

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Railway applications – Energy measurement on board trains –
Part 2: Energy measurement**

standards.iteh.ai

**Applications ferroviaires – Mesure d'énergie à bord des trains –
Partie 2: Mesure d'énergie**

<https://standards.iteh.ai/catalog/standards/sist/0c210274-dbd4-4eea-9ee6-cd4abe79fb30/iec-62888-2-2018>



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2018 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
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 - webstore.iec.ch/advsearchform

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 21 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67 000 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: sales@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 - webstore.iec.ch/advsearchform

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 21 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

67 000 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: sales@iec.ch.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Railway applications – Energy measurement on board trains –
Part 2: Energy measurement**
(standards.iteh.ai)

**Applications ferroviaires – Mesure d'énergie à bord des trains –
Partie 2: Mesure d'énergie**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 45.060.01

ISBN 978-2-8322-5152-2

**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.....	11
2 Normative references	12
3 Terms, definitions, abbreviated terms and symbols.....	14
3.1 Terms and definitions.....	14
3.2 Abbreviated terms.....	17
3.3 Symbols.....	18
4 Requirements	18
4.1 General.....	18
4.2 Energy Measurement Function (EMF)	18
4.2.1 General	18
4.2.2 Electrical requirements	19
4.2.3 Accuracy requirements	20
4.2.4 Traction supply system change.....	22
4.2.5 Re-verification	22
4.3 Sensors	22
4.3.1 General.....	22
4.3.2 General requirements	22
4.3.3 Voltage sensors.....	24
4.3.4 Current sensors	28
4.4 Energy Calculation Function (ECF).....	34
4.4.1 General.....	34
4.4.2 General requirements	34
4.4.3 Electrical requirements	35
4.4.4 Accuracy requirements	38
4.4.5 Effect of temperature on error limits.....	39
4.4.6 Limits of additional error due to influence quantities	41
4.4.7 Electromagnetic compatibility	42
4.4.8 Data transfer from ECF to DHS.....	43
5 Conformance test	44
5.1 General.....	44
5.1.1 Conformance test requirements	44
5.1.2 Applicability	44
5.1.3 Methodology.....	44
5.2 Testing framework	45
5.2.1 General	45
5.2.2 Reporting.....	45
5.3 Design review	46
5.3.1 General	46
5.3.2 Device design review.....	46
5.3.3 EMF design review	47
5.4 Type testing	47
5.4.1 General	47
5.4.2 Common type testing.....	47
5.4.3 Sensor type test	51

5.4.4	ECF type test.....	58
5.5	Routine test	69
5.5.1	General	69
5.5.2	Visual Inspection	69
5.5.3	Insulation test	69
5.5.4	Accuracy tests	69
Annex A	(normative) Test with magnetic induction of external origin	72
A.1	General.....	72
A.2	Test method 1	72
A.3	Test method 2.....	72
A.4	Position of EUT.....	73
Annex B	(normative) EMF configurations	74
B.1	Background.....	74
B.2	General.....	74
B.3	EMF with several CMFs in parallel	74
B.4	EMF with several VMFs connected to one ECF	75
B.5	EMF with several pairs of VMF and CMF	75
B.6	Several EMFs in parallel	76
B.7	One VMF or CMF connected to several ECFs	77
B.8	EMF without VMF.....	77
Annex C	(informative) Expressing EMF accuracy.....	78
C.1	Summary	78
C.2	Error limits or uncertainty	78
C.3	Presentation of error limits	78
C.4	Uncertainty calculations	79
C.4.1	AC active power	79
C.4.2	Primary values.....	80
C.4.3	Uncertainty in the measurement of active power (Watts).....	80
C.4.4	Relative uncertainty	81
C.4.5	Uncertainty in the measurement of reactive power (var)	82
C.4.6	Relative uncertainty	84
Annex D	(informative) Re-verification and defining of its regime recommendations	85
D.1	Re-verification	85
D.1.1	Background	85
D.1.2	Approaches to re-verification	85
D.2	Defining re-verification regime recommendations	86
D.2.1	General approach	86
D.2.2	Testing regime.....	87
Annex E	(informative) Durability test.....	88
E.1	Durability test.....	88
E.2	Initial measurements.....	88
E.3	Conditioning.....	88
E.4	Intermediate measurements.....	89
E.5	Final temperature ramp.....	90
E.6	Final measurements and acceptance criteria	90
E.7	Information to be given in the test report.....	91
Bibliography	92

