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Interested committees:

Title: BS IEC 62888-2 Railway applications - Energy measurement on board trains

Part 2: Energy measurement

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

PROJECT NUMBER:

IEC 62888-2 ED2

DATE OF CIRCULATION:

2024-02-23

CLOSING DATE FOR COMMENTS:

2024-05-17

SUPERSEDES DOCUMENTS:

9/3012/RR

IEC TC 9 : ELECTRICAL EQUIPMENT AND SYSTEMS FOR RAILWAYS

SECRETARIAT:

France

SECRETARY:

Mr Denis MIGLIANICO

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC☐ ENVIRONMENT☐ QUALITY ASSURANCE☐ SAFETY

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (See AC/22/2007 or NEW GUIDANCE DOC).

TITLE:

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

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS –
ENERGY MEASUREMENT ON BOARD TRAINS –****Part 2: Energy measurement**

FOREWORD

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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
xxxxxxx	xxxxxxx

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.

INTRODUCTION

Three levels are introduced for categorising EMS as described in IEC 62888-1:202x, 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 and on-ground Data Collecting System (DCS). 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

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 railway traction unit. If the traction unit is designed for use on AC electric traction 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. IEC 62888-2 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.

IEC 62888-2 has been developed taking into account that in some applications, the EMF should be subjected to metrological principles. The relevant metrological requirements are covered in IEC 62888-2.

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

IEC 62888-3 – Data handling

The scope of IEC 62888-3 is the Data Handling System (DHS) and the associated requirements of the Data Collecting System (DCS).

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 (CEMD) and transfer it to an on-ground Data Collecting System (DCS). The DHS can support other functions on board or on ground with data, as long as this does not conflict with the main goal.

The DCS on ground receives CEMD, stores the CEMD and transfer it to upstream servers such as settlement system.

IEC 62888-3 also defines the conformance test of the DHS and for the transfer of CEMD to an on-ground DCS .

IEC 62888-4 – Communication

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

IEC 62888-4 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 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.

IEC 62888-6 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 widely omitted for clarity, except for the train to ground communication. Not all interfaces are shown.

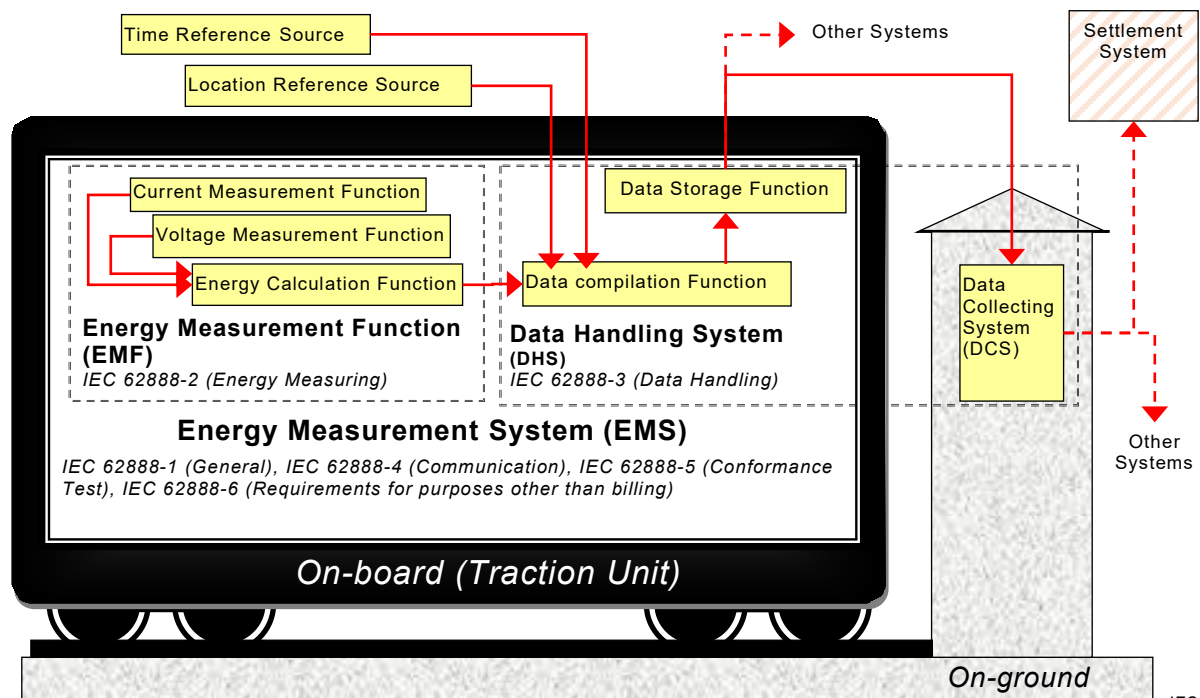


Figure 1 – EMS functional structure and dataflow diagram

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.

