



BSI Standards Publication

## Railway applications — Energy measurement on board trains

---

Part 2: Energy measuring

# National foreword

This British Standard is the UK implementation of EN 50463-2:2017+A1:2024. It supersedes BS EN 50463-2:2017, which will be withdrawn on 7 November 2024.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags. Text altered by CENELEC corrigendum October 2018 is indicated in the text by AC1 AC1.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CENELEC text carry the number of the CENELEC amendment. For example, text altered by CENELEC amendment A1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee GEL/9, Railway Electrotechnical Applications.

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

## Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2024  
Published by BSI Standards Limited 2024

ISBN 978 0 539 25612 3  
ICS 45.060.10

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

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2017.

## Amendments/corrigenda issued since publication

| Date             | Text affected                                      |
|------------------|----------------------------------------------------|
| 30 November 2018 | Implementation of CENELEC corrigendum October 2018 |
| 31 August 2024   | Implementation of CENELEC amendment A1:2024        |

English Version

## Railway applications - Energy measurement on board trains - Part 2: Energy measuring

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

Bahnanwendungen - Energiemessung auf Bahnfahrzeugen  
- Teil 2: Energiemessung

This European Standard was approved by CENELEC on 2017-05-08. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

## Contents

Page

|                                                                   |    |
|-------------------------------------------------------------------|----|
| European foreword.....                                            | 7  |
| European foreword to Amendment 1.....                             | 8  |
| Introduction.....                                                 | 9  |
| 1 Scope.....                                                      | 12 |
| 2 Normative references.....                                       | 13 |
| 3 Terms, definitions, abbreviations and symbols.....              | 14 |
| 3.1 Terms and definitions .....                                   | 14 |
| 3.2 Abbreviations .....                                           | 17 |
| 3.3 Symbols .....                                                 | 18 |
| 4 Requirements .....                                              | 18 |
| 4.1 General.....                                                  | 18 |
| 4.2 Energy Measurement Function (EMF).....                        | 19 |
| 4.2.1 General .....                                               | 19 |
| 4.2.2 Electrical requirements.....                                | 19 |
| 4.2.3 Accuracy requirements.....                                  | 20 |
| 4.2.4 Traction system change .....                                | 22 |
| 4.2.5 Re-verification.....                                        | 22 |
| 4.3 Sensors.....                                                  | 22 |
| 4.3.1 General .....                                               | 22 |
| 4.3.2 General requirements .....                                  | 23 |
| 4.3.3 Voltage sensors.....                                        | 24 |
| 4.3.4 Current sensors.....                                        | 29 |
| 4.4 Energy Calculation Function (ECF) .....                       | 35 |
| 4.4.1 General .....                                               | 35 |
| 4.4.2 General requirements .....                                  | 35 |
| 4.4.3 Electrical requirements.....                                | 37 |
| 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..... | 42 |
| 4.4.7 Electromagnetic compatibility .....                         | 44 |
| 4.4.8 Data transfer from ECF to DHS .....                         | 45 |
| 5 Conformity assessment.....                                      | 46 |
| 5.1 General.....                                                  | 46 |
| 5.1.1 Introduction.....                                           | 46 |
| 5.1.2 Applicability .....                                         | 46 |
| 5.1.3 Methodology .....                                           | 46 |
| 5.2 Testing framework.....                                        | 47 |
| 5.2.1 General .....                                               | 47 |

|                       |                                                                     |    |
|-----------------------|---------------------------------------------------------------------|----|
| 5.2.2                 | Reporting.....                                                      | 47 |
| 5.3                   | Design review.....                                                  | 48 |
| 5.3.1                 | General .....                                                       | 48 |
| 5.3.2                 | Device design review .....                                          | 48 |
| 5.3.3                 | EMF design review .....                                             | 49 |
| 5.4                   | Type testing.....                                                   | 49 |
| 5.4.1                 | General .....                                                       | 49 |
| 5.4.2                 | Common type testing.....                                            | 49 |
| 5.4.3                 | Sensor type test.....                                               | 53 |
| 5.4.4                 | ECF type test.....                                                  | 60 |
| 5.5                   | Routine test .....                                                  | 71 |
| 5.5.1                 | General .....                                                       | 71 |
| 5.5.2                 | Visual Inspection .....                                             | 71 |
| 5.5.3                 | Insulation test .....                                               | 71 |
| 5.5.4                 | Accuracy tests .....                                                | 72 |
| Annex A (normative)   | Test with magnetic induction of external origin .....               | 74 |
| A.1                   | General.....                                                        | 74 |
| A.2                   | Test method 1.....                                                  | 74 |
| A.3                   | Test method 2.....                                                  | 74 |
| Annex B (normative)   | EMF Configurations .....                                            | 76 |
| B.1                   | Background.....                                                     | 76 |
| B.2                   | General.....                                                        | 76 |
| B.3                   | EMF with several CMF's in parallel .....                            | 76 |
| B.4                   | EMF with several VMF's connected to one ECF .....                   | 77 |
| B.5                   | EMF with several pairs of VMF and CMF.....                          | 77 |
| B.6                   | Several EMF's in parallel.....                                      | 78 |
| B.7                   | One VMF or CMF connected to several ECFs.....                       | 78 |
| B.8                   | EMF without VMF .....                                               | 79 |
| Annex C (informative) | Expressing EMF accuracy .....                                       | 80 |
| C.1                   | Summary.....                                                        | 80 |
| C.2                   | Error limits or uncertainty.....                                    | 80 |
| C.3                   | Presentation of error limits.....                                   | 80 |
| C.4                   | Uncertainty calculations .....                                      | 81 |
| C.4.1                 | AC active power.....                                                | 81 |
| C.4.2                 | Primary values .....                                                | 82 |
| C.4.3                 | Uncertainty in the measurement of active power (Watts) .....        | 82 |
| C.4.4                 | Relative uncertainty .....                                          | 83 |
| C.4.5                 | Uncertainty in the measurement of reactive power (var) .....        | 84 |
| C.4.6                 | Relative uncertainty .....                                          | 85 |
| Annex D (informative) | Recommendations for re-verification and defining of its regime..... | 86 |
| D.1                   | Re-verification .....                                               | 86 |
| D.1.1                 | Introduction and background.....                                    | 86 |

