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TITLE OF THE CD (English):

OIML R 46-1

Electrical Energy Meters – Alternating Current (a.c.)

Part 1: Metrological and Technical Requirements

Contents

Foreword

[To be inserted by BIML]

1 Introduction

This Recommendation is provided as model regulations for OIML member states when implementing metrological controls for electricity meters. It provides regulatory controls for regulators to use to provide confidence in the measurement results from electricity meters.

There are other international standard-setting bodies for electricity meters. In particular, the International Electrotechnical Commission (IEC) has a range of standards for electricity meters. IEC standards cover many topics including safety, test procedures and data/communication protocols. The scope of this Recommendation does overlap with parts of some IEC standards [1], [2], [3], [4] and [5].

A key objective of this revision of OIML R 46 was to minimise differences between OIML and IEC requirements.

2 Scope

This Recommendation specifies the metrological and technical requirements applicable to electricity meters subject to legal metrological controls. The requirements are to be applied during type approval, verification, and re-verification. They also apply to modifications that may be made to existing approved devices.

The provisions set out here apply only to electrical energy meters designed to measure on alternating current (a.c.) circuits. Meters can be direct connected for system voltages up to 1000 V, or transformer operated.

Electromechanical meters are out of scope for the purpose of type evaluation and approval. However, electromechanical meters are in scope for the purposes of verification.

3 Terms and definitions

The terminology used in this Recommendation conforms to the *International Vocabulary of Basic and General Terms in Metrology (VIM)* [6] and the *International Vocabulary of Legal Metrology (VIML)* [7]. Terminology from OIML International Document D 11 *General requirements for measuring instruments – Environmental conditions* [8], and OIML International Document D 31 *General requirements for software controlled measuring instruments* [9] is also applicable particularly for 7.3 Requirements for software-controlled meters. In addition, for the purposes of this Recommendation, the following definitions shall apply.

3.1 Meters and their constituents

3.1.1

electrical energy meter
electricity meter
meter
measuring system

instrument or combination of instruments intended to measure electrical energy

3.1.2

active energy meter

meter intended to measure active energy by integrating active power with respect to time

3.1.2.1

watthour meter

active energy meter that provides measurements in units of watthour (or kWh, MWh or GWh)

3.1.3

reactive energy meter

meter intended to measure reactive energy by integrating reactive power with respect to time

3.1.3.1

var hour meter

reactive energy meter that provides measurements in units of var hour (or kvarh, Mvarh,or Gvarh)

3.1.4

apparent energy meter

meter intended to measure apparent energy by integrating apparent power with respect to time

3.1.4.1

volt ampere hour meter

apparent energy meter that provides measurements in units of volt ampere hours (kVAh, MVAh, or HVAh)

3.1.5

interval meter

meter which displays and stores the result as measured in predetermined periodic time intervals

3.1.6

multi-tariff meter
multi-rate meter

electricity meter intended to measure and display electrical energy where energy will have more than one tariff rate

Note: The tariff rate may be determined by time, load or some other quantity.

3.1.7

direct connected meter

meter intended for use by direct connection to the circuit(s) being measured, without the use of external instrument transformer(s)

3.1.8

transformer-operated meter

meter intended for use with one or more external instrument transformers

3.1.9

electromechanical meter

meter in which currents in fixed coils react with the currents induced in the conducting moving element, generally (a) disk(s), which causes their movement proportional to the energy to be measured

[IEC 62052-11:2020 [1], 3.1.1]

Note: Electromechanical meters are out of scope of this Recommendation for type approval.

3.1.10

static meter

meter in which current and voltage act on solid state (electronic) elements to produce an output proportional to the energy to be measured

[IEC 62052-11:2020 [1], 3.1.2]

3.1.11

measuring element

part of the meter which produces an output proportional to the energy

[IEC 62052-11:2020 [1], 3.2.1]

3.1.12

current circuit

internal connections of the meter and part of the measuring element through which flows the current of the circuit to which the meter is connected

[IEC 62052-11:2020 [1], 3.2.18]

3.1.13

voltage circuit

internal connections of the meter and part of the measuring element, and in some cases, part of the meter's power supply, energized with the voltage of the measured electrical circuit to which the meter is connected

[IEC 62052-11:2020 [1], 3.2.19]

3.1.14

auxiliary device

device internal or external to the meter intended to perform a particular function in addition to the energy measurement functions

Note 1: Some examples include: clock, tariff / load / supply control switch, pulse input / output, and data exchange unit.

Note 2: An auxiliary device may be internal or external to the meter.

[IEC 62052-11:2020 [1], 3.2.23]

3.1.15

auxiliary circuit

circuit other than the voltage circuits, current circuits and auxiliary power supply circuit, intended to be connected to (an) external device(s)

[IEC 62052-11:2020 [1], 3.2.20]

3.1.16

indicating device

part of the meter that displays the measurement results either continuously or on demand

Note: An indicating device may also display other information.

3.1.17

register

part of the meter that stores the measured values

Note: The register may be an electromechanical device or an electronic device and may be integral to the indicating device.

3.1.18

primary rated register
(for transformer-operated meters)

register that stores the value of energy determined by applying the transformation ratio(s) of any transformer(s) used to measure energy at the primary side of instrument transformer(s)

3.1.19

register multiplier

constant, derived from the transformation ratio(s) due to the used instrument transformer(s), with which the register reading shall be multiplied to obtain the value of the metered energy

3.1.20

meter constant

value expressing the relation between the energy registered by the meter and the corresponding value of the test output

Note 1: For static meters, the meter constant is typically expressed as impulse per unit of energy (e.g. imp/kWh, imp/kvarh), or as units of energy per impulse (e.g. Wh/imp, varh/imp).

Note 2: For electromechanical meters, the meter constant is typically expressed as revolutions per unit of energy (e.g. rev/kWh, rev/kvarh), or as units of energy per revolution (e.g. Wh/rev, varh/rev).

3.1.21

test output

output which can be used for testing the meter, providing pulses or the means to provide pulses corresponding to the energy measured by the meter

3.1.22

sub-assembly

part of a device having a recognizable function of its own

3.1.23

low-power instrument transformer
LPIT

instrument transformer with no rated output power

[IEC 61689-6:2016, 3.1.601]

3.1.24

electronic LPIT
EIT

LPIT in which signal processing is performed by active electronic components

[IEC 61689-6:2016, 3.1.601]

3.1.25

multi-branch meter
branch circuit power meter
multi-load meter

meter designed to measure energy on multiple branch circuits of electrical distribution network

Note: Multi-branch meters are typically connected via LPITs, and may have a large number of measuring channels, one for each branch circuit in the distribution panel board or switchboard.

3.1.26

channel
(for multi-branch meters)

analogue or digital input in a multi-branch meter associated with one connected circuit or phase

3.1.27

memory

element which stores digital information

[IEC 62052-11:2020 [1], 3.2.9]

3.1.28

non-volatile memory

memory which can retain information in the absence of power

[IEC 62052-11:2020 [1], 3.2.10]

3.1.29

demand meter

meter intended to measure demand

3.1.30

demand register

register which stores the value of the demand measured by the meter

3.1.31

maximum demand register

demand register which stores the value of maximum demand

Note: Maximum demand is defined as subsequent to the most recent maximum demand reset.

3.1.32

maximum demand reset device
reset device

device which enables the maximum demand register to be reset to zero, manually or by other means.

3.1.33

test mode

a mode of operation or output which facilitates meter accuracy testing by introducing shorter test periods and/or greater resolution of readings.

Note: The output of a test mode feature or operation is not the output used in establishing the basis of a charge for electricity legal units of measure during normal meter operation

3.1.34

reference meter

meter used to measure the unit of electrical energy, designed and operated to obtain the highest accuracy and stability in a controlled laboratory environment and traceable to national or international primary standards

[IEC 62052-11:2020 [1], 3.1.11]

3.2 Metrological characteristics

3.2.1

indication

quantity value provided by a measuring instrument or a measuring system

Note 1: An indication may be presented in visual or acoustic form or may be transferred to another device. An indication is often given by the position of a pointer on the display for analog outputs, a displayed or printed number for digital outputs, a code pattern for code outputs, or an assigned quantity value for material measures.