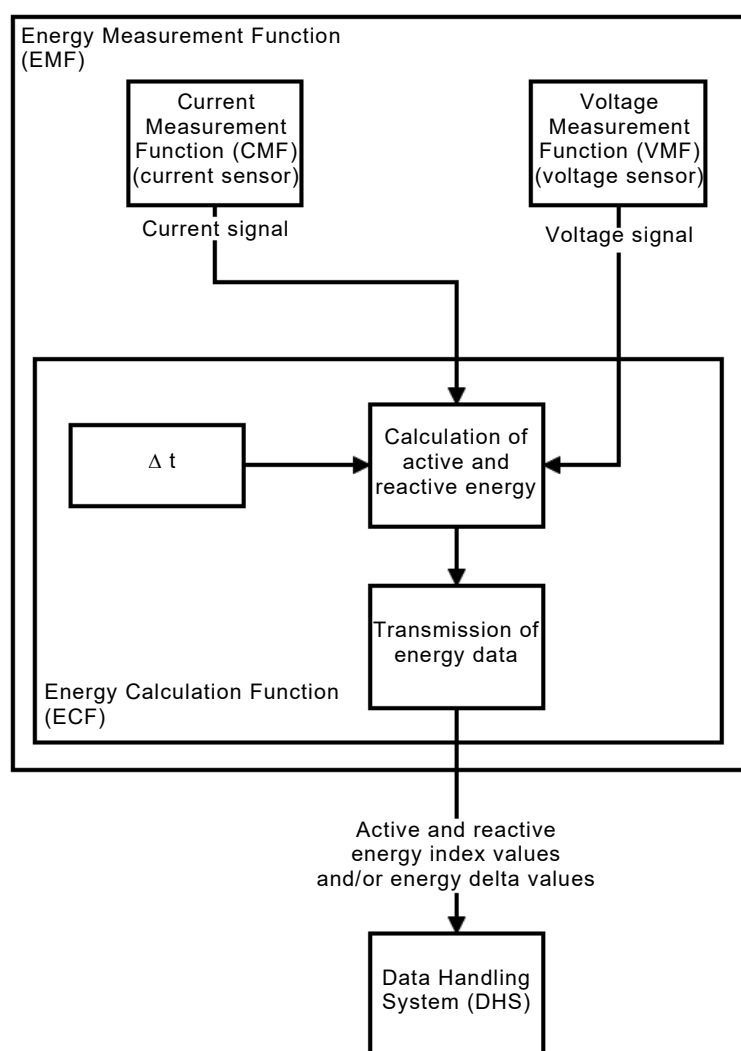
This document also gives requirements for the Current Measurement Function (e.g. current sensor), the Voltage Measurement Function (e.g. voltage sensor) and the Energy Calculation Function (e.g. energy meter).

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.

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)*

- 126 IEC 60077-4:2019, *Railway applications – Electric equipment for rolling stock – Part 4:*
127 *Electrotechnical components – Rules for AC circuit-breakers*
- 128 IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*
- 129 IEC 60121:1960, *Recommendation for commercial annealed aluminium electrical conductor*
130 *wire*
- 131 IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
132 IEC 60529:1989/AMD1:1999
133 IEC 60529:1989/AMD2:2013
- 134 IEC 60571:2012, *Railway applications – Electronic equipment used on rolling stock*
- 135 IEC 60850:2014, *Railway applications – Supply voltages of traction systems*
- 136 IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and*
137 *measurement techniques – Electrostatic discharge immunity test*
- 138 IEC 61000-4-3:2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and*
139 *measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
140
- 141 IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and*
142 *measurement techniques – Electrical fast transient/burst immunity test*
- 143 IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and*
144 *measurement techniques – Surge immunity test*
- 145 IEC 61000-4-6:2023, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and*
146 *measurement techniques – Immunity to conducted disturbances, induced by radio-frequency*
147 *fields*
- 148 IEC 61373:2010, *Railway applications – Rolling stock equipment – Shock and vibration tests*
- 149 IEC 61869 (all parts), *Instrument transformers*
- 150 IEC 61992-1:2006, *Railway applications – Fixed installations – D.C. switchgear – Part 1:*
151 *General*
- 152 IEC 62236-1:2018, *Railway applications – Electromagnetic compatibility – Part 1: General*
- 153 IEC 62236-3-2:2018, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling*
154 *stock – Apparatus*
- 155 IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements –*
156 *Clearances and creepage distances for all electrical and electronic equipment*
- 157 IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1:*
158 *Equipment on board rolling stock*
- 159 IEC 62313:2009, *Railway applications – Power supply and rolling stock – Technical criteria for*
160 *the coordination between power supply (substation) and rolling stock to achieve*
161 *interoperability*

IEC 62888-1:202X, *Railway applications – Energy measurement on board trains – Part 1: General*

IEC 62888-3: 202X, *Railway applications – Energy measurement on board trains – Part 3: Data handling*

IEC 62888-4: 202X, *Railway applications – Energy measurement on board trains – Part 4: Communication*

IEC 62888-5:202X, *Railway applications – Energy measurement on board trains – Part 5: Conformance test*

IEC 62888-6:202X, *Railway applications – Energy measurement on board trains – Part 6: Requirements for purposes other than billing.*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62888-1:202X and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1 Accuracy class accuracy class

designation that identifies a set of error limits for measured quantities under reference conditions and the additional percentage errors due to influence quantities

Note 1 to entry: An individual accuracy class is associated with each metrological function of the EMF.