|                                                                                                                                                                                                                   |    |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| D.1.2 Approaches to re-verification.....                                                                                                                                                                          | 86 |
| D.2 Recommendations for defining the re-verification regime .....                                                                                                                                                 | 87 |
| D.2.1 General approach .....                                                                                                                                                                                      | 87 |
| D.2.2 Testing regime .....                                                                                                                                                                                        | 88 |
| Annex E (informative) Durability test .....                                                                                                                                                                       | 89 |
| E.1 General.....                                                                                                                                                                                                  | 89 |
| E.2 Initial measurements .....                                                                                                                                                                                    | 89 |
| E.3 Conditioning.....                                                                                                                                                                                             | 89 |
| E.4 Intermediate measurements .....                                                                                                                                                                               | 90 |
| E.5 Final temperature ramp.....                                                                                                                                                                                   | 91 |
| E.6 Final measurements and acceptance criteria.....                                                                                                                                                               | 91 |
| E.7 Information to be given in the test report .....                                                                                                                                                              | 91 |
| Annex ZZ (informative) Relationship between this European Standard and the Essential Requirements of EU Directive 2016/797/EU aimed to be covered .....                                                           | 93 |
| Bibliography.....                                                                                                                                                                                                 | 94 |
|                                                                                                                                                                                                                   |    |
| Figures                                                                                                                                                                                                           |    |
| Figure 1 — EMS functional structure and dataflow diagram .....                                                                                                                                                    | 11 |
| Figure 2 — EMF functional block diagram.....                                                                                                                                                                      | 12 |
| Figure 3 — Example of energy index 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 $U_{min1} \leq U \leq U_{max2}$ . .....                                           | 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 $1 \% I_n \leq I < 5 \% I_n$ ..... | 33 |
| Figure 6 — Primary current and voltage ranges .....                                                                                                                                                               | 39 |
| 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.....                                                                   | 41 |
| Figure 8 — Test point matrix for ECF accuracy tests (type test) .....                                                                                                                                             | 62 |
| Figure 9 — Test point matrix for tests of ambient temperature variation and influence quantities.....                                                                                                             | 63 |
| Figure 10 — Test circuit diagram for determining the influence on accuracy of odd harmonics or sub-harmonics in the current circuit .....                                                                         | 66 |
| Figure 11 — Phase-fired waveform (shown for 50 Hz) .....                                                                                                                                                          | 66 |
| Figure 12 — Analysis of harmonic content of phase-fired waveform (shown for 50 Hz) .....                                                                                                                          | 67 |
| Figure 13 — Burst fire waveform (shown for 50 Hz).....                                                                                                                                                            | 67 |
| Figure 14 — Analysis of harmonics (shown for 50 Hz) .....                                                                                                                                                         | 68 |
| Figure 15 — Test point matrix for ECF Accuracy Tests (type test).....                                                                                                                                             | 73 |

|                                                                |    |
|----------------------------------------------------------------|----|
| Figure A.1 — Test configuration for test method 1 .....        | 74 |
| Figure A.2 — Test configuration for test method 2 .....        | 75 |
| Figure B.1 — EMF with several CMF's in parallel .....          | 76 |
| Figure B.2 — EMF with several VMF's connected to one ECF ..... | 77 |
| Figure B.3 — EMF with several pairs of VMF and CMF .....       | 78 |
| Figure B.4 — EMF with several ECF's .....                      | 78 |
| Figure B.5 — One VMF connected to two ECF's .....              | 79 |
| Figure B.6 — EMF without VMF .....                             | 79 |

## Tables

|                                                                                              |    |
|----------------------------------------------------------------------------------------------|----|
| Table 1 — Nominal traction system voltages .....                                             | 20 |
| Table 2 — Reference conditions .....                                                         | 21 |
| Table 3 — EMF percentage error limits .....                                                  | 22 |
| Table 4 — Percentage error limits - VMF .....                                                | 26 |
| Table 5 — Maximum percentage error for a VMF including ambient temperature variation .....   | 27 |
| Table 6 — Temperature coefficient for VMF .....                                              | 28 |
| Table 7 — Influence quantities for voltage sensors .....                                     | 29 |
| Table 8 — Percentage error limits — AC CMF .....                                             | 31 |
| Table 9 — Percentage error limits – DC CMF .....                                             | 31 |
| Table 10 — Maximum percentage error for a CMF including ambient temperature variation .....  | 32 |
| Table 11 — Temperature coefficient for CMF .....                                             | 33 |
| Table 12 — Percentage error limits with harmonics — AC current sensor .....                  | 34 |
| Table 13 — Influence quantities for current sensors .....                                    | 34 |
| Table 14 — Variations due to short-time overcurrents .....                                   | 38 |
| Table 15 — Variations due to self-heating .....                                              | 38 |
| Table 16 — ECF percentage error limits for active energy .....                               | 39 |
| Table 17 — Maximum percentage error for an ECF including ambient temperature variation ..... | 40 |
| Table 18 — Temperature coefficient for the ECF .....                                         | 41 |
| Table 19 — Influence quantities for the ECF .....                                            | 43 |

