BRITISH STANDARD

BS EN 61377-1:2006
Incorporating corrigendum no. 1

Railway applications — Rolling stock —

Part 1: Combined testing of inverter-fed alternating current motors and their control system

The European Standard EN 61377-1:2006 has the status of a British Standard

ICS 45.060

BSi
British Standards

National foreword

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Applications ferroviaires - Matériel roulant Partie 1: Essais combinés de moteurs à courant alternatif alimentés par onduleur et de leur régulation

Bahnanwendungen - Bahnfahrzeuge Teil 1: Kombinierte Prüfung von wechselrichtergespeisten Wechselstrommotoren und deren Steuerung

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CENELEC

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Foreword

The text of document 9/904/FDIS, future edition 1 of IEC 61377-1, 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 61377-1 on 2006-03-01.

This European Standard supersedes EN 61377:1996 + corrigendum November 1996.

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)	2006-12-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2009-03-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61377-1:2006 was approved by CENELEC as a European Standard without any modification.

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RAILWAY APPLICATIONS – ROLLING STOCK –

Part 1: Combined testing of inverter-fed alternating current motors and their control system

1 Scope and object

This part of IEC 61377 applies to the combinations of motor(s), inverter and their control system, and its object is to specify:

– the performance characteristics of electric drives consisting of an inverter, alternating current motors, and the related control system;

– methods of verifying these performance characteristics by tests.

Two categories of combined systems can be considered:

a) alternating current motors fed from an inverter without any control between the mechanical output (torque, speed) and the inverter itself (mostly auxiliary motors, for example cooling fan motors). The motor works exactly as if it were fed from a busbar (at variable frequency and voltage or not);

b) alternating current motor(s) (paralleled or not) with a control between the mechanical output and the inverter.

The first category of systems is tested according to IEC 60349-2 and IEC 61287-1.

This standard applies to the second category, mainly traction drives.

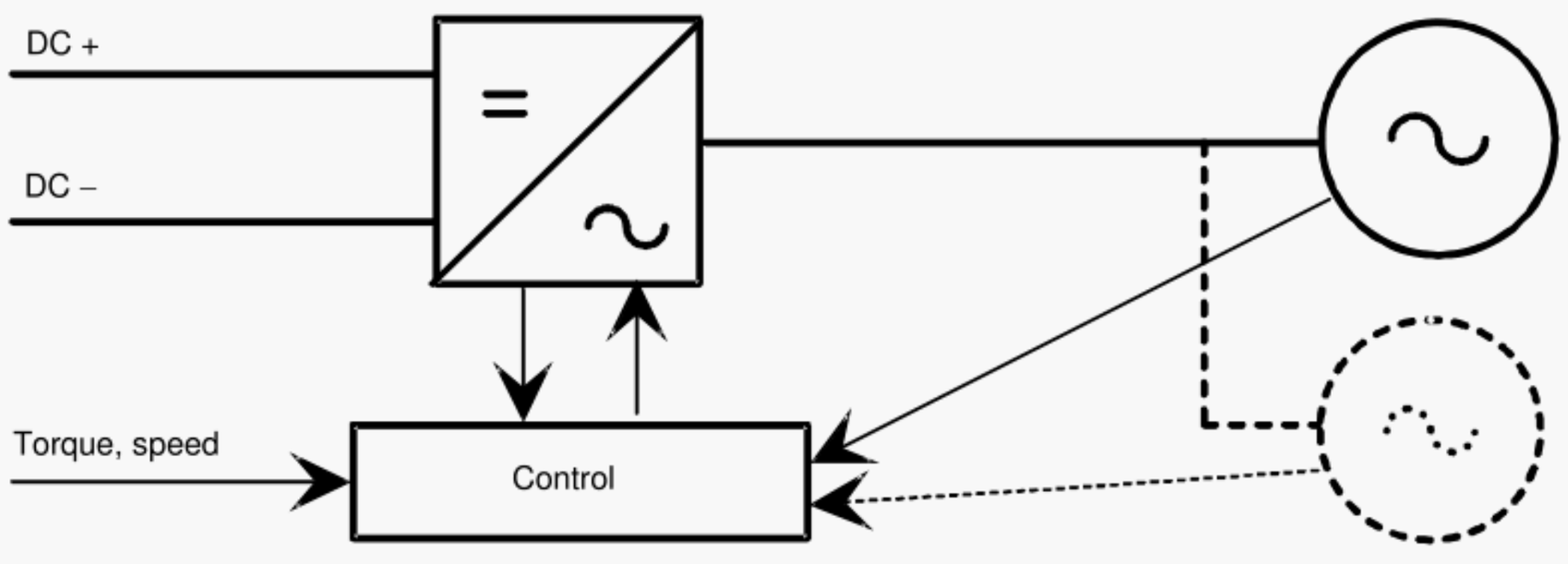


Figure 1 – Traction drive

IEC 60349-2 applies to convertor-fed alternating current motors, IEC 61287-1 to power electronic convertors, IEC 60571 to electronic equipments, and this standard applies to the combination of motor(s), inverter, and their control system. As a consequence, IEC 60349-2 describes the tests to demonstrate the compliance of the motor to its specification, IEC 61287-1 does the same for the inverter. It is self-evident that some of the tests mentioned in this standard generally may replace the corresponding ones described in the above-mentioned standards. An agreement should be reached between the parties to avoid the duplication of tests.

A complete combined test is heavy, and often requires high power, which is not always available in a workshop. An agreement between user and manufacturer may be reached to allow testing either in the workshop or on the vehicle. Testing may be split off partially in a workshop and partially on track.

At the time of drafting this standard, only the following combinations of motors and inverters were used for traction applications, but it may also apply to other combinations which may be used in the future:

– asynchronous motors fed by voltage stiff (voltage source) inverter;
– asynchronous motors fed by current stiff (current source) inverter;
– synchronous motors fed by current stiff (current source) inverter.

The input of these inverters can be a d.c. supply line, a rectifier, a chopper, an input convertor, a diesel generator with integrated rectifiers, etc.

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 amendment) applies. .

IEC 60050(411), *International Electrotechnical Vocabulary (IEV) – Chapter 411: Rotating machinery*

IEC 60050(551), *International Electrotechnical Vocabulary (IEV) – Chapter 551: Power electronics*

IEC 60050(811), *International Electrotechnical Vocabulary (IEV) – Chapter 811: Electric traction*

IEC 60349-2:2002, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 2: Electronic convertor-fed alternating current motors*

IEC 60571, *Electronic equipment used on rail vehicles*

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

IEC 61287-1:1995, *Railway applications – Power convertors installed on board rolling stock – Part 1: Characteristics and test methods*

IEC 61377-2:2002, *Railway applications – Rolling stock – Combined testing – Part 2: Chopper-fed direct current traction motors and their control*

IEC 61377-3:2002, *Railway applications – Rolling stock – Part 3: Combined testing of alternating current motors, fed by an indirect convertor, and their control system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050(411), IEC 60050(551), IEC 60050(811), IEC 61287-1, IEC 60349-2 and the following apply:

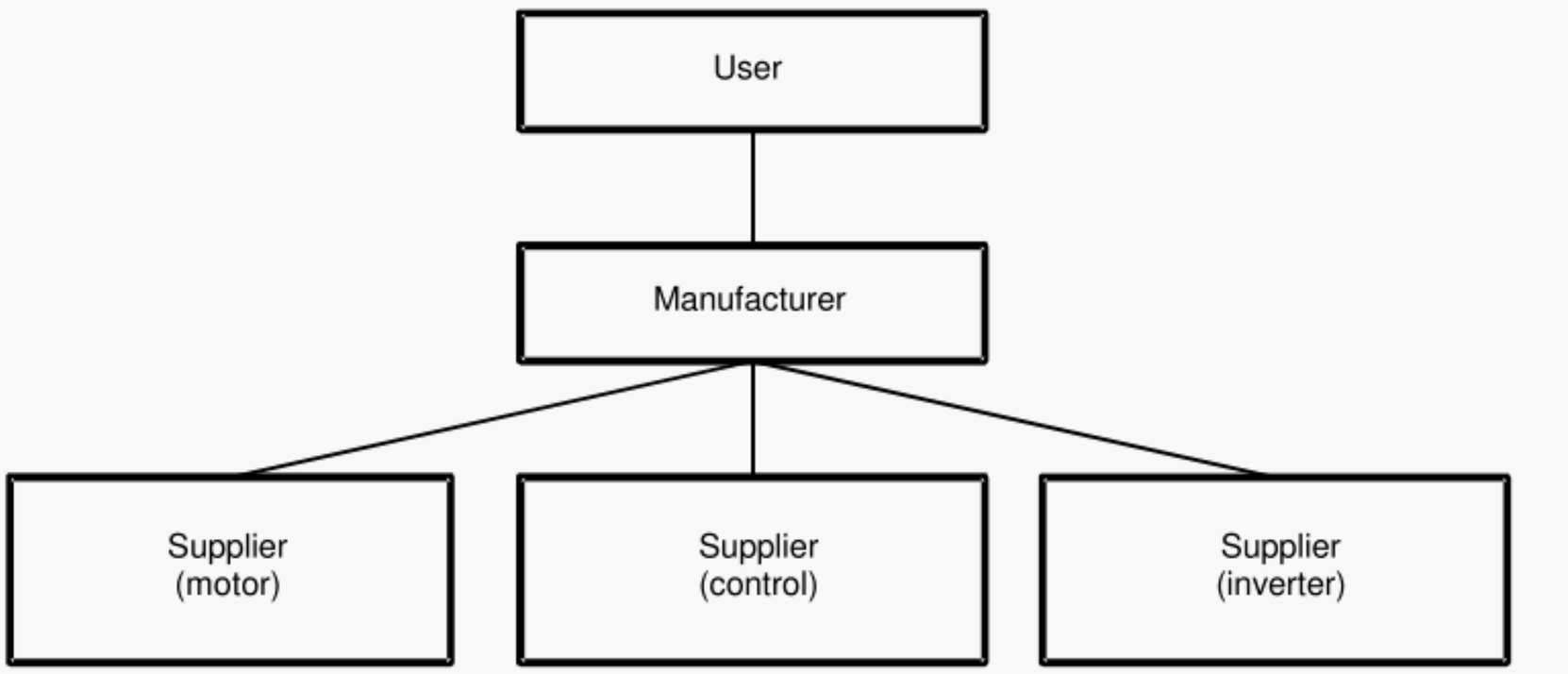
3.1
combined system
unit consisting of the inverter, the motor(s), their related control system, equivalent power cables connecting them, and an equivalent cooling system