Note 2 to entry: The suffix “R” is used to differentiate classes according to this standard from other technical standards.

3.1.2 Burden

Admittance (or impedance) of the secondary circuit expressed in siemens (or ohms) and power factor

Note: The burden is usually expressed as the apparent power in volt-amperes absorbed at a specified power factor and at the rated secondary voltage or current.

[IEC 61869-1]

3.1.3 Rated burden

Value of the burden on which the accuracy requirements of this specification are based.

[IEV 321-01-26]

3.1.4 Rated output power

The value of the apparent power (in volt-amperes) at a specified power factor which the transformer is intended to supply to the secondary circuit at the rated secondary voltage or current and with rated burden connected to it.

[IEV 321-01-27 modified]

3.1.5

consumed active energy

active energy taken from the contact line by the traction unit on which the EMF is installed

3.1.6

consumed reactive energy

reactive energy taken from the contact line by the traction unit on which the EMF is installed

3.1.7

electronic sensor

device in which electronic circuits are used to process a measured signal

Note 1 to entry: Electronic circuits for processing the measurement signal include items such as analogue to digital converters, signal amplifiers, etc.

3.1.8

influence quantity

external condition which affects metrological performance

3.1.9

percentage error

$$\varepsilon = \left| \frac{Q_M - Q_T}{Q_T} \right| \times 100$$

where

Q_M is the measured quantity;

Q_T is the true quantity

Note 1 to entry: Since the true quantity cannot be determined, it is approximated by a quantity with a stated uncertainty that can be traced to standards agreed upon between supplier and purchaser or to national standards.

3.1.10

phase influence function

function of the real or apparent phase angle between a measured voltage and a measured current

Note 1 to entry: Phase influence function expressed as a power factor refers to measurements of real and apparent powers and energies, while $\sin \varphi$ refers to reactive powers and energies.

Note 2 to entry: For DC measurements the requirements for a phase influence function of 1 need to be used.

3.1.11

Power Factor

PF

under periodic conditions, ratio of the absolute value of the active power P to the apparent power S

Note 1 to entry: Under sinusoidal conditions, the power factor is the absolute value of the active factor.

[SOURCE: IEC 60050-131:2002, 131-11-46]

3.1.12**rated continuous thermal current** $I_{CMF,cth}$

value of current which can be permitted to flow continuously into the primary input of a current sensor

3.1.13**rated dynamic current** $I_{CMF,dyn}$

peak value of the primary current which a current sensor will withstand without being damaged

3.1.14**rated primary current of the EMF** $I_{n,EMF}$

value of current which is used to define the relevant performance of the EMF

Note 1 to entry: The term current refers to RMS value for AC unless otherwise specified.

3.1.15**rated primary voltage of the EMF** $U_{n,EMF}$

value of voltage which is used to define the relevant performance of the EMF

Note 1 to entry: The term voltage refers to RMS value for AC unless otherwise specified.

3.1.16**rated short-time thermal current** $I_{CMF,th}$

value of the primary current which a current sensor will withstand for a specified time period without being damaged

3.1.17**reference conditions**

set of influence quantities, with reference values and tolerances, with respect to which the error limits are specified for an input quantity range

3.1.18**regenerated active energy**

active energy fed back into the contact line by the traction unit on which the EMF is installed

3.1.19**regenerated reactive energy**

reactive energy fed back into the contact line by the traction unit on which the EMF is installed

3.1.20**register**

electronic device which stores the information representing the measured energy and associated quality code

Note 1 to entry: Registers can also be accessed and displayed locally via a service tool and if available via a local display.

3.1.21**response time** $t_{s,r}$

duration between the instant of a step change in the measured quantity and the instant when the output signal reaches 90 % of the intended value

3.1.22**temperature coefficient**

ratio between the temperature change and the resulting change in measurement error

3.2 Abbreviated terms

For the purpose of this document, the abbreviated terms given in IEC 62888-1:20xx and the following apply.

EUT Equipment Under Test

3.3 Symbols

f_a maximum frequency without aliasing

f_n rated frequency

$I_{CMF,cth}$ rated continuous thermal current

$I_{CMF,dyn}$ rated dynamic current

$I_{CMF,th}$ rated short-time thermal current

$I_{n,CMF}$ rated primary current of the CMF

$I_{n,ECF}$ rated primary current of the ECF

$I_{n,EMF}$ rated primary current of the EMF

$t_{s,r}$ response time

U_{max1} highest permanent voltage according to IEC 60850:2014

U_{max2} highest non-permanent voltage according to IEC 60850:2014

U_{max3} highest long-term overvoltage according to IEC 60850:2014

U_{min1} lowest permanent voltage according to IEC 60850:2014

U_{min2} lowest non-permanent voltage according to IEC 60850:2014

$U_{n,EMF}$ rated primary voltage of the EMF

$U_{n,VMF}$ rated primary voltage of the VMF

ε_{CMF} maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the CMF

ε_{ECF} maximum percentage error allowed in accordance with the selected accuracy class for the ECF

ε_{EMF} calculated maximum percentage error of the EMF

ε_{VMF} maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the VMF

4 Requirements**4.1 General**

The requirements in IEC 62888-1:2018, Clause 4, apply to any device containing one or more functions of the Energy Measurement Function (EMF), where applicable. IEC 62888-2:2018 defines additional requirements for a complete EMF and to any device comprising one or more functions of the EMF.

