BS EN 61377:2016

BSI Standards Publication

Railway applications — Rolling stock — Combined test method for traction systems

bsi.

National foreword

This British Standard is the UK implementation of EN 61377:2016. It is identical to IEC 61377:2016. It supersedes BS EN 61377-1:2006, BS EN 61377-2:2002 and BS EN 61377-3:2002, which are withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/9, Railway Electrotechnical Applications, to Subcommittee GEL/9/2, Railway Electrotechnical Applications - Rolling stock.

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

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Published by BSI Standards Limited 2016

ISBN 978 0 580 83950 4
ICS 45.060.01

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2016.

Amendments/corrigenda issued since publication

Date	Text affected

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 61377

April 2016

ICS 45.060

Supersedes EN 61377-1:2006, EN 61377-2:2002, EN 61377-3:2002

English Version

Railway applications - Rolling stock - Combined test method for traction Systems (IEC 61377:2016)

Applications ferroviaires - Matériel roulant - Méthode d'essais combinés pour systèmes de traction (IEC 61377:2016)

Bahnanwendungen - Bahnfahrzeuge - Kombiniertes Prüfverfahren für Traktionssysteme (IEC 61377:2016)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

The text of document 9/2078/FDIS, future edition 2 of IEC 61377, prepared by IEC/TC 9 "Electrical equipment and systems for railways" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61377:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-11-23
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-02-23

This document supersedes EN 61377-1:2006, EN 61377-2:2002 and EN 61377-3:2002.

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

IEC 60077-3	NOTE	Harmonized as EN 60077-3.
IEC 60077-4	NOTE	Harmonized as EN 60077-4.
IEC 60310	NOTE	Harmonized as EN 60310.
IEC 60322	NOTE	Harmonized as EN 60322.
ISO 14253-2	NOTE	Harmonized as EN ISO 14253-2.
ISO/IEC 17025	NOTE	Harmonized as EN ISO/IEC 17025.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60050	Series	International Electrotechnical Vocabulary	-	-
IEC 60349-1	-	Electric traction - Rotating electrical machines for rail and road vehicles - Part 1: Machines other than electronic converter-fed alternating current motors	EN 60349-1	-
IEC 60349-2	-	Electric traction - Rotating electrical machines for rail and road vehicles - Part 2: Electronic converter-fed alternating current motors	EN 60349-2	-
IEC/TS 60349-3	-	Electric traction - Rotating electrical machines for rail and road vehicles - Part 3: Determination of the total losses of converter-fed alternating current motors by summation of the component losses	-	-
IEC 60349-4	-	Electric traction - Rotating electrical machines for rail and road vehicles - Part 4: Permanent magnet synchronous electrical machines connected to an electronic converter	EN 60349-4	-
IEC 60850	-	Railway applications - Supply voltages of traction systems	-	-
IEC 61133	-	Railway applications - Rolling stock - Testing of rolling stock on completion of construction and before entry into service	-	-
IEC 61287-1	-	Railway applications - Power converters installed on board rolling stock - Part 1: Characteristics and test methods	EN 61287-1	-
IEC 62313	-	Railway applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock	-	-

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS – ROLLING STOCK –
COMBINED TEST METHOD FOR TRACTION SYSTEMS**

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61377 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This edition cancels and replaces IEC 61377-1 (2006), IEC 61377-2 (2002) and IEC 61377-3 (2002). It constitutes a technical revision.

This edition includes the following main technical changes with regard to the previous editions: it includes updates as necessary in order to meet the current technical state of the art, to improve clarity and to create an edition that considers all types of motors part of a traction system.

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

FDIS	Report on voting
9/2078/FDIS	9/2113/RVD

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

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

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

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

RAILWAY APPLICATIONS – ROLLING STOCK – COMBINED TEST METHOD FOR TRACTION SYSTEMS

1 Scope

This International Standard applies to the traction system consisting (when it applies) of traction motor(s), converter(s), traction control equipment including software, transformer, input filters, brake resistors, main circuit-breaker, cooling equipment, transducers, contactors, etc.

Figure 1 is just an overview and is not representative of all traction system architectures.

Current collector, mechanical braking systems and gearbox are not in the scope of this standard.

Types of motors applicable in this standard are asynchronous, or synchronous including permanent magnet (PMM), or direct current (DC).

The auxiliary converter(s) is (are) part of the scope when the auxiliary converter is enclosed within the traction converter. Otherwise, when the traction system feeds an auxiliary system outside the traction converter, the auxiliary system can be replaced by an equivalent load.

NOTE 1 Energy storage system is not considered in this standard since there is no specific type test standard for energy storage system.

NOTE 2 Auxiliary loads validation is not part of this standard.

NOTE 3 The gearbox can be part of test set-up, but it is not a part of traction system.

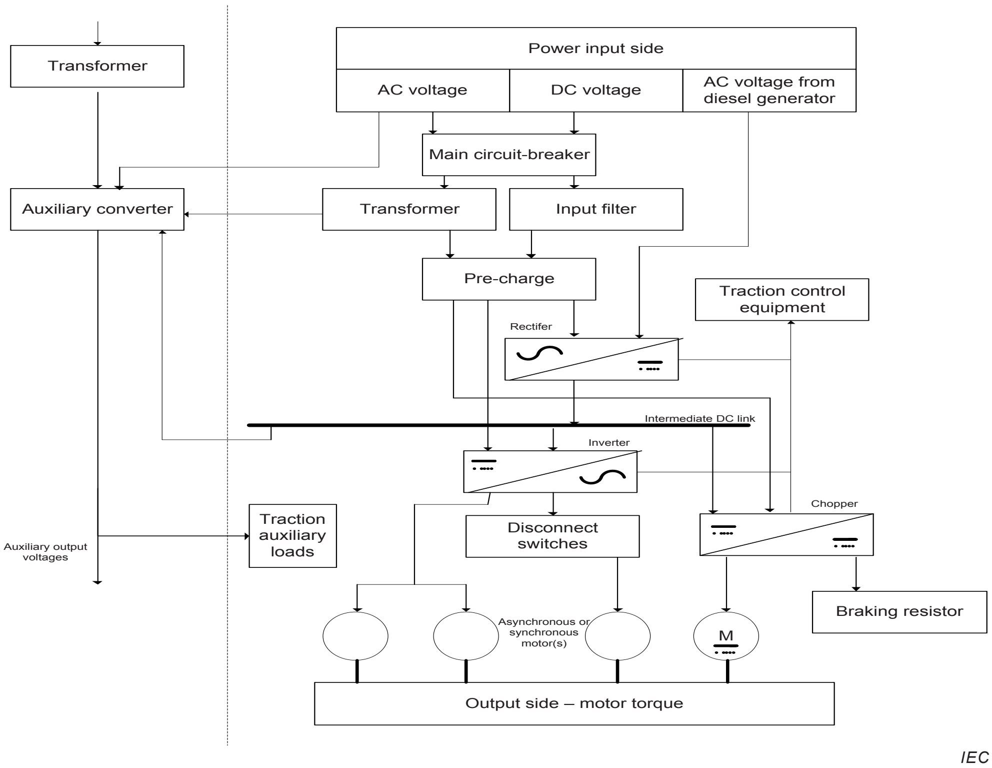


Figure 1 – Overview of traction system architecture

The objective of this standard is to specify the type test of a traction system, mainly comprising of:

– test of performance characteristics;
– test methods of verifying these performance characteristics.

This standard does not specify the type test of each individual component.

The traction system under test incorporates at least one complete traction conversion line (at least one traction converter and its related loads, one transformer in the case of AC supply or input filter in the case of DC supply). The representativeness of the traction system under test versus the actual traction system is agreed between the user and manufacturer.

Figure 2 gives one example of the relationship between the traction system under test and the whole traction system.

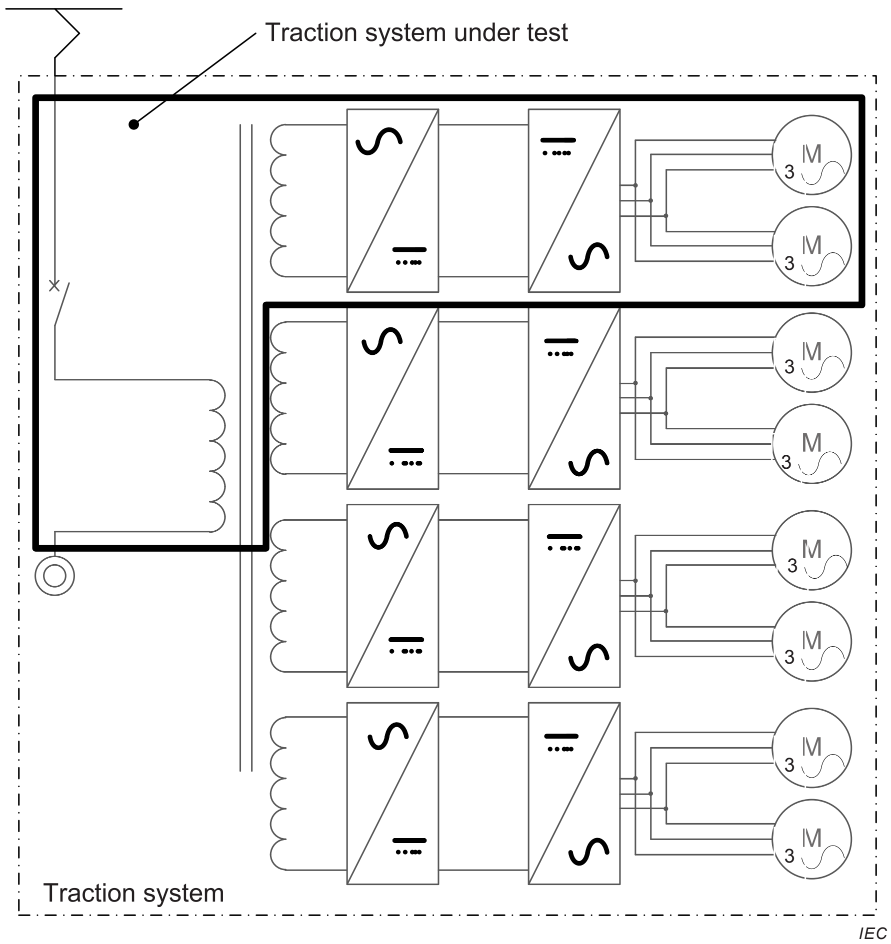


Figure 2 – Example of relationship between the “traction system under test” and the “traction system”

The traction system under test is equipped with components that are representative of the production series.

Deviations may be permitted by agreement between user and manufacturer, and are justified from an impact stand point in advance of the test. Using equivalent components or parts is permitted if no significant influence on the test result is expected.