3.2
user
organization which orders the combined system. The user is normally an organization which uses the vehicle or the equipment, unless the responsibility is delegated to a main contractor or consultant

3.3
manufacturer
organization which has the technical responsibility for the supply of the combined system

NOTE The manufacturer as defined above may also be the supplier of the motor, of the inverter, of the control, or of all of them, or of none of them.

3.4
supplier
organization which has the responsibility of one or more of the constituents of the combined system



IEC 241/06

3.5
manufacturer's works
location where tests are generally performed

3.6
duty
statement of the load to which the combined system is subjected, including, if applicable, electric braking, no load, rest and de-energized periods, including their durations and sequence in time

3.7
duty cycle of vehicle/load profile
duty cycle of vehicle is the speed and mass of train and track over the time.

The load profile for converter is calculated by the engineering from the duty cycle of vehicle. Load profile (current/power versus time) is the repetitive cycle or the load current/power under specified conditions such as starting and braking. Also the voltage has to be considered

3.8
rating of a combined system
combination of simultaneous values of electrical and mechanical quantities, with their duration and sequence, assigned to the combined system by the manufacturer

3.9
rated value
numerical value of any quantity included in a rating

3.10
continuous rating
mechanical output that the combined system can deliver on the test bed at a given speed for an unlimited time without exceeding the limits of temperature rise given in IEC 60349-2 and IEC 61287-1

NOTE Several continuous ratings may be specified.

3.11
short-time rating (for example 1 h)
mechanical output that the combined system can deliver on the test bed at a given speed for the stated time without exceeding the limits of temperature rise given in Table 2 of IEC 60349-2 and in IEC 61287-1, starting with the combined system cold, all other requirements of here mentioned standards being satisfied

3.12
short-time overload rating
mechanical output that the combined system can deliver on the test bed at a given speed for the stated time. The test is carried out as specified in 8.1.6 of IEC 60349-2, without exceeding the limits of temperature rise given in Table 3 of IEC 60349-2 and in IEC 61287-1

NOTE Short-time overload ratings are of value in determining the suitability of combined systems for duties which involve relatively long periods of operation below the continuous rating followed by a period above it. These are most likely to occur in locomotive applications. They are not relevant to repeated short-load cycles of rapid transit and similar duties, and should not be specified for such applications.

3.13
intermittent duty rating
duty cycle on which the combined system may be operated without the temperature rise at any point exceeding the limits given in IEC 60349-2 and IEC 61287-1

3.14
periodic duty rating
periodic duty on which the combined system may be operated without the temperature rise at any point exceeding the limits given in IEC 60349-2 and IEC 61287-1

4 Environmental conditions

Environmental conditions relative to motor, inverter, and control system are detailed in IEC 60349-2, IEC 61287-1 and IEC 60571.

5 Combined system characteristics

5.1 Specified characteristics

Combined system specifications shall, as a general rule, include characteristic curves. These curves are defined as the "specified characteristics". They shall be plotted to the designed operating limits of each variable. They shall generally be drawn for the d.c. supply voltage of the traction system at its specified nominal value. They may also be drawn for the lower and higher voltage of the supply of the traction system if agreed between user and manufacturer. These characteristics shall be drawn for a reference temperature of the windings of the motor of 150 °C, and the temperature of the parts of the inverter expected by the supplier.

Figure 2 gives some examples of the points where d.c. voltage and current may be defined in order to have safe measurement conditions.

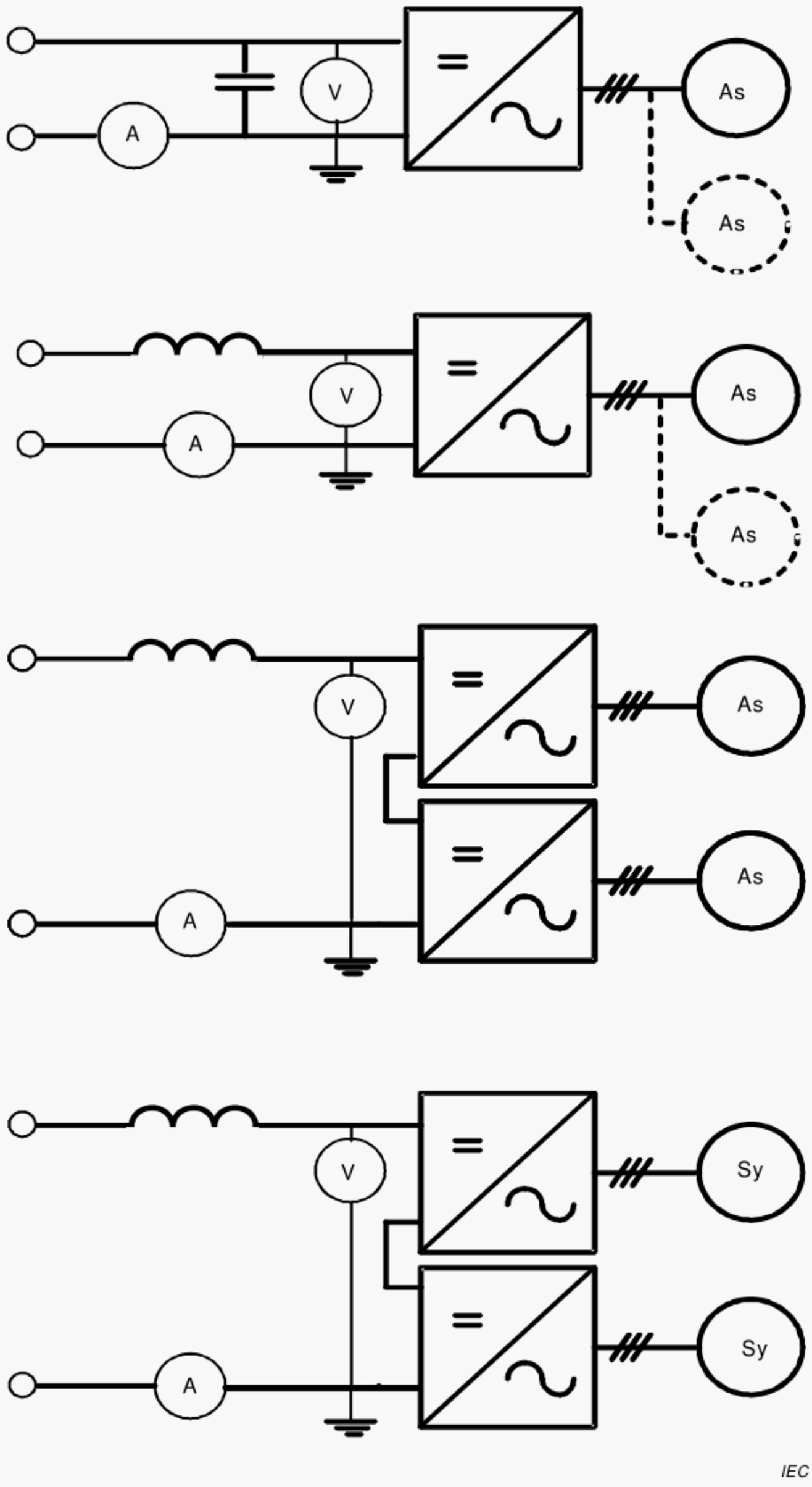


Figure 2 – Example of measurement points of the d.c. input

As an alternative to the torque and speed, the characteristics may show tractive effort at the wheels and vehicle speed. In which case, the gear ratio, wheel diameter and transmission losses shall be stated. If conventional values are used for the latter, they shall be in accordance with Figure B.1 of IEC 60349-2.

The specified characteristics shall be submitted to the user before the order for the combined system is placed, unless otherwise specified.

The values of the supply voltage of the traction system shall be specified by the user. They should preferably be the standard values according to IEC 60850.