4.2 Energy Measurement Function (EMF)

4.2.1 General

4.2.1.1 Introduction

The Energy Measurement Function (EMF) is made up of the following functions, which can be contained in one or more devices:

- Voltage Measurement Function (VMF);
- Current Measurement Function (CMF);
- Energy Calculation Function (ECF).

NOTE 1 In this document, the voltage sensor and current sensor are used as terms for the device implementing measurement functions. It is possible that one or more devices may be used to fulfil the role of one function. It is also possible that different functions are combined in one device.

NOTE 2 Multiple CMFs and VMFs can be used with a single ECF (see Annex B).

The purpose of the EMF is to measure the voltage and current, calculate the energy and produce energy data.

The EMF provides energy data through an interface to the Data Handling System (DHS).

4.2.1.2 General requirements

If functions are grouped together in a single device, such grouping shall not degrade the performance (including accuracy) of the system.

4.2.1.3 Identification and marking of the EMF

The EMF function shall be clearly identified.

Devices containing the EMF will have the marking as specified in IEC 62888-1:2018, 4.3.1.1. In addition, all devices that include functions which are subject to metrological assessment shall include a metrological mark.

If different functions are included in one device, it is not necessary to duplicate the marking.

In case of EMF as a function included in the function of traction equipment or auxiliary equipment, marking of equipment type is not necessary.

4.2.1.4 Essential information

For all devices containing the EMF the essential information as specified in IEC 62888-1:2018, 4.3.1.2 shall be available in a format (e.g. hardcopy or electronic) agreed between supplier and purchaser.

The k-factor of the EMF shall also be stated.

4.2.2 Electrical requirements

4.2.2.1 Rated voltages

The characteristics of the voltage systems to which the EMF can be connected are specified in IEC 60850:2014.

The rated primary voltage of the EMF ($U_{n,EMF}$) shall be equal to the nominal voltage of the traction supply system as listed in IEC 60850:2014 and in Table B.1 of IEC 60850:2014, Annex B.

Other voltages may be agreed between the involved parties.

If the EMF is designed to be used on more than one traction supply system it shall have a rated primary voltage assigned for each traction supply system.

4.2.2.2 Rated current

The standard values of rated primary current of the EMF ($I_{n,EMF}$) are:

10 A – 12,5 A – 15 A – 20 A – 25 A – 30 A – 40 A – 50 A – 60 A – 75 A, and their decimal multiples.

NOTE For example, decimal multiples of 10 A are 100 A, 1 000 A, 10 000 A.

The rated primary current ($I_{n,EMF}$) of the EMF shall be between 80 % and 120 % of the rated traction unit current.

If an EMF is designed to be used on more than one traction supply system it may have more than one value of rated primary current assigned.

4.2.2.3 Rated frequency (f_n)

The rated frequency of the EMF shall be equal to the frequency of the traction supply system for which it is designed to operate, selected according to IEC 60850:2014. Other frequencies may be agreed between the involved parties.

If an EMF is designed to be used on more than one traction supply system it may have more than one value of rated frequency.

4.2.3 Accuracy requirements

4.2.3.1 General

The accuracy of the EMF is determined by the accuracy of the functions included within the EMF.

For any device which includes one or more functions of the EMF, any interface constraint (e.g. cable type, maximum / minimum burden, etc.), which is necessary to ensure accuracy is assured, shall be clearly stated.

The following subclauses detail the requirements and procedure for determination of the accuracy of the complete EMF.

4.2.3.2 Limits of error for the EMF

The percentage error for the complete EMF shall be determined in accordance with the following formula:

$$\varepsilon_{EMF} = \sqrt{(\varepsilon_{VMF})^2 + (\varepsilon_{CMF})^2 + (\varepsilon_{ECF})^2}$$

where

ε_{EMF} is the calculated maximum percentage error of the EMF;

ε_{VMF} is the maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the VMF under the reference conditions;

ε_{CMF} is the maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the CMF under the reference conditions;

ε_{ECF} is the maximum percentage error allowed in accordance with the selected accuracy class for the ECF under the reference conditions.

NOTE Informative Annex C provides further explanation about the method above.

For EMFs with more than one VMF, CMF or ECF, the formula above shall be used, but with errors for the squared terms being determined in accordance with appropriate rules in Annex B.

Errors caused by digits number, quantization, sampling periods are the matter of the interface.