2 Normative references

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

IEC 60050 (all parts): *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 60349-1, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 1: Machines other than electronic converter-fed alternating current motors*

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

IEC TS 60349-3, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 3: Determination of the total losses of converter-fed alternating current motors by summation of the component losses*

IEC 60349-4, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 4: Permanent magnet synchronous electrical machines connected to an electronic converter*

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

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

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

IEC 62313, *Railway applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock*

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, and the following apply:

3.1
traction system
system which provides traction torque, converting the input supply energy into mechanical energy in motoring and the mechanical energy into electrical or thermal energy in braking (if applicable), comprising of the entire conversion equipment located between the current collector (excluded) and the motor shaft(s) and including all associated auxiliary equipment needed to operate the system

3.2
traction system under test
representative traction system for combined test, according to Clause 1

3.3
component
constituent of traction system

3.4
user
organization which orders the traction system (see Figure 3)

Note 1 to entry: The user is normally an organization which operates the vehicle equipped with the traction system, unless the responsibility is delegated to a main contractor or consultant.

3.5
manufacturer
organization which has the technical responsibility for the supply of the traction system (see Figure 3)

Note 1 to entry: The manufacturer can be the supplier of one or more components of traction system, or of none of them.

3.6
supplier
organization which has the responsibility of one or more of the components

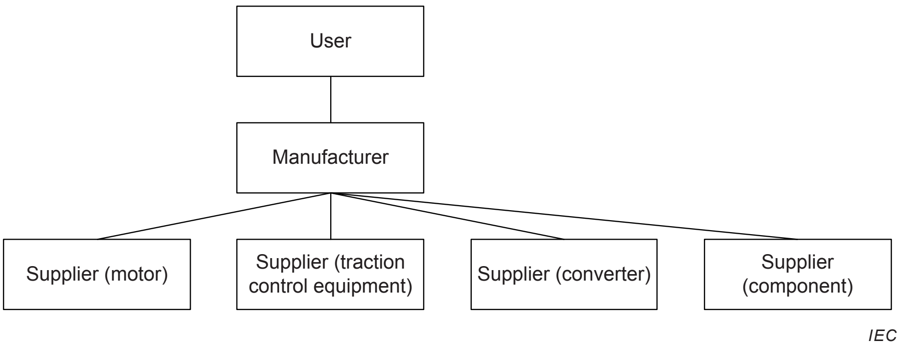


Figure 3 – Traction system – relationship between user, suppliers and manufacturer

3.7
duty
load to which the traction system is subjected, including motoring, coasting, and, if applicable, electrical braking

3.8
duty cycle
specified sequence of operation conditions, e.g. the speed and torque over the time on an elementary route

Note 1 to entry: Some examples of elementary route are:

- Main line train: route between two cities back and forth;
- Tramway: route between two stops;
- Metro: route between two stations.

Note 2 to entry: Typical duty cycle is defined as an agreement between the user and manufacturer.

3.9
route profile
repetition or combination of typical duty cycles in order to achieve steady temperature (repetitive peak temperatures over successive duty cycles are within a given tolerance) or to represent the daily operation of the vehicle

3.10
constant load
load applied at constant operating conditions (e.g. speed, voltage)

Note 1 to entry: Several loads can be specified.

3.11
route profile load
load based on route profile on which the traction system under test is operated

3.12
speed
motor speed in r/min

Note 1 to entry: Motor speed (r/min) is convertible from vehicle speed (km/h) based on specified wheel diameter and gear ratio.

3.13
maximum working speed
motor speed which corresponds to the maximum vehicle design speed at fully worn wheels or the minimum rolling diameter of rubber tyres

3.14
test plan
list of all tests to be undertaken by the manufacturer that includes the mandatory and optional tests to be agreed with the user

Note 1 to entry: In the test plan it is recommended to describe the components used in the traction system under test.

3.15
test specification
all information, requirements and parameters to be applied to carry out and assess the test, including e.g. scope of test, test objective, test conditions, test method, test procedure, evaluation method, measurements, acceptance criteria with tolerances

3.16
test result
final assessment of test

3.17
optional test
test that is not mandatory and subject to agreement between the user and manufacturer

4 Traction system characteristics

Traction 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 AC or DC 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 the user and manufacturer.

These characteristics shall be drawn for a reference temperature of the motor (winding or magnet) and the design temperature of the parts of the converter, transformer and line filter, etc., expected by the supplier.

The reference temperature of the motor (winding or magnet) shall be according to the values as in IEC 60349 series or subject to agreement between the user and manufacturer.

The following characteristics are defined:

a) Specified characteristics: values defined in order to fulfil the user contractual requirements. They are the reference values for measurement and shall be validated on the test bench.
b) Internal characteristics: internal design values which shall be measured and used to prove the design but do not have an influence on the acceptance of the combined test, such as root-mean-square value of current/voltage of traction motor for example.

Provided that the measurement results are compliant with the specified characteristics, the test results remain valid, even if the internal characteristics are not exactly the same as the ones specified. The difference should be agreed between the user and manufacturer.

The set of specified characteristics on fixed operating points over the speed-torque curve, at given line voltages (according to IEC 60850 or otherwise specified if outside the scope of IEC 60850) and given wheel diameter is:

- torque versus speed;
- efficiency of the traction system versus speed at maximum torque reference along the curve.

Specified and internal characteristics can be measured during a speed sweep test or a test at constant speed .

NOTE 1 In the case of speed sweep the inertia mass of the motor rotor considerably influences measurement of the motor shaft torque.

The set of specified characteristics on the route profile at a specific line voltage is:

- torque reference value and speed versus time at the given wheel diameter;
- line current and voltage;
- all relevant peak temperatures (see Figure 4);
- input electrical energy consumption in kWh (integrated value over entire route profile).

NOTE 2 Specified and internal characteristics except those listed above are described in the following clauses for each test.

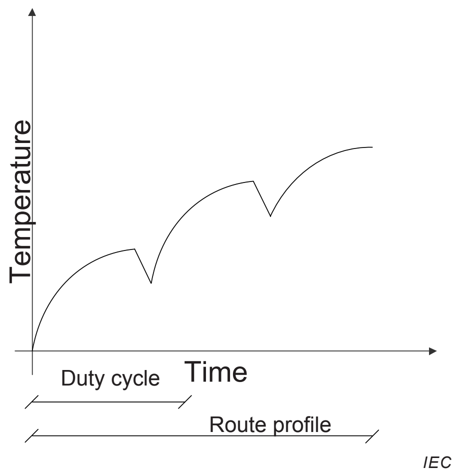


Figure 4 – Example of peak temperatures on route profile

5 General test requirements

The combined test gives the opportunity to run the components of the traction system under test with operating conditions close to service.

All components shall be previously type-tested according to their relevant standards (except some specific tests which are specified to be carried out on the combined test). It is not necessary to repeat a test on the combined test bench which was already carried out at the component type test level.

NOTE The type tests of the components or parts of them can be carried out on the same test bench of the combined test, but they are not in the scope of this standard. The results of the component type tests are provided as reference for the combined test.

The tests in this standard are classified as mandatory tests and optional tests. The mandatory tests shall be carried out (if applicable). Each optional test is subject to an agreement. Table A.1 shows tests being mandatory or optional and should be used to mark the optional tests agreed between the user and manufacturer. The specific test items for DC motors are defined in Annex C.

The tests specified in this standard shall be carried out on one traction system of every new design unless the manufacturer can demonstrate the compliance (to one, several or all tests) with this standard, through tests performed on the existing traction system. This shall be subject to a contractual agreement between the user and manufacturer.

If modifications of the design of the components are decided after the combined test has been performed, the impact of these modifications on the performances of the traction system shall be evaluated. An agreement may then be reached between the user and manufacturer as to whether or not to carry out the combined test again, or to carry out only some of the tests. Modifications of the software can be validated by appropriate software tests (e.g. using a real time simulator).

The versions used of all components (including software) shall be traceable for each test, if relevant.

An agreement between the user and manufacturer may be made to perform testing either on the test bench or on the vehicle. Testing may be split partially on the test bench and partially on the vehicle. Type tests on the vehicle are specified in IEC 61133. Some of these tests may be performed in the combined test. Their acceptance is subject to agreement.

A test plan and a test specification for the combined test of the traction system should be submitted to the user and agreed with the user. After the test, a test result should be submitted. Raw data and evaluation procedures do not need to be included in the test result.

6 General test conditions

6.1 Test setup

6.1.1 Setup of traction system under test

The components to be equipped with temperature sensors are proposed by the manufacturer in agreement with the user.

When they are relevant for validation purposes, the components of the traction system shall be equipped with temperature sensors by the supplier. The component suppliers are responsible for defining the best location depending on the expected highest temperature. If sensors cannot be placed at the hottest spot, the component supplier shall provide temperature correction.

The exact train wiring conditions are not mandatory in the setup of traction system under test.

6.1.2 Test bench architecture

6.1.2.1 General

Test bench architecture should consist of the following:

a) test bench power supply;
b) traction load system;
c) auxiliary power supply and train auxiliary load.

6.1.2.2 Test bench power supply

The test bench power supply should provide a voltage range in order to operate under the conditions specified in IEC 60850 (or otherwise specified if outside the range of IEC 60850). Voltage range or power limitation of the power supply shall be agreed with the user. Characteristics of the traction system in the voltage area exceeding these voltage limits may be tested with reduced limit values/parameters.

Inductance, capacitance, resistance, frequency and voltage waveform (ripple, peaks, harmonics and interferences) of power supply system should have no relevant influence on the operation of the traction system and no relevant influence on test results.

6.1.2.3 Traction load system

6.1.2.3.1 General

There are mainly the following two methods for loading the traction system:

a) speed controlled load system;
b) inertial load.

6.1.2.3.2 Speed controlled load system

There are the following options:

a) Option 1:

   The mechanical energy generated from the traction system under test is converted into electrical energy by the load system and sent back to the grid or to the test bench power supply (see Figure 5).

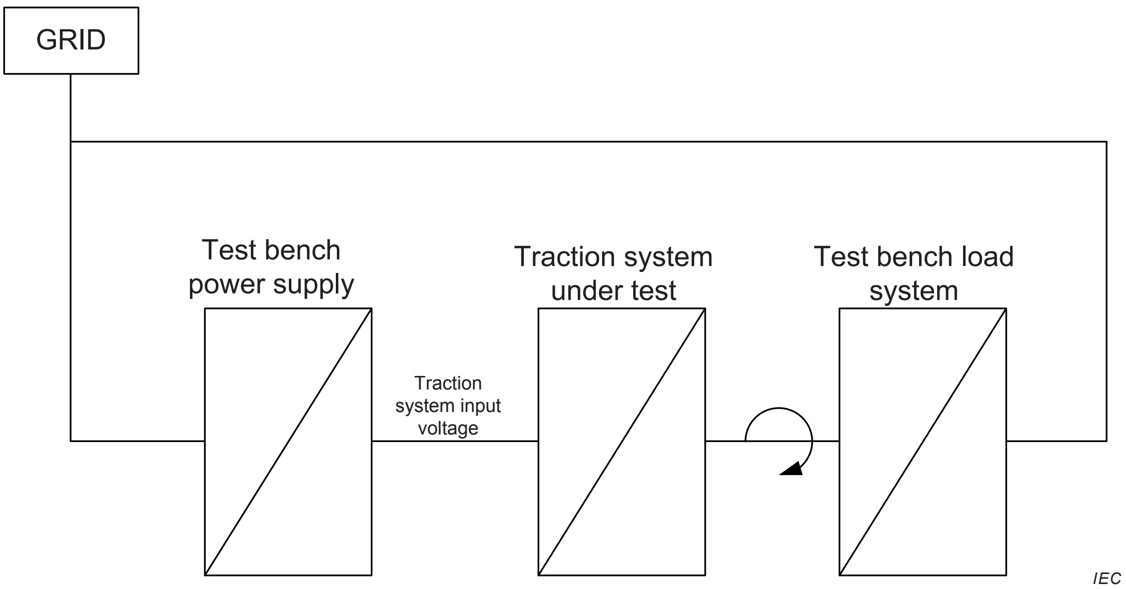


Figure 5 – Example of test bench architecture with speed controlled load system

b) Option 2:

Two identical traction systems under test are installed back to back as shown in the Figure 6.