Note 2: An indication and a corresponding value of the quantity being measured are not necessarily values of quantities of the same kind.

[OIML V 2-200:2012 [6], 4.1]

3.2.2

relative error of indication
error of indication

indication minus reference quantity value, divided by the reference quantity value

Note 1: The relative error is usually expressed as a percentage of the reference quantity value.

Note 2: Since this Recommendation deals only with relative error, the short form “error” is used for relative error.

3.2.3

maximum permissible error
mpe

extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument or measuring system

Note 1: Usually, the term “maximum permissible errors” or “limits of errors” is used where there are two extreme values.

Note 2: The term “tolerance” should not be used to designate “maximum permissible error”.

[OIML V 2-200:2012 [6], 4.26]

Note 3: In this Recommendation, the maximum permissible error is a combination of the base maximum permissible error and the maximum permissible error shift as described in Annex C.

Note 4: For the application of this Recommendation, "specifications or regulations" means: the provisions contained in this Recommendation, and the terms "measuring instrument" and "measuring system" mean: electricity meter.

3.2.4

base maximum permissible error (*b*)
base mpe

extreme value of the error of indication of a meter, permitted by this Recommendation, when the current and power factor are varied within the rated operating conditions, and when the meter is otherwise operated at reference conditions

Note: In this Recommendation, the maximum permissible error is a combination of the base maximum permissible error and the maximum permissible error shift as described in Annex C.

3.2.5

error shift

change in the error of indication of a meter as a result of an influence or disturbance quantity which is acting or has acted upon the meter

3.2.6

maximum permissible error shift

extreme value of the change in error of indication of a meter, permitted by this Recommendation, when a single influence factor is taken from its value at reference conditions and varied within the rated operating conditions

Note 1: For each influence factor there is one corresponding maximum permissible error shift.

Note 2: In this Recommendation, the maximum permissible error is a combination of the base maximum permissible error and the maximum permissible error shift as described in Annex C.

3.2.7

intrinsic error

error of indication, determined under reference conditions

[OIML V 1:2013 [7], 0.06]

3.2.8

initial intrinsic error

intrinsic error of a measuring instrument as determined prior to performance tests and durability evaluations

[OIML V 1:2013 [7], 5.11]

3.2.9

influence quantity

quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result

[OIML V 2-200:2012 [6], 2.52]

Note 1: The concept of influence quantity is understood to include values associated with measurement standards, reference materials and reference data upon which the result of a measurement may depend, as well as phenomena such as short-term measuring instrument fluctuations and quantities such as ambient temperature, barometric pressure and humidity.

Note 2: In the GUM [10], the concept 'influence quantity' is defined as in the second edition of the VIM, covering not only the quantities affecting the measuring system, as in the definition above, but also those quantities that affect the quantities actually measured. Also, in the GUM this concept is not restricted to direct measurements. [OIML V 2-200:2012 [6], 2.52, Note 2]

3.2.10

influence factor

influence quantity having a value which ranges within the rated operating conditions of a measuring instrument

[OIML V 1:2013 [7], 5.18]

3.2.11

disturbance

influence quantity having a value within the limits specified in this Recommendation, but outside the specified rated operating conditions of a measuring instrument

[OIML V 1:2013 [7], 5.19]

Note: An influence quantity is a disturbance if the rated operating conditions for that influence quantity are not specified.

3.2.12

rated operating condition

operating condition that must be fulfilled during measurement in order that a measuring instrument or measuring system perform as designed

Note 1: Rated operating conditions generally specify intervals of values for a quantity being measured and for any influence quantity.

[OIML V 2-200:2012 [6], 4.9]

Note 2: In this Recommendation, the terms “measuring instrument” and “measuring system” are equivalent to “electricity meter”.

3.2.13

reference condition

operating condition prescribed for evaluating the performance of a measuring instrument or measuring system or for comparison of measurement results

Note 1: Reference operating conditions specify intervals of values of the measurand and of the influence quantities.

Note 2: In IEC 60050-300, item 311-06-02, the term “reference condition” refers to an operating condition under which the specified instrumental measurement uncertainty is the smallest possible.

[OIML V 2-200:2012 [6], 4.11]

Note 3: For the application of this Recommendation, the terms “measuring instrument” and “measuring system” mean: electricity meter.

3.2.14

accuracy class

class of measuring instruments or measuring systems that meet stated metrological requirements that are intended to keep measurement errors or instrumental measurement uncertainties within specified limits under specified operating conditions

[OIML V 2-200:2012 [6], 4.25]

Note: In this Recommendation, the stated metrological requirements for accuracy class include permissible responses to disturbances.

3.2.15

durability

ability of the measuring instrument to maintain its performance characteristics over a period of use

[OIML V 1:2013 [7], 5.15]

3.2.16
fault

difference between the error of indication and the intrinsic error of a measuring instrument

Note 1: Principally, a fault is the result of an undesired change of data contained in or flowing through a measuring instrument.

Note 2: From the definition it follows that in this Recommendation, a "fault" is a numerical value which is expressed either in a unit of measurement or as a relative value, for instance as a percentage.

[OIML D 11:2013 [8], 3.10]

Note 3: In this Recommendation, the above definition does not apply to the term 'earth fault', in which the word 'fault' has its usual dictionary meaning.

3.2.17
fault limit

value specified in this Recommendation delimiting non-significant faults

[OIML V 1:2013 [7], 5.13]

3.2.18
significant fault

fault exceeding the applicable fault limit value

[OIML D 11:2013 [8], 3.12]

Note: Other criteria may also be considered to be significant faults (see 6.4.2) including:

- a change larger than the critical change value has occurred in the measurement registers due to disturbances;
- the functionality of the meter has become impaired or the meter has been damaged.

3.2.19
checking facility

facility that is incorporated in a measuring instrument and which enables significant faults to be detected and acted upon

Note 1: "Acted upon" refers to any adequate response by the measuring instrument (luminous signal, acoustic signal, prevention of the measurement process, etc.).

[OIML V 1:2013 [7], 5.07]

Note 2: For the application of this Recommendation, the term "measuring instrument" means: electricity meter.

Note 3: For integrating instruments like electricity meters that continuously accumulate electrical energy, 'acted upon' is taken to mean recording an event in an event record. The event record would include the kind of disturbance, time, duration and the amount of energy measured during the disturbance.

3.2.20
energy accumulation register

register for storing accumulated energy

Note: Meters may be designed with multiple energy accumulation registers for different quantities and directions of energy flow.

3.2.21
legally relevant

attribute of a part of a measuring instrument, device or software subject to legal control

[OIML V 1:2013 [7], 4.08]

3.2.22

sealing

means intended to protect the measuring instrument against any unauthorized modification, readjustment, removal of parts, software, etc.

Note: This may be achieved by hardware, software or a combination of both.

[OIML V 1:2013 [7], 2.20]

3.2.23

metrology seal

specific securing measure which can be applied to an electricity meter to ensure its metrological integrity

[IEC 62052.11:2020 [1], 3.4.10]

Note: The sealing requirements in this Recommendation relate to the metrology seal, unless stated otherwise.

3.2.24

installation seal

specific securing measure which can be applied by an installer to ensure the integrity of the meter installation

[IEC 62052.11:2020 [1], 3.4.11]

Note: The sealing requirements in this Recommendation do not relate to the installation seal, unless stated otherwise.

3.3 Operating conditions and electrical quantities

3.3.1

current (I)

value of the electrical current flowing through the meter

Note: The term "current" in this Recommendation indicates r.m.s. (root mean square) values unless otherwise specified.

3.3.2

starting current (I_{st})

lowest current at which the meter shall register electrical energy at unity power factor and, for poly-phase meters, with balanced load

3.3.3

minimum current (I_{min})

lowest current at which the meter lies within a constant value of base maximum permissible error

Note: Below the minimum current and down to the starting current, the value of base maximum permissible errors are specified as a function of current.

3.3.4

transitional current (I_{tr})

current at and above which the meter lies within the smallest base maximum permissible error corresponding to the accuracy class of the meter

3.3.5

maximum current (I_{max})

highest current at which the meter accuracy requirements are specified

3.3.6

nominal current (I_n)

current in accordance with which the relevant performance of the meter is fixed

[IEC 62052-11:2020 [1], 3.5.4]

Note: This definition is included for harmonisation with IEC current terminology. This Recommendation does not use the nominal current to set the performance requirements. Refer to Annex E for more information.