Table 20 — Test current for harmonics.....55

Table ZZ.1 — Correspondence between this European Standard, Commission Regulation (EU) N° 1302/2014 concerning the Technical Specification for Interoperability relating to the ‘rolling stock — locomotives and passenger rolling stock’ subsystem of the rail system in the European Union\* and Directive (EU) 2016/797.....93

## European foreword

This document (EN 50463-2:2017) has been prepared by CLC/TC 9X “Electrical and electronic applications for railways”.

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2018-04-06
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2020-10-06

This document supersedes EN 50463-2:2012.

EN 50463-2:2017 includes the following significant technical changes with respect to EN 50463-2:2012:

- updated requirements for events, quality codes, flags and logs (Clause 4);
- updated for consistency between Table 16 and Figure 6 regarding “Area 2” (Clause 4).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s) see informative Annex ZZ, which is an integral part of this document.

This document is Part 2 of the EN 50463 series which consists of the following parts, under the common title *Railway applications — Energy measurement on board trains*:

- *Part 1: General*;
- *Part 2: Energy measuring*;
- *Part 3: Data handling*;
- *Part 4: Communication*;
- *Part 5: Conformity assessment*.

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

The requirements for Energy Measurement Systems in the relevant Technical Specifications for Interoperability are supported by this series of European Standards.

## European foreword to Amendment 1

This document (EN 50463-2:2017/A1:2024) has been prepared by CLC/TC 9X “Electrical and electronic applications for railways”.

The following dates are fixed:

- latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2025-07-08
- latest date by which the national standards conflicting with this document have to be withdrawn (dow) 2027-07-08

EN 50463-2:2017 is amended to update Annex ZZ in order to implement CLC/TC 9X Decision 65/17, which is herein reported:

“Noting the recommendation of the CAG, TC 9X decides to task the secretariat to prepare the NWIP for amendments of EN 50463 series “Railway applications – Energy measurement on board trains - Part 1: General; - Part 2: Energy measuring; - Part 3: Data handling; - Part 5: Conformity assessment” to update the Annex ZZ of these parts.”

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a standardization request addressed to CENELEC by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

For the relationship with EU Legislation, see informative Annex ZZ, which is an integral part of this document.

Any feedback and questions on this document should be directed to the users’ national committee. A complete listing of these bodies can be found on the CENELEC website.

## Introduction

The Energy Measurement System provides measurement and data suitable for billing and may also be used for energy management, e.g. energy saving.

This series of European Standards uses the functional approach to describe the Energy Measurement System and on-ground Data Collecting System. 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.

### a) Structure and main contents of the EN 50463 series:

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

#### 1) EN 50463-1 — General:

The scope of EN 50463-1 is the Energy Measurement System (EMS).

EN 50463-1 provides system level requirements for the complete EMS and common requirements for all devices implementing one or more functions of the EMS.

#### 2) EN 50463-2 — Energy measuring:

The scope of EN 50463-2 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 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 system and the Current Measurement Function measures the current taken from and returned to the Contact Line 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 Billing Data (CEBD).

The standard has been developed taking into account that in some applications, the EMF may be subjected to legal metrological control. All relevant metrological aspects are covered in this part of EN 50463.

EN 50463-2 also defines the conformity assessment of the EMF.

#### 3) EN 50463-3 — Data handling:

The scope of EN 50463-3 is the Data Handling System (DHS) and the associated requirements of Data Collecting System (DCS).

The on board DHS receives, produces and stores data, ready for transmission to any authorized receiver of data on board or on ground. The main goal of the DHS is to produce Compiled Energy Billing Data and transfer it on an interoperable basis to an on-ground Data Collecting System (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.

The DCS on-ground receives Compiled Energy Billing Data and transfer it to settlement system.

EN 50463-3 also defines the conformity assessment of the DHS and for the transfer of CEBD to an on-ground Data Collecting System (DCS).

**4) EN 50463-4 — Communication:**

The scope of EN 50463-4 is the communication services.

This part of EN 50463 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 reference to the on board to ground communication service and covers the requirements necessary to support data transfer between DHS and DCS including the transfer of CEBD on an interoperable basis.

EN 50463-4 also defines the conformity assessment of the communications services.

**5) EN 50463-5 — Conformity assessment:**

The scope of EN 50463-5 is the conformity assessment procedures for the EMS.

EN 50463-5 also covers re-verification procedures and conformity assessment in the event of the replacement of a device of the EMS.

