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(JARI/JSA)

**Rolling stock — Combined testing of
power convertor with ac motors —
Part 2: Convertor-inverter system
with intermediate dc link**

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Land, Infrastructure, Transport and Tourism through deliberations at the Japanese Industrial Standards Committee according to the proposal for establishment of Japanese Industrial Standard by Japan Association of Rolling Stock Industries (JARI) /Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

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JIS E 5011 consists of the following 2 parts under the general title “*Rolling sotck — Combined testing of power convertor with ac motor s*”:

Part 1: Inverter system

Part 2: Convertor-inverter system with intermediate dc link

Rolling stock — Combined testing of power convertor with ac motors — Part 2 : Convertor-inverter system with intermediate dc link

Introduction

This Japanese Industrial Standard has been prepared based on the first edition of IEC 61377-3 published in 2002 by modifying some of the technical contents so as to add specification items and contents that are not given in the corresponding International Standard (e.g. division of the test into the in-the-workshop test and the on-the-vehicle test, and the torque characteristics measurement conditions).

The portions with continuous sidelines and dotted underlines are the matters in which the contents of the corresponding International Standard have been modified. A list of modifications with explanations is given in Annex JA.

1 Scope

This Standard applies to the combinations of motor(s), indirect convertors and their control system and its object is to specify :

- the performance characteristics of electric drives consisting of a power electronic convertor (hereafter referred to as "convertor", 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 motor(s) fed from a convertor without any control between the mechanical output (torque, speed) and the convertor 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 category **a)** of systems is tested according to **JIS E 5008** and **JIS E 6102**.

This Standard applies to the category **b)**, mainly traction drives (see figure 2).

JIS E 6102 applies to convertor-fed alternating current motors, **JIS E 5008** to convertors ; **JIS E 5006** applies to electronic equipments, and this Standard applies to the combination of motor(s), convertors, and their control system. As a consequence, **JIS E 6102** describes the tests to demonstrate the compliance of the motor to its specification, **JIS E 5008** does the same for the convertor. It is self-evident that some of the tests

mentioned in this Standard may in general replace the corresponding ones described in the above-mentioned standards. An agreement should be reached between the user and the manufacturer (hereafter referred to as "the interested parties") to avoid the duplication of tests (see, for example, the "Possible duplication of test" column in table 1).

A complete combined test is heavy, and often requires high power, which is not always available in a workshop. An agreement between the interested parties may be reached to allow testing either in the workshop or on the vehicle. Further, the test items to be performed may be divided into in-the-workshop tests and on-the-vehicle tests.

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

- a) asynchronous motors fed by voltage stiff (voltage source) inverter ;
- b) synchronous motors fed by voltage stiff (voltage source) inverter ;
- c) asynchronous motors fed by current stiff (current source) inverter ;
- d) synchronous motors fed by current stiff (current source) inverter.

The input of these inverters (see figure 2) can be a d.c. supply line or an intermediate d.c. link, which can be obtained from an a.c. line by means of a rectifier or from a d.c. line by means of a chopper or from autonomous supplies (such as on-board generators, accumulators or other electric energy sources).

NOTE 1 The indirect power convertor is "a device to convert input energy to output energy by means of an intermediate link". Namely, the indirect power convertor is a device which supplies power to motors or other loading devices by means of a narrowly-defined convertor, power rectifier, which is connected with an intermediate dc link and further by means of an inverter (a reverse conversion device) which is connected with the link.

NOTE 2 The International Standard corresponding to this Standard and the symbol of degree of correspondence are as follows :

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* (MOD)

The symbols which denote the degree of correspondence in the contents between **JIS** and the corresponding International Standard are IDT (identical), MOD (modified) and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. For standards with the year indication, only the editions of the indicated year shall be applied and any revisions (including amend-

ments) made thereafter shall not be applied. For those without the indication of the year, the most recent edition (including amendments) shall be applied.

JIS E 4001 *Railway rolling stock — Vocabulary*

NOTE : Corresponding International Standard : IEC 60050-811 *International Electrotechnical Vocabulary (IEV) — Chapter 811 : Electric traction (MOD)*

JIS E 5006 *Electronic equipment for rolling stock*

NOTE : Corresponding International Standard : IEC 60571 *Electronic equipment used on rail vehicles (MOD)*

JIS E 5008 : 2009 *Rolling stock — Power convertors installed on board rolling stock*

NOTE : Corresponding International Standard : IEC 61287-1 : 2005 *Railway applications — Power convertors installed on board rolling stock — Part 1 : Characteristics and test methods (MOD)*

JIS E 6102 : 2004 *AC traction motors for rolling stock*

NOTE : Corresponding International Standard : IEC 60349-2 : 2002 *Electric traction — Rotating electrical machines for rail and road vehicles — Part 2 : Electronic convertor-fed alternating current motors (MOD)*

IEC 60050-411 *International Electrotechnical Vocabulary (IEV) — Chapter 411 : Rotating machinery*

IEC 60050-551 *International Electrotechnical Vocabulary (IEV) — Chapter 551 : Power electronics*

IEC 60850 *Railway applications — Supply voltages of traction systems*

3 Terms and definitions

For the purposes of this Standard, the terms and definitions given in JIS E 4001, JIS E 5008, JIS E 6102, IEC 60050-411 and IEC 60050-551, and the following apply :

3.1 combined system

unit consisting of the indirect convertor, 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 (see figure 1).

