winding shall commence not later than 45 s after the "commencement of cooling" and shall be continued for at least 5 min.

The time between successive measurements on each winding shall not exceed 20 s during the first 3 min and 30 s thereafter.

The temperature rises calculated from these readings shall be plotted as a function of time using a logarithmic scale for temperature and a linear scale for time. The resulting curve shall be extrapolated to the time of "commencement of cooling" to give the temperature rise at the end of the test.

Annex B
(informative)

Test method using a rotary test facility of a LIM

B.1 General

A rotary test facility consists of an arch-formed primary whose arch-length is equal to the primary iron length of the primary side of a tested LIM, and rotatable drum of secondary reaction plate, between which the nominal gap length is kept constant.

The diameter of the rotor shall be sufficiently larger than the pole pitch of the primary to ensure that there is no interference by the residual eddy currents induced in the rotor by the trailing end of the primary magnetic field on the entry end field of the primary.

An example of the facility is shown in Figure B.1.

Tests to demonstrate compliance with the specified characteristics shall be carried out by measuring the electrical input to the arch-formed primary side and the mechanical output from the rotating secondary side. The output may either be measured directly or be calculated from the measured output of a driven electrical machine of known efficiency.

Load tests shall be carried out at approximately the reference temperature to which the results shall be corrected if the correction is significant. Sufficient test readings shall be taken to enable the declared characteristics of the LIM to be plotted.

The electrical input to the converter shall be measured by an agreed method, but it shall not influence the acceptance of the LIM.

The test shall be carried out in only one direction of rotation.

The instruments used to measure the complex waveforms of the input to the arch-formed primary shall indicate the value of the current, voltage and power with sufficient accuracy to enable compliance with the specified tolerances to be demonstrated.

B.2 Thrust

The thrust shall be calculated from the measured value of the torque of the rotating axis of the drum of the secondary reaction plate. The operating speeds for measuring the thrust are decided in agreement between user and manufacturer, but the thrust measurement at rated speed, i.e., the speed at which the applied primary voltage is equal to the rated voltage, is mandatory.

B.3 Normal force

The normal force of the arch-formed LIM primary is measured by stress gauges attached to the support between fixed frame and suspended table supporting the arch-formed primary side of the LIM.

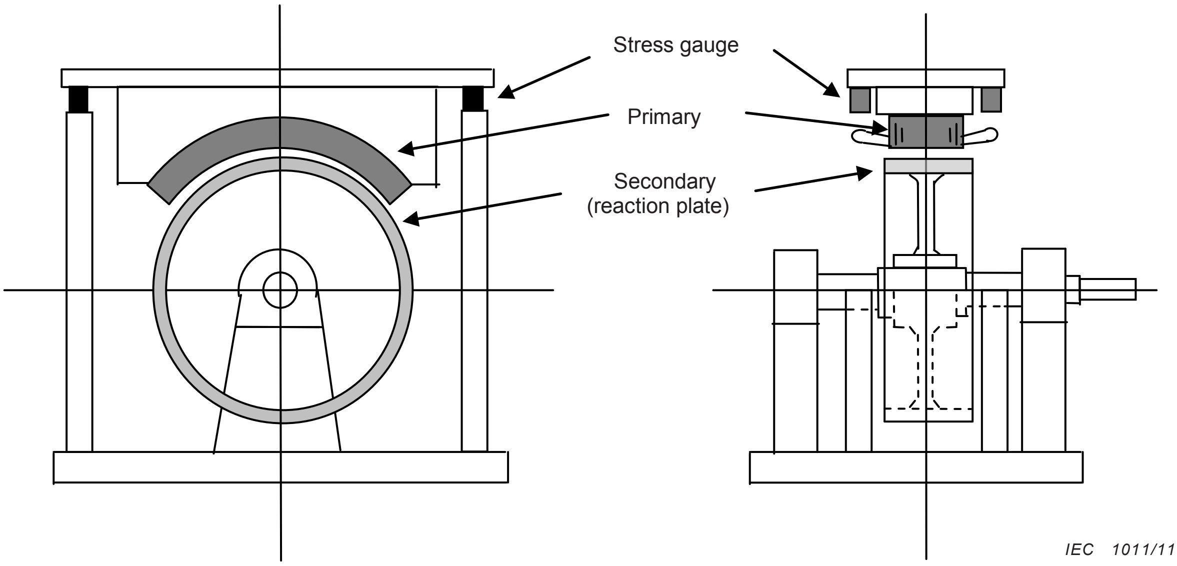

Figure B.1 – Rotary test facility for LIM

Annex C
(normative)

Supply voltages of traction systems

The nominal, lowest and highest voltages of the traction supply system shall be specified by the user. They should preferably be the standard values which have been adopted in IEC 60850.

The nominal voltage is the basis of LIM ratings and characteristics and for the calculation of vehicle performance.

Performance at other than nominal voltage may vary inherently or may be controlled to reduce such a variation, but the holding of constant performance over a wide range of system voltage is not generally desirable.

Annex D
(normative)

Agreement between user and manufacturer

D.1 Special requirements of the user to be specified and agreed with the manufacturer

Clause	Subject
4	Exceptional environmental conditions
5.3	Voltage of the specified characteristics
7.1.3	Test quantities for the secondary
7.1.4	Investigation tests
Annex C	Supply voltage values

D.2 Special requirements of the manufacturer to be specified and agreed with the user

Clause	Subject
5.4	Declared characteristics different from an existing one
7.1.2.4	Exemption from or reduction of type test
7.1.3	Alternative routine test procedure
8.1.2	Special external cooling arrangements

D.3 Special requirements of the manufacturer to be specified and agreed with the system integrator

Clause	Subject
8.2.1	Characteristics check method

D.4 Other special requirements which may be subject to an agreement between user and manufacturer

Clause	Subject
6.1	Terminal and lead markings not in accordance with IEC 60034-8
8.1.5	Limits of temperature rise
9.1.1	Additional sinusoidal thermal test
9.1.3	Use of d.c. for dielectric tests
9.1.4.1	Acceptance criteria of structural check

Bibliography

IEC 60034-5, *Rotating electrical machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code) – Classification*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

IEC 61260, *Electroacoustics – Octave-band and fractional-octave-band filters*

IEC 61287-1, *Railway applications – Power convertors installed on board rolling stock – Part 1: Characteristics and test methods*

IEC 61377-1, *Railway applications – Rolling stock – Part 1:Combined testing of inverter-fed alternating current motors and their control system*

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