3.3.7

voltage (*U*)

value of the electrical voltage supplied to the meter

Note: The term “voltage” in this Recommendation indicates r.m.s. (root mean square) values unless otherwise specified.

3.3.8

nominal voltage (U_{nom})

voltage specified by the manufacturer for normal operation of the meter

Note: Meters designed for operation across a range of voltages may have several nominal voltage values.

3.3.9

frequency (*f*)

frequency of the voltage (and current)

3.3.10

nominal frequency (f_{nom})

frequency of the voltage (and current) specified by the manufacturer for normal operation of the meter

3.3.11

harmonic

part of a signal that has a frequency that is an integer multiple of the fundamental frequency of the signal

3.3.12

sub-harmonic

part of a signal that is an integer submultiple of the fundamental frequency

3.3.13

harmonic number
harmonic order

integer number used to identify a harmonic

Note: The harmonic number is the ratio of the frequency of a harmonic to the fundamental frequency of the signal.

3.3.14

power factor (PF)

ratio of the active power to the apparent power

Note: At sinusoidal and either one-phase or symmetrical three-phase conditions, the power factor = cos θ = the cosine of the phase difference θ between voltage U and current I.

3.3.14.1

power factor inductive

power factor value when the phase angle (θ) of voltage relative to current is greater than 0° and less than or equal to 180° ($0° < \theta \leq 180°$)

3.3.14.2

power factor capacitive

power factor value when the phase angle (θ) of voltage relative to current is greater than 180° and less than or equal to 360° ($180° < \theta \leq 360°$).

3.3.15

bi-directional (energy) flow

capability of the meter to measure energy flow in both directions (positive and negative)

3.3.16

positive-direction only (energy) flow

capability of the meter to measure energy flow in only one direction (positive direction)

3.3.17

uni-directional (energy) flow

capability of the meter to measure energy flow regardless of the direction of energy flow

3.3.18

positive (energy) flow

direction of energy flow towards the consumer

3.3.19

negative (energy) flow

(for bi-directional and uni-directional meters)

direction of energy flow opposite to positive

Note: For positive-direction only, the opposite direction is termed reverse energy flow (see 3.2.20).

3.3.20

reverse (energy) flow

(for positive-direction only meters)

direction of flow in the opposite direction to positive

3.3.21

active power (*P*)

rate at which energy is transported

Note: Refer to 5.2.2 for more information.

3.3.21.1

active power, fundamental frequency only (*W*)

active power associated only with the fundamental frequency

3.3.21.2

active power, fundamental frequency only, delivered (W_{del})

active power, fundamental frequency only, in the delivered direction (import or positive direction)

3.3.21.3

active power, fundamental frequency only, received (W_{rec})

active power, fundamental frequency only, in the received direction (export or negative direction)

3.3.22

active energy (*E*)

active power integrated over time

Note: Refer to 5.2.2 for more information.

3.3.22.1

watt hour (*WH*)

active energy associated only with the fundamental frequency

3.3.22.2

Watt hour, delivered (WH_{del})

watt hours in the delivered direction (import or positive), that is, when the phase angle (θ) of voltage relative to current is greater than 0° and less than or equal to 90° (0° < θ ≤ 90°), or, greater than 270° and less than or equal to 360° (270° < θ ≤ 360°)

3.3.22.3

watt hour, received (WH_{rec})

watt hours in the received direction (export or negative direction) , that is, when the phase angle (θ) of voltage relative to current is greater than 90° and less than or equal to 270° (90° < θ ≤ 270°)

3.3.23

reactive power (*Q*)

at a single sinusoidal frequency component of a periodic signal in a single-phase circuit, the product of the r.m.s values of current and voltage, and the sine of the phase angle between them, where the phase angle is the angle of the voltage signal vector with respect to the current signal vector

[IEC 62052-11:2020 [1], 3.1.16, modified]

Note: Refer to 5.2.3 for more information.

3.3.23.1

reactive power, fundamental frequency (*VAR*)

reactive power associated only with the fundamental frequency

3.3.24

reactive energy, fundamental frequency (*VARH*)

reactive energy

var hours

reactive power, fundamental frequency, integrated over time

Note: Refer to 5.2.3 for more information.

3.3.24.1

reactive energy, delivered ($VARH_{del}$)
var hours, delivered

reactive energy in the delivered direction (import, positive direction), that is, when the phase angle (θ) of voltage relative to current is greater than 0° and less than or equal to 180° (0° < θ ≤ 180°)

3.3.24.2

reactive energy, received ($VARH_{rec}$)

var hours, received

reactive energy in the received direction (export, negative direction), that is, when the phase angle (θ) of voltage relative to current is greater than 180° and less than or equal to 360° (180° < θ ≤ 360°)

3.3.24.3

reactive energy, quadrant 1 ($VARH_{q1}$)
var hours, quadrant 1

reactive energy delivered associated with watt hours delivered, that is, when the phase angle (θ) of voltage relative to current is greater than 0° and less than or equal to 90° (0° < θ ≤ 90°)

3.3.24.4

reactive energy, quadrant 2 (*$VARH_{q2}$*)
var hours, quadrant 2

reactive energy delivered associated with watt hours received, that is, when the phase angle (θ) of voltage relative to current is greater than 90° and less than or equal to 180° (90° < $\theta \leq$ 180°)

3.3.24.5

reactive energy, quadrant 3 (*$VARH_{q3}$*)
var hours, quadrant 3

reactive energy received associated with watt hours received, that is, when the phase angle (θ) of voltage relative to current is greater than 180° and less than or equal to 270° (180° < $\theta \leq$ 270°)

3.3.24.6

reactive energy, quadrant 4 (*$VARH_{q4}$*)
var hours, quadrant 4

reactive energy received associated with watt hours delivered, that is, when the phase angle (θ) of voltage relative to current is greater than 270° and less than or equal to 360° (270° < $\theta \leq$ 360°)

3.3.24.7

reactive energy in a poly-phase circuit

algebraic sum of the reactive energy of phases

[IEC 62052.11:2016, 3.1.6.2]

3.3.25

apparent power (*S*)

[to be added]

Note: Refer to 5.2.4 for more information.

3.3.26

apparent energy (*VAH*)
volt ampere hours

[to be added]

Note: Refer to 5.2.4 for more information.

3.3.26.1

volt ampere hours, delivered (*VAH_{del}*)

volt ampere hours associated with watt hours delivered, that is, when the phase angle of voltage relative to current is greater than 0° and less than or equal to 90°, or when it is greater than 270° and less than or equal to 360°

3.3.26.2

volt ampere hours, received (*VAH_{rec}*)

volt ampere hours associated with watt hours received, that is, when the phase angle of voltage relative to current is greater than 90° and less than or equal to 270°

3.3.27

critical change value

maximum amount of change allowed in the meter's energy registers during disturbance tests without any current flowing in the meter's current circuits

[IEC 62052.11:2020 [1], 3.6.3]

3.3.28

demand

rate at which a particular quantity (e.g. active energy, reactive energy, etc.) is being supplied to the load

Note: Demand is generally calculated as an average obtained over a specified time interval. This value can be calculated by dividing the integrated quantity (e.g. watthours) by the elapsed time in the designated interval (e.g. 15 minutes).

3.3.29

maximum demand
peak demand

highest value of demand measurement by the meter, subsequent to the most recent maximum demand reset

3.3.30

demand interval

interval of time on which a demand measurement is based

3.3.31

demand subinterval
subinterval

interval of time that is a submultiple of the demand interval and used with the sliding window demand response

3.3.32

demand response

method of calculating demand based on the demand interval

3.3.32.1

sliding window

demand response whereby at the end of each new subinterval, the value of the oldest subinterval demand value is discarded, and a new demand value is calculated based on the sum of energy registered in the most recent contiguous subintervals which comprise the demand interval

3.3.32.2

block

demand response whereby a new demand value is calculated based on the energy registered during the demand interval

4 Description of the instrument

[To be added]

5 Electrical quantities and Units

5.1 Units of measurement

The units of measurement for active electrical energy shall be one of the following units: Wh, kWh, MWh, GWh.