5.2 Declared characteristics

Characteristic curves obtained from the results of type tests carried out in accordance with 7.5.

5.3 Combined system characteristics

The specified and declared characteristics of the combined system shown as a function of speed, over the whole application range are:

a) external characteristics such as the mean mechanical torque, the mean values of the d.c. input: voltage, current and power of the combined system;

b) internal characteristics such as the root-mean-square value of the output current of the inverter, the root-mean-square of the fundamental components of the output current and voltage of the inverter, the slip of asynchronous motors, and the excitation current for synchronous motors;

c) internal values such as switching transients, which are the point-to-point and point-to-earth peak voltage, temperatures, etc.

NOTE Internal switching transients are of use to check the dielectric test voltage of the constituents.

If the efficiency is an important parameter, it shall be requested, and this characteristic shall also be shown. Efficiency is particularly important for combined systems used on thermal/electric rolling stock, or battery-fed vehicles.

The efficiency characteristic of the combined system shall take into account the motor, the inverter, the cables and other relevant components.

The measurement of efficiency shall include excitation losses in the case of synchronous machines.

The characteristics shall be drawn at least for the maximum torque reference (main controller demand) over the entire speed range of the application, in motoring and braking if electric braking is proposed.

Only external characteristics, and the maximum internal repetitive switching transients are mandatory.. The other internal characteristics and values shall be measured, but the results shall not influence the acceptance of the combined system.

Figures 3 to 6 show examples of the most common mandatory curves.

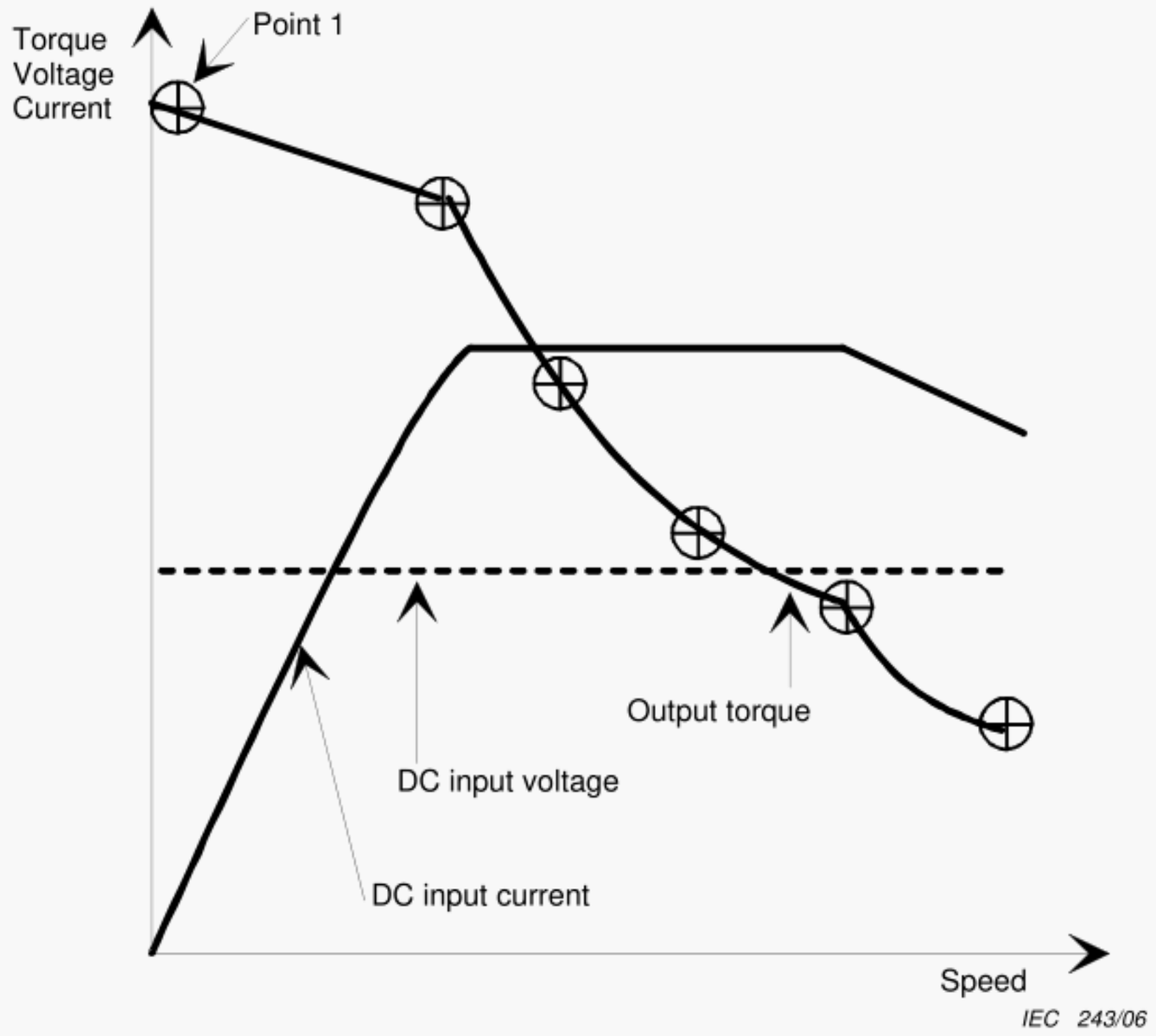


Figure 3a – Characteristics of a voltage source asynchronous combined system: example 1

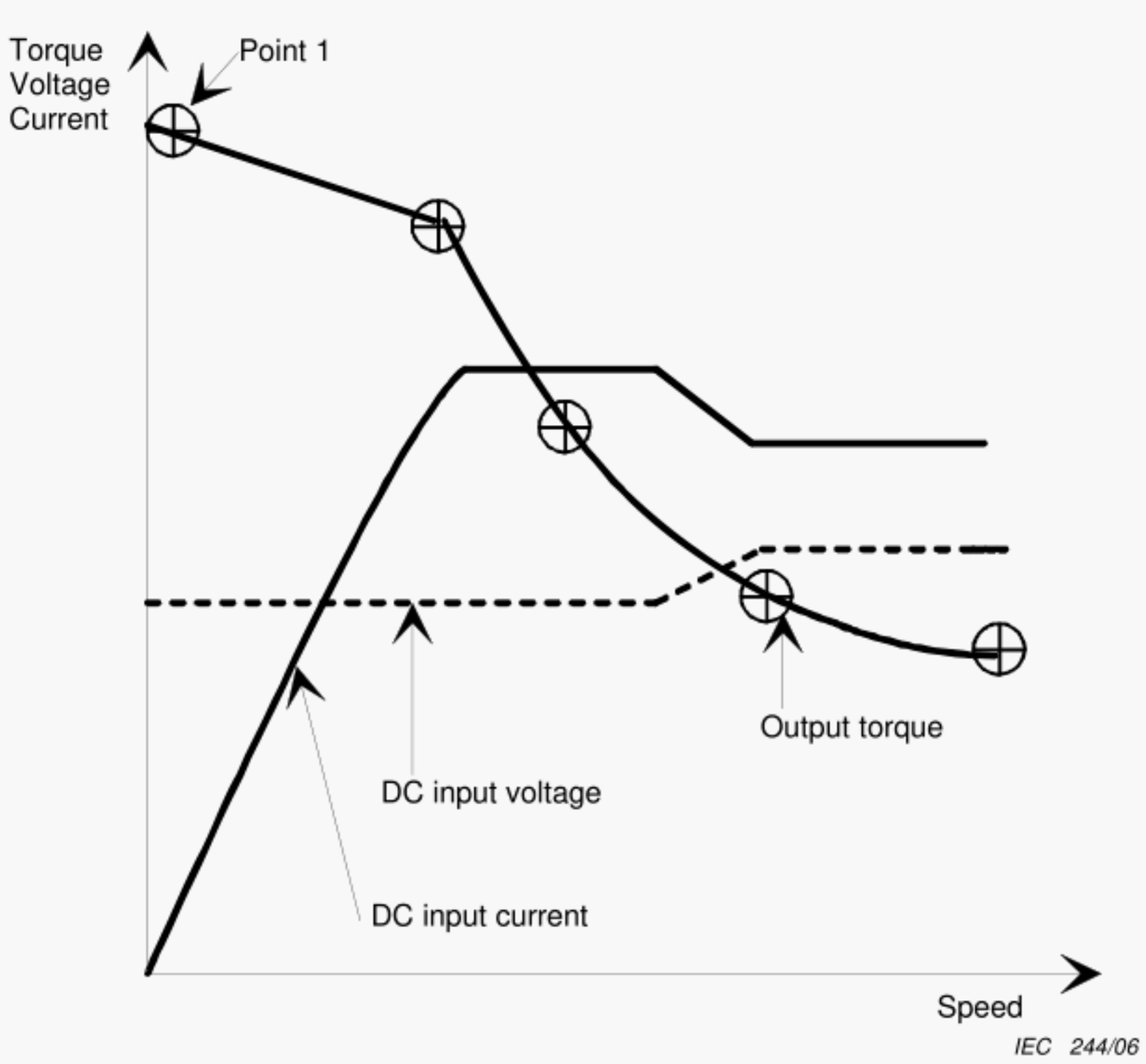


Figure 3b – Characteristics of a voltage source asynchronous combined system: example 2