The mechanical energy generated by the traction system under test is converted into electrical energy by the second traction system.

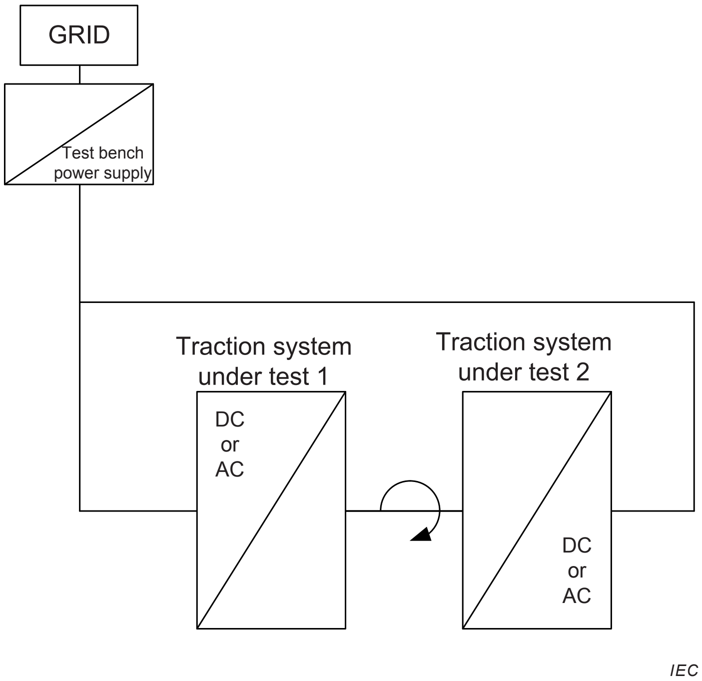


Figure 6 – Example of test bench architecture with back to back method

6.1.2.3.3 Inertia load

Flywheels are used to simulate inertia load equivalent to the vehicle. Due to limitations of the test bench facility (it may not be possible to run at constant speed with the tractive effort), load conditions (e.g. torque vs time) are not necessarily the same as the real operating ones. Calculation may be used to demonstrate the validity of the inertial load method and the representativeness of load conditions to simulate the real operating conditions.

6.1.2.4 Auxiliary power supply and train auxiliary loads

6.1.2.4.1 General

The scope of this clause includes all the loads outside the traction system but supplied from the traction system, for instance, the train auxiliary loads or auxiliary converter itself when fed by the traction system (from a traction DC link or transformer auxiliary winding).

The traction auxiliary loads are loads essential to operate the traction system, e.g. motor fans, water pump.

The train auxiliary loads are the ones on the vehicle which are powered by the auxiliary converter or the traction system but are not essential to the traction system, these auxiliary loads may be simulated by an equivalent passive or active load.

The traction system supplier decides whether or not the auxiliary loads are simulated depending on the impact on validation.

6.1.2.4.2 Auxiliary loads supply

A commercial power supply may be used for the traction auxiliary load.

Figure 7 gives examples of simulation of auxiliary loads and traction auxiliary load power supplies.

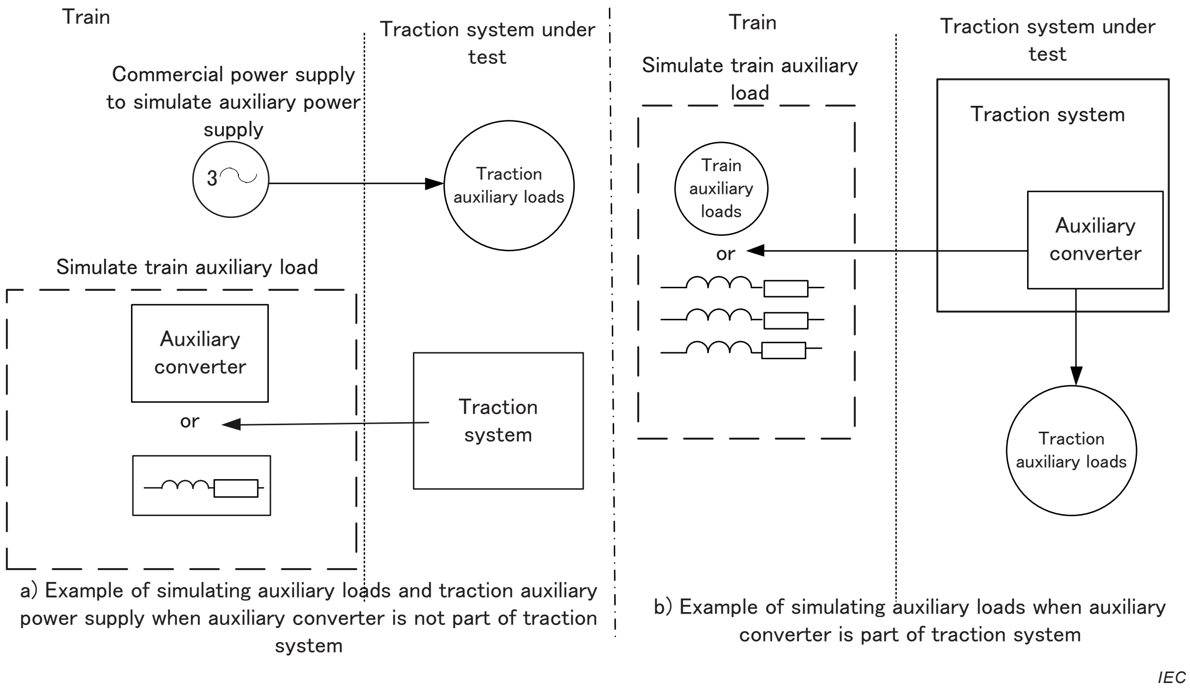


Figure 7 – Examples of simulating auxiliary load and traction load power supply

In example a) of Figure 7, the auxiliary converter is not a part of the traction system under test. In this case, an equivalent passive load or active load can be used to simulate the auxiliary converter and a commercial power supply can be used to supply traction auxiliary power.

In example b) of Figure 7, the auxiliary converter is part of the traction system under test. In this case, an equivalent passive or active load can be used to simulate the train auxiliary loads.

6.2 Cooling during the test

The traction system shall be tested with its cooling arranged (taking into account dynamic pressure drop):

- as it would be in service, including ducting and filters regarded as part of the vehicle;

or

- with arrangements giving equivalent conditions.

Cooling corresponding to that produced by the motion of the vehicle can be simulated for parts of the equipment which are naturally cooled. Simulations of this kind of cooling are done by agreement between the user and manufacturer.

Measurements of internal characteristics (cooling agent flow rate, pressure, temperatures, etc.) are performed in order to show that the cooling conditions are equivalent to those specified.

If the test is not performed at the specified maximum ambient temperature, temperature measurement results shall be corrected linearly (between 10 °C and 40 °C ambient temperature, or when the temperature difference between the specified maximum ambient temperature and the measured ambient temperature is within ±30 K) to extrapolate the results to the maximum operating temperature. Outside that range, the extrapolation should be done by agreement between the user and manufacturer.

6.3 Mechanical output measurement

6.3.1 General

The torque of the traction system under test is evaluated by the summation of all motor torques.

The mechanical output shall be measured directly on the motor(s) shaft(s). If the gearbox is part of the test setup, the torque may be measured on the output shaft of the gearbox.

Alternatively, if agreed between the user and manufacturer, the mechanical output (of one or all motors of the traction system) may be derived from alternative methods. Examples of alternative methods are:

a) summation of losses method;
b) comparison of power;
c) comparison of current;
d) back to back method.

6.3.2 Summation of losses method

The torque on motors can be calculated according to methods described in IEC TS 60349-3 and the calculation is made by summation of losses (see Figure 8).

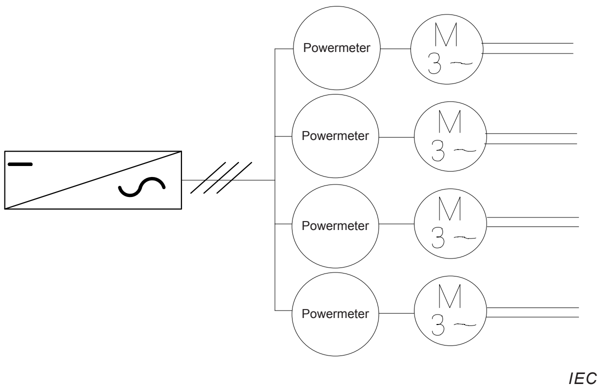


Figure 8 – Example of measurement using summation of losses method

$$P\text{losses} = 3 \times R \times I^2$$

where

Plosses	is the stator resistance losses;
R	is the stator resistance known from the motor type test adjusted with the measured temperature;
I	is the fundamental phase current.

The air-gap torque is calculated:

$$T\text{air-gap} = (P\text{el} - P\text{losses} - P\text{iron})/((2 \times \pi \times N\text{s})/60)$$

where

Tair-gap is the air-gap torque;

$P\text{el}$	is the electrical fundamental input power of motor;
$P\text{losses}$	is the stator resistance losses;
$P\text{iron}$	is the iron losses;
$N\text{s}$	is the synchronous speed of the motor.

The torque of motor is calculated:

$$T = T\text{air-gap} - (P\text{f} + P\text{stray})/((2 \times \pi \times N)/60)$$

where

T	is the torque value of the motor;
$T\text{air-gap}$	is the air-gap torque;
$P\text{f}$	is the friction losses according to the motor type test;
$P\text{stray}$	is the stray losses defined in IEC TS 60349-3, if not known from the motor type tests;
N	is the mechanical speed of each motor.

The torque result is:

$$T = \left(\frac{60}{2 \times \pi \times N}\right) \times \left(\left(P\text{el} - 3 \times R \times I^2 - P\text{iron}\right) \times \left(\frac{N}{N\text{s}}\right) - P\text{f} - P\text{stray}\right)$$

This method is only applicable for asynchronous motors.