The units of measurement for reactive electrical energy shall be one of the following units: varh, kvarh, Mvarh, Gvarh.

The units of measurement for apparent electrical energy shall be one of the following units: VAh, kVAh, MVAh, GVAh.

For demand meters, the units of measurement for demand shall be an appropriate unit of electrical power (e.g. kW, kvar or kVA).

5.2 Electrical quantities

5.2.1 General

There are a range of electrical quantities that a meter may have capability to measure. The basic quantities are active, reactive and apparent power and energy. Equations are provided for these basic quantities and for energy flow in different directions.

Some quantities are defined based on the fundamental frequency components only. Where the current and voltage waveforms are not sinusoidal, it is necessary to distinguish between quantities associated with only the fundamental frequency, and, quantities associated with the entire waveforms (fundamental and harmonics).

Figure 1 illustrates four quadrant power and associated conventions for describing directions that are used in this Recommendation. Positive energy flow is associated with delivered or imported power, and negative energy flow is associated with received or exported energy flow.

Note: The terms in Figure 1 are from the perspective of the utility business.

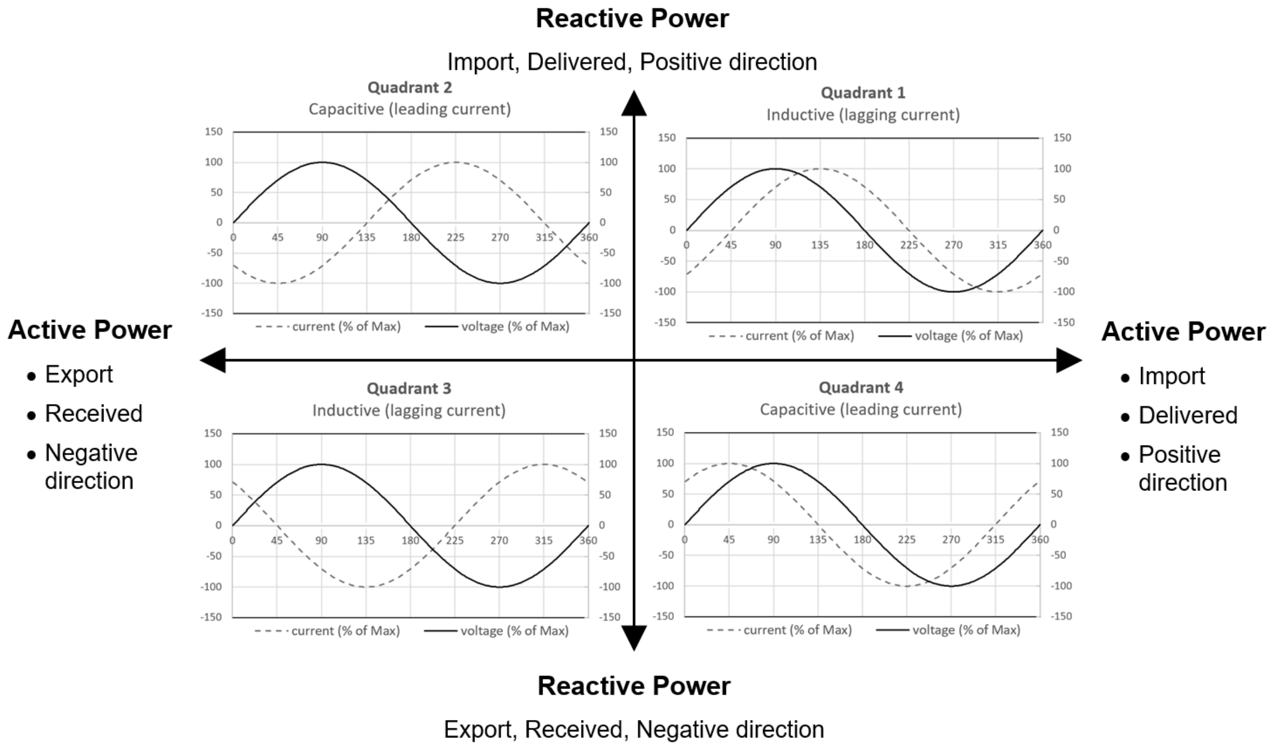

Figure 1 – Four quadrant power, normal conventions

5.2.2 Active power and energy

Active power and energy shall be determined on the basis of the following equations:

Instantaneous active power, expressed in watts (W)

$p(t) = u(t) \cdot i(t)$

where:

$u(t)$ is the instantaneous voltage expressed in volts (V)

$i(t)$ is the instantaneous current expressed in amperes (A)

Active power under sinusoidal conditions, expressed in watts (W)

$P = U \cdot I \cdot \cos\theta$

where:

U is the r.m.s. voltage expressed in volts (V)

I is the r.m.s current expressed in amperes (A)

θ is the phase angle of the voltage relative to the current

Active power (fundamental frequency only), expressed in watts (W)

$W = U_1 \cdot I_1 \cdot \cos\theta_1$

where:

U_1 is the r.m.s. voltage at the fundamental frequency expressed in volts (V)

I_1 is the r.m.s current at the fundamental frequency expressed in amperes (A)

θ_1 is the phase angle of U_1 relative to I_1 expressed in degrees (°)

Active energy, expressed in watt hours (Wh)

$$E(t) = \int_0^T p(t) \cdot dt = \int_0^T u(t) \cdot i(t) \cdot dt$$

Watt hours (WH) (active energy under sinusoidal conditions, fundamental frequency only), expressed in watt hours (Wh)

$$WH = \int W \cdot dt = \int U_1 \cdot I_1 \cdot \cos\theta \cdot dt$$

Directional quantities for active power and watt hours

Delivered: for $0° < \theta \leq 90°$, or, $270° < \theta \leq 360°$

$W_{del} = U \cdot I \cdot \cos\theta$

$$WH_{del} = \int W_{del}\, dt$$

Received: for $90° < \theta \leq 270°$

$W_{rec} = U \cdot I \cdot \cos\theta$

$$WH_{rec} = \int W_{rec}\, dt$$

5.2.3 Reactive power and energy

Reactive power and energy shall be determined on the basis of the following equations:

Reactive power expressed in volt ampere reactive (var)

$Q = U_x \cdot I_x \cdot \sin\theta_x$

where:

U_x is the r.m.s. voltage at a single frequency expressed in volts (V)

I_x is the r.m.s current at a single frequency expressed in amperes (A)

θ_x is the phase angle of U_x relative to I_x

Reactive power (fundamental frequency only) expressed in volt ampere reactive (var)

$VAR = U_1 \cdot I_1 \cdot \sin\theta_1$

Reactive energy (fundamental frequency only) expressed in volt ampere hour reactive (varh)

$$VARH = \int VAR \cdot dt = \int U_1 \cdot I_1 \cdot \sin\theta_1 \cdot dt$$

Directional quantities for reactive power and energy (fundamental frequency only)

Four quadrants:

$VAR_{q1} = U_1 \cdot I_1 \cdot \sin\theta_1$ for $0° < \theta \leq 90°$ (quadrant 1)

$VAR_{q2} = U_1 \cdot I_1 \cdot \sin\theta_1$ for $90° < \theta \leq 180°$ (quadrant 2)

$VAR_{q3} = U_1 \cdot I_1 \cdot \sin\theta_1$ for $180° < \theta \leq 270°$ (quadrant 3)

$VAR_{q4} = U_1 \cdot I_1 \cdot \sin\theta_1$ for $270° < \theta \leq 360°$ (quadrant 4)

Delivered: for $0° < \theta \leq 180°$

$$VAR_{del} = VAR_{q1} + VAR_{q2} = U_1 \cdot I_1 \cdot \sin\theta_1$$

$$VARH_{del} = \int VAR_{del} \cdot dt = \int U_1 \cdot I_1 \cdot \sin\theta_1 \cdot dt$$

Received: for $180° < \theta \leq 360°$

$$VAR_{rec} = VAR_{q3} + VAR_{q4} = U_1 \cdot I_1 \cdot \sin\theta_1$$

$$VARH_{rec} = \int VAR_{rec} \cdot dt = \int U_1 \cdot I_1 \cdot \sin\theta_1 \cdot dt$$