Figure 3 – Mandatory characteristics – voltage source asynchronous combined system (two examples)

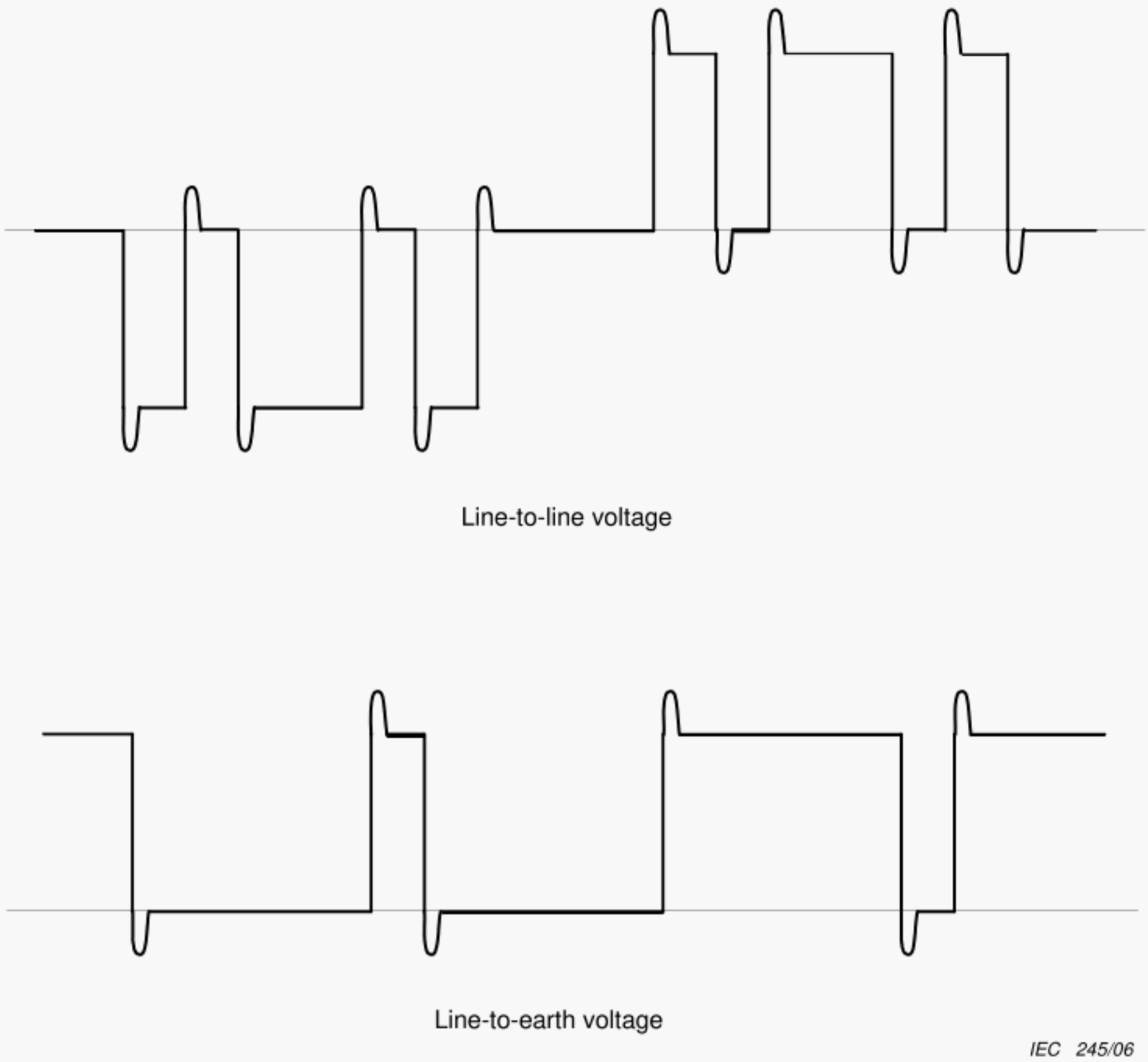


Figure 4 – Mandatory characteristics – voltage source asynchronous combined system