6.3.3 Comparison of power method

If one motor torque is measured ($T1$), each individual torque can be calculated with the following equation (see Figure 9):

$$\frac{T\text{i}}{T1} = \frac{N1}{N\text{i}} \times \frac{\left(P\text{el\_i} - 3 \times R\text{i} \times I\text{i}^2 - P\text{iron\_i}\right) \times N\text{i} / N\text{s\_i} - P\text{f\_i} - \text{Pstray\_i}}{\left(P\text{el\_1} - 3 \times R1 \times I1^2 - P\text{iron\_1}\right) \times N1 / N\text{s\_1} - P\text{f\_1} - \text{Pstray\_1}}$$

where

$T1$	is the measured torque of the one motor;
$P\text{el\_1}$	is the electrical fundamental input power of the one motor;
$I1$	is fundamental phase current;
$N1$	is the mechanical speed of the one motor;
$R1$	is the stator resistance known from the motor type test adjusted with the measured temperature;
$P\text{iron\_1}$	is the iron losses of the one motor;
$N\text{s\_1}$	is the synchronous speed of the one motor;
$P\text{f\_1}$	is the friction losses of the one motor according to the motor type test;
$P\text{stray\_1}$	is stray losses of the one motor defined in IEC TS 60349-3, if not known from the motor type tests;

$T\text{i}$, $P\text{el\_i}$, $I\text{i}$, $N\text{i}$, $R\text{i}$, $P\text{iron\_i}$, $N\text{s\_i}$, $P\text{f\_i}$, $P\text{stray_i}$are values of the other motors.

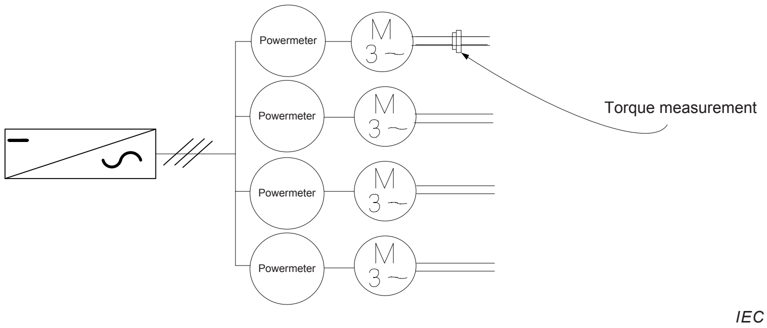


Figure 9 – Example of measurement using comparison of power method

This method is only applicable for asynchronous motors.

Providing that efficiencies of motors under test are assumed to be the same and the difference of power is less or equal to 20 %, comparison of power method can be simplified (applicable for all type of motors):

$$Ti \approx T1 \times Pel\_i/Pel\_1 \times N1/Ni$$

where

$T1$	is the measured torque of the one motor;
Pel_1	is the electrical fundamental input power of the one motor;
$N1$	is the mechanical speed of the one motor;
Ti, Pel_i, Ni	are values of the other motors.

6.3.4 Comparison of current method

In the case of paralleled motors with equal speeds (e.g. all motors are mechanically coupled) and provided that the efficiencies and power factors of the motors under test are assumed to be the same and the difference of motor currents is less or equal to 5 %, the sum of the torques (instead of measurement of each single torque) may be calculated from the one measured torque (reference torque) and the measured motor currents (or their sum) (see Figure 10):

$$Ti \approx T1 \times Iel\_i/Iel\_1$$

where

$T1$	is the measured torque of the one motor;
Iel_1	is the motor fundamental current of the one motor;
Ti, Iel_i	are values of the other motors.

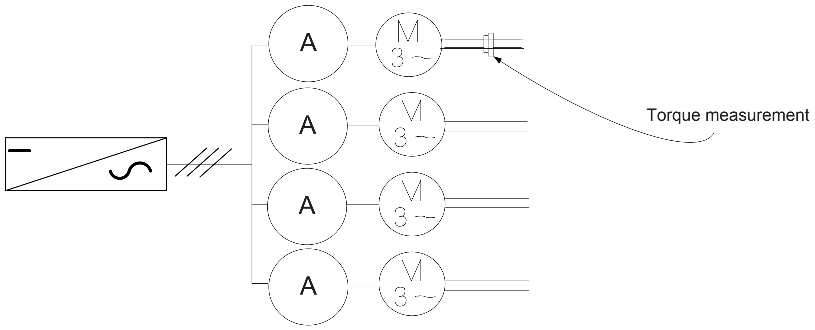


Figure 10 – Example of measurement using comparison of current method

6.3.5 Back to back method

When the efficiencies of motors under test and load motors are assumed to be the same, the torque is calculated from the total measured power of the motors (both motors under test and load motors) (see Figure 11).

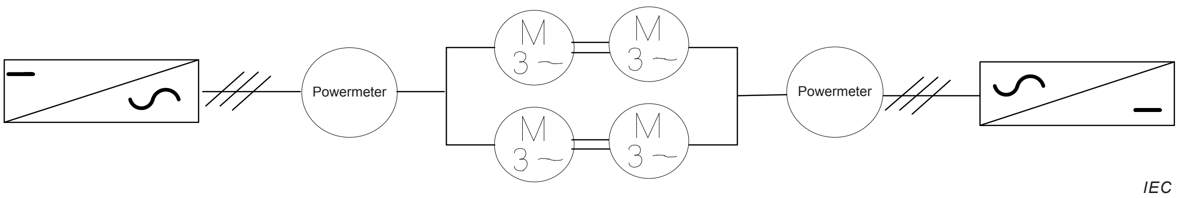


Figure 11 – Example of measurement using back to back method

6.4 Tolerances and measuring accuracy

The acceptance criteria indicate the specified values with acceptable tolerance limits and apply to the measurement results as defined below. The tolerance limit is defined in each test specification in the following clauses.

The corrected results are the reading values corrected with systematic errors.

NOTE 1 Systematic errors are for example offsets or errors indicated in the calibration curves of instruments.

The measurement result is the corrected result adjusted by the accuracy (considered in this standard as the class of the apparatus or the instruments' deviation taken from calibration protocols) of the measuring equipment. The measurement result shall be within the requested tolerance limits.

The manufacturer is responsible for choosing the pertinent accuracy of the measuring equipment.

NOTE 2 This only applies to the validation of the specified characteristics. Internal characteristics can be measured by measuring devices of the traction system (such as current/voltage transducers, software calculated values).

6.5 Environmental conditions

The ambient temperature, air pressure and humidity shall be recorded if relevant for the test. Special environmental conditions required for the tests shall be described in the test specification.

7 Torque characteristic test

7.1 General

The aim of this test is to demonstrate the compliance with the specified torque characteristics of the traction system. The test shall be carried out by running the motor(s) at a given speed applying the torque reference value from the traction control system.

The parameters described in the test conditions shall be in compliance with those used in specified characteristics, as defined in Clause 4.

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

If there are different sets of reference values (characteristic curves), for example in different operating conditions, every set of reference values shall be measured.

The tests for torque characteristics comprise of the measurement of specified characteristics (see Clause 4):

– torque versus speed;

and internal characteristics (recommended items):

– motor phase fundamental RMS current (or torque current);
– motor phase total RMS current;
– motor phase-to-phase RMS fundamental voltage (or modulation index);
– motor phase-to-phase total RMS voltage or harmonic content;
– DC link voltage;
– line voltage.

Temperature is an important parameter which influences the output torque, especially for traction system with asynchronous motors and PMM. The torque characteristic tests include testing at motor hot and motor cold.

7.2 Torque characteristics test at motor hot

7.2.1 Test objective

The aim of the test is to demonstrate the compliance with the specified torque characteristics at motor hot.

7.2.2 Test conditions

The motors are in a hot condition when the stator winding temperatures are equal to the reference temperature as in IEC 60349 series or subject to agreement between the user and manufacturer, with a tolerance of ± 20 K.

To achieve the hot condition, the following possibilities may be used:

a) run the system to load the motor (at constant load or other loads) until the temperature measured at the stator winding, chosen to be representative of the average temperature, reaches the hot condition;
b) run the system according to the test condition in Clause 9 or an equivalent one, providing the hot condition is achieved during the test.

7.2.3 Test procedure

This test can be performed by measuring the torque at:

a) constant speed

It is recommended to measure alternately at low speed and high speed to keep the temperature of the motor as constant as possible. Measurements shall be performed quickly to keep the temperature of the motor windings within the range defined in 7.2.2.

The number of plotted points shall be sufficient to have a precise view of the characteristics. Figure 12 gives examples of the number of points needed.

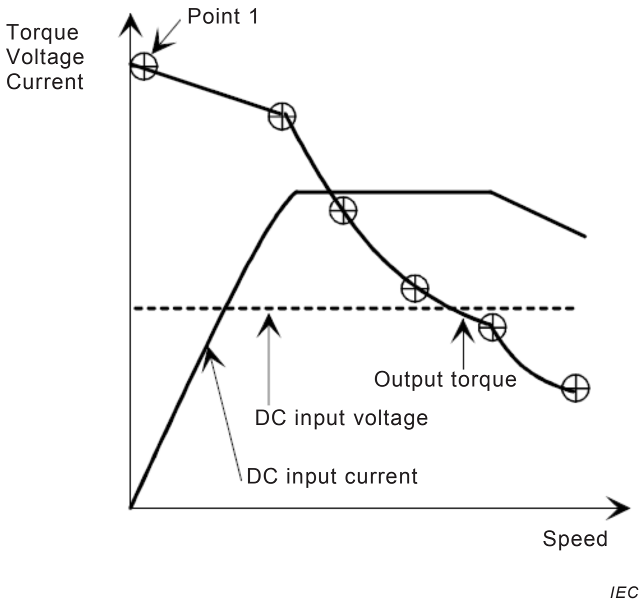


Figure 12 – Torque characteristics of a traction system

b) speed sweep

The measurement of torque is performed with the torque characteristic in Figure 12, sweeping in motoring from zero to maximum speed and in braking from the maximum to the minimum speed.

NOTE In case of speed sweep the inertia mass of the motor rotor influences the measurement of the motor shaft torque considerably.

7.2.4 Acceptance criteria

The difference between the measurement result of the sum of the torques (as defined in 6.3 and in 6.4) and the specified value shall be within the tolerance of ± 5 % of the specified value from the lowest speed (Point 1 in Figure 12) to 90 % of the maximum working speed.

7.3 Torque characteristics test at motor cold

7.3.1 Test objective

This test is to demonstrate compliance with the specified torque characteristics of the traction system at motor cold.

7.3.2 Test conditions

The motor is in the cold condition when the temperature difference between the motor (stator, stator winding or frame) and the ambient is within 20 K.

The cold condition may be reached by keeping the motor in the off-state in its ambient temperature or by forced air.

7.3.3 Test procedure

The measurement shall be performed just after the system has been started up. The measurements shall be performed at a single point at the lowest speed (point 1 in Figure 12, for which it has already been measured at system hot in 7.2.3).

7.3.4 Acceptance criteria

The difference between the measurement result of the sum of the torques (as defined in 6.3 and in 6.4) and the specified value shall be within the tolerance of ± 5 % of the specified value.