**b) 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.

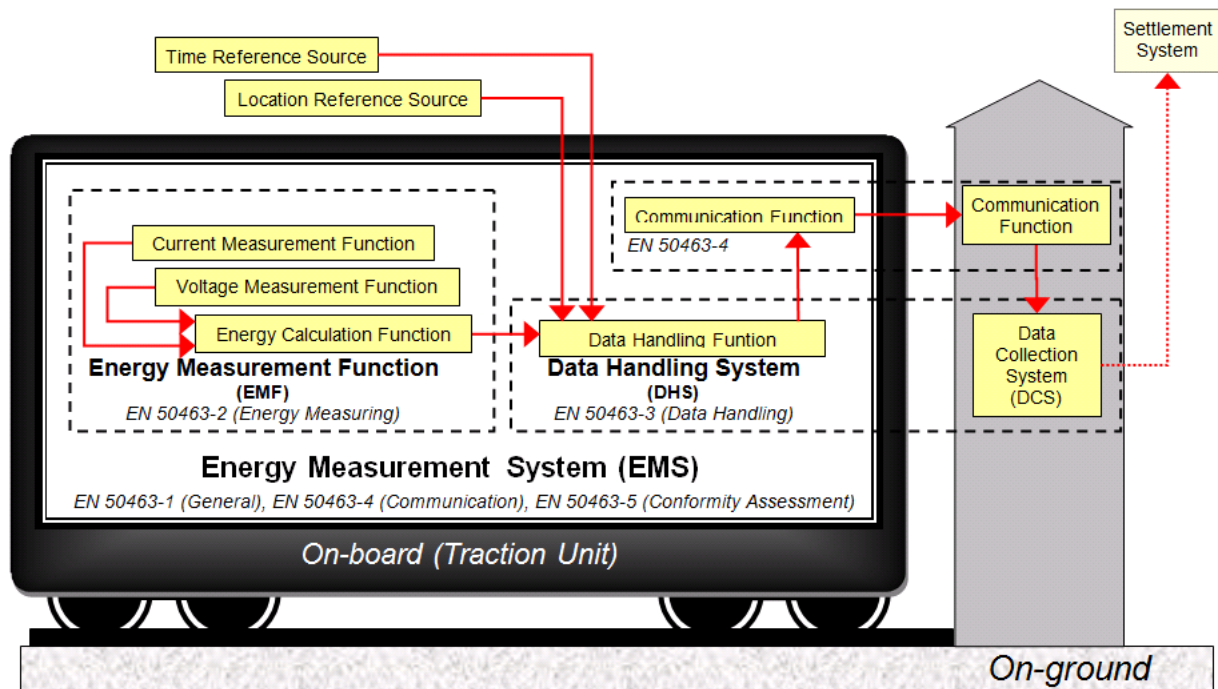


Figure 1 — EMS functional structure and dataflow diagram

## 1 Scope

This European Standard covers 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 European Standard 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 Conformity Assessment 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.

The standard has been developed taking into account that in some applications the EMF can be subjected to legal metrological control. All relevant metrological aspects are covered in this part.

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

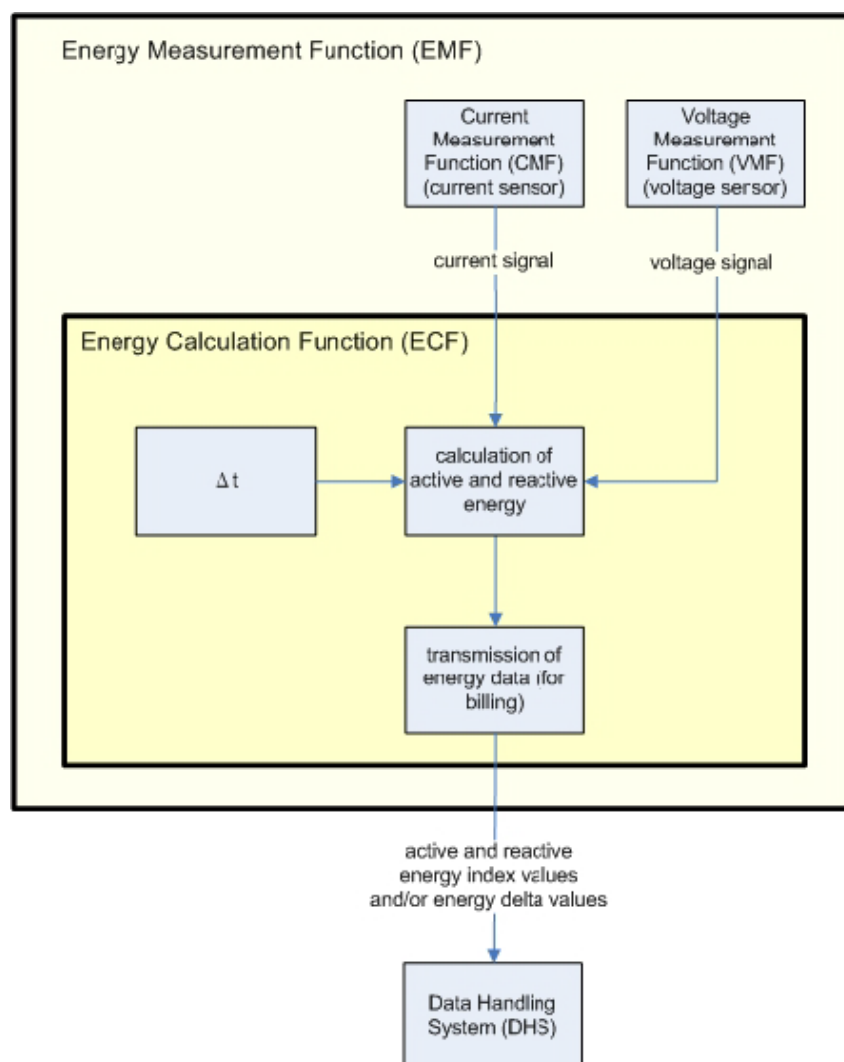


Figure 2 — EMF functional block diagram

## 2 Normative references

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

EN 45545-2:2013+A1:2015, *Railway applications — Fire protection on railway vehicles — Part 2: Requirements for fire behaviour of materials and components*