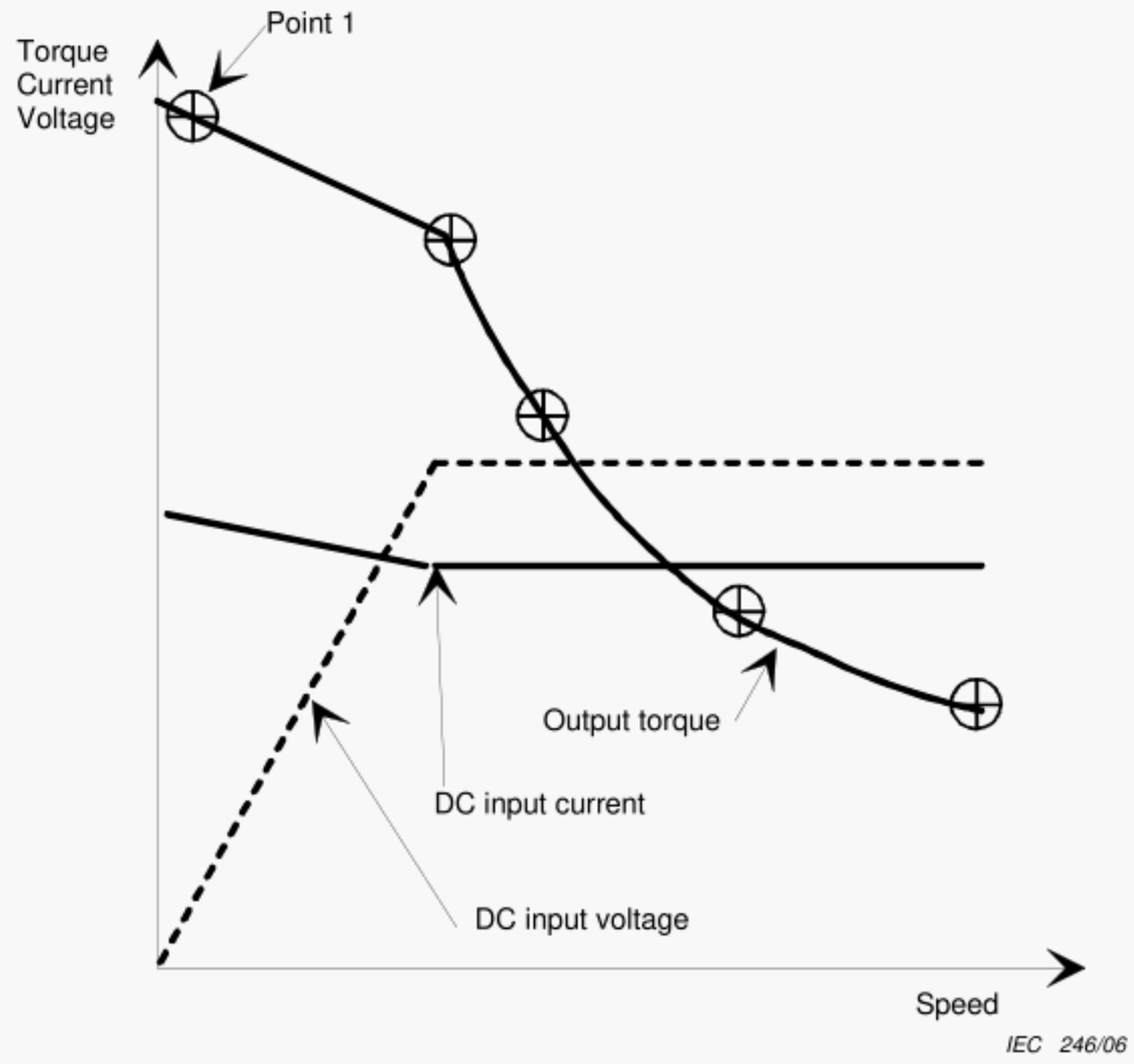


Figure 5a – Characteristics of a current source asynchronous combined system

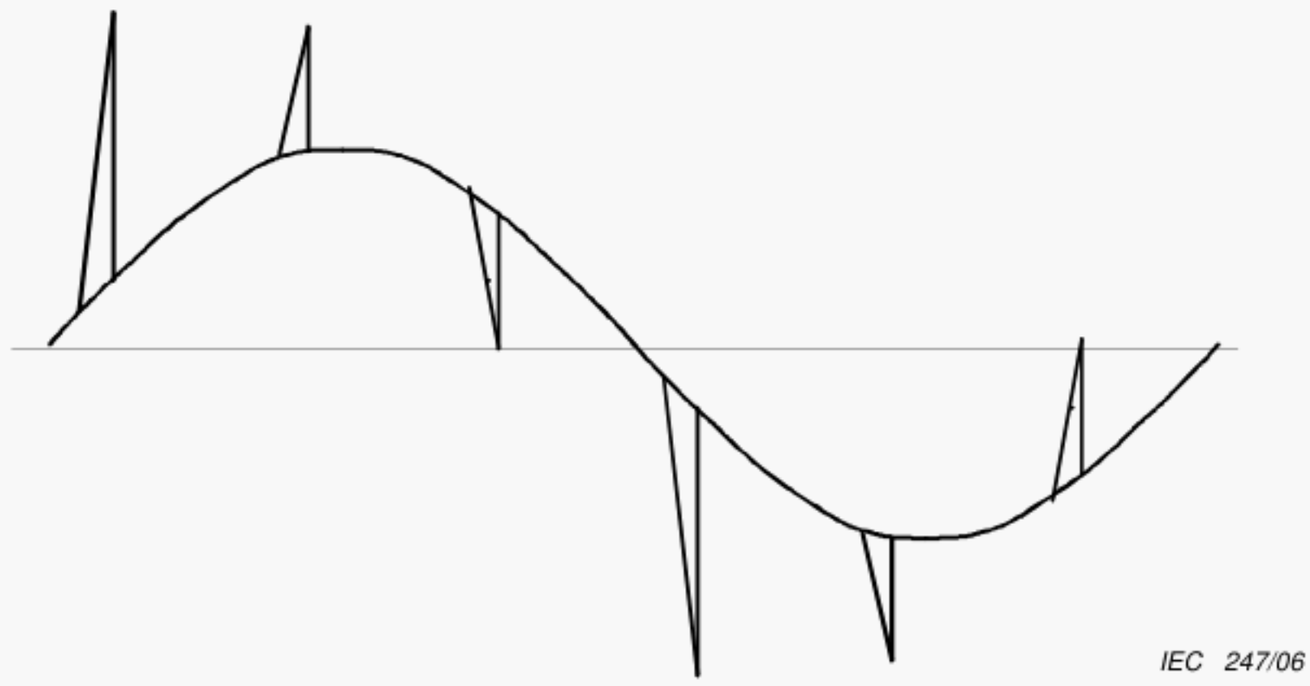


Figure 5b – Line-to-line voltage

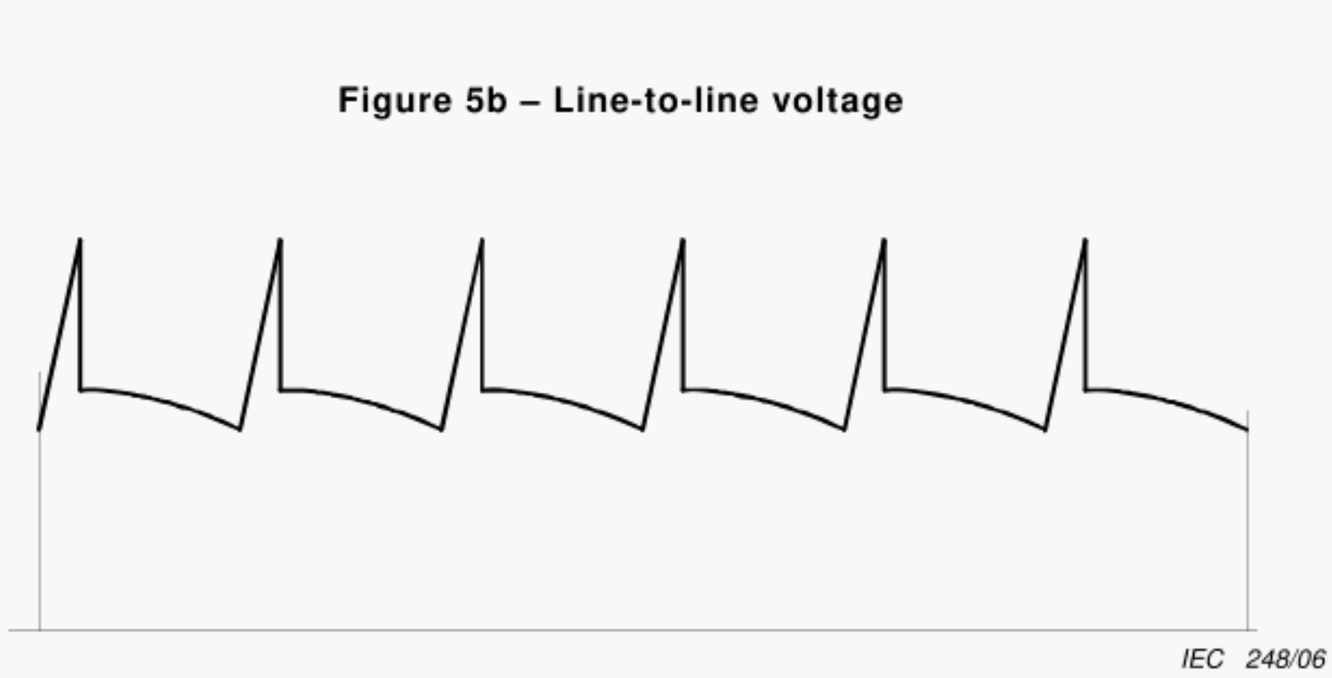


Figure 5c – Line-to-earth voltage

Figure 5 – Mandatory characteristics – current source asynchronous combined system

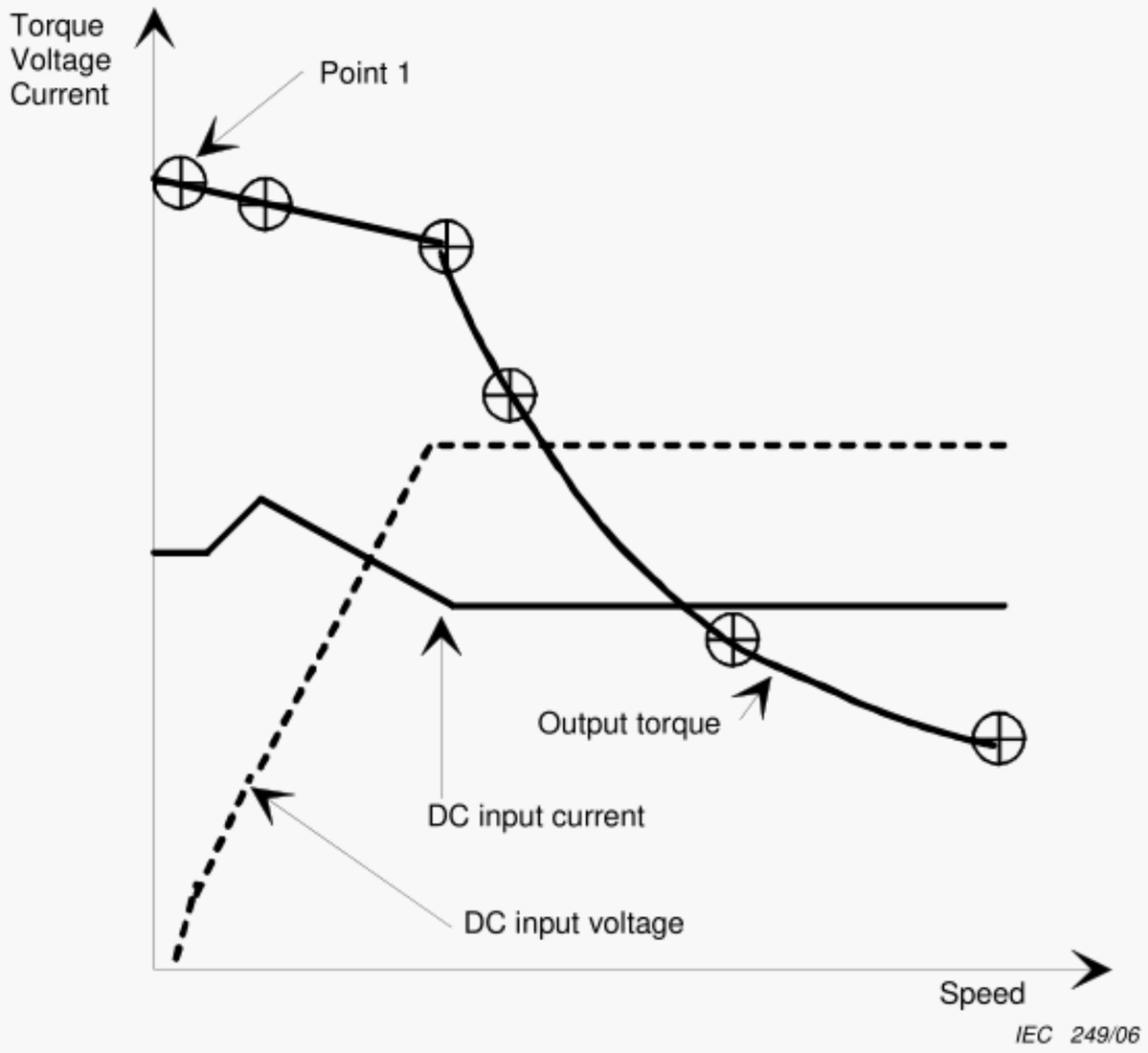


Figure 6a – Characteristics of a current source synchronous combined system

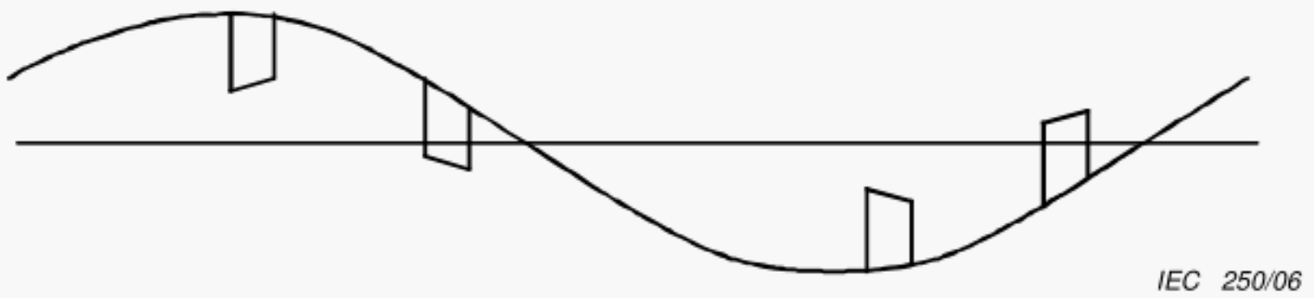


Figure 6b – Load communication: line-to-line voltage

Figure 6c – Load communication: line-to-earth voltage

Figure 6d – Self communication: line-to-line voltage

Figure 6e – Self communication: line-to-earth voltage

Figure 6 – Mandatory characteristics – current source synchronous combined system

