

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Railway applications – Rolling stock – Power supply with onboard energy
storage system –
Part 1: Series hybrid system**

**Applications ferroviaires – Matériel roulant – Alimentation équipée d'un système
embarqué de stockage de l'énergie –
Partie 1: Système hybride série**



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2016 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.



IEC 62864-1

Edition 1.0 2016-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Railway applications – Rolling stock – Power supply with onboard energy storage system –
Part 1: Series hybrid system**

**Applications ferroviaires – Matériel roulant – Alimentation équipée d'un système embarqué de stockage de l'énergie –
Partie 1: Système hybride série**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 45.060

ISBN 978-2-8322-3453-2

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	10
2 Normative references.....	11
3 Terms, definitions and abbreviations	11
3.1 Terms and definitions	11
3.2 Abbreviations	14
4 Power source configuration of hybrid systems	15
4.1 General.....	15
4.1.1 Overview	15
4.1.2 System configuration requirements.....	15
4.1.3 Major operating modes of the series hybrid system.....	16
4.1.4 Typical configuration of the series hybrid systems.....	18
4.2 Application examples	19
4.2.1 Diesel electric vehicles.....	19
4.2.2 Fuel cell vehicles	20
4.2.3 DC contact line powered vehicles: parallel connection of ESS.....	21
4.2.4 DC contact line powered vehicles: series connection of ESS.....	23
4.3 Performance of the series hybrid systems.....	24
4.3.1 Improving efficiency	24
4.3.2 Boosting the motoring performance	25
4.3.3 Degraded mode operation	27
5 Environmental conditions	28
5.1 General.....	28
5.2 Altitude	28
5.3 Temperature	28
6 Functional and system requirements	29
6.1 Mechanical requirements.....	29
6.1.1 Mechanical stress	29
6.1.2 Protection against external mechanical influences	29
6.2 Control requirement	29
6.3 Electrical requirement	29
6.3.1 External charge and discharge function	29
6.3.2 Operating with energy storage system only.....	30
6.4 Disconnecting requirement.....	30
6.5 Degraded mode	30
6.6 Safety requirements	30
6.6.1 Protection against electrical hazards	30
6.6.2 Fire behaviour and protection.....	30
6.6.3 Protection against any other impacts	30
6.6.4 Short-circuit protection.....	30
6.7 Lifetime requirements.....	30
6.8 Additional requirement for noise emission of hybrid system.....	31
7 Kinds of tests	31
7.1 General.....	31

7.2	Type test.....	31
7.3	Optional test	32
7.4	Routine test	32
7.5	Test categories	32
7.6	Acceptance criteria.....	34
8	Combined tests	34
8.1	General.....	34
8.2	Test conditions.....	34
8.3	ESS control.....	34
8.3.1	ESS charge/discharge control function	34
8.3.2	External charge test	34
8.3.3	Disconnection test.....	34
8.3.4	Degraded mode test.....	35
8.3.5	SOC/SOE test.....	35
8.4	Output torque.....	35
8.4.1	Sweeping speed under full torque test	35
8.4.2	Output torque test with energy storage system only	35
8.5	System sequence test	35
8.6	Energy efficiency and consumption.....	36
8.6.1	General	36
8.6.2	Energy efficiency and consumption measurement	37
8.6.3	Determination of fuel consumption and exhaust gas emission (in case of engine or fuel cell)	38
8.7	Duration of vehicle operation by ESS.....	39
8.7.1	General	39
8.7.2	Duration measurement of ESS	39
8.8	Environmental test	39
8.8.1	General	39
8.8.2	Low-temperature operation test	39
8.8.3	High-temperature operation test	39
8.9	Short-circuit protection test.....	40
8.10	ESU endurance test	40
9	Vehicle test	40
9.1	General.....	40
9.2	ESS disconnection test.....	40
9.3	Vehicle sequence test	40
9.4	Drive system energy consumption measurement.....	41
9.5	Determination of fuel consumption and exhaust gas emission (in case of engine or fuel cell)	42
9.5.1	Determination of fuel consumption.....	42
9.5.2	Determination of the exhaust gas emission levels	42
9.6	Auxiliary circuit energy consumption measurement	42
9.7	Duration of vehicle operation by ESS.....	42
9.8	Determination of acoustic noise emission	42
Annex A (informative) State of charge (SOC) and state of energy (SOE) for batteries and capacitors		43
A.1	Content of capacity and energy	43
A.1.1	General	43
A.1.2	Theoretical energy	44