The allocation of the errors to the related function (VMF, CMF, ECF) shall be stated in the documentation.

4.2.3.3 Reference conditions

Table 1 details the reference conditions to be used for any part of the EMF and the complete EMF.

If the tests have to be made at a temperature other than the reference temperature, including permissible tolerances, the results shall be corrected by applying the appropriate temperature coefficient of the equipment under test.

Table 1 – Reference conditions

Influence quantity	Reference value	Permissible tolerances
Ambient temperature	23 °C ^a	± 2 °C
EUT Temperature	Thermal steady state condition	≤ 1,5 °C/min
Frequency	Rated frequency	± 0,3 %
Wave-form AC	Sinusoidal voltages and currents	Distortion factor less than: 2 %
Wave-form DC	Pure DC voltages and currents	Ripple less than 1 %
Auxiliary power supply voltage	Rated auxiliary power supply voltage	± 5 %
Continuous magnetic induction of external origin	Equal to zero	Induction value shall be less than 0,05 mT
Electromagnetic RF fields, 30 kHz to 2 GHz	Equal to zero	< 1 V/m
Conducted disturbances, induced by radio frequency fields, 150 kHz to 80 MHz	Equal to zero	-
Magnetic induction of external origin at the reference frequency	Magnetic induction equal to zero	Induction value shall be less than 0,05 mT
^a If the tests have to be made at a temperature other than the reference temperature, including permissible tolerances, the results shall be corrected by applying the appropriate temperature coefficient of the item.		

4.2.3.4 Limits of error due to variations in input quantities

When all functions of the EMF pass the accuracy tests as detailed in Clause 5, and the input quantities and power factor are within the range given in Table 2, the percentage error when calculated in accordance with 4.2.3.2 shall not exceed the limits given in Table 2. These limits shall apply to the measurement of energy in each direction.

Table 2 – EMF percentage error limits at reference conditions

System type	Input quantity range		PF = Power Factor or $\sin \varphi^c$	Percentage error limit, active energy	Percentage error limit, reactive energy
	Value of current ^a	Value of voltage ^b			
AC	$10 \% I_n \leq I \leq 120 \% I_n$	$U_{\min 1} \leq U \leq U_{\max 2}$	$0,85 \leq \text{PF}$ or $\sin \varphi = 1$ Inductive	1,5	3,0
DC	$10 \% I_n \leq I \leq 120 \% I_n$	$U_{\min 1} \leq U \leq U_{\max 2}$	N/A	2,0	N/A

^a I_n is the rated primary current of the EMF.

^b The values of $U_{\min 2}$ and $U_{\max 2}$ are as specified in IEC 60850:2014.

^c The power factor is taken from IEC 62313:2009, Table 1. The reactive energy cannot be measured accurately for power factor near 1. Therefore the reactive energy is tested at $\sin \varphi = 1$.

The accuracy classes of the VMF, CMF and ECF (which together form an EMF) shall be selected to ensure that the EMF accuracy requirements detailed above are achieved.

4.2.3.5 Starting conditions

The EMF shall measure energy if the primary current is equal to or greater than $0,4 \% I_n$, and the voltage is at $U_{\min 2}$ or above.

If the primary current is zero, no energy shall be added to the energy registers.

4.2.4 Traction supply system change

When there is a changeover between traction supply systems the EMF shall ensure that all consumption is measured.

4.2.5 Re-verification

The supplier shall provide recommendations to the purchaser regarding any re-verification activities (testing and surveillance) that are considered necessary to ensure that the metrological performance of the functions making up the EMF can be expected to remain within the specified accuracies during the intended design life of the device containing these functions.

The recommendations shall be accompanied by supporting evidence based on technical justification to explain why the ongoing metrological performance can be expected to remain within the accuracy limits for the duration of the design life. The supporting evidence shall also indicate which aspects of the devices (making up the EMF) are relevant to ensure the ongoing metrological performance perspective. The supplier shall clearly identify all aspects which require planned intervention (i.e. re-verification testing and surveillance). The supplier shall clearly describe how this planned intervention should be undertaken.

Further information on re-verification is included in the Annex D.

4.3 Sensors

4.3.1 General

Sensors measure the primary voltage and primary current input to the EMF and provide an output (digital or analogue) for use by the Energy Calculation Function (ECF).

Sensors may be self-powered (i.e. drawing any power they require from the sensor input) or may be separately powered from an auxiliary power supply external to the sensor.

4.3.2 General requirements

4.3.2.1 General

Voltage and current sensor requirements may be realised using separate devices or within a combined device.

Where sensor technology is covered by IEC 61869, these standards may be applied to sensors as applicable. Where requirements in IEC 61869 conflict with the requirements in IEC 62888 series the latter shall take precedence.

4.3.2.2 Insulation requirements

4.3.2.2.1 Insulation withstand for passive analogue sensors

For passive analogue sensors having insulation between the input and output, insulation withstand of the primary side shall be according to IEC 62497-1 and the rated power-frequency withstand voltage of the output signal to ground shall be 3 kV (RMS) according to IEC 61869-1 and IEC 61869-2.