Figure 1 – EMS functional structure and dataflow diagram	10
Figure 2 – EMF functional block diagram	12
Figure 3 – Example of energy index value and delta value	15
Figure 4 – Example of maximum percentage error for a VMF of class 0,5 R and a VMF of class 1,0 R with input signal in the range $U_{\min 1} \leq U \leq U_{\max 2}$	27
Figure 5 – Example of maximum percentage error for a CMF class 1,0 R AC with input signals in the range $10 \% I_n \leq I \leq 120 \% I_n$, $5 \% I_n \leq I < 10 \% I_n$ and $1 \% I_n \leq I < 5 \% I_n$	32
Figure 6 – Primary current and voltage ranges	38
Figure 7 – Example of maximum percentage error for an ECF of class 0,5 R and an ECF of class 1,0 R with input signals in Area 1 and Area 2	40
Figure 8 – Test point matrix for ECF accuracy tests (type test)	60
Figure 9 – Test point matrix for tests of ambient temperature variation and influence quantities (type test)	61
Figure 10 – Test circuit diagram for determining the influence on accuracy of odd harmonics or sub-harmonics in the current circuit	64
Figure 11 – Phase-fired waveform (shown for 50 Hz)	64
Figure 12 – Analysis of harmonic content of phase-fired waveform (shown for 50 Hz)	65
Figure 13 – Burst fire waveform (shown for 50 Hz)	65
Figure 14 – Analysis of harmonics (shown for 50 Hz)	66
Figure 15 – Test point matrix for ECF accuracy tests (routine test)	71
Figure A.1 – Test configuration for test method 1	72
Figure A.2 – Test configuration for test method 2	73
Figure B.1 – EMF with several CMFs in parallel	74
Figure B.2 – EMF with several VMFs connected to one ECF	75
Figure B.3 – EMF with several pairs of VMF and CMF	76
Figure B.4 – EMF with several ECFs	76
Figure B.5 – One VMF connected to two ECFs	77
Figure B.6 – EMF without VMF	77
Table 1 – Reference conditions	21
Table 2 – EMF percentage error limits at reference conditions	21
Table 3 – Percentage error limits – VMF	26
Table 4 – Maximum percentage error for a VMF including ambient temperature variation	26
Table 5 – Temperature coefficient for VMF	27
Table 6 – Influence quantities for voltage sensors	28
Table 7 – Percentage error limits – AC CMF	30
Table 8 – Percentage error limits – DC CMF	31
Table 9 – Maximum percentage error for a CMF including ambient temperature variation	31
Table 10 – Temperature coefficient for CMF	32
Table 11 – Percentage error limits with harmonics – AC current sensor	33
Table 12 – Influence quantities for current sensors	33
Table 13 – Variations due to short-time overcurrents	37
Table 14 – Variations due to self-heating	37

Table 15 – ECF percentage error limits for active energy.....	38
Table 16 – Maximum percentage error for an ECF including ambient temperature variation.....	39
Table 17 – Temperature coefficient for the ECF	40
Table 18 – Influence quantities for the ECF	41
Table 19 – Test current for harmonics.....	54

iTeh STANDARD PREVIEW
(standards.iteh.ai)

[IEC 62888-2:2018](https://standards.iteh.ai/catalog/standards/sist/0c210274-dbd4-4eea-9ee6-cd4abe79fb30/iec-62888-2-2018)

<https://standards.iteh.ai/catalog/standards/sist/0c210274-dbd4-4eea-9ee6-cd4abe79fb30/iec-62888-2-2018>

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –
ENERGY MEASUREMENT ON BOARD TRAINS –**

Part 2: Energy measurement

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 62888-2 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This standard is based on EN 50463.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
9/2321/FDIS	9/2332/RVD

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

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

A list of all parts in the IEC 62888 series, published under the general title *Railway applications – Energy measurement on board trains*, can be found on the IEC website.