5.2.4 Apparent power and energy

Apparent power and energy shall be determined on the basis of the following equations:

Apparent power expressed in volt ampere (VA)

$$S = \sqrt{P^2 + Q^2}$$

Apparent power (fundamental frequency only) expressed in volt ampere (VA)

$$VA = \sqrt{W^2 + VAR^2}$$

Apparent energy (fundamental frequency only) expressed in volt ampere (VAh)

$$VAH = \int VA \cdot dt = \int \sqrt{W^2 + VAR^2} \cdot dt$$

Directional quantities for apparent power and energy (fundamental frequency only)

Delivered:

$$VA_{del} = \sqrt{W_{del}^2 + \left(VAR_{q1} + VAR_{q4}\right)^2}$$

$$VAH_{del} = \int VA_{del}\, dt$$

Received:

$$VA_{rec} = \sqrt{W_{rec}^2 + \left(VAR_{q2} + VAR_{q3}\right)^2}$$

$$VAH_{rec} = \int VA_{rec}\, dt$$

6 Metrological requirements

6.1 Rated operating conditions

6.1.1 Frequency

All values in the range f_{nom} ± 2 % where f_{nom} is to be specified by the manufacturer.

If the manufacturer specifies more than one nominal frequency, the rated operating conditions shall include the frequency ranges, f_{nom} ± 2 %, for all nominal frequencies.

6.1.2 Voltage

All values in the range U_{nom} ± 10 % where U_{nom} is to be specified by the manufacturer.

Meters designed to operate across a range of voltages shall have applicable U_{nom} values specified by the manufacturer. If the manufacturer specifies more than one nominal voltage, the rated operating conditions shall include the voltage ranges, U_{nom} ± 10 %, for all nominal voltages.

6.1.3 Current

I_{st} to I_{max}

I_{max}, I_{tr}, I_{min} and I_{st} are to be specified by the manufacturer in accordance with Table 1 and Table 2.

Continuous current at I_{max} is the value associated with self-heating.

Note: Annex E provides additional information about accuracy classes and current values.

Table 1 – Minimum current ratios for direct-connected meters

Direct connected	Accuracy class				
	A / 2	**B / 1**	**C / 0.5**	**D / 0.2**	**E / 0.1**
I_{max}/I_{tr}	≥ 50	≥ 50	≥ 50	≥ 50	≥ 50
I_{max}/I_{min}	≥ 100	≥ 125	≥ 250	≥ 250	≥ 250
I_{max}/I_{st}	≥ 1000	≥ 1250	≥ 1250	≥ 1250	≥ 1250

Table 2 – Minimum current ratios for transformer-operated meters

Transformer-operated	Accuracy class				
	A / 2	**B / 1**	**C / 0.5**	**D / 0.2**	**E / 0.1**
I_{max}/I_{tr}	≥ 24	≥ 24	≥ 24	≥ 24	≥ 24
I_{max}/I_{min}	≥ 60	≥ 120	≥ 120	≥ 120	≥ 120
I_{max}/I_{st}	≥ 480	≥ 600	≥ 1200	≥ 1200	≥ 1200

6.1.4 Power factor

For classes A / 2 and B / 1: From 0.5 inductive to 1 to 0.8 capacitive

For classes C / 0.5, D / 0.2 and E / 0.1: From 0.5 inductive to 1 to 0.5 capacitive.

For bi-directional meters the power factor range limits are valid in both directions.

6.1.5 Temperature

From lower temperature limit to upper temperature limit as specified by manufacturer.

The manufacturer shall specify the lower temperature limit from the values:

–55 °C, –40 °C, –25 °C, –10 °C, +5 °C.

The manufacturer shall specify the upper temperature limit from the values:

+30 °C, +40 °C, +55 °C, +70 °C.

6.1.6 Humidity

The manufacturer shall specify the environment class for which the instrument is intended:

H1: enclosed locations where the instruments are not subjected to condensed water, precipitation, or ice formations,

H2: enclosed locations where the instruments may be subjected to condensed water, to water from sources other than rain and to ice formations,

H3: open locations with average climatic conditions.

6.1.7 Connection modes

The manufacturer shall specify whether the meter is intended for direct connection, connection through current transformers or through current and voltage transformers.

The manufacturer shall specify the connection mode(s), the number of measurement elements of the meter and the number of phases of the electric system for which the meter is intended.

A meter in accordance with this Recommendation may have (but is not limited to) one or more of the following connection modes:

a) single-phase two-wire, 1 element
b) single-phase three-wire, 1 element (applicable only for balanced and symmetrical voltages)
c) single-phase three-wire, 2-element
d) three-phase four-wire 3-element
e) three-phase three-wire 2-element (applicable only in cases where leakage currents can be ruled out)
f) two-phase three-wire 2-element (intended for operation on two phases of a three-phase service. Can also be a three-phase meter operated as two-phase three-wire)

The manufacturer may specify alternative connection modes for poly-phase meters. These alternative connection mode(s) shall also be part(s) of the rated operating conditions.

6.1.8 Harmonics

The voltage and current shall be allowed to deviate from the sinusoidal form as described in 6.3.1.5.

6.1.9 Load balance

The load balance shall be allowed to vary from fully balanced conditions to current in only one current circuit for poly-phase meters and for single-phase 3-wire meters.

For bi-directional, poly-phase meters, the manufacturer shall specify if the rated operating conditions includes concurrent flow of current in the positive and negative directions on different phases.

6.1.10 Magnetic fields

AC, power frequency, continuous fields as described in 6.3.1.7

6.1.11 Electromagnetic fields

Radiated, radio-frequency, electromagnetic fields as described in 6.3.1.8.

Conducted disturbances induced by radio-frequency fields as described in 6.3.1.9.

Note: National authorities or regional legislation may specify certain values for various rated operating conditions. See Annex D.

6.2 Accuracy requirements

6.2.1 General

The manufacturer shall specify the accuracy class of the meter.

Accuracy classes shall be designated either by one of the letters: A, B, C, D or E, or equivalently, by one of the numbers: 2, 1, 0.5, 0.2 or 0.1.

Note: Refer to Annex E for additional information about accuracy classes and current values. Class B/class 1 is the lowest accuracy class recommended for large consumers, i.e. where consumption exceeds 5000 kWh/year, or another value chosen by the appropriate authority.

The meter shall be designed and manufactured such that its error does not exceed the base maximum permissible error (base mpe) for the specified class, when operated at reference conditions (see 6.2.2).

Outside of reference conditions, this Recommendation specifies additional error shift limits for influence factors (see 6.3).

Note: The error shift limits for temperature dependence are in the form of limits on the temperature coefficient.

The meter shall be designed and manufactured such that, when exposed to disturbances, significant faults do not occur, unless the fault is detected and acted upon by the means of a checking facility (see 6.4). The meter shall clearly indicate if such an event has occurred (see 3.2.18 and 3.2.19).

Note: The fault detection indication could take the form of a light flashing in the event of a fault.

6.2.2 Base maximum permissible errors

The intrinsic error (expressed in percent) shall be within the base maximum permissible error stated in Table 3 when the current and power factor are varied within the rated operating conditions, and when the meter is otherwise operated at reference conditions. National authorities may specify the base maximum permissible errors for subsequent verification and in-service inspections.

Table 3 - Base maximum permissible errors

Quantity		**Base maximum permissible errors (%) for meters of class**				
Current *I*	**Power factor**	**A / 2**	**B / 1**	**C / 0.5**	**D / 0.2**	**E / 0.1**
$I_{tr} \leq I \leq I_{max}$	Unity	± 2.0	± 1.0	± 0.5	± 0.2	± 0.1
	0.5 inductive to 1 to 0.8 capacitive (1)	± 2.5	± 1.5	± 0.6	± 0.3	± 0.15
	0.5 inductive to 1 to 0.5 capacitive			± 1.0	± 0.5	± 0.25
$I_{min} \leq I < I_{tr}$	Unity	± 2.5	± 1.5	± 1.0	± 0.4	± 0.2
	0.5 inductive to 1 to 0.8 capacitive	± 2.5	± 1.8	± 1.0	± 0.5	± 0.25
$I_{st} \leq I < I_{min}$	Unity	$\pm 2.5 \cdot I_{min}/I$	$\pm 1.5 \cdot I_{min}/I$	$\pm 1.0 \cdot I_{min}/I$	$\pm 0.4 \cdot I_{min}/I$	$\pm 0.2 \cdot I_{min}/I$
(1) The national authority may specify that the power factor requirement is from 0.5 inductive to 1 to 0.5 capacitive.						