For passive analogue sensors having two or more outputs separated by insulation, the rated power-frequency withstand voltage between the sections shall be 3 kV (RMS) according to IEC 61869-1 and IEC 61869-2.

Where passive analogue sensors have no galvanic isolation between the input and output, the rated withstand voltage of the output signal to ground shall be equal to that applied to the input.

4.3.2.2.2 Insulation withstand for electronic analogue sensors

For electronic analogue sensors with multiple low voltage circuits having galvanic isolation between them, the rated power-frequency withstand voltage between these circuits shall be in accordance with IEC 62497-1, taking into account the rated insulation voltage and the overvoltage category.

4.3.2.3 Requirements for outputs

4.3.2.3.1 General

Sensors can have three different types of output: analogue dedicated, digital dedicated or digital shared outputs. The output shall be compatible with the device performing the Energy Calculation Function. The requirements on dataflow security are given in IEC 62888-1:2018, 4.3.5 and shall be applied according to the output type.

4.3.2.3.2 Requirements for dedicated analogue outputs

A sensor may have multiple outputs as long as these outputs do not influence any outputs used in the Energy Measurement Function.

If agreed between the supplier and purchaser, equipment may be temporarily connected to any outputs of the EMF, e.g. for short-term monitoring, periodic testing and calibration purposes. The design of these outputs shall take account of the effect of such temporary connections to ensure that no additional errors are introduced, e.g. the effect of additional burden.

4.3.2.3.3 Requirements for digital dedicated or digital shared outputs

Requirements for communication protocols stack and communication security can be found in IEC 62888-4:2018, 4.3.4.2, 4.3.4.3 and 4.3.4.4.

4.3.2.3.4 Burden requirements

For voltage transducers with current outputs, the voltage across the burden shall not exceed 45 V (AC rms or DC) at maximum input voltage.

4.3.2.3.5 Essential information

In addition to the requirements given in IEC 62888-1:2018, 4.3.1.2, the following essential information relevant to control the operation of the sensors shall be available on an accompanying document:

- a) the accuracy-class of the sensors;
- b) if applicable: the auxiliary power supply voltage and form (e.g. 230 V 50 Hz, 110 V DC), together with the tolerance, maximum power consumption and the supply voltage interruption class according to IEC 60571:2012, 5.1.1.2;
- c) main diagrams (e.g. overall schematics, general arrangements, etc.) and drawings including their drawing number, version identifier and title;
- d) terminal marking identification information for:
 - the primary and secondary connections;
 - if applicable, other accessible terminals e.g. testing and service points;
 - if applicable, auxiliary power supply voltage connections;
 - if applicable, the relative polarities of connections and connector details.
- e) the rated primary input;
- f) the rated frequency(s) of the primary input (e.g. DC, 16,7 Hz, 50 Hz, 60 Hz);
- g) if applicable, the maximum frequency which can be measured without aliasing (see 4.3.3.1.6 and 4.3.4.1.7);
- h) in case of analogue outputs, the rated secondary output signal information;
- i) if applicable, k-factor of sensor inclusive of measurement units;
- j) in case of digital outputs, the communication protocol and, if applicable, how communication security is achieved;
- k) all other sensor rated values and classification information (e.g. electrical, mechanical, EMC and environmental ratings and classifications);
- l) if applicable, software version and other information necessary for configuration control;
- m) integration and installation constraints.

4.3.3 Voltage sensors**4.3.3.1 Electrical requirements****4.3.3.1.1 Rated primary voltage ($U_{n,VMF}$)**

The rated primary voltage of the sensor input shall be equal to the highest nominal voltage of the traction supply systems used at which the sensor is designed to be used, selected from the values given in 4.2.2.1.

4.3.3.1.2 Rated secondary values for analogue sensors**4.3.3.1.2.1 General**

The rated secondary values of the sensor output shall be compatible with the input of the ECF to which it is intended to be connected.

The rated values shall be agreed between supplier and purchaser.

4.3.3.1.2.2 Rated secondary output signal for analogue sensors

The rated output signal, either as a voltage or a current, shall be defined, the preferred values are:

- a) for voltage transformers: 100 V, 110 V or 150 V (AC);
- b) for electronic sensors with voltage output: 2 V, 4 V or 10 V (AC or DC);
- c) for electronic sensors with current output: 20 mA, 50 mA or 100 mA (AC or DC).

4.3.3.1.2.3 Rated output burden for analogue sensors

The rated output burden shall be defined to be matched with the input circuit of ECF, the preferred values are:

- a) for rated secondary voltage > 10 V: 1 VA, 2 VA, 4 VA or 5 VA;
- b) for rated secondary voltage ≤ 10 V: 0,001 VA, 0,01 VA, 0,1 VA or 0,5 VA;
- c) for current outputs, a burden such that the voltage across the burden at maximum input voltage shall not exceed 45 V (AC RMS or DC).