A.1.3	Rated energy	44
A.1.4	Usable energy	44
A.2	Content of SOC and SOE	45
A.2.1	General	45
A.2.2	Theoretical purpose	45
A.2.3	Common purpose	45
A.2.4	Effective or practical purpose	46
A.2.5	Coefficient of usage	46
Annex B (informative)	Energy related terms and definitions	48
B.1	General.....	48
B.2	Terms and definitions for regenerative indices	48
B.3	Energy-related performance indices of the series hybrid systems	49
B.3.1	General	49
B.3.2	Measuring locations	49
B.3.3	Class of primary power source	50
B.3.4	Energy consumption.....	51
B.3.5	Regenerative efficiency	53
Annex C (informative)	Laws and regulations for fire protection applicable for this standard	55
C.1	General.....	55
C.2	China.....	55
C.3	Europe.....	55
C.4	Japan	55
C.5	Russia	55
C.6	United states of America	55
Annex D (informative)	List of subclauses requiring agreement between the user and the manufacturer	56
Bibliography	58
Figure 1	– Hierarchy of standards related to IEC 62864-1	9
Figure 2	– Block diagram of a series hybrid system	16
Figure 3	– Example configuration of a series hybrid system in which all main circuit subsystems are connected to the common DC link	19
Figure 4	– Series hybrid system in diesel electric vehicles	20
Figure 5	– Series hybrid system in fuel cell vehicles	21
Figure 6	– Series hybrid system in contact line powered vehicles with parallel connection of energy storage	22
Figure 7	– Series hybrid system in contact line powered vehicles with series connection of energy storage	23
Figure 8	– Diesel electric propulsion system (without an ESS)	24
Figure 9	– Contact line powered propulsion system (without an ESS).....	25
Figure 10	– Boosting of the motoring performance by onboard ESS	27
Figure 11	– An example of degraded mode performance by onboard ESS	28
Figure A.1	– Difference of capacity and energy content	43
Figure B.1	– Example block diagram of a series hybrid system	50
Table 1	– Major operating modes of the series hybrid system	18

Table 2 – List of tests32

Table D.1 – List of subclauses requiring agreement between the user and the manufacturer56

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS – ROLLING STOCK –
POWER SUPPLY WITH ONBOARD ENERGY STORAGE SYSTEM –**

Part 1: Series hybrid system

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62864-1 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

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

FDIS	Report on voting
9/2154/FDIS	9/2176/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.

A list of all parts in the IEC 62864 series, published under the general title *Railway applications – Rolling stock – Power supply with onboard energy storage system*, can be found on the IEC website.

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.

INTRODUCTION

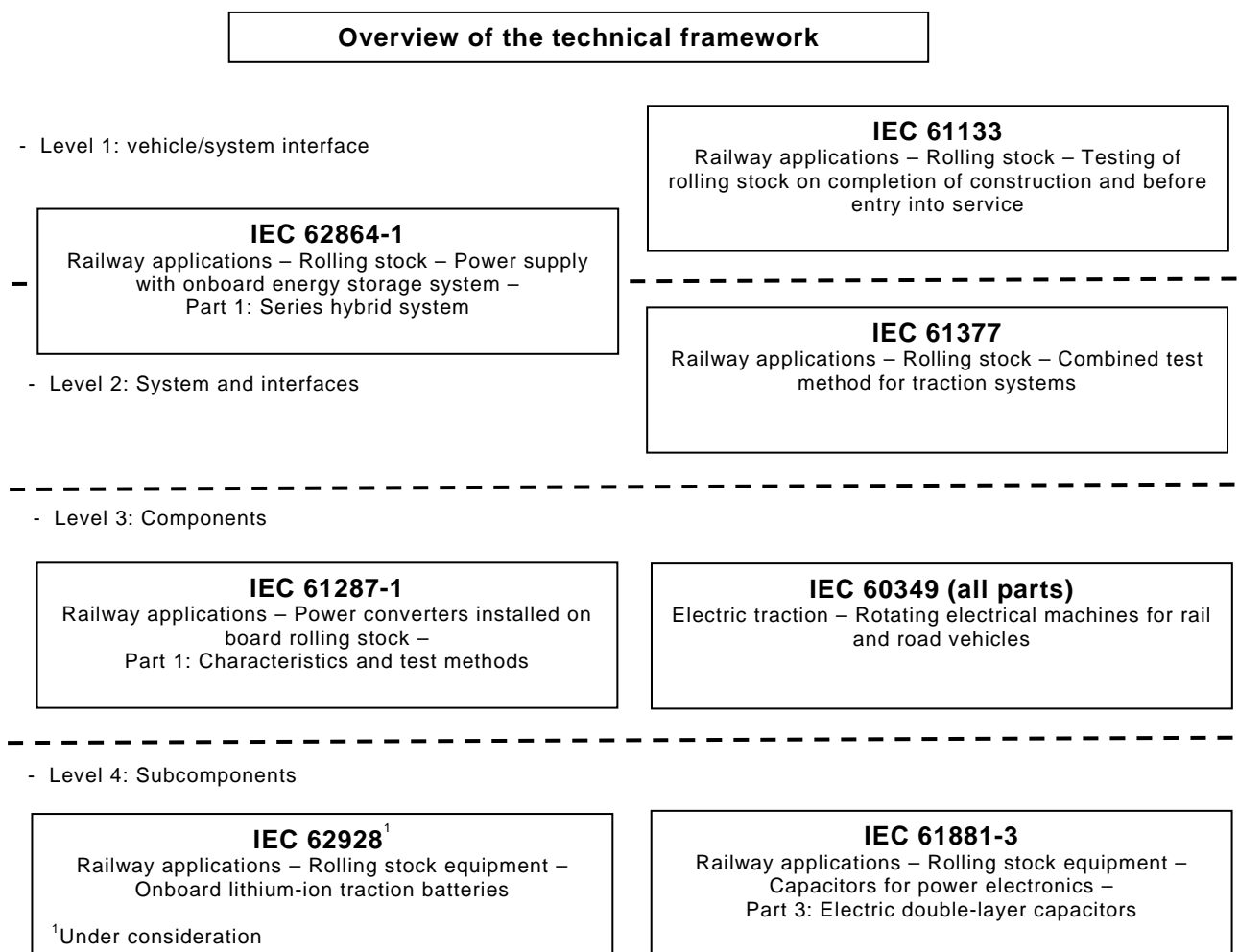
There is an increasing need for efficient use of energy due to the decrease in fossil fuel based energy sources as well as the need to reduce emissions (e.g. CO₂, NO_x, PM, etc.) that contribute to global climate change. The railway system, which is essentially an energy-efficient transportation system, should also meet these requirements. In addition to saving energy, it is necessary to achieve a reduction in peak power, voltage stabilization and the ability to run without collecting power in scenic reserve areas, and the running capability to safely reach the next station in the event of electrical power failure onboard or at power supply system. To address these issues, hybrid systems are appearing in railway vehicles. These hybrid system vehicles are equipped with an energy storage system that allows effective use of regenerative energy. A hybrid system should be required to improve energy efficiency by actively controlling the power flow among the engine or power supply system, auxiliary power supply, traction and braking system, the energy storage system, etc.