5.4 Exchange of information and responsibility

IEC 60349-2 and IEC 61287-1 point out the need for the exchange of information between the motor supplier and the inverter supplier, to ensure that the combined system will meet the requirements of the above-mentioned standards, the documents recording this exchange of information being an integral part of the specification of the motor and of the inverter.

Subclause 3.3 defines the manufacturer as the organization which has the technical responsibility for the supply of the combined system. As a consequence, it is responsible for the technical specification of the constituents of the combined system in order to meet the requirements of this standard.

6 Test categories

6.1 General

There are three categories of tests:

– type tests;
– investigation tests;
– routine tests.

This standard is not directly concerned with routine tests. Each component of the system is routine tested according to its relevant standard.

6.2 Type tests

Type tests are intended to prove the ratings, characteristics and performances of a new combined system. They shall be carried out on one combined system of every new design.

If modifications of the design, or manufacturing process of the constituents are decided after the combined system has been type-tested, the influence of these modifications on the performances of the combined system shall be evaluated. Then an agreement may be reached between user and manufacturer not to carry out the type test again, or to carry out only some of the tests.

Subject to agreement between user and manufacturer, a type test is not required if the manufacturer produces a full type test report carried out on a combined system of the same design, with the same cooling conditions, at the same rating or higher.

6.3 Investigation tests

The object of investigation tests is to obtain additional information on the inverter when it feeds the motor, or on the motor when it is fed by the inverter, or on the control of the combined system. They will be carried out when a previous agreement has been reached between user and manufacturer. The results of these tests shall not influence the acceptance of the system unless so agreed between user and manufacturer.

7 Tests

7.1 General

Combined testing gives the opportunity to run the constituents of the combined system with the actual parameters as in service. The torque of the motor, the d.c. link voltage, the output current and voltage of the inverter, etc., are those produced in service.

The manufacturer shall provide to the user before the commencement of testing, a test specification defining the tests to be undertaken from this standard and the acceptance criteria to meet the contract requirements. Following the completion of testing, the manufacturer shall supply the user with a full test report.

7.2 Test conditions

7.2.1 Cooling during the tests

The combined system shall be tested with its cooling arranged as in service, including ducting and filters regarded as part of the vehicle, or with arrangements giving equivalent conditions. Measurements of relevant parameters (flow, pressure, temperatures, etc.) may be performed in order to show that the cooling conditions are equivalent to those encountered on the vehicle.

Cooling corresponding to that produced by the motion of the vehicle may be simulated for parts of the equipment for which natural cooling is of importance.

All simulations of cooling shall be subject to agreement.

Details about the cooling of each component are given in the relevant standards.

7.2.2 Power supply

The power supply can be derived from the vehicle d.c. supply or from another source available at the test bed. System inductance, capacitance and resistance shall be taken into account only if they have a valuable influence on the test result.

7.2.3 Mechanical output measurement

The mechanical output shall be measured directly (torquemeter) or indirectly (calibrated machine) at the motor(s) shaft(s). The accuracy of the measurements shall be that mentioned in the relevant clauses of this standard.

Alternatively, if agreed between user and manufacturer, the mechanical output may be derived by summation of losses or back-to-back method if two combined systems are available; these methods are being confirmed (Figure 7 gives an example of a test bed arrangement for a back-to-back method of test).

NOTE The summation of losses method includes the evaluation of the losses of

- the motor, derived from measurements on the a.c. input (IEC 60349-3: *Electric traction – Rotating electrical machines for rail and road vehicles – Part 3: Determination of the total losses of convertor-fed alternating current motors by summation of the component losses* which is a technical specification and deals with the method of summation of losses; in this case, the accuracy of the measurements will be that stated in the report);
- the inverter, generally derived from the d.c. input measurements;
- the cables, and, if any, the resistors, and inductances necessary to run the combined system.

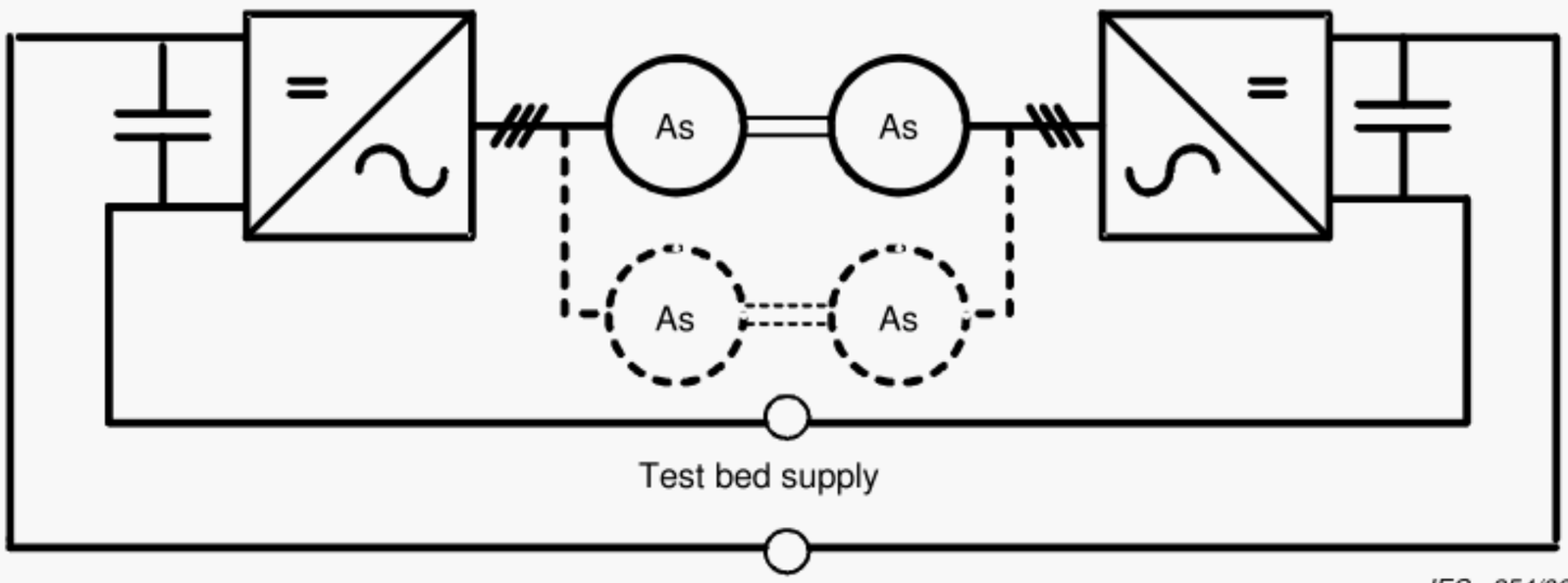


Figure 7 – Test bed arrangement for back-to-back test of an asynchronous combined system

7.2.4 Special conditions for paralleled asynchronous motors

When several asynchronous motors are fed in parallel by one inverter, the difference in wheel diameter can bring some of the motors to their worst conditions of load (case 1). The controller may be designed to retain all the motors within a load which would apply if there was no difference in wheel diameter by reduction of the tractive effort (case 2). As a consequence, the effect of the difference in wheel diameter will affect the torque characteristics, or the temperature rise of the motors, or both. The maximum permissible difference in wheel diameter shall be agreed between user and manufacturer.

The characteristics and temperature-rise tests shall in any case be performed as if there was no wheel diameter mismatch.

If the controller is designed so that some of the motors are brought to their worst condition of load (case 1), an additional temperature-rise test of the motors shall be performed. If the control is designed to retain all the motors within a load by reduction of the tractive effort (case 2), an additional torque characteristic should be obtained by calculation or may be obtained by a complete test if agreed between user and manufacturer.

7.3 Temperature-rise tests

7.3.1 General

The tests shall be carried out at the agreed ratings of the system.

NOTE For paralleled motors, additional tests may be required according to 7.2.4.

In the case of a continuous rating test, the time to reach a steady temperature may be shortened by commencing the test at an increased load or reduced ventilation of some elements of the system, 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.