EN 45545-5:2013+A1:2015, *Railway applications — Fire protection on railway vehicles — Part 5: Fire safety requirements for electrical equipment including that of trolley buses, track guided buses and magnetic levitation vehicles*

EN 50121-1:2017, *Railway applications — Electromagnetic compatibility — Part 1: General*

EN 50121-3-2:2015, *Railway applications — Electromagnetic compatibility — Part 3-2: Rolling stock - Apparatus*

EN 50123-1:2003, *Railway applications — Fixed installations — D.C. switchgear — Part 1: General*

EN 50124-1:2001, *Railway applications — Insulation coordination — Part 1: Basic requirements — Clearances and creepage distances for all electrical and electronic equipment*

EN 50125-1:2014, *Railway applications — Environmental conditions for equipment — Part 1: Rolling stock and on-board equipment*

EN 50155:2017, *Railway applications — Rolling stock — Electronic equipment*

EN 50163:2004, *Railway applications — Supply voltages of traction systems (IEC 60850:2000, not equivalent)*

EN 50388:2012, *Railway Applications — Power supply and rolling stock — Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability*

EN 50463-1:2017, *Railway applications — Energy measurement on board trains — Part 1: General*

EN 50463-3:2017, *Railway applications — Energy measurement on board trains — Part 3: Data handling*

EN 50463-4:2017, *Railway applications — Energy measurement on board trains — Part 4: Communication*

EN 50463-5:2017, *Railway applications — Energy measurement on board trains — Part 5: Conformity assessment*

EN 60044 (all parts), *Instrument transformers (IEC 60044, all parts)*

EN 60068-2-1:2007, *Environmental testing — Part 2-1: Tests — Test A: Cold (IEC 60068-2-1:2007)*

EN 60068-2-2:2007, *Environmental testing — Part 2-2: Tests — Test B: Dry heat (IEC 60068-2-2:2007)*

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

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

EN 60085:2008, *Electrical insulation — Thermal evaluation and designation (IEC 60085:2007)*

EN 60529:1991, *Degrees of protection provided by enclosures (IP Code) (IEC 60529:1989)*

EN 61000 (all parts), *Electromagnetic compatibility (EMC) (IEC 61000, all parts)*

EN 61373:2010, *Railway applications — Rolling stock equipment — Shock and vibration tests (IEC 61373:2010)*

EN 61869-3:2011, *Instrument transformers — Part 3: Additional requirements for inductive voltage transformers (IEC 61869-3:2011)*

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

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

### **3 Terms, definitions, abbreviations and symbols**

#### **3.1 Terms and definitions**

For the purposes of this document, the terms and definitions given in EN 50463-1:2017 and the following apply.

Note 1 to entry: When possible, the following definitions have been taken from the relevant chapters of the International Electrotechnical Vocabulary (IEV), IEC 60050–311, IEC 60050–312, IEC 60050–313, IEC 60050–314, IEC 60050–321 and IEC 60050–811. In such cases, the appropriate IEV reference is given. Certain new definitions or modifications of IEV definitions have been added in this standard in order to facilitate understanding. Expression of the performance of electrical and electronic measuring equipment has been taken from EN 60359.

##### **3.1.1**

##### **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**

##### **consumed active energy**

active energy taken from the Contact Line by the traction unit on which the EMF is installed

##### **3.1.3**

##### **consumed reactive energy**

reactive energy taken from the Contact Line by the traction unit on which the EMF is installed

##### **3.1.4**

##### **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.

##### **3.1.5**

##### **energy delta value**

energy consumed and/or regenerated during a time period

Note 1 to entry: See Figure 3 for example.

**3.1.6****energy index value**

total accumulated energy consumption and/or energy regeneration at the end of a time period

Note 1 to entry: See Figure 3 for example.

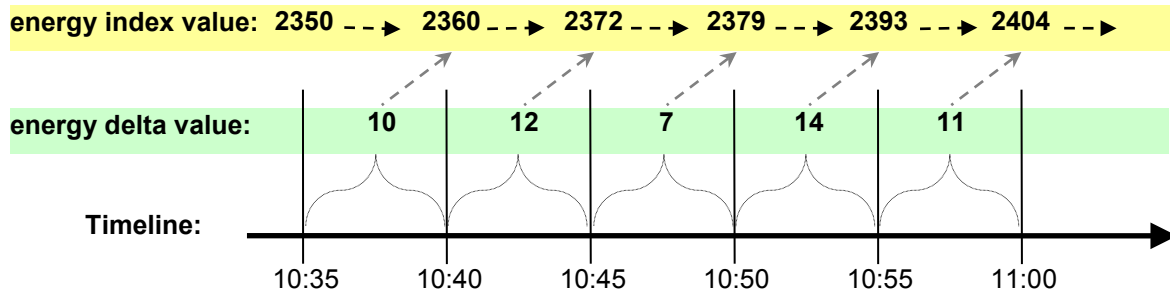


**Figure 3 — Example of energy index value**

**3.1.7****flag**

code indicating information relevant to the functioning of the EMS

Note 1 to entry: Examples include operational status, etc.