The purpose of introducing hybrid systems includes:

- reducing energy consumption;
- improving vehicle performance;
- providing the ability to run with energy stored onboard; and
- improving environmental characteristics.

The aim of this standard is to establish the basic system configuration for series hybrid systems (electrically connected) and the tests to verify effective use of energy, as well as to provide railway operators and manufacturers with guidelines for manufacturing and evaluating hybrid systems.

The hierarchy of relevant standards related to hybrid systems are summarized in Figure 1. The standards listed in Figure 1 are not exhaustive.



IEC

Figure 1 – Hierarchy of standards related to IEC 62864-1

In this standard, the hybrid system has the following four levels of hierarchy:

- a) vehicle/system interface (level 1);
- b) systems and interfaces (level 2);
- c) components (level 3); and
- d) subcomponents (level 4).

Detailed descriptions of the levels are described in 7.1.

E.g. subcomponent (level 4) is a cell, module etc. (for a battery, a subcomponent is defined in IEC 62620).

RAILWAY APPLICATIONS – ROLLING STOCK – POWER SUPPLY WITH ONBOARD ENERGY STORAGE SYSTEM –

Part 1: Series hybrid system

1 Scope

This part of IEC 62864 applies to series hybrid systems (electrically connected) with onboard energy storage (hereinafter referred as hybrid system).

A hybrid system has two (or more) power sources including energy storage system (ESS) on board to achieve the following features by combining converter and motors and performing energy management control:

- improving energy and fuel efficiency, improving acceleration characteristics, increasing running distance and uninterrupted running in the event of the loss of the primary power source (PPS), by using an ESS in addition to the primary power source under conditions where the power and capacity of the power source including regenerative power are limited, thus alleviating those limitations;
- reducing fuel consumption, reducing emissions (e.g. CO₂, NO_x, PM, etc.);
- reducing environmental impact (e.g. visible obstruction, noise, etc.).

By extension, systems that have only onboard ESS, without other PPSs, is also considered in this standard.

This standard intends to specify the following basic requirements, characteristics, functions and test methods for hybrid systems:

- energy management to control the power flow among primary power source, energy storage system and power converters;
- energy consumption, energy efficiency and regenerated energy;
- vehicle characteristics achieved by energy storage system;
- test methods of combined test; and
- test methods of completed vehicles based on factory (stationary) and field (running) tests.

NOTE Converter in this standard means combined equipment consisting of one or more converters (e.g. rectifier, inverter, chopper, etc.).

The interfaces between the following power sources are covered:

- external electric power supply system;
- onboard ESSs (including pure onboard energy storage);
- fuel cell, diesel electric generator; and
- other power sources.

As for the combination of inverters and motors, this standard applies to asynchronous motors or synchronous motors that are powered via voltage-source inverters.

Power source systems and combination of inverters and motors are not limited to the listed above, but this standard can also be applied to future systems.