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

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

iTeh STANDARD PREVIEW (standards.iteh.ai)

[IEC 62888-2:2018](#)

<https://standards.iteh.ai/catalog/standards/sist/0c210274-dbd4-4eea-9ee6-cd4abe79fb30/iec-62888-2-2018>

INTRODUCTION

Three levels are introduced for categorizing EMS as described in IEC 62888-1:2018, 4.1.

This is Part 2 of the IEC 62888 series, which consists of the following parts, under the common title *Railway applications – Energy measurement on board trains*:

Part 1: General

Part 2: Energy measurement

Part 3: Data handling

Part 4: Communication

Part 5: Conformance test

Part 6: Requirements for purposes other than billing

This series of International Standards follows the functional guidelines description in Annex A, “Principles of conformity assessment”, of ISO/IEC 17000:2004 tailored to the Energy Measurement System (EMS).

The Energy Measurement System (EMS) provides measurement and data suitable for applications such as energy management, energy saving, billing and others.

This series of International Standards uses the functional approach to describe the EMS. These functions are implemented in one or more physical devices. The user of this series of standards is free to choose the physical implementation arrangements.

Structure and main contents of the IEC 62888 series

[IEC 62888-2:2018](https://standards.iteh.ai/catalog/standards/cist/0c210274-d11c-4e00-9ea6-cd4abc79fb30/iec-62888-2-2018)

This series of International Standards is divided into six parts. The titles and brief descriptions of each part are given below:

IEC 62888-1 – General

The scope of IEC 62888-1 is the Energy Measurement System (EMS).

IEC 62888-1 provides system level requirements for the complete EMS and common requirements for all devices implementing one or more functions of the EMS.

IEC 62888-2 – Energy measurement

The scope of IEC 62888-2 is the Energy Measurement Function (EMF).

The EMF provides measurement of the consumed and regenerated active energy of a traction unit. If the traction unit is designed for use on AC traction supply systems, the EMF also provides measurement of reactive energy. The EMF provides the measured quantities via an interface to the Data Handling System.

The EMF consists of the three functions: Voltage Measurement Function, Current Measurement Function and Energy Calculation Function. For each of these functions, accuracy classes are specified and associated reference conditions are defined. This part also defines all specific requirements for all functions of the EMF.

The Voltage Measurement Function measures the voltage of the contact line (CL) system and the Current Measurement Function measures the current taken from and returned to the CL system. These functions provide signal inputs to the Energy Calculation Function.

The Energy Calculation Function inputs the signals from the Current and Voltage Measurement Functions and calculates a set of values representing the consumed and regenerated energies. These values are transferred to the Data Handling System and are used in the creation of Compiled Energy Measured Data.

All relevant metrological aspects are covered in this part of IEC 62888.

IEC 62888-2 also defines the conformance test of the EMF.

IEC 62888-3 – Data handling

The scope of IEC 62888-3 is the Data Handling System (DHS).

The on board DHS receives, produces and stores data, ready for transmission to any authorised receiver of data on board or on ground. The main goal of the DHS is to produce Compiled Energy Measured Data and transfer it to an on-ground Data Collection Service (DCS). The DHS can support other functionality on board or on-ground with data, as long as this does not conflict with the main goal.

IEC 62888-3 also defines the conformance test of the DHS.

IEC 62888-4 – Communication

The scope of IEC 62888-4 is the communication services.

This part of IEC 62888 gives requirements and guidance regarding the data communication between the functions implemented within EMS as well as between such functions and other on board units where data are exchanged using a communications protocol stack over a dedicated physical interface or a shared network.

It includes the on board to ground communication service and covers the requirements necessary to support data transfer between DHS and DCS.

IEC 62888-4 also defines the conformance test of the communications services.

IEC 62888-5 – Conformance test

The scope of IEC 62888-5 is the conformance test procedures for the EMS.

IEC 62888-5 also covers re-verification procedures and conformance test in the event of the replacement of a device of the EMS.

IEC 62888-6 – Requirements for purposes other than billing

The scope of IEC 62888-6 is to specify the requirements for EMS to be used for benchmarking, daily energy consumption monitoring, technical research and development.