Note: The combined maximum permissible error (CMPE) and the combined maximum error (CME) resulting from the type evaluation can be calculated as presented in Annex C. Regional or national authorities may require this CME to fulfil the CMPE or to meet other limits (not related to the CMPE) determined by the regional or national authorities.

6.2.3 No load

No significant energy shall be registered under conditions of no load.

For demand meters, there shall be no significant registration of demand at no load. Demand values shall not exceed 0.1 % of the maximum demand rating. These requirements apply to all demand values provided by the meter via the display and any data output.

Note 1: The test procedure is specified in section OIML R 46-2 2.2.3.

Note 2: The meter is always allowed to stop for currents below I_{st}.

6.2.4 Starting current

With voltage circuit(s) energised at nominal voltage, static meters shall start and continue to register at the current (and, in the case of poly-phase meters, with balanced load) specified by the manufacturer.

If the meter is designed for the measurement of energy in both directions, then the starting current test shall be applied with energy flowing in each direction.

6.3 Influence factors

6.3.1 Description of the influence factors

6.3.1.1 General

Influence factors and their value ranges are listed under Rated Operating Conditions (see 6.1). Some additional details such as value ranges and scope of applicability to different meters are described below. Unless otherwise stated below, the influence factors apply to all meters.

Influence factors shall not unduly affect the performance of the meter. Allowed effects of influence factors are specified in 6.3.1.10.

6.3.1.2 Temperature

Description:	Ambient temperature.
Value range:	Lower to upper temperature limit.

6.3.1.3 Self-heating

Description:	Heat generated by the meter itself during operation
Value range:	Continuous current flowing through the meter at I_{max}

6.3.1.4 Load balance

Description:	Unequal currents in each current circuit caused by different devices or loads.
Value range:	Current in one current circuit only.
Applicability:	Only applicable for poly-phase meters and single-phase 3-wire meters

6.3.1.5 Harmonics

Description:	Non-sinusoidal waveforms in the voltage and current circuits may be caused by non-linear loads on the electrical network.
Value ranges:	1) Harmonics in voltage and current: Current and voltage signal, the amplitude of a single harmonic shall not be more than 0.12 U_1/h for voltage and I_1/h for the current, where h is the harmonic number and U_1 and I_1 are the respective fundamentals: a) Quadriform waveform b) Peaked waveform 2) Integral cycle load control test(1): Current signal, twice amplitude, switched off every second period. Note (1): This is also known as interharmonics in the current circuit – burst fired waveform test. 3) Odd harmonics in the AC current circuit: a) Current signal, 45° phase-fired waveform. b) Current signal, 90° phase-fired waveform. c) Current signal, 135° phase-fired waveform. 4) High-order harmonics: a) Voltage circuits, 0.02 U_{nom}, 15 f_{nom} to 40 f_{nom}. b) Current circuits, 0.1 I_{tr}, 15 f_{nom} to 40 f_{nom}. 5) DC in the AC current circuit(1): Current signal, twice amplitude ($I = I_{max}/\sqrt{2}$), half-wave rectified, only applicable for static direct-connected meters(2). Note (1): This influence is also known as DC and even harmonics in the a.c. current circuit. Note (2): National authorities may determine if this requirement is applicable.
Applicability:	DC in the AC current circuit is only for direct-connected meters.

6.3.1.6 Reversed phase sequence

Description / value range:	Reversal or interchange of any two phases.
Applicability:	Only applicable to poly-phase meters and single-phase 3-wire meters

6.3.1.7 Magnetic field (AC, power frequency) of external origin.

Description:	A power frequency (f_{nom}) magnetic field of origin external may be generated by nearby powerlines or electrical equipment.
Value range:	400 A/m

6.3.1.8 Radiated, RF, electromagnetic fields.

Description:	Radiated, RF, electromagnetic fields may be caused by radio transmitters and communication devices.
Value range:	a) f = 80 MHz to 2.0 GHz, Field strength ≤ 10 V/m b) f = 2.0 GHz to 6.0 GHz, Field strength ≤ 3 V/m

6.3.1.9 Conducted disturbances, induced by radio frequency fields.

Description:	Conducted disturbances, induced by radio frequency fields may be caused by radio transmitters and communication devices.
Value range:	f = 150 kHz to 80 MHz, Amplitude ≤ 10 V

6.3.1.10 Fast load current variation

Description:	Fast load current variations may be caused by loads such as temperature regulated heaters, air conditioners, and arc welding systems.
Value range:	10 I_{tr} for direct connected meters; 20 I_{tr} for transformer-operated meters t_{on} = 10 s, t_{off} = 10 s, 4 hours t_{on} = 5 s, t_{off} = 5 s, 4 hours t_{on} = 5 s, t_{off} = 0.5 s, 4 hours

6.3.2 Allowed effects of the influence factors

The temperature coefficient of the meter shall fulfil the requirements of Table 4 when the meter is otherwise operated at reference conditions.

Table 4 - Limits for temperature coefficient of error

Influence quantity	Power factor	Limits for temperature coefficient (%/°C[3]) for meters of class				
		A / 2	B / 1	C / 0.5	D / 0.2	E / 0.1
Temperature coefficient (%/°C [3]), over any interval, within the temperature range, which is not less than 15 °C and not greater than 23 °C, for current $I_{tr} \le I \le I_{max}$	1	± 0.1	± 0.05	± 0.03[1]	± 0.01[2]	± 0.005[2]
	0.5 inductive	± 0.15	± 0.07	± 0.05[1]	± 0.02[2]	± 0.01[2]

[1] These values are doubled above 70 °C. National authorities can specify 50 °C to compensate for higher current rating.

[2] These values are doubled above 70 °C and below –10 °C. National authorities can specify 50 °C to compensate for higher current rating.

[3] The SI unit of measurement for temperature is Kelvin (K). Temperature ranges expressed in °C are equivalent to temperature ranges express in K.

Note: The test procedure is specified in OIML R 46-2 2.3.1.

When the load current and power factor are held constant at a point within the rated operating range with the meter otherwise operated at reference conditions, and when any single influence quantity is varied from its value at reference conditions to its extreme values defined in 6.1 and 6.3.1, the variation of error shall be such that the additional percentage error is within the corresponding limit of error shift stated in Table 5. The meter shall continue to function after the completion of each of these tests.

Table 5 - Limit of error shift due to influence factors

Influence quantity	Test Clause, OIML R 46-2	Value of current	Power factor cos θ(1)	Limit of error shift (%) for meters of class				
				E / 0.1	**D / 0.2**	**C / 0.5**	**B / 1**	**A / 2**
Self-heating	2.3.2	I_{max}	1	± 0.05	± 0.1	± 0.5	± 0.7	± 1
			0.5	± 0.05	± 0.1	± 0.7	± 1.0	± 1.5
Load balance	2.3.3	$I_{tr} \leq I \leq I_{max}$	1	± 0.15	± 0.3	± 0.7	± 1.0	± 1.5(2)
			0.5	± 0.25	± 0.5	± 1	± 1.5	± 2.5(2)
Voltage variation(3)	2.3.4	$I_{tr} \leq I \leq I_{max}$	1	± 0.05	± 0.1	± 0.25	± 0.5	± 1.0
			0.5	± 0.1	± 0.2	± 0.5	± 1.0	± 1.5
Frequency variation	2.3.5	$I_{tr} \leq I \leq I_{max}$	1	± 0.05	± 0.1	± 0.2	± 0.5	± 0.8
			0.5	± 0.05	± 0.1	± 0.2	± 0.7	± 1.0
Harmonics in voltage and current circuits	2.3.6.1	$I_{tr} \leq I \leq I_{max}$	1	± 0.2	± 0.4	± 0.5	± 0.8	± 1.0
Integral cycle load control test	2.3.6.2	10 I_{tr}	1	± 0.3	± 0.6	± 1.5	± 3.0	± 6.0
Odd harmonics in the current circuit	2.3.6.3	10 I_{tr}	1	± 0.3	± 0.6	± 1.5	± 3.0	± 6.0
High-order harmonics	2.3.6.4	I_{tr}	1	± 0.25	± 0.5	± 0.5	± 1.0	± 1.0
DC in the AC current circuit	2.3.6.5	$I_{max}/\sqrt{2}$	1	± 0.5	± 1	± 1.5	± 3.0	± 6.0
Reversed phase sequence	2.3.7	10 I_{tr}	1	± 0.05	± 0.05	± 0.1	± 0.5	± 1.0
Magnetic field (AC, power frequency) of external origin	2.3.8	10 I_{tr}, I_{max}	1	± 0.25	± 0.5	± 1.0	± 2.0	± 3.0
Radiated, RF, electromagnetic fields	2.3.9.1	10 I_{tr}	1	± 0.5	± 1	± 2.0	± 2.0	± 3.0
Conducted disturbances, induced by radio frequency fields	2.3.9.2	10 I_{tr}	1	± 0.5	± 1	± 2.0	± 2.0	± 3.0
Fast load current variation	2.3.10	10 I_{tr}	1	± 0.25	± 0.5	± 1.0	± 2.0	± 3.0