4.3.3.1.3 Influence of input overvoltage

The sensors shall not be damaged by overvoltage of U_{max3} in accordance with IEC 60850:2014, Table A.1. Other voltages of U_{max3} listed in Table A.1 shall be agreed between the involved parties.

The sensors shall perform correctly when returned to initial working conditions.

4.3.3.1.4 Rated burden and rated output power for analogue sensors

The rated burden shall be defined to be matched with the input circuit of ECF. For passive analogue sensors with iron core the preferred values of the rated output power are:

- a) for rated secondary voltage > 10 V: 1 VA, 2 VA, 4 VA or 5 VA;
- b) for rated secondary voltage ≤ 10 V: 0,001 VA, 0,01 VA, 0,1 VA or 0,5 VA;

The output power can be used under any value between 0% and 100% of the rated output power with a power factor of 1.

Note: These requirements are based on requirements stated in IEC 61869-3 clause 5.6.301.3 and clause 7.2.6.301 (Table 305). A direct reference has been avoided due to different accuracy class definition in the two standards

For active analogue sensors, the accuracy shall be verified in the datasheet range.

4.3.3.1.5 Response time ($t_{s,r}$)

Sensors for DC measurement shall have a maximum response time of 10 ms.

If the DC sensor is to be used in a system where the energy content associated with harmonics is significant, a shorter response time need to be agreed between the involved parties.

4.3.3.1.6 Bandwidth requirements for electronic sensors

The supplier shall provide a curve showing the variation in performance of the sensor for variation in frequency.

For a sensor with digital output, the supplier shall specify the maximum frequency (f_a) which can be measured without aliasing.

For sensors with a digital output, f_a is usually half the sampling frequency used.

NOTE This will give an overall view of the frequency performances of the sensor.

4.3.3.1.7 Power frequency withstand voltage for earthed terminals

Any terminal of the voltage sensor's measuring circuit which is intended to be connected to (the traction unit) earth and which is also insulated from the metallic case or other accessible conductive parts of the sensor, shall withstand a rated power frequency short duration withstand voltage according to IEC 60571.

4.3.3.2 Short circuit withstand and fault protection for analogue sensors

Application of a short circuit to the analogue output or outputs of a sensor shall not damage the sensor. The duration of the short circuit shall be

- 1 s (for passive sensors), or
- 60 s (for electronic sensors).

For electronic sensors, the supplier shall indicate the type of current limiting measures used (if any).

For electronic sensors, the supplier shall specify any time delay between removal of the short circuit and the outputs returning to within specified accuracy limits. The time delay shall not exceed 5 s.

Fault protection for electronic sensors shall be provided in accordance with IEC 60571:2012, 7.2.2.

Note: requirements for European countries are also stated in EN 50155:2021

4.3.3.3 Limit of temperature rise

Sensors with electrical insulation shall be assigned a thermal class in accordance with IEC 60085. The permitted temperature limits for other components shall be stated by the supplier.

The sensor shall not exceed these limits and shall not be damaged when operating under the following conditions:

- continuous operation at $U_{\max 2}$ and at the rated frequency;
- maximum applicable ambient temperature of the temperature class selected in accordance with environmental requirements of IEC 62888-1:2018, 4.3.6.2;
- output conditions which creates the highest temperatures in the sensor;
- if applicable, the auxiliary power supply which creates the highest temperatures in the sensor.

4.3.3.4 Accuracy requirements

The VMF shall be assigned an accuracy class selected from Table 3.

Table 3 – Percentage error limits – VMF

Accuracy class	$\pm$ Maximum percentage voltage (ratio) error at voltage defined in IEC 60850:2014		$\pm$ Maximum phase displacement at voltage defined in IEC 60850:2014	
	ε_{VMF}		AC VMH (min) at rated frequency	
	$U_{\min 2} \leq U < U_{\min 1}$	$U_{\min 1} \leq U \leq U_{\max 2}$	$U_{\min 2} \leq U < U_{\min 1}$	$U_{\min 1} \leq U \leq U_{\max 2}$
0,2 R	0,4	0,2	15	10
0,5 R	1,0	0,5	30	20
0,75 R	1,5	0,75	45	30
1,0 R	2,0	1,0	60	40

For traction unit designed for multiple traction supply systems, a single voltage sensor can be used if it achieves the accuracy requirement defined in Table 4 for each rated voltage.

Unless otherwise specified, the requirements of class 0,2 R apply.

4.3.3.5 Effect of temperature on error limits

4.3.3.5.1 Limits of error including the effects of ambient temperature variation

The maximum percentage error, including the effects of temperature variation, shall not exceed the values given in Table 4.

In order to be able to achieve compliance with the maximum error limits specified in Table 4, a VMF of a given class can have its maximum error at reference temperature constrained to a value lower than the maximum allowed by the accuracy class as specified in Table 3. If this is the case, the supplier shall declare this lower maximum error limit at reference temperature and give evidence to demonstrate this lower limit will ensure the maximum limits given in Table 4 are not exceeded.