This part provides the requirements for monitoring consumed energy on-board in daily services in an easy way and the measured data are applicable for general purposes in industry such as energy management, energy saving, etc. However, this part is not applicable for billing purposes.

EMS functional structure and dataflow

Figure 1 illustrates the functional structure of the EMS, the main sub-functions and the structure of the dataflow and is informative only. Only the main interfaces required by this standard are displayed by arrows.

Since the communication function is distributed throughout the EMS, it has been omitted for clarity. Not all interfaces are shown.

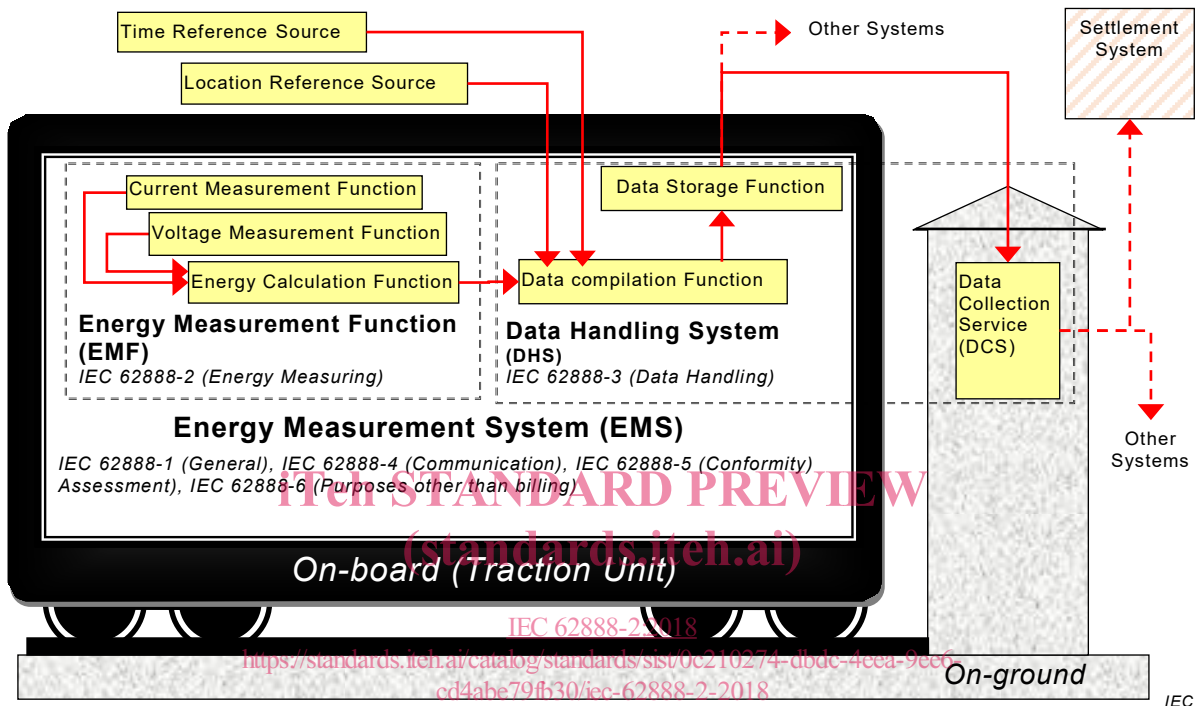


Figure 1 – EMS functional structure and dataflow diagram

RAILWAY APPLICATIONS – ENERGY MEASUREMENT ON BOARD TRAINS –

Part 2: Energy measurement

1 Scope

This part of IEC 62888 specifies the requirements applicable to the Energy Measurement Function (EMF) of an Energy Measurement System (EMS) for use on board traction units for measurement of energy supplied directly from/to the Contact Line system.

This document also gives requirements for the Current Measurement Function (e.g. current sensor), the Voltage Measurement Function (e.g. voltage sensor) and the Energy Calculation Function (e.g. energy meter).