(1) Inductive

(2) The error shift may exceed the value specified in the table provided the error is within ± 2.5 %.

(3) For poly-phase meters the requirement is for symmetrical voltage variations.

6.4 Disturbances

6.4.1 Description of the disturbances

6.4.1.1 Magnetic field (AC, power frequency) of external origin

Description:	A power frequency (f_{nom}) magnetic field of origin external may be generated by nearby powerlines or electrical equipment.
Value range:	1000 A/m, 3 s

6.4.1.2 Electrostatic discharges

Description:	An electrostatic discharge may result from an electrostatically charged object (such as a person) touching, or coming in close contact with, a meter.
Value range:	8 kV contact discharge; 15 kV air discharge.

6.4.1.3 Fast Transients

Description:	Fast transient may be generated by power circuit switching and may be propagated onto power lines and signal lines.
Value range:	Voltage and current circuits: 4 kV; Auxiliary circuits: 2 kV.

6.4.1.4 Severe voltage variations

Description:	Severe voltage variations may be caused by faults in the supply network.
Value range:	$0.8\ U_{nom} \leq U < 0.9\ U_{nom}$; $1.1\ U_{nom} < U \leq 1.15\ U_{nom}$; $U < 0.8\ U_{nom}$

6.4.1.5 One or two phases interrupted

Description:	One or two phases interrupted(1) may be cause be faults in the supply network.
Value range:	One or two phases removed.
Applicability:	Poly-phase meters. Two phases interrupted is only for those connection modes where a missing phase means that energy can be delivered. This requirement applies only to fault conditions of the network, not for an alternative connection mode. A poly-phase meter which is powered from only one of its phases shall not have the voltage of that phase interrupted for the purposes of this test.

Note (1): This is also known as voltage unbalance.

6.4.1.6 Continuous (DC) magnetic induction of external origin

Description:	Continuous (DC) magnetic induction of external origin may be caused by a nearby permanent magnet(1)
Value range:	Flux density(2) as the centre of the pole surface: 400 mT ± 10 mT

Note (1): Manufacturers may additionally include an alarm upon detection of a continuous (DC) magnetic induction of greater than 400 mT.

Note (2): National authorities may select a lower magnetic induction for national requirements.

6.4.1.7 Voltage dips and interruptions

Description:	Voltage dips and interruptions may be caused by load changes or other faults on supply networks.
Value range:	100 % voltage reduction, 5/6 cycles(1) 100 % voltage reduction, 50/60 cycles(1) 100 % voltage reduction, 1/1(1) 95 % voltage reduction, 250/300 cycles(1) 60 % voltage reduction, 5/6(1) 60 % voltage reduction, 50/60 cycles(1) 30 % voltage reduction, 0.5/0.5 cycle(1) 30 % voltage reduction, 1/1 cycle(1) 50 % voltage reduction, 3000/3600 cycles(1) (1) "Cycle(s)" means a number of nominal power line frequency at either 50 Hz or 60 Hz (e.g.) "50/60" means "50 cycles for 50 Hz test" and "60 cycles for 60 Hz test".

6.4.1.8 Radiated, RF, electromagnetic fields

Description:	Radiated, RF, electromagnetic fields may be caused by radio transmitters and communication devices.
Value range:	f = 80 MHz to 2.0 GHz, 30 V/m, amplitude modulated, without current. f = 2.0 GHz to 6.0 GHz, 10 V/m, amplitude modulated, without current.

6.4.1.9 Surges on AC mains power lines

Description:	Surges may be caused by switching and lightning transients.
Value range:	Voltage circuits [(1)]: 2 kV line to line, 4 kV line to earth; Auxiliary circuits: 1 kV line to line, 2 kV line to earth. [(1)] In meters without PE terminal: 4 kV line to neutral.

6.4.1.10 Damped oscillatory waves immunity test

Description:	Damped oscillatory waves are a phenomena associated with some high and medium voltage substations.
Value range:	Voltage circuits: Common mode 2.5 kV, differential mode 1.0 kV.
Applicability:	Transformer-operated meters.

6.4.1.11 Short-time overcurrent

Description:	A short-time overcurrent may be caused by a short-circuit, fault or other condition on the supply network.
Value range:	30 I_{max} for direct-connected meters, 20 I_{max} for transformer-operated meters.

6.4.1.12 Impulse voltage

Description:	Impulse voltages may be caused by lightning strikes.
Value range:	1.5 kV (≤ 100 V); 2.5 kV (≤ 150 V); 4 kV (≤ 300 V); 6 kV (≤ 600 V). Alternatively, national authorities may specify higher values up to: 3 kV (≤ 100 V); 6 kV (≤ 150 V); 10 kV (≤ 300 V); 12 kV (≤ 600 V).

6.4.1.13 Earth fault

Description:	An earth fault is the unintended connection of circuits to earth (ground).
Value range:	Earth fault in one phase.
Applicability:	This test only applies to three-phase four-wire transformer-operated meters connected to distribution networks which are equipped with earth fault neutralizers or in which the star point is isolated.

6.4.1.14 Operation of auxiliary devices

Description:	The operation of auxiliary devices.
Value range:	Auxiliary devices operated with $I = I_{min}$ and I_{max}
Applicability:	All meters with auxiliary devices.

6.4.1.15 Vibration

Description:	Vibration may occur during transportation of the meter.
Value range:	Vibration in three mutually perpendicular axes

6.4.1.16 Shock

Description:	Shocks may be caused by dropping the meter during transportation or other similar events.
Value range:	Pulse shape: Half-sine, Peak acceleration: 300 ms^{-2}, Pulse duration: 18 ms

6.4.1.17 Protection against solar radiation

Description:	Solar radiation is the exposure to sunlight.
Value range:	0.76 $W \cdot m^2 \cdot nm^{-1}$ at 340 nm, with cycling rig for 66 days
Scope:	For outdoor meters only.

6.4.1.18 Dry Heat

Description:	Dry heat is very high temperature with low humidity.
Value range:	One standard temperature higher than upper specified temperature limit, 2 h

6.4.1.19 Cold

Description:	Cold is low temperature below the lower temperature limit.
Value range:	One standard temperature lower than lower specified temperature limit, 2 h

6.4.1.20 Damp Heat

Description:	Damp heat is high temperature with high humidity.
Value range:	H1: 30 °C, 85 %; H2: Cyclic 25 °C, 95 % to 40 °C, 93 %; H3: Cyclic 25 °C, 95 % to 55 °C, 93 %.