In the case of a periodic duty rating test, the time to reach a steady temperature may be shortened by commencing the test at a calculated equivalent rating, and going on with repeated cycles.

Subclause 5.4 states the technical responsibility of the manufacturer of the combined system. As a consequence, it is not necessary that the supplier carries out the temperature-rise test of a constituent, according to its relevant standard. The constituent may be deemed to have passed the temperature-rise test, provided the temperature rises during the combined testing

do not exceed the values specified in the constituent standards. If there are no values specified in the constituent standard, then values may be agreed upon. This remains valid even if the electric parameters are not exactly those agreed upon between the supplier and the manufacturer.

7.3.2 Measurement of temperatures

The measurement of the temperature of the parts of the combined system is described in the relevant standards.

7.4 Additional tests for paralleled asynchronous motors

The conditions of additional tests are subject to agreement between user and manufacturer:

7.4.1 Temperature-rise tests of one motor

This test shall be carried out for case 1 as specified in 7.2.4.

This test, unless otherwise specified, shall consider that only one motor runs a wheel which has the maximum difference in wheel diameter The control reference shall be modified so that the slip corresponds to the worst conditions of load due to the difference in wheel diameter. Figure 8 shows an example of the effect of the difference in wheel diameter on the torque characteristic, and the evolution of the slip.

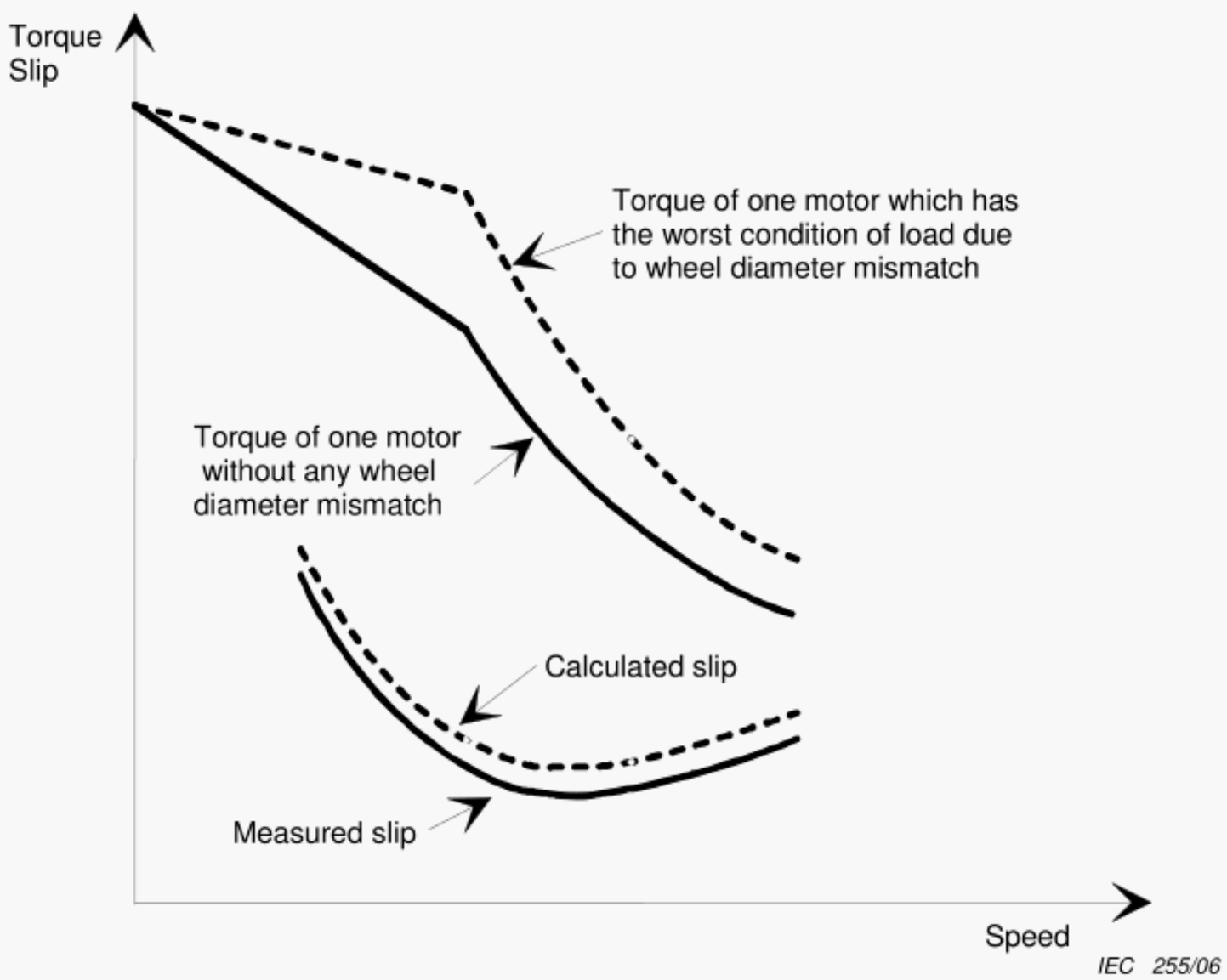


Figure 8 – Effect of wheel diameter mismatch on the torque characteristic of asynchronous motors

NOTE The corresponding slip equals:

$$s \pm (\Delta D/D)\,[(n-1)/n]$$

(+ in motoring, – in braking)

where

s (p.u.) is the slip measured during the characteristic tests (motor hot, refer to 7.5.1.2);

n is the number of motors in parallel;

$\Delta D/D$ (p.u.) is the maximum difference in wheel diameter.

For all applications designed for continuous and one hour ratings (mainly locomotives) and where braking mode is not relevant, the temperature-rise tests for the continuous ratings, increased according to the worst load conditions (for differences between wheels diameters), shall be carried out. This is generally sufficient to show that the motor is suitable for the application.

Whenever braking mode is relevant, the temperature-rise test shall be carried out, using the specified duty cycle in order to reach the maximum temperature conditions. This takes care of higher load conditions in motoring and lower load conditions in braking (mainly mass transit applications).

7.4.2 Complete test

The paralleled motors shall be fed by one inverter. Unless otherwise specified, they shall be loaded to have the same speed, except one which shall be loaded in order to have a speed which corresponds to the maximum permissible difference in wheel diameter.

NOTE This test requires a special test bed. If agreed between user and manufacturer, it could be substituted by a calculation of the reduction of the tractive effort.

7.5 Characteristic tests and tolerances

7.5.1 Torque characteristics

7.5.1.1 General

Tests to demonstrate compliance with the specified torque characteristics shall be carried out by running the motor(s) at a given speed. The torque reference (main controller demand*)* shall then be given to the control unit in order to measure the characteristics of the combined system. The (mean) motor output torque, the (mean) voltage, current and power, on the d.c. side of the inverter, shall then be measured.

The characteristics shall be drawn at least for the maximum torque reference (main controller demand) over the entire speed range of the application, in motoring and braking if electric braking is proposed. They may also be drawn for ¼, ½ and ¾ of the maximum torque reference at any speed, if agreed between user and manufacturer.

NOTE For paralleled motors, additional tests may be required according to 7.4.

The limits of error of the measurement instrument shall be not greater than

- ±2 % of the maximum mechanical torque reference at the speed considered;
- ±1 % for the mean values of the d.c. voltage current and power;
- ±2 % for a.c. values.

Provided that the torque characteristics measured at the combined system test meet the requirements of this standard, this remains valid, even if the electric parameters of the motor (flux and current) are not exactly those agreed upon between the supplier and the manufacturer, and tested according to IEC 60349-2.

Temperature is an important parameter, especially for asynchronous drives, which influences the output torque to a level dependant on the control performance. The measurement of the torque characteristics gives the opportunity to check the influence of heating on the output torque.

7.5.1.2 Torque characteristics, motor hot

The torque characteristics shall be measured at the end of the temperature-rise test performed according to 7.3, which is likely to produce the maximum temperature rise of the rotor cage of an asynchronous motor, or the maximum temperature rise of the stator windings of a synchronous motor, in order to obtain the characteristics of the combined system at that temperature. Measurements shall be performed quickly, and shall begin with the lowest speed achievable on the test bed (point 1 of Figures 3 to 6). The number of plotted points shall be sufficient to have a precise view of the characteristics, with all their discontinuity. Figures 3 to 6 give examples of the number of points needed.

Tolerances: the declared torque at any speed on the specified characteristic between the values corresponding to the maximum torque and 90 % of the maximum speed shall be not less than 95 % of the specified value.

7.5.1.3 Torque characteristics, motor cold

The motor being cold, according to IEC 60349-2, Clause A.1, the torque shall be measured at the same lowest speed for which it has already been measured motor hot (point 1 of Figures 3 to 6). Measurements shall be carried out quickly, and temperatures shall be measured at the end of the test to ensure that the temperature has not varied significantly. The torque shall not be less than 95 % of the specified value.

7.5.1.4 Sweeping speed test at full torque

The torque characteristic shall be swept up and down over all the speed range, the torque reference being at its maximum value, both in motoring and braking if relevant. No tripping, shutting down the system, shall be observed. The rate of change in speed shall be appropriate to each application.