**3.1.8****index value overrun**

return to zero of the index value after reaching the maximum value allowed by the register

**3.1.9****influence quantity**

external condition which affects metrological performance

**3.1.10****k-factor**

multiplicand necessary to convert a secondary value into a primary value

Note 1 to entry: Each Voltage Measurement Function and/or Current Measurement Function can have a specific k-factor. If the k-factor is applied to Energy Data, this factor is the product of the k-factors of the Voltage Measurement Function and/or Current Measurement Function used.

**3.1.11****percentage error**

value given by the following formula:

$$\text{Percentage error} = \left| \frac{\text{measured quantity} - \text{true quantity}}{\text{true quantity}} \right| \times 100$$

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.

### 3.1.12

#### 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.

### 3.1.13

#### Power Factor ( $\cos \varphi$ )

##### PF

ratio of the absolute value of the active power  $P$  to the apparent power  $S$

[SOURCE: IEC 60050-131:2002, IEV 131-11-46, modified — The original definition was shortened and the original NOTE was not reproduced here.]

### 3.1.14

#### primary value

value referred to the measuring inputs of an EMF

### 3.1.15

#### 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

### 3.1.16

#### rated dynamic current

$I_{CMF,dyn}$

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

### 3.1.17

#### 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.

### 3.1.18

#### 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.

### 3.1.19

#### 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

### 3.1.20

#### rated traction unit current

maximum current that the traction unit is designed to draw from the Contact Line when operating under normal conditions and with a voltage in the range from  $U_{min1}$  to  $U_{max2}$  according to EN 50163

**3.1.21****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

[SOURCE: IEC 311-06-02, modified — The wording of the definition was fully modified.]

**3.1.22****regenerated active energy**

active energy fed back into the Contact Line by the traction unit on which the EMF is installed

**3.1.23****regenerated reactive energy**

reactive energy fed back into the Contact Line by the traction unit on which the EMF is installed

**3.1.24****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.

[SOURCE: IEC 60050-314:2001, IEC 314-07-09, modified]

**3.1.25****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

**3.1.26****secondary value**

value of current, voltage, power or energy which is equal to a primary value when multiplied by a specific k-factor

**3.1.27****temperature coefficient**

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

**3.1.28****time period**

period of time for which energy data is produced

**3.1.29****Time Reference Period****TRP**

period of time for which CEBD is produced

**3.2 Abbreviations**

For the purposes of this document, the following abbreviations apply.

|      |                              |
|------|------------------------------|
| CEBD | Compiled Energy Billing Data |
| CMF  | Current Measurement Function |
| DHS  | Data Handling System         |
| ECF  | Energy Calculation Function  |

|      |                                                   |
|------|---------------------------------------------------|
| EMF  | Energy Measurement Function                       |
| EMS  | Energy Measurement System                         |
| EUT  | Equipment under test                              |
| PF   | Power Factor                                      |
| RAMS | Reliability, Availability, Maintenance and Safety |
| TRP  | Time Reference Period                             |
| VMF  | Voltage Measurement Function                      |

### 3.3 Symbols

For the purposes of this document, the following symbols apply.

|                     |                                                                                                     |
|---------------------|-----------------------------------------------------------------------------------------------------|
| $f_a$               | 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 EN 50163                                                     |
| $U_{max2}$          | highest non permanent voltage according to EN 50163                                                 |
| $U_{max3}$          | highest long term overvoltage according to EN 50163                                                 |
| $U_{min1}$          | lowest permanent voltage according to EN 50163                                                      |
| $U_{min2}$          | lowest non permanent voltage according to EN 50163                                                  |
| $U_{n,EMF}$         | rated primary voltage of the EMF                                                                    |
| $U_{n,VMF}$         | rated primary voltage of the VMF                                                                    |
| $\varepsilon_{CMF}$ | maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the CMF |
| $\varepsilon_{ECF}$ | maximum percentage error allowed in accordance with the selected accuracy class for the ECF         |
| $\varepsilon_{EMF}$ | calculated maximum percentage error of the EMF                                                      |
| $\varepsilon_{VMF}$ | maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the VMF |

## 4 Requirements

### 4.1 General

The requirements in EN 50463-1:2017, Clause 4, apply to any device containing one or more functions of the Energy Measurement Function (EMF), where applicable. EN 50463-2 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 Marking of the EMF

Devices containing the EMF will have the marking as specified in EN 50463-1:2017, 4.3.1.1. In addition, all devices that include functions which are subject to legal metrological control shall include a metrological mark.

If different functions are included in one device marking need not to be duplicated.

#### 4.2.1.4 Essential information

For all devices containing the EMF the essential information as specified in EN 50463-1:2017, 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.

NOTE Further requirement regarding the additional information requirement for sensors and the ECF can be found in 4.3.2.4 and 4.4.2.5 of this standard.

