

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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**Applications ferroviaires – Traction électrique – Moteurs à induction linéaires
(LIM) du type à primaire court alimentés par des convertisseurs de puissance**

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Applications ferroviaires – Traction électrique – Moteurs à induction linéaires (LIM) du type à primaire court alimentés par des convertisseurs de puissance

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CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions.....	8
4 Environmental conditions.....	12
5 Characteristics.....	13
5.1 Exchange of information.....	13
5.2 Reference temperature.....	14
5.3 Specified characteristics.....	14
5.4 Declared characteristics.....	14
5.5 Efficiency characteristics.....	15
5.6 Traction motor characteristics.....	15
6 Marking.....	15
6.1 Primary nameplate.....	15
6.2 Secondary marking.....	15
7 Test categories.....	16
7.1 Test categories.....	16
7.1.1 General.....	16
7.1.2 Type tests.....	16
7.1.3 Routine tests.....	17
7.1.4 Investigation tests.....	17
7.2 Summary of tests.....	17
8 Type tests.....	18
8.1 Temperature-rise tests.....	18
8.1.1 General.....	18
8.1.2 Ventilation during temperature-rise tests.....	18
8.1.3 Measurement of temperature.....	18
8.1.4 Judgement of results.....	18
8.1.5 Limits of temperature rise.....	18
8.2 Characteristic tests and tolerances.....	19
8.2.1 General.....	19
8.2.2 Tolerances.....	20
8.3 Shock and vibration tests.....	20
9 Routine tests.....	20
9.1 Routine tests of primary.....	20
9.1.1 General.....	20
9.1.2 Characteristic tests and tolerance.....	21
9.1.3 Dielectric tests.....	21
9.1.4 Structural tests.....	22
9.2 Routine tests of secondary.....	23
9.2.1 Dimension test.....	23
9.2.2 Chemical composition test.....	23
9.2.3 Tension test.....	23
9.2.4 Bending test.....	23

9.2.5	Shear test.....	23
9.2.6	Ultrasonic flaw detection.....	23
9.2.7	Friction test	23
9.2.8	Electrical conductivity test	23
10	Investigation tests	24
10.1	General	24
10.2	Noise test.....	24
Annex A	(normative) Measurement of temperature	25
Annex B	(informative) Test method using a rotary test facility of a LIM.....	27
Annex C	(normative) Supply voltages of traction systems	29
Annex D	(normative) Agreement between user and manufacturer	30
Bibliography	31
Figure B.1	– Rotary test facility for LIM	28
Table 1	– Technical items transferred and requested between the manufacturer of the primary and his counterparts.....	14
Table 2	– Summary of tests for the primary.....	17
Table 3	– Summary of tests for secondary.....	18
Table 4	– Limits of temperature rise for continuous and other ratings.....	19
Table 5	– Dielectric test voltages.....	22

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

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

FDIS	Report on voting
9/1531/FDIS	9/1544/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.

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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

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3.15

maximum thrust

maximum value of thrust in an operation

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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

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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:

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

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where

v_p is the primary speed (m/s).

3.35**slip frequency**

frequency of the secondary currents :

$$f_s = sf$$

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

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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.