7.5.2 Efficiency characteristics of the combined system (optional type test)

If loss measurements are required, they shall be carried out at the end of the temperature-rise test as described in 7.3. They shall be derived from the measurement of the d.c. power input and of the mechanical output. A small number of points is generally adequate.

The limits of error of the measurements of the d.c. power input shall be not greater than ±1 %, the torque measurement device shall be accurate to within ±0,5 % of the maximum torque reference at the speed considered, and the speed measurement device shall be accurate to within ±0,1 %. In case of limits of error higher then the limits specified in this standard, the tolerances shall be agreed between user and manufacturer. The limits of error used, together with the resulting efficiency tolerance, shall be shown on the efficiency characteristic.

The summation of losses and back-to-back methods mentioned in 7.2.3 may be used if agreed between user and manufacturer.

NOTE In high efficiency equipment, a measurement system with higher accuracy should be used.

7.6 Miscellaneous tests

7.6.1 Protection system testing

7.6.1.1 Power supply for control equipment of the combined system

The combined system shall operate with any variation of the supply, within the specified range, without any interruption of the system or fault indication. The loss of one or several power supplies shall cause the off-state of the inverter without any failure or malfunction in the combined system. The system shall be able to restart in a controlled manner when the control supplies are re-established

The power supply of the control equipment should be independent from the input supply voltage of the traction drive.

7.6.1.2 Supply voltage of the traction drive

A check shall be made, by varying the d.c. supply voltage from maximum to minimum of the specified operating range for the combined system, that the control system operates correctly, and that the combined system output is regulated and inhibited in accordance with the agreed curve. Figure 9 shows an example of the operating range of a voltage source combined system.

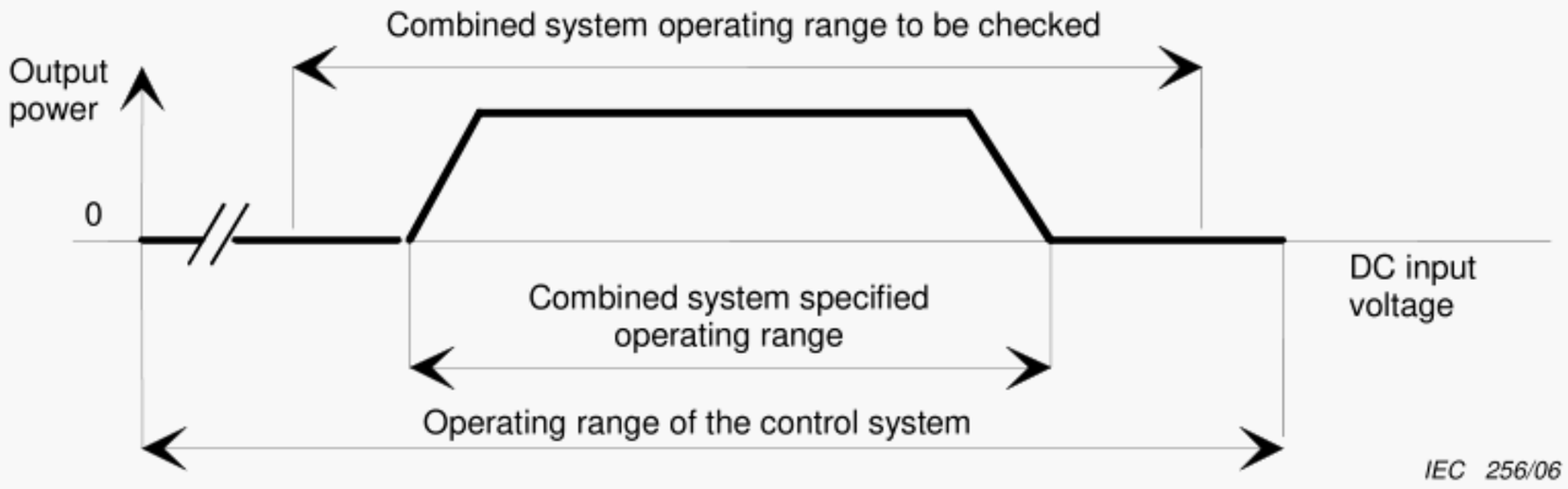


Figure 9 – Example of operating range of a voltage source combined system

7.6.1.3 Traction supply voltage interruption (optional type test)

The test may be performed by operating two contactors in sequence such as to generate a short-time interruption of the traction supply voltage with a specified duration.

Figure 8 of IEC 61377-2 or Figure 10 of IEC 61377-3 gives an example of a possible test circuit.

7.6.1.4 Sudden variation of traction supply voltage (optional type test)

The test may be performed by using a contactor in parallel to a resistor connected as in Figure 9 of IEC 61377-2 or Figure 11 of IEC 61377-3, which gives an example of possible circuit configuration.

The test is carried out in both motoring and braking.

7.6.2 Harmonics in the input current of the inverter (optional type test)

The inverter may interfere with the railway signalling system, the power supply system, or other stationary and on-board equipment. This is due to harmonic current generation on the power supply side of the inverter. Because of this, it is important to measure the a.c. harmonics currents on the input of the inverter at different stator frequencies.

The user shall specify the maximum allowable harmonic currents (value and time duration), as a function of frequency, of the input current of the combined system.

The measurement results may be used to improve the calculation of the total harmonic interference level from a vehicle, taking into consideration the total number of inverters, line filter design, etc.

NOTE 1 For the measurements, a high precision current sensor, together with a frequency analyser, should be used.

NOTE 2 The power supply harmonics should be considered when measuring the total harmonic content.

7.6.3 Interference test (optional type test)

The test shall be carried out in accordance with 4.2.8 of IEC 61287-1.

7.7 Investigation tests

These tests shall be subject to agreement between user and manufacturer.

7.7.1 Failure conditions

Loss of feedback signal, etc.

7.7.2 Sudden variation of load

Slipping condition, etc.

Table 1 – List of tests

Subject	Subclause	Type test	Investigation test	Possible duplication of test with IEC 60349-2 and IEC 61287-1
Temperature-rise tests	7.3	X		X
Additional test for paralleled asynchronous motors	7.4	If applicable		
Torque characteristics, motor hot	7.5.1.2	X		
Torque characteristics, motor cold	7.5.1.3	X		
Sweeping speed test at full torque	7.5.1.4	X		
Efficiency characteristics	7.5.2	Optional		X
Power supply for control equipment	7.6.1.1	X		
Supply voltage of traction drive	7.6.1.2	X		
Traction supply voltage interruption	7.6.1.3	Optional		
Sudden variation of traction supply voltage	7.6.1.4	Optional		
Harmonics in the input current of the inverter	7.6.2	Optional		
Interference test	7.6.3	Optional		X
Failure conditions	7.7.1		X	
Sudden variation of load	7.7.2		X	

Annex A
(normative)

Agreement between user and manufacturer

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

Subclause	Subject
	Scope and object
	Duplication of tests
	Test either in workshop or on the vehicle
5.1	Drawing of characteristics for the lower and higher voltage of the traction supply
6.2	Cases in which a type test is not required or shall not be performed again
6.3	Investigation tests
7.2.1	Simulation of cooling
7.2.3	Measurement of the mechanical output by summation of losses or back-to-back method
7.2.4	Maximum permissible difference in wheel diameter
7.2.4	Additional torque characteristic in some uses of paralleled motors
7.3.1	Temperature-rise tests
7.4	Additional tests for paralleled asynchronous motors
7.5.1.1	Number of characteristics to be drawn
7.5.2	Efficiency characteristics: tolerances and method of test
7.7	Investigation tests
Table 1	Note: optional tests

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

NOTE 2 Where a standard cited below belongs to the EN 50000 series, this European Standard applies instead of the relevant International Standard.

Publication	Year	Title	EN/HD	Year
IEC 60050-411	-[1)]	International Electrotechnical Vocabulary (IEV) Chapter 411: Rotating machinery	-	-
IEC 60050-551	-[1)]	International Electrotechnical Vocabulary Part 551: Power electronics	-	-
IEC 60050-811	-[1)]	International Electrotechnical Vocabulary (IEV) Chapter 811: Electric traction	-	-
IEC 60349-2	2002	Electric traction - Rotating electrical machines for rail and road vehicles Part 2: Electronic convertor-fed alternating current motors	EN 60349-2[2)]	2001
IEC 60571	-[1)]	Electronic equipment used on rail vehicles	EN 50155 + A1	2001[3)] 2002
IEC 60850	-[1)]	Railway applications - Supply voltages of traction systems	EN 50163	2004[3)]
IEC 61287-1	1995	Railway applications - Power convertors installed on board rolling stock Part 1: Characteristics and test methods	EN 61287-1	2006
IEC 61377-2	2002	Railway applications - Rolling stock - Combined testing Part 2: Chopper-fed direct current traction motors and their control	EN 61377-2	2002
IEC 61377-3	2002	Railway applications - Rolling stock Part 3: Combined testing of alternating current motors, fed by an indirect convertor, and their control system	EN 61377-3	2002

1) Undated reference.
2) EN 60349-2:2001 (IEC 60349-2:1993, mod.) corresponds to IEC 60349-2:2002.
3) Valid edition at date of issue.

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