7.4 Starting torque at zero speed

7.4.1 Test objective

The aim of this test is to check the ability of the traction system to apply full torque at zero speed, e.g. with locked rotor or equivalent method.

This test is required for traction systems of locomotives only.

This test can be substituted with a torque characteristic test at motor cold, if the lowest speed defined in 7.3.3 is zero speed.

7.4.2 Test conditions

The test has to be carried out on at least one motor, at hot and cold conditions as defined in 7.2.2 and 7.3.2.

7.4.3 Test procedure

With the rotor locked, the traction motor is driven at the maximum reference torque and then the torque is measured.

7.4.4 Acceptance criteria

The difference between the measurement result and the specified value shall be within the tolerance of ± 5 % of the specified value.

8 Efficiency and energy consumption test

8.1 General

The aim of this test is to demonstrate the compliance with the specified efficiency or energy consumption characteristics of the traction system.

The efficiency of the traction system is the ratio between output mechanical power and the sum of input power sources necessary to convert the electrical power into mechanical output power.

The energy consumption of the traction system is the total energy absorbed from the sum of input power sources to run the traction motors on a specific route profile.

NOTE The input power sources are line power input, generator input power, auxiliary input power (for example control electronics, excitation of DC motors) necessary to operate the traction system.

The user and manufacturer shall agree whether to perform a measurement of efficiency or of energy consumption.

All components of the traction system as defined in 3.2 shall be incorporated as far as they are directly related to the traction system. If the auxiliary converter is part of the traction system, it shall be loaded with the load related to the traction system only. The power of the other auxiliaries and the losses in the traction components to provide this power shall not be regarded as related to the traction system.

If the scope of the traction system under test is different from that of the traction system, for example transformer and auxiliary system only partly used, the specified characteristics shall be defined according to the scope of the traction system under test.

If cooling is controlled by temperature this shall be taken into consideration and the cooling devices shall be operated in the specified way. The ambient temperature shall be recorded. If this is not possible (for example the cooling control system is not available) the cooling systems may be operated at their full power, and the reduced cooling power demand may be considered by calculation.

The efficiency and losses of the traction system at the specified operating points in steady state (at full or part load) may be directly measured by the direct measurement of input power and output power, or by direct measurement of the losses, or measured with the back to back test setup, or summation of losses may be used, or combinations of these methods.

8.2 Efficiency characteristics

8.2.1 Test objective

The aim of this test is to measure and validate the efficiency of the traction system under specified operating conditions.

8.2.2 Test conditions

The efficiency may be measured during the tests in 7.2.

8.2.3 Test procedure

The tests for efficiency characteristics comprise of the measurement of:

a) Specified characteristics and the related operating conditions:
   - efficiency versus speed and torque;
   - line voltage;
   - relevant temperature for efficiency.

   Since efficiency is not directly measured, the following set of measurement shall be performed at the same time in order to calculate the efficiency:
   - speed, torque, active power of all input power sources.

b) Internal characteristics (recommended items):
   - line current.

8.2.4 Acceptance criteria

The measured values shall be reached:

$$1 - \eta_M < (1 - \eta_S) \times 1{,}15$$

where

η_M is the measured efficiency;

η_S is the specified efficiency.

NOTE 15 % is the tolerance of the losses on component as per IEC 60349 series.

8.3 Energy consumption on route profile

8.3.1 Test objective

The aim of this test is to measure and validate the energy consumption of the traction system on the route profile specified in the test specification.

The load condition may be different from an actual one due to the limitations of the test facilities. This test aims to verify the design values under test conditions with the measurements results.

8.3.2 Test conditions

Test condition is according to the route profile specified in the test specification, of which characteristic is defined in Clause 4.

The characteristics of the route profile shall be recalculated before tests, using the result of torque characteristics described in Clause 7, instead of the reference torque.

8.3.3 Test procedure

The tests for energy consumption comprise of the measurement of the following items:

a) specified characteristics and the related operating conditions:
   - energy consumption versus time;
   - line voltage versus time;
   - relevant temperature for energy;
   - active line power (or active line current) versus time;
   - motor speed versus time;

b) internal characteristics (recommended items):
   - torque reference versus time.

The energy measurement shall be signed to make a clear distinction between energy absorbed and energy returned to the power source.

The energy consumption should be measured by the measurement of the input power and its integration with time, or directly by an energy measurement system. Both the measurement methods should follow the requirements of the relevant standard for energy measurement.

Alternative methods may be used by agreement between the user and manufacturer.

8.3.4 Acceptance criteria

The measured energy consumption (in kWh) shall be in accordance with the specified energy consumption with a tolerance of ± 10 %, unless otherwise specified.

9 Temperature rise test

9.1 General

The aim of this test is to verify the temperature design values with the measurement results under test conditions.

Temperature rise tests are carried out by one of the following methods:

- the constant load test (9.2);
- the route profile load test (9.3).

The method adopted shall be agreed between the user and manufacturer.

The load condition may be different from an actual one due to limitations of test facilities. In this case, the manufacturer shall demonstrate that the test result is equivalent.

The temperature rise of components of the traction system under test shall be measured. The components to be monitored during the temperature rise test shall be agreed between the user and manufacturer. It is permitted to perform the test without components which do not have an impact on the thermal behaviour of the traction system.

The test with wheel diameter differences may be done at the constant load or on the route profile. The method adopted shall be agreed between the user and manufacturer.

9.2 Temperature rise test at constant load

9.2.1 Test objective

This test is to demonstrate that temperature rises do not exceed the design values, at the ratings of the system agreed between the user and manufacturer.

9.2.2 Test conditions

At the ratings of the traction system under test agreed between the user and manufacturer, it shall be loaded according to 6.1.2 in motoring or braking (or both if it is necessary to verify all components), and full resistive braking also to check the brake resistors (if in the scope of test), whichever will cause a higher temperature rise.

The time to reach a steady temperature may be shortened by starting the test at an increased load or reduced ventilation of some components 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 on all relevant components individually (temperature change is less than 4 K within 1 h).

9.2.3 Test procedure

Measure the temperature rise of all relevant components and cooling agents, for example:

- motor stator;
- motor rotor (by temperature sensor or calculated values from traction control software), as internal characteristic;
- inverter cooling agent or heatsink temperature;
- transformer cooling agent in case of AC supply, line reactor cooling agent in case of DC supply;
- brake resistor (if in the scope of test);
- ambient temperature.

The direct measurement of the winding temperature is not required, as this was measured during the type test. It is sufficient to evaluate and compare the cooling agent temperature with that from the type test. In case only a part of the transformer winding is used in the test the measurement of transformer temperature rise is optional.

9.2.4 Acceptance criteria

The measured temperatures shall demonstrate that the temperatures of all relevant components stay within limits according to relevant standards and specifications.

9.3 Temperature rise on route profile

9.3.1 Test objective

This test is to demonstrate that temperature rises do not exceed the design values on the route profile specified in the test specification with the ratings of the system agreed between the user and manufacturer.

9.3.2 Test conditions

Test conditions are the same as in 8.3.2 unless otherwise specified.

This temperature rise should be measured considering the repetitive peak temperatures as defined in Clauses 4 and 3.9. The route profile is continued until the steady temperature is achieved (repetitive peak temperature increase over successive duty cycles is less than 4 K within 1 h or in the case of cycles longer than 1 h, 4 K at the same instant of two consecutive duty cycles). 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.

As an alternative, the test may be done by reproducing the daily operation of the vehicle.

9.3.3 Test procedure

The test procedure is, as far as applicable, as in 8.3.3 unless otherwise specified.

Measure the temperature rise of all relevant components and cooling agents, for example:

- motor stator;
- all relevant peak temperatures according to Clause 4;
- motor rotor (by temperature sensor or calculated values from traction control software), as internal characteristic;
- inverter cooling agent or heatsink temperature;
- transformer cooling agent in case of AC supply, line reactor cooling agent in case of DC supply;
- brake resistor (if in the scope of test);
- ambient temperature.

The direct measurement of the winding temperature is not required, as this was measured during type test. It is sufficient to evaluate and compare the cooling agent temperature with that from the type test. In case only a part of the transformer windings is used in the test the measurement of transformer temperature rise is optional.

9.3.4 Acceptance criteria

The measured temperatures shall demonstrate that the temperatures of all relevant components stay within the limits according to relevant standards and specifications.

9.4 Test with wheel diameter differences for paralleled asynchronous motors

9.4.1 General

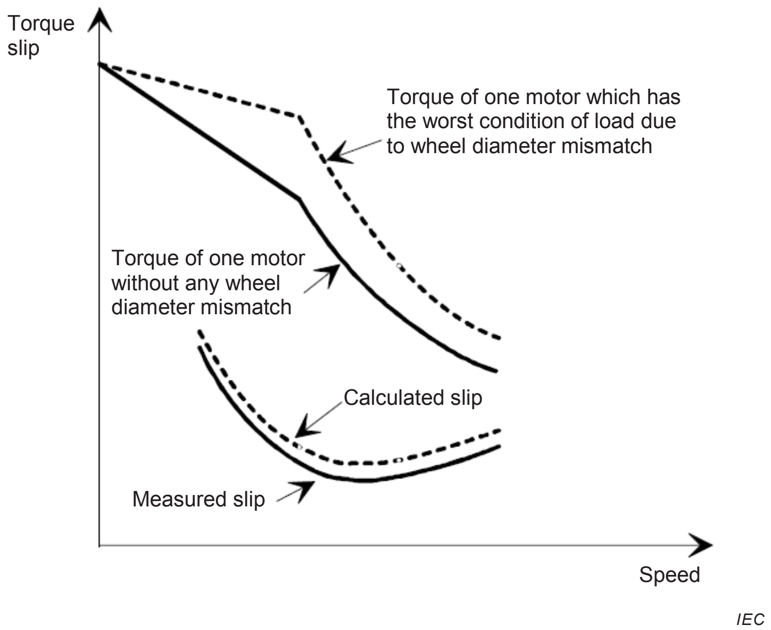
The test shall be performed either at constant load or on a route profile.

9.4.2 Test objective

The aim of the test is to check the motor temperature and system reactions (torque reduction) when there is a difference in speed due to wheel diameter difference.

This test is only applicable for asynchronous motors.

Figure 13 shows an example of the effect of the wheel diameter mismatch on the torque characteristic, and the evolution of the slip:



NOTE 1 The calculated slip equals:

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

(+ in motoring, – in braking)

where

s_c is the calculated slip;

s is the slip measurement during the characteristic tests (motor hot, refer to 7.2);

n is the number of motors in parallel;

$\Delta D/D$ is the maximum difference in wheel diameter.

NOTE 2 Wheel speed difference can also be caused by wheel slip. In this case motor overload conditions cannot be clearly defined. This condition is not considered here.

Figure 13 – Effect of wheel diameter mismatch on the torque characteristic of asynchronous motor

9.4.3 Test conditions

The test conditions are defined in 9.2.2 and 9.3.2.