### 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 EN 50163.

The rated primary voltage of the EMF ( $U_{n,EMF}$ ) shall be equal to the nominal voltage of the traction system as detailed in EN 50163 and listed in Table 1.

Table 1 — Nominal traction system voltages

| Nominal voltages<br>$U_n$<br>V | System     |
|--------------------------------|------------|
| 25 000                         | 50 Hz AC   |
| 15 000                         | 16,7 Hz AC |
| 3 000                          | DC         |
| 1 500                          | DC         |
| 750                            | DC         |
| 600                            | DC         |

If the EMF is designed to be used on more than one traction system it shall have a rated primary voltage assigned for each traction 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 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 system for which it is designed to operate, selected from Table 1.

If an EMF is designed to be used on more than one traction 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, 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:

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

where

$\varepsilon_{EMF}$  is the calculated maximum percentage error of the EMF;

- $\varepsilon_{VMF}$  is the maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the VMF under the reference conditions;
- $\varepsilon_{CMF}$  is the maximum percentage (ratio) error allowed in accordance with the selected accuracy class for the CMF under the reference conditions;
- $\varepsilon_{ECF}$  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.

#### 4.2.3.3 Reference conditions

The following table details the reference conditions to be used for any part of the EMF and the complete EMF.

**Table 2 — Reference conditions**

| Influence quantity                                                                                                                                                                                                                                 | Reference value                  | Permissible tolerances                     |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|--------------------------------------------|
| Ambient temperature                                                                                                                                                                                                                                | 23 °C <sup>a</sup>               | ±2 °C                                      |
| Frequency                                                                                                                                                                                                                                          | Rated frequency                  | ±0,3 %                                     |
| Wave-form AC                                                                                                                                                                                                                                       | Sinusoidal voltages and currents | Distortion factor less than:<br>2 %        |
| Wave-form DC                                                                                                                                                                                                                                       | Pure DC voltages and currents    | Ripple less than 1 %                       |
| Auxiliary supply voltage                                                                                                                                                                                                                           | Rated auxiliary 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 |
| <sup>a</sup> 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. |                                  |                                            |

#### 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 3, the percentage error when calculated in accordance with 4.2.3.2 shall not exceed the limits given in Table 3. These limits shall apply to the measurement of energy in each direction.

Table 3 — EMF percentage error limits

| 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 <sup>a</sup>      | Value of voltage <sup>b</sup>       |                                                         |                                       |                                         |
| AC          | 10 % $I_n \leq I \leq 120$ % $I_n$ | $U_{\min 1} \leq U \leq U_{\max 2}$ | 0,85 $\leq$ PF<br>or<br>$\sin \varphi = 1$<br>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                                     |

<sup>a</sup>  $I_n$  is the rated primary current of the EMF.

<sup>b</sup> The values of  $U_{\min 1}$  and  $U_{\max 2}$  are as specified in EN 50163:2004, Table 1.

<sup>c</sup> The Power Factor is taken from EN 50388:2012, 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 system change

When there is a changeover between traction 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 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 realized using separate devices or within a combined device.

Where sensor technology is covered by the EN 60044 series, these standards may be applied to sensors as applicable. Where requirements in the EN 60044 series conflicts with the requirements in the EN 50463 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, the rated power-frequency withstand voltage of the output signal to ground shall be 3 kV (rms) according to EN 60044-1 and EN 61869-3.

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 EN 60044-1 and EN 61869-3.

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 EN 50124-1, 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 EN 50463-1:2017, 4.3.5 and shall be applied according to the output type.

#### 4.3.2.3.2 Requirements for dedicated 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 outputs

Requirements for communication protocols stack and communication security can be found in EN 50463-4:2017, 4.2.2, 4.2.3 and 4.2.4.

### 4.3.2.4 Essential information

In addition to the requirements given in EN 50463-1:2017, 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 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 EN 50155:2017, 5.1.1.4;
- 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:
  - 1) the primary and secondary connections;
  - 2) if applicable, other accessible terminals e.g. testing and service points;
  - 3) if applicable, auxiliary voltage connections;
  - 4) 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 and 50 Hz);
- g) if applicable, the maximum frequency which can be measured without aliasing (see 4.3.3.1.5 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 nominal voltage of the highest traction system nominal voltage at which the sensor is designed to be used, selected from the values given in Table 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.

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  $\leq 10$  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  $U_{\max 3}$  in accordance with EN 50163:2004, Table A.1.

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

#### 4.3.3.1.4 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 can be appropriate.

#### 4.3.3.1.5 Bandwidth requirements for electronic sensors

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

NOTE 1 This will give an overall view of the frequency performances of the sensor.

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

#### 4.3.3.1.6 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 of 3 kV (rms) for 1 min.

#### 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 EN 50155:2017, 7.2.3.

#### 4.3.3.3 Limit of temperature rise

Sensors with electrical insulation shall be assigned a thermal class in accordance with EN 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 EN 50463-1:2017, 4.3.6.3;
- output conditions which create 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 4.

**Table 4 — Percentage error limits - VMF**

| Accuracy class | ± Maximum percentage voltage (ratio) error at voltage defined in EN 50163<br>$\varepsilon_{VMF}$ |                                     | ± Maximum phase displacement at voltage defined in EN 50163<br>AC $\overline{AC_1}$ VMF $\overline{AC_1}$ (minutes) 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 systems, a single voltage sensor can be used if it achieves the accuracy requirement defined in Table 4 for each rated voltage.