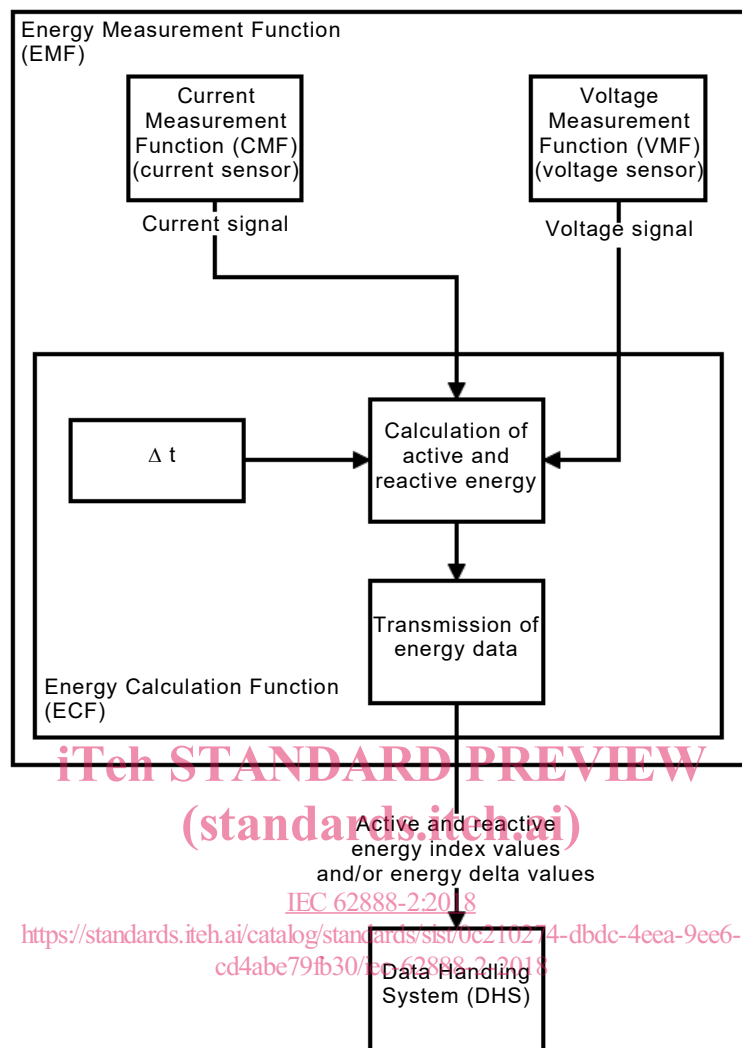
The conformance test arrangements for the Voltage Measurement Function, Current Measurement Function, the Energy Calculation Function and a complete Energy Measurement Function are also specified in this document.

This document has been developed taking into account that in some applications the EMF may be subjected to metrological assessment. All relevant metrological aspects are covered in this part and they are applicable to EMS Level 1.

Specific requirements for EMS Level 2 and Level 3 are specified in IEC 62888-6.

[IEC 62888-2:2018](https://standards.iteh.ai/catalog/standards/sist/0c210274-dhdc-4eea-9ee6-cd4abe-79fb30/iec-62888-2-2018)

Figure 2 shows the flow between the functional blocks of the EMF. Only connections between the functional blocks required by this document are displayed.



IEC

Figure 2 – EMF functional block diagram

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60028:1925, *International standard of resistance for copper*

IEC 60044-8:2002, *Instrument transformers – Part 8: Electronic current transformers*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60077-4:2003, *Railway applications – Electric equipment for rolling stock – Part 4: Electrotechnical components – Rules for AC circuit-breakers*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60121:1960, *Recommendation for commercial annealed aluminium electrical conductor wire*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60529:1989/AMD1:1999

IEC 60529:1989/AMD2:2013

IEC 60571:2012, *Railway applications – Electronic equipment used on rolling stock*

IEC 60850:2014, *Railway applications – Supply voltages of traction systems*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-3:2006/AMD1:2007

IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61373:2010, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 61869 (all parts), *Instrument transformers*

IEC 61869-1, *Instrument transformers – Part 1: General requirements*

IEC 61869-2:2012, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61992-1:2006, *Railway applications – Fixed installations – D.C. switchgear – Part 1: General*

IEC 62236-1:2008, *Railway applications – Electromagnetic compatibility – Part 1: General*

IEC 62236-3-2:2008, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*