9.4.4 Test procedure

9.4.4.1 General

Measure the temperature rise of the following of the motor with the highest load:

- motor stator;
- motor rotor (by temperature sensor or calculated values from the traction control software), as internal characteristic.

9.4.4.2 Case 1 – increased motor temperature

9.4.4.2.1 General

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. If the controller is designed in a way that some of the motors are brought to their worst condition of load, an additional temperature-rise test of the motors shall be performed.

This test may be carried out by one of the three following methods:

a) (only for constant load) as a test with the considered constant speed difference of one motor. The speeds of the paralleled motors are controlled individually to a speed difference which corresponds to the maximum permitted wheel diameter difference. The test shall be done in the worst condition, either in motoring or in braking or in both. In motoring, one motor shall be given a speed which is lower than the rest of the motors, resulting in a higher torque. In braking, one motor shall be given a speed which is higher than the rest of motors, resulting in a higher torque.

b) (only for route profile) as a test with the considered constant speed difference of one motor. The speeds of the paralleled motors are controlled individually to a speed difference which corresponds to the maximum permitted wheel diameter difference. One motor shall be given a speed which is lower than the rest of the motors, resulting in higher torque in motoring as well as a lower torque in braking.

c) or the test may be carried out with one or more motors at equivalent constant slip in overload conditions according to the specified wheel diameter difference. This test 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 maximum permissible difference in wheel diameter, keeping other parameters (e.g. flux) unchanged. The applicability of this method shall be demonstrated. The test can be performed in conjunction with the motor type test.

If agreed between the user and manufacturer, the test could be substituted by a calculation of the temperature rise, based on measurements during the type test of components and the combined test.

9.4.4.2.2 Acceptance criteria

The temperature rise of the motor in the worst condition shall remain within the specified limits and the system shall react properly. The impact on torque should be demonstrated.

9.4.4.3 Case 2 – reduced torque

9.4.4.3.1 General

The control may be designed to keep all the motors within a load which would apply if there was no difference in wheel diameter by reduction of the tractive effort. 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.

In this case, when the control is designed to keep all the motors within a permissible load by reduction of the tractive effort, an additional torque characteristic should be obtained. This may be done by measurement, calculation, or simulation (for example simulation of different speed signals), or other tests to demonstrate the protective reaction of the system may be carried out. The test may be carried out with reduced limit values.

If agreed between the user and manufacturer, the test could be substituted by a calculation of the temperature rise and torque, based on measurements during the type test of components and the combined test.

9.4.4.3.2 Acceptance criteria

Reduction of torque or power of each single motor or the sum of all motors shall be shown and the temperature shall be kept within the specified limits.

10 System function test

10.1 Start from backward/reverse motion

10.1.1 Test objective

The aim of this test is to demonstrate the ability of the traction system to move a vehicle from backward/reverse direction into forward direction, simulating the starting function on some gradient.

If starting from backward/reverse motion is not a requirement of a traction system, this test is not applicable.

10.1.2 Test conditions

The test shall be carried out on a test bench in order to simulate the specified load of the vehicle on the specified gradient.

NOTE Motor temperature is not relevant for this test.

10.1.3 Test procedure

The traction system under test shall start from the backward/reverse direction and go into the forward direction, with full torque applied.

10.1.4 Acceptance criteria

The traction system under test shall be able to accelerate into the required direction without any interruption of operation.

10.2 Motoring-braking transition

10.2.1 Test objective

The aim of this test is to demonstrate the ability of the system to perform the transition from motoring to braking and vice-versa under different conditions.

The test is not applicable for DC motors.

10.2.2 Test conditions

The test shall perform the following transitions (if applicable):

- motoring to rheostatic braking, and vice-versa;
- motoring to regenerative braking, and vice-versa.

NOTE 1 Motor temperature is not relevant for this test.

NOTE 2 Transition from motoring to emergency brake is included, if applicable.

The transition is tested with full motoring/braking torque/power at the following two speeds (see Figure 14):

- speed of point 1: maximum torque difference between motoring and braking;
- speed of point 2: maximum power difference between motoring and braking.

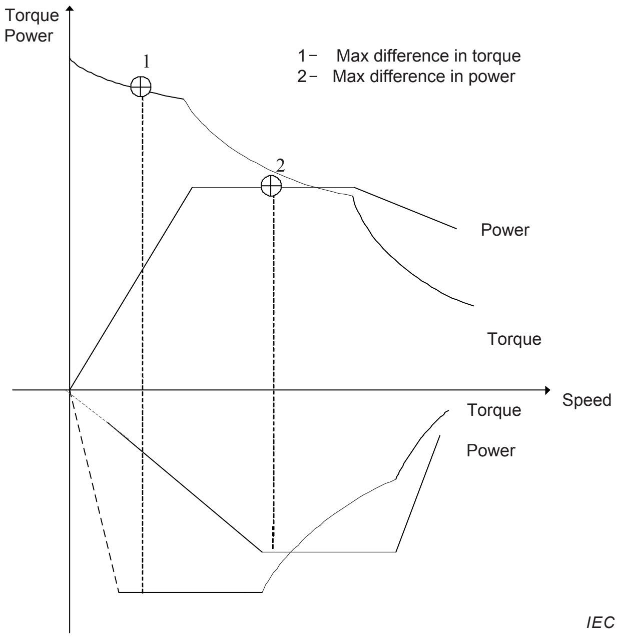


Figure 14 – Test conditions for motoring-braking transition

10.2.3 Test procedure

The transition, at maximum change rate of torque reference, is realized by motoring/braking command at each test condition.

10.2.4 Acceptance criteria

The change rate of torque shall be within the specified values.

Instead of measuring the torque directly, it is possible to measure other parameters, e.g. line current, motor current, input power.

The traction system under test shall be able to perform transitions required without any protective actions (e.g. overcurrent, overvoltage, etc.).

11 Variation of line voltage

11.1 Test objective

The aim of this test is to verify that the traction system operates correctly in the specified voltage range, according to IEC 60850 or the specification.

11.2 Test conditions

The test shall be carried out over the entire voltage range, as in the example in Figure 15:

- maximum voltage at full power (point 1);
- minimum voltage at full power (point 2);
- and at least one point in the area of under-voltage and over-voltage where power reduction usually occurs (point 3 and point 4), according to IEC 62313 or specifications.

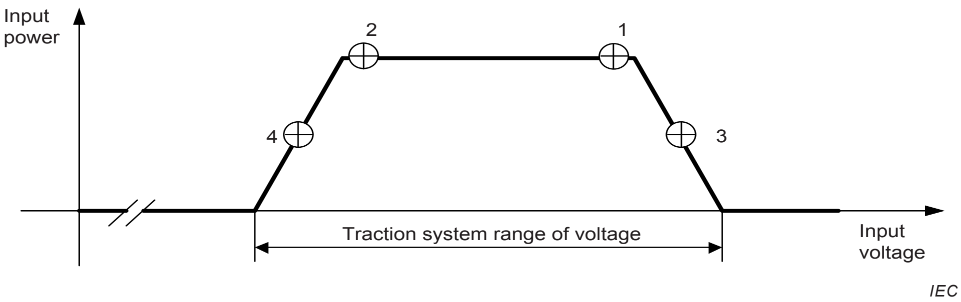


Figure 15 – Test conditions in traction system range of voltage

NOTE The impact of auxiliary loads is defined in 6.1.2.4.

The test shall be carried out in braking and motoring in a speed point of constant maximum power area at maximum torque reference (see bold area in Figure 16).

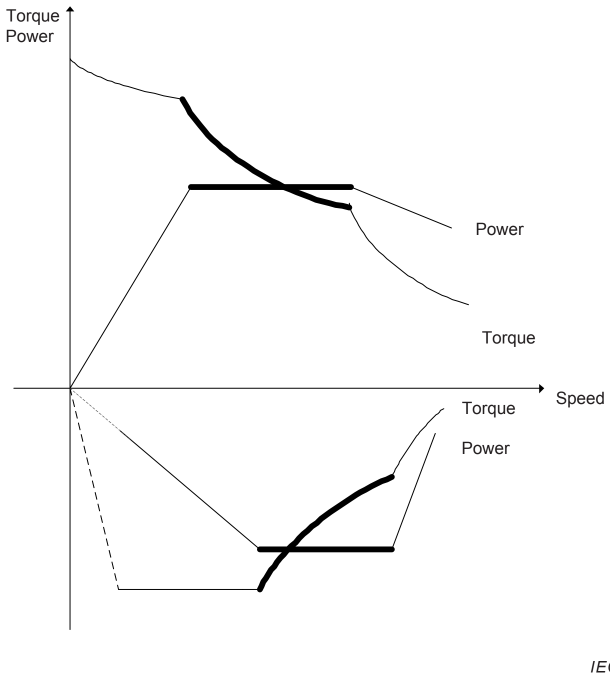


Figure 16 – Test conditions for variation of the voltage

11.3 Test procedure

At a constant line voltage value, the full torque reference is applied in accordance with the test conditions.

The tests comprise of the measurement of one or more of the following specified characteristics:

- line current;

- line power;
- input fundamental power factor (in case of AC input);
- torque.

11.4 Acceptance criteria

The input power (or input current, or torque, or input fundamental power factor) at each operating point specified in the test conditions shall be as specified.

12 System protection test

12.1 General

The aim of this test is to verify that system protection functions work correctly.

Where it has no influence on the test result, the carrying out of tests on the traction system under test without some components or without a high voltage power supply should generally be accepted.

As a minimum, the tests shall not adversely affect the traction system. The traction system shall continue to deliver the expected performance without permanent damage, even in the most severe operating conditions.

NOTE Other system protection tests that are not included in the Clause 12 are subject to agreement between the user and manufacturer.

12.2 Rapid voltage changes test

12.2.1 Test objective

The aim of this test is to check that the traction system is able to sustain a rapid voltage change (substation changes, load changes on the line).

12.2.2 Test conditions

The supply voltage shall be increased suddenly from approximately the nominal supply voltage.

The line voltage shall jump from Un +10 % Un to Un and back in motoring mode, and from Un –10 % Un to Un and back in braking mode at full power in traction and at the maximum regenerated braking current obtainable (if regenerative braking is applicable), as in Figure 17 and Figure 18. The rise time and fall time of the voltage changes is subject to agreement between the user and manufacturer.