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Table 4 – Maximum percentage error for a VMF including ambient temperature variation

Value of voltage	System type	± Maximum percentage error limits for a VMF	
		Ambient temperature variation, main range	Ambient temperature variation, extended range
		–10 °C to +60 °C	–40 °C to –10 °C and + 60 °C to + 75 °C
$U_{\min 2} \leq U \leq U_{\max 2}$	AC and DC	$N^b + (0,01 \times \Delta T^a)$	$N_1^d + (0,02 \times \Delta T_1^c)$

^a ΔT is the temperature variation in Kelvin between reference temperature 23 °C and the ambient temperature.

^b The term N is the maximum allowable percentage ratio error allowed for the VMF class as specified in Table 3. For example, for a class 0,5 R VMF and input signal in the range $U_{\min 1} \leq U \leq U_{\max 2}$, the formula for the main temperature range becomes $0,5 + (0,01 \times \Delta T)$ and for the input signal in the range $U_{\min 2} \leq U \leq U_{\min 1}$ the formula becomes $1,0 + (0,01 \times \Delta T)$.

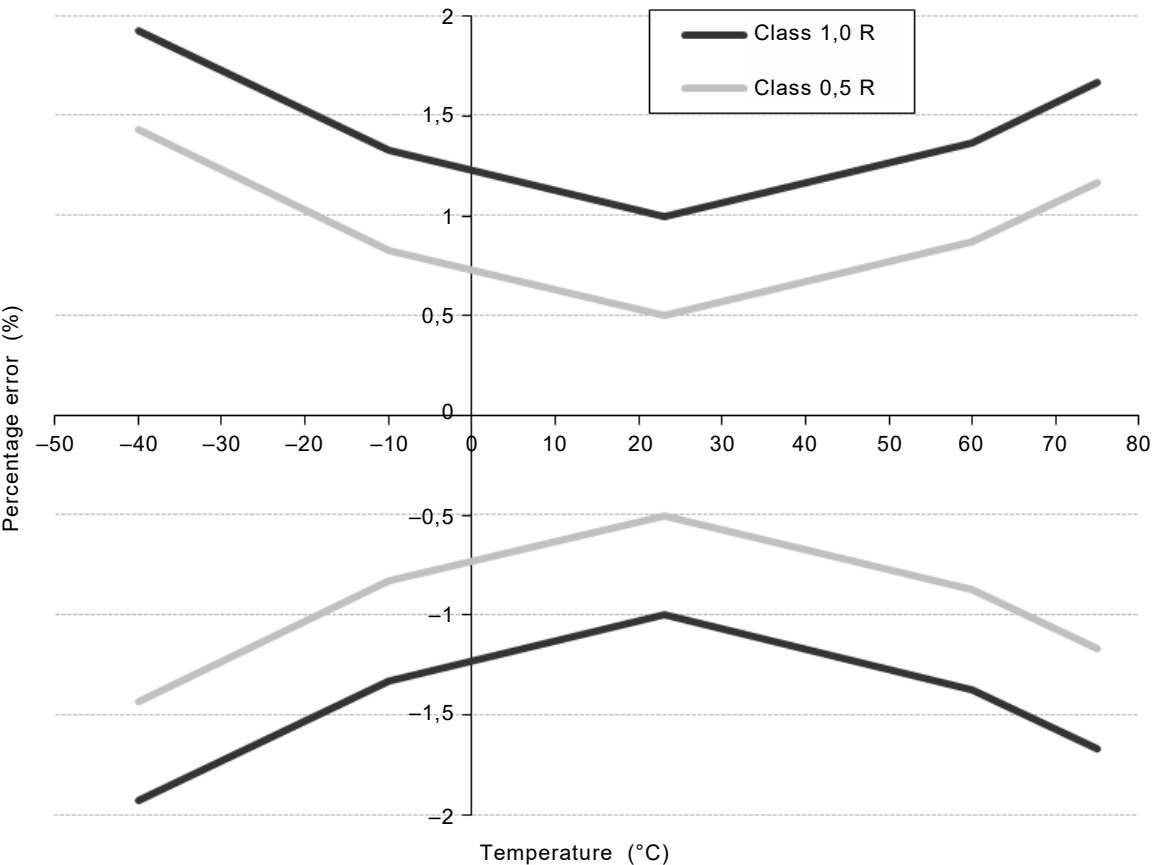
^c ΔT_1 is the difference between the ambient temperature and the boundary temperature of main range.

^d N_1 is the error limit at the boundary temperature of main range.

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631 NOTE 1 Maximum phase displacement is identical for all temperatures and is defined in Table 4.

632 NOTE 2 As an example, the maximum percentage error limits with an input signal in the range $U_{\min 1} \leq U \leq U_{\max 2}$
633 for a class 0,5 R and a class 1,0 R VMF over the temperature range in accordance with Table 4 are shown in
634 Figure 3.



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636 **Figure 3 – Example of maximum percentage error for a VMF of class 0,5 R and**
637 **a VMF of class 1,0 R with input signal in the range $U_{\min 1} \leq U \leq U_{\max 2}$**