#### 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 5.

In order to be able to achieve compliance with the maximum error limits specified in Table 5, 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 4. 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 5 are not exceeded.

Table 5 — 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<br>- 10 °C to + 50 °C<br>(or + 60 °C for indoor) | Ambient temperature variation, extended range<br>- 40 °C to - 10 °C<br>(and + 60 °C to + 75 °C for indoor) |
| $U_{\min 2} \leq U \leq U_{\max 2}$ | AC and DC   | $N^b + (0,01 \times \Delta T^a)$                                                           | $N^b + (0,02 \times \Delta T^a)$                                                                           |

<sup>a</sup>  $\Delta T$  is the temperature variation in Kelvin between reference temperature 23 °C and the ambient temperature.

<sup>b</sup> The term N is the maximum allowable percentage ratio error allowed for the VMF class as specified in Table 4. 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  $1,0 + (0,01 \times \Delta T)$ .

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

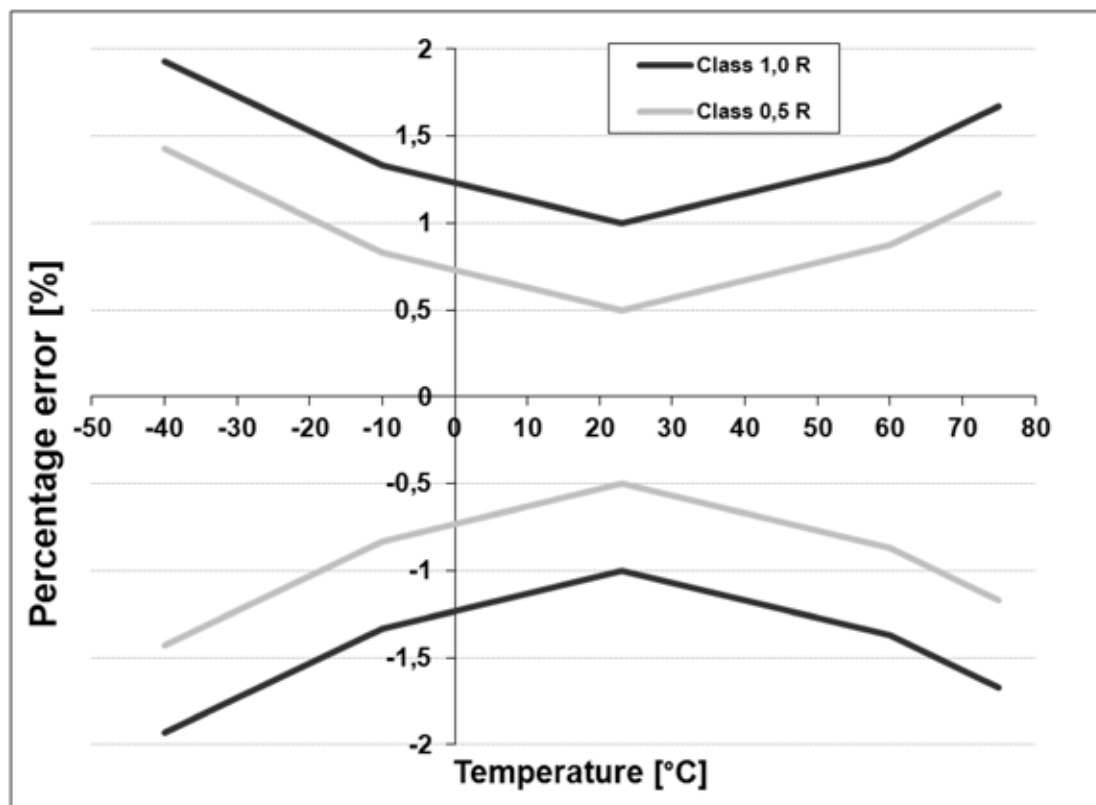


Figure 4 — Example of maximum percentage error for a VMF of class 0,5 R and a VMF of class 1,0 R with input signal in the range  $U_{\min 1} \leq U \leq U_{\max 2}$

#### 4.3.3.5.2 Mean temperature coefficient of a VMF

In addition to the requirements in 4.3.3.5.1, the mean temperature coefficient of a VMF shall not exceed the limits specified in Table 6.

Table 6 — Temperature coefficient for VMF

| Accuracy class | $\pm$ Mean temperature coefficient<br>%/K |
|----------------|-------------------------------------------|
|                | $U_{\min 2} \leq U \leq U_{\max 2}$       |
| 0,2 R          | 0,02                                      |
| 0,5 R          | 0,025                                     |
| 0,75 R         | 0,03                                      |
| 1,0 R          | 0,035                                     |

The maximum additional percentage error due to temperature variation specified in Table 5 and the temperature coefficients specified in Table 6 only apply in the range defined by the device's maximum and minimum ambient temperature limits according to the applicable temperature class requirements of EN 50463-1:2017, 4.3.6.3.

#### 4.3.3.6 Limits of additional error due to influence quantities

The limit of variation in errors due to changes in an influence quantity with respect to reference conditions, as given in Table 2, shall not exceed the limits for the relevant accuracy class given in Table 7.