3.3 manufacturer or prime contractor

organization which has the technical responsibility for the supply of the combined system (see figure 1)

NOTE : A convertor supplier may be a prime contractor.

3.4 supplier or subcontractor

organization which has the responsibility of one or more of the electric constituents such as convertor, control system and motor(s) (see figure 1)

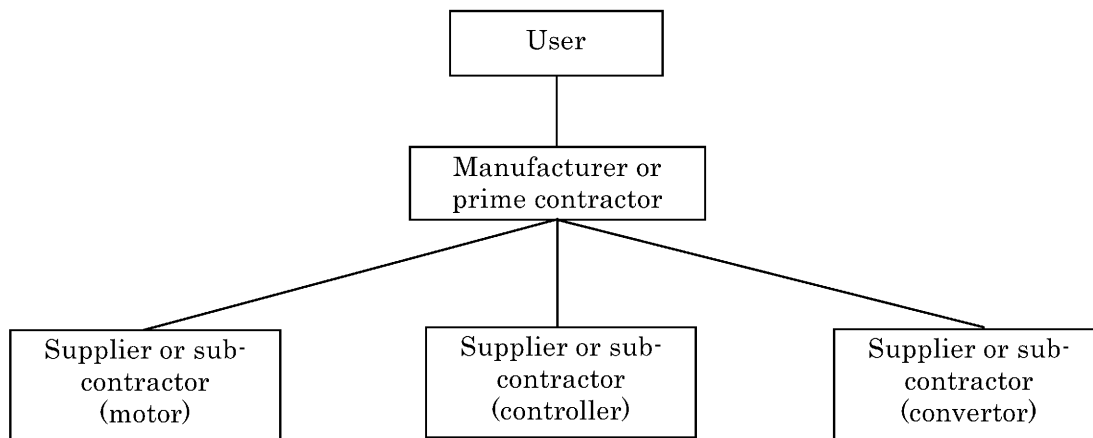


Figure 1 Combined system — involved manufacturer and supplier

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, as well as their durations and sequence in time

3.7 duty cycle of vehicle/load profile

variation of load determined by the speed and mass of a train which runs on the track having gradients and curves at various spots

The load profile for convertor 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 Missing number (to be in line with "Terms and definitions" in Part 1)

3.9 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

3.10 rated value

numerical value of any quantity included in a rating

3.11 continuous rating

mechanical output that the combined system can deliver on the test bed under specified conditions without exceeding the limits of temperature rise given in **JIS E 5008** and **JIS E 6102**

NOTE : Several continuous ratings may be specified (in the case of multi-power

source system, for example).

3.12 short-time rating (for example, 1 h rating)

mechanical output that the combined system can deliver on the test bed under specified conditions for the stated time without exceeding the limits of temperature rise given in table 2 of **JIS E 6102** and in **JIS E 5008**, starting with the combined system cold, all other requirements of the standards mentioned here being satisfied

NOTE : When the stated time is one hour, the rating is 1 h rating.

3.13 short-time overload rating

mechanical output that the combined system can deliver on the test bed under specified conditions for the stated time

The test is carried out as specified in 8.1.6 of **JIS E 6102**, without exceeding the limits of temperature rise given in table 3 of **JIS E 6102** and in **JIS E 5008**

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.

3.14 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 **JIS E 5008** and **JIS E 6102**

3.15 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 **JIS E 5008** and **JIS E 6102**

4 Environmental conditions

Environmental conditions relative to motor, convertor, and the control system are detailed in **JIS E 5006**, **JIS E 5008** and **JIS E 6102**.

5 Combined system characteristics

5.1 Specified characteristics

Combined system specifications shall, as a general rule, include characteristic curves specified in this Standard. 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 a.c. or 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 the interested parties. These characteristics shall be drawn for a reference temperature of the windings of the motor as specified in 5.2 of JIS E 6102, and the temperature of the parts of the convertor expected by the supplier.

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 **JIS E 6102**.

The specified characteristics shall be submitted to the user before the combined test is performed, 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

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

NOTE : The term "declared characteristics" is sometimes referred to as "determined characteristics" (see 5.4 of **JIS E 6102**).

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 values of the input : voltage, current and power of the combined system ;
- b) internal characteristics such as the current and voltage of the intermediate d.c. link, if any, 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, the excitation current for synchronous motors ;
- c) internal values such as switching transients, which are the point-to-point and point to earth peak voltages, temperatures, etc.

NOTE 1 Internal switching transients are of use to check the dielectric test voltage of the constituents.

NOTE 2 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.

NOTE 3 The efficiency characteristic of the combined system shall take into account the relevant components, such as the motor, the convertor, the cables, cooling fans and the pumps.

NOTE 4 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 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 tran-

sients are mandatory. The other internal characteristics and values may 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.

5.4 Exchange of information and responsibility

JIS E 6102 and JIS E 5008 point out the need for the exchange of information between the motor supplier and the convertor 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 convertor.

Definition 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

6.0A Classification of tests

Classification of tests shall be in accordance with table 1.

Routine tests shall be carried out in accordance with the relevant standards of each constituent equipment or device of the system.

The special requirements of the user to be specified and agreed between the interested parties shall be in accordance with Annex A.