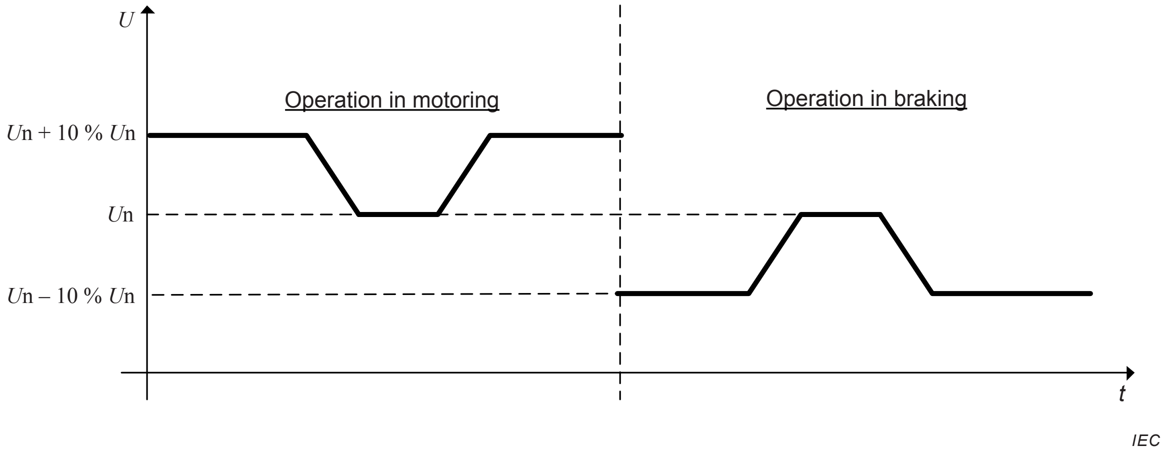


Figure 17 – Rapid voltage change with DC line voltage

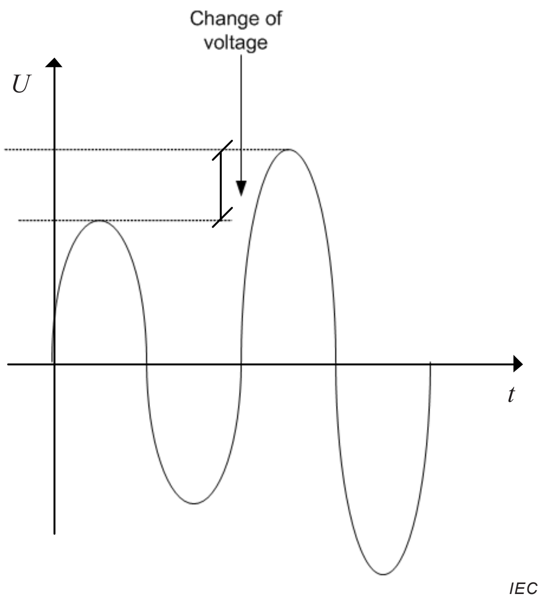


Figure 18 – Rapid voltage change with AC line voltage

12.2.3 Test procedure

The test may be performed by the following methods:

- using the controller of the test bench power supply;
- using a contactor in parallel with a resistor connected as in Figure 19, which gives an example of possible circuit configuration;
- using a tap-changer.

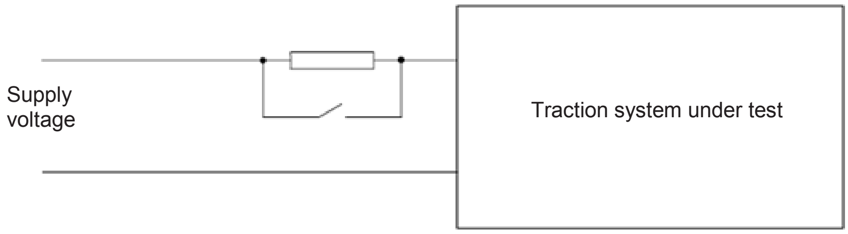


Figure 19 – Example of method to create a rapid voltage change

12.2.4 Acceptance criteria

The traction system should sustain the voltage change without interruption of operation.

12.3 Traction supply voltage interruption

12.3.1 Test objective

The aim of this test is to check that the traction system reacts to a voltage interruption, as specified in IEC 60850 or the specification, generally caused by circuit breakers tripping and auto-reclosing operations after the detection of faults.

12.3.2 Test conditions

The voltage is interrupted, for a period less than 10 s, at nominal voltage, at full power in motoring and at the maximum regenerated braking current obtainable (if regenerative braking is applicable).

NOTE The duration of interruption is according to power supply characteristics or it is possible to refer to IEC 60850 if not specified.

All protective devices, including no-voltage protection devices, shall be in operation for these tests.

12.3.3 Test procedure

For motoring and regenerative braking, the external supply voltage shall be disconnected and reconnected (e.g. by means of the circuit-breaker) with the total time of interruption, as defined in the test conditions.

12.3.4 Acceptance criteria

The traction system shall react as specified without damage.

NOTE IEC 62313 gives the requirements of the coordination between the traction system and the power supply.

12.4 Traction supply contact loss

12.4.1 Test objective

The aim of this test is to check that the traction system reacts to a voltage contact loss in order to simulate the train condition of a pantograph bouncing or crossing a neutral section, etc.

12.4.2 Test conditions

The voltage contact is lost, for a period between 10 ms and 200 ms or based on an agreement between the user and manufacturer, at nominal voltage, at full power in motoring and at the maximum regenerated braking current obtainable (if regenerative braking is applicable).

NOTE It is accepted that during contact loss the input voltage of the traction system does not go to 0 V.

12.4.3 Test procedure

For motoring and regenerative braking, the external supply voltage shall be disconnected and reconnected, e.g. as in Figure 20, with the total time of contact loss, as defined in the test conditions.

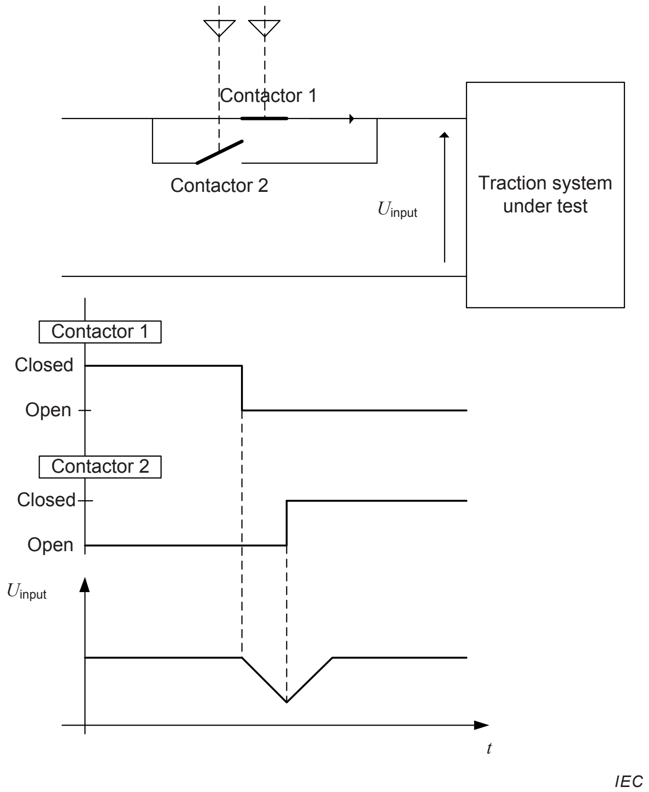


Figure 20 – Example of method to simulate the traction supply contact loss

12.4.4 Acceptance criteria

The traction system shall react as specified without damage.

12.5 Sudden loss of regeneration capability

12.5.1 Test objective

The aim of this test is to simulate a loss of regenerative capacity in order to check that the transition takes place from regenerative to rheostatic braking.

The test is only applicable if rheostatic braking system is available.

12.5.2 Test conditions

At nominal voltage, the regeneration capability is interrupted at maximum regenerated braking power obtainable.

12.5.3 Test procedure

The interruption of regeneration capability may be obtained through the following methods for AC and DC line, for example:

- disconnect the power supply;
- block the regenerative capability of the power supply (e.g. using of non-regenerative power supply and resistive load in parallel as shown in Figure 21 for DC).

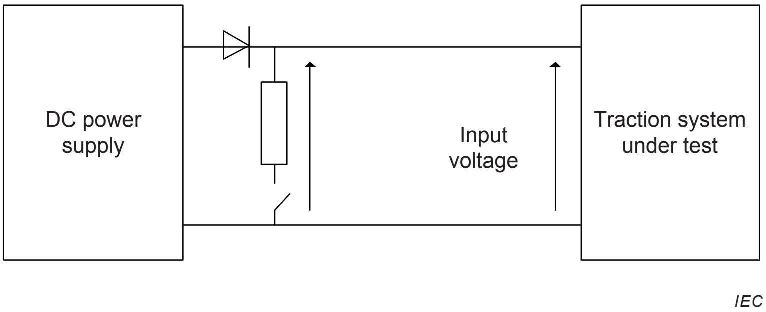


Figure 21 – Example of method to create loss of regenerative capability

12.5.4 Acceptance criteria

A smooth transition from regenerative braking to rheostatic braking should occur without significant torque variation.

NOTE It is possible to measure the motor current instead of measuring the torque directly.

The input voltage shall remain below the specified maximum value.

12.6 Traction inverter stop

12.6.1 Test objective

The aim of this test is to verify that after a sudden load reduction as a consequence of immediate switch-off of a traction inverter, the traction system does not suffer damage.

12.6.2 Test conditions

The test shall be done at the following operating points, in braking and motoring:

- maximum power (for all type of motors);
- 90 % of maximum motor working speed in normal operation (only in case of PMM).

12.6.3 Test procedure

When conditions described in 12.6.2 are reached, all inverters connected to a common DC link shall be stopped through immediate switch-off of traction inverter semi-conductor command pulses.

If inverters are on a common DC link but are independently controlled and protected, it is not necessary to stop them at the same time.

12.6.4 Acceptance criteria

The system shall be able to restart and resume operation as before according to a specified sequence (fault resetting).

12.7 Temperature calculation functions

12.7.1 General

The temperatures calculated in the traction system are internal values, which are used for protection functions.

For relevant components and only when the traction system is equipped with temperature calculation functions as protection functions, the temperature calculation functions done by the traction control equipment of the traction system shall be validated during the temperature rise test (Clause 9).

NOTE The over-temperature protection functions are validated during software validation or during some device tests.

12.7.2 Test objective

The aim of this test is to validate the temperature calculation functions as a basis for the protection function.

12.7.3 Test conditions

Refer to Clause 9.

12.7.4 Test procedure

Refer to Clause 9.

12.7.5 Acceptance criteria

The temperature calculation functions meet their purpose.

12.8 Over-current and over-voltage protection

The test shall be done during the component and the converter type tests according to IEC 61287-1.

12.9 Control battery supply interruption

12.9.1 Test objective

The aim of this test is to verify that the traction system under test does not suffer damage during control battery supply interruption.

12.9.2 Test conditions

The test shall be done at the following operating points, in braking and motoring:

- maximum power (for all type of motors);
- 90 % of maximum motor working speed in normal operation (only in case of PMM).

If there are restrictions due to the possibility of damage to the test bench facilities, it is permitted to perform this test in a low voltage condition or by using a different load instead of motors.

12.9.3 Test procedure

When conditions described above are reached, the control battery power supply shall be interrupted.

12.9.4 Acceptance criteria

The system shall be able to restart and resume operation as before according to the specified sequence (fault resetting).

13 Fault management test

13.1 General

The aim of this test is to test the management of faults inside the traction system by monitoring:

- fault detection;
- protective function;
- fault indication;
- remedy action (if applicable).

The test methods shall initiate the protective functions. Hardware simulating the fault condition is accepted.

If it does not have influence on the test result, carrying out tests with traction system under test without some components or without high voltage power supply should generally be acceptable.

If parts (or all) of the functions have been tested at the component level, it is permitted to test only the remaining functions.

The acceptance criteria for the test in the following subclauses are that the traction system under test does not suffer damage and the correct fault detection, the correct protective function, the correct fault indication and the remedy action (if applicable) are applied.

13.2 Loss of sensor function

Relevant for this test are sensor faults (e.g. voltage transducers, current transducers, temperature transducers).

It is permitted to perform this test by creating fault conditions for the sensors in the off-state, before start-up of the system.

13.3 Loss of command and feedback signals

Relevant for this test are the loss of hardware command and feedback signals for components (e.g. main circuit-breaker, contactors).

It is permitted to perform this test by creating fault conditions for the signal in the off-state, before start-up of the system.

13.4 Fault in cooling systems

Relevant for this test are interruptions or reductions in cooling performance. Examples are:

- stopped or reduced speed of components, e.g. pumps, fans;
- interrupted or reduced cooling medium flow.

It is permitted to perform this test by creating fault conditions in the off-state, before start-up of the system.

13.5 Earth and short-circuit faults

The user shall specify in the specification whether the traction system is earth faults and short-circuit proof or not.

Relevant for this test are earth faults or short-circuit conditions as specified. Faults occurring inside components may be excluded.

For example, the test cases should be the following:

- at the DC link (including resonant circuit if applicable);
- at the output;
- at the input;
- at the braking rheostat.

It is permitted to perform this test by creating a fault condition in the off-state, before start-up of the system.

If there are restrictions due to the possibility of damage to the test bench facilities, the test method shall be defined by agreement between the user and manufacturer.

Annex A
(normative)

List of combined tests

Table A.1 – List of combined tests

No. of test	Specified in clause/ subclause	Test case	Mandatory tests	Optional tests, subject to agreement
1	7.2	Torque characteristics test at motor hot	X	
2	7.3	Torque characteristics test at motor cold	X	
3	7.4	Starting torque at zero speed		X
4	8.2	Efficiency characteristics		X (alternative to 8.3)
5	8.3	Energy consumption on route profile		X (alternative to 8.2)
6	9.2	Temperature rise test at constant load	X (alternative 9.3)	
7	9.3	Temperature rise on route profile	X (alternative 9.2)	
8	9.4	Test with wheel diameter differences for paralleled asynchronous motors		X
9	10.1	Start from backward/reverse motion		X
10	10.2	Motoring-braking transition	X	
11	11	Variation of line voltage	X	
12	12.2	Rapid voltage changes test		X
13	12.3	Traction supply voltage interruption		X
14	12.4	Traction supply contact loss		X
15	12.5	Sudden loss of regeneration capability	X	
16	12.6	Traction inverter stop		X
17	12.7	Temperature calculation function		X
18	12.8	Over-current and over-voltage protection		X
19	12.9	Control battery supply interruption		X
20	13.2	Loss of sensor function		X
21	13.3	Loss of command and feedback signals		X
22	13.4	Fault in cooling systems		X
23	13.5	Earth and short-circuit faults		X
24	C.3	Commutation test (only for DC motor)	X	

Annex B
(informative)

List of clauses with agreements between the user and manufacturer

Table B.1 – List of subclauses including agreements between the user and manufacturer

Clause/ Subclause number	Clause/Subclause title	Clause/Subclause title	Subject
1		Scope	Representativeness of the traction system under test versus the traction system and deviations
4		Traction system characteristics	Level of voltage of the supply, reference temperature of the motor and difference in internal characteristics measurement results
5		General test requirements	Optional test, needs to repeat type test in case of existing traction system, modifications, and test on vehicle
6.1.1	Setup of traction system under test	General test conditions	Components to be equipped with temperature sensors
6.1.2.2	Test bench power supply	General test conditions	Voltage range or power limitation of the power supply
6.2	Cooling during the test	General test conditions	Simulations of the cooling and ambient temperature correction
6.3.1	General	Mechanical output measurement	Alternative methods to measure the mechanical output
7.1	General	Torque characteristic test	Measurement of ¼, ½ and ¾ of the maximum torque reference
7.2.2	Test conditions	Torque characteristic test	Stator winding temperatures
8.1	General	Efficiency and energy consumption test	Measurement of efficiency or of energy consumption
8.3.3	Test procedure	Efficiency and energy consumption test	Energy consumption measurement method
9.1	General	Temperature rise test	Temperature rise test method
9.2.1	Test objective	Temperature rise test	Ratings of the system
9.2.2	Test conditions	Temperature rise test	Ratings of the system
9.3.1	Test objective	Temperature rise test	Ratings of the system
9.4.4.2.1	General	Temperature rise test	Calculation method instead of test
9.4.4.3.1	General	Temperature rise test	Calculation method instead of test
12.1	General	System protection test	Other system protection tests
12.2.2	Test conditions	System protection test	The rise time and fall time of the voltage changes
12.4.2	Test conditions	System protection test	Period of the voltage contact loss
13.5	Earth and short-circuit faults	Fault management test	Test method
Annex A	Table A.1 – List of combined tests	(normative) List of combined tests	Optional tests

Annex C
(normative)

Special test items and conditions for DC motors

C.1 General

Special conditions and test items for DC motors are specified in this annex.

The following clauses are not applicable to DC motors:

- 9.4 Test with wheel diameter differences for paralleled asynchronous motors (Figure 13 and formula of slip are not applicable);
- 10.2 Motoring-braking transition.

C.2 Test bench architecture

C.2.1 Test setup

An example of the configuration for braking with separately excited DC motor is shown in Figure C.1.

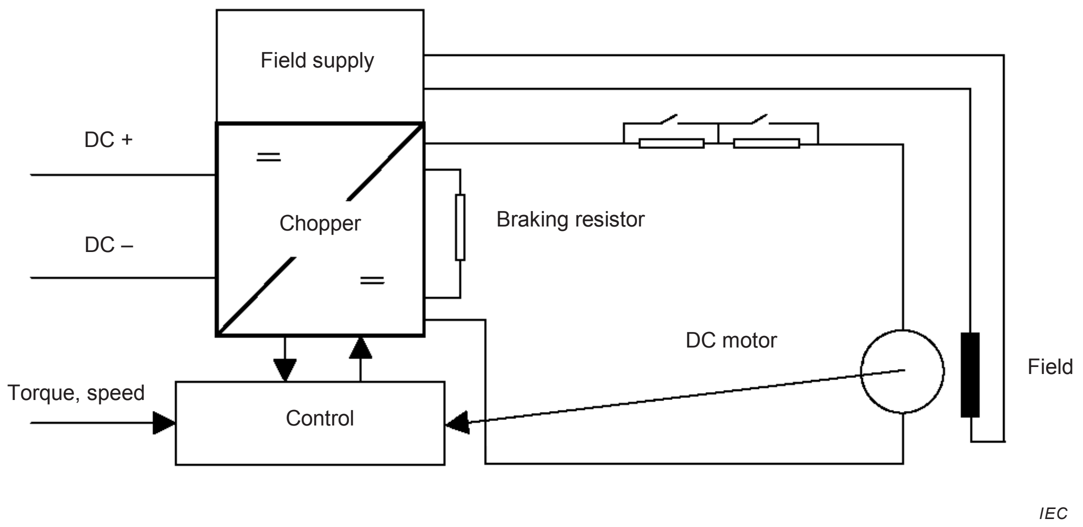


Figure C.1 – Example of braking configuration for a traction system under test with separately excited DC motor

C.2.2 Load system

The arrangement for back to back test for a chopper and DC motor is shown in Figure C.2.

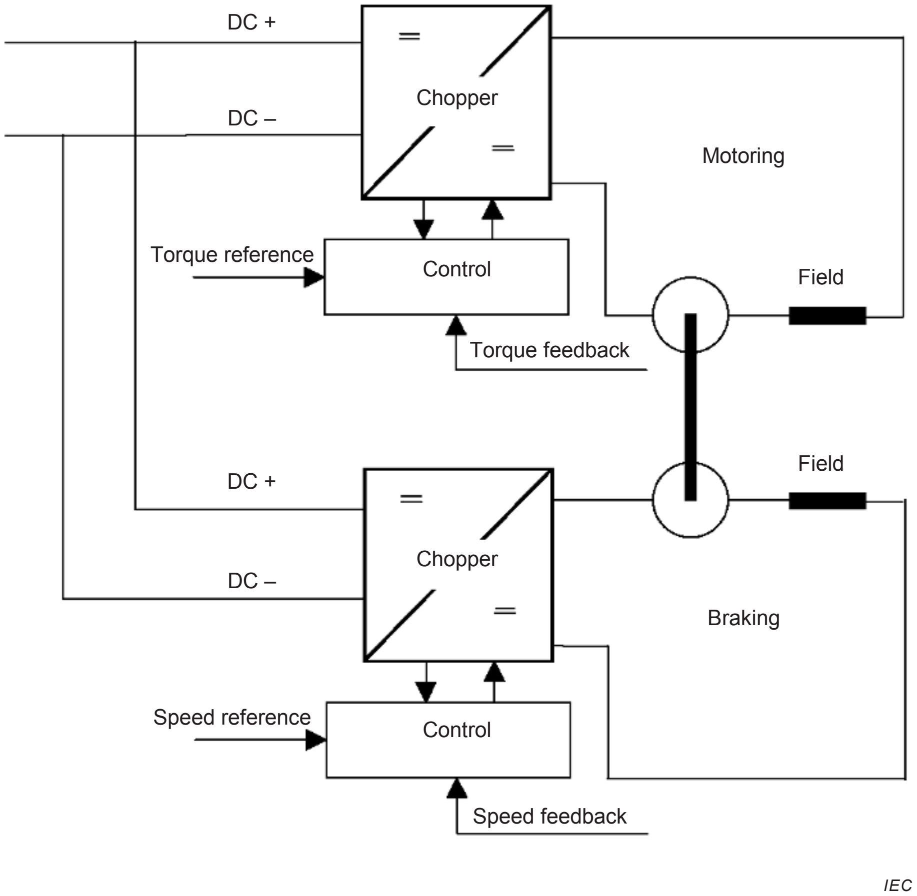


Figure C.2 – Test bench arrangement for back to back test of the traction system under test with a DC motor

C.3 Commutation test

The commutation test on DC motors shall be carried out in accordance with IEC 60349-1.

The test defined in 8.3.2 and 8.3.3, point 1 (Com 1), of IEC 60349-1, shall be carried out in both motoring and braking, at maximum working speed and maximum current, with the supply voltage generating the worst current ripple condition.

The test defined in 8.3.2 and 8.3.3, point 3 (Com 3), of IEC 60349-1, shall be carried out at the worst ripple condition.

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