6.4.1.21 Durability

Description:	The use of a meter for a sustained period of time. This disturbance is associated with the performance of the meter over long-term use.
Value range:	High current and/or temperature for a sustained period of time

6.4.1.22 Ring wave

Description:	Ring waves are oscillatory transients and may be caused by switching of electrical networks and reactive loads, faults or insulation breakdown of power supply circuits or lighting.
Value range:	Voltage and current circuits: 4 kV (line to ground); 2 kV (line to line)

6.4.1.23 Differential mode current disturbances (2-150 kHz)

Description:	Differential mode current disturbances in the range of 2 kHz to 150 kHz may be generated by equipment such as power electronics, inverters and mains communication systems.
Value range:	Differential mode current disturbances in the range of 2 kHz to 150 kHz

6.4.2 Allowed effects of disturbances

The meter shall withstand disturbances, as described in 6.4.1, which may be encountered under conditions of normal use; as stated in 6.2.1, no significant fault shall occur for any disturbance.

An error shift larger than the fault limit prescribed in Table 6 constitutes a significant fault. For disturbances where no current is applied, a change in the registers or pulses of the test output shall not be considered as a significant fault if the change in the registers or equivalent energy of the test output, expressed in kWh, is less than critical change value. The critical change value (x), is derived from the following formula:

$$x = 10^{-6} \times m \times U_{nom} \times I_{max}$$

where

x is the critical change value expressed in kWh or kvarh

m is the number of measuring elements

U_{nom} is the nominal voltage expressed in volts

I_{max} is the maximum current expressed in amperes.

Table 6 - Fault limits and other significant fault criteria for disturbances

Disturbance quantity		Test Clause, OIML R 46-2	Significant fault criteria[1]	Fault limit[2] (%) for meters of class				
				A / 2	B / 1	C / 0.5	D / 0.2	E / 0.1
Magnetic field (AC, power frequency) of external origin		2.4.1	Critical change value.	–	–	–	–	–
Electrostatic discharges		2.4.2	Critical change value.	–	–	–	–	–
Fast transients		2.4.3	Fault limit.	± 6.0	± 4.0	± 2.0	± 1.0	± 0.05
Severe voltage variations[3]		2.4.4	Fault limit.	± 1.5	± 1	± 0.6	± 0.3	
One or two phases interrupted		2.4.5	Fault limit.	± 4	± 2	± 1	± 0.5	± 0.25
Continuous (DC) magnetic induction of external origin		2.4.6	Fault limit.	± 3	± 1.5	± 0.75	± 0.5	
Voltage dips and interruptions		2.4.7	Critical change value.	–	–	–	–	–
Radiated, RF, electromagnetic fields		2.4.8	Critical change value.	–	–	–	–	–
Surges on AC mains power lines		2.4.9	Critical change value.	–	–	–	–	–
Damped oscillatory waves immunity test		2.4.10	Fault limit. Meter function not perturbed during test.	± 3.0	± 2.0	± 2.0	± 1.0	± 0.05
Short-time overcurrent	Transformer-operated	2.4.11	Fault limit.	± 1.0	± 0.5	± 0.05	± 0.05	
	Direct connected			± 1.5	± 1.5	± 0.05	± 0.05	
Impulse voltage		2.4.12	Critical change value. No flashover, disruptive discharge or puncture during test.	–	–	–	–	–
Earth fault		2.4.13	Fault limit.	± 1.0	± 0.7	± 0.3	± 0.1	± 0.05
Operation of auxiliary devices		2.4.14	Fault limit.	± *b*/3[5]	± *b*/3	± *b*/3	± *b*/3	
Vibration		2.4.15.1	Fault limit[6].	± *b*/3	± *b*/3	± *b*/3	± *b*/3	
Shock[5]		2.4.15.2	Fault limit[6].	± *b*/3	± *b*/3	± *b*/3	± *b*/3	
Protection against solar radiation		2.4.16	Critical change value[7].	–	–	–	–	–

Disturbance quantity	Test Clause, OIML R 46-2	Significant fault criteria[1]	Fault limit[2] (%) for meters of class				
			A / 2	**B / 1**	**C / 0.5**	**D / 0.2**	**E / 0.1**
Dry heat	2.4.17.1	Fault limit.	± *b*/3	± *b*/3	± *b*/3	± *b*/3	
Cold	2.4.17.2	Fault limit.	± *b*/3	± *b*/3	± *b*/3	± *b*/3	
Damp Heat	2.4.17.3 2.4.17.4	Fault limit	± 0.2	± 0.1	± 0.05	± 0.05	
Durability	2.4.18	Fault limit.	± *b*/3	± *b*/3	± *b*/3	± *b*/3	
Ring wave	2.4.19	Critical change value.	–	–	–	–	–
Differential mode current disturbances (2-150 kHz)	2.4.20	Fault limit.	± 6.0	± 4.0	± 2.0	± 0.8	± 0.5

(1) In all cases, a significant fault occurs if the functionality of the meter becomes impaired, or the meter is damaged (including evidence of corrosion).

(2) Fault limits are error shift limits associated with disturbances.

(3) Below 0.8 U_{nom}, the limits are +10 % to -100 %.

(5) *b* is the base maximum permissible error.

(6) Supply and load control switches are allowed to change state during these disturbances.

(7) Also see 7.1, 7.2, and 7.4.1

6.5 Durability

The meter shall be designed to maintain an adequate stability of its metrological characteristics over a period of time specified by the manufacturer, provided that it is properly installed, maintained and used according to the manufacturer's instructions when in the environmental conditions for which it is intended. The manufacturer shall provide evidence to support the durability claim.

The meter shall be designed to reduce as far as possible the effect of a defect that would lead to an inaccurate measurement result.

The meter shall be designed and manufactured such that either

a) significant durability errors do not occur, or

b) significant durability errors are detected and acted upon by means of a durability protection.

7 Technical Requirements

7.1 Meter markings

7.1.1 All meters

National authorities shall determine what information must be marked on every meter. It is recommended that the following be considered:

a) Manufacturer
b) Manufacturer address
c) U_{nom}
d) I_{max}
e) I_{tr}
f) I_{min}
g) I_{st}
h) Approval mark(s)
i) Serial number
j) Number of phases

k) Number of wires
l) Register multiplier (if other than unity)
m) Meter constant(s)
n) Year of manufacture
o) Accuracy class
p) Directionality of energy flow
q) Meter type (model designation)
r) Temperature range
s) Humidity and water protection information
t) Impulse voltage protection information
u) f_{nom}
v) The connection mode(s) for which the meter is specified
w) Connection terminals uniquely identified to distinguish between terminals.

The markings shall be indelible, distinct and legible from outside the meter. The markings of meters intended for outdoor locations shall withstand solar radiation. Multiple values of U_{nom} and f_{nom} may be marked if so specified by the manufacturer.

If the serial number is affixed to dismountable parts, the serial number shall also be provided in a position where it is not readily disassociated from parts determining the metrological characteristics.

Symbols or their equivalent may be used where appropriate. See e.g. IEC 62053-52, *Electricity metering equipment (AC) – Particular requirements – Part 52: Symbols* [12], or other designations accepted by local jurisdictions.

7.1.2 Demand meters

In addition to the requirements applicable to all meters (see 7.1.1) demand meter shall be marked with the following information:

1) Response period or demand interval
2) Update interval (if applicable)
3) Maximum demand rating
4) All information essential for determination of the demand from the meter indication.
5) For primary rated meters; also:
   a) Current transformer rating, e.g. CT 100-5 A
   b) Voltage transformer rating, e.g. VT

7.2 Metrological seals

The meter case shall have a means for applying a metrology seal(s) in such a way that the internal parts of the meter are accessible only after breaking the sealing mechanism. Seal(s) is(are) not required if the meter case cannot be opened without damaging it to such an extent that the attempt is clearly visible and the meter case cannot be reused.

The connection terminals of the transformers including LPITs, both at the meter and at the LPIT end, shall have means for being sealed with a metrology seal.

Metrological seals on electricity meters intended for outdoor locations shall withstand solar radiation.

Note: For software-controlled meters, refer to 7.3 for further requirements related to metrological seals.

7.3 Requirements for software-controlled meters

Requirements for software-controlled meters are provided in Annex B.

7.4 Suitability for use

7.4.1 Readability of result

The meter shall have one (or more) indicating device(s) which is (are) capable of presenting or displaying the numerical value of each legal unit of measure for which the meter is approved. The indicating device shall be easy to read and the characters of measurement results shall as minimum be 4 mm high. Any decimal fractions shall be clearly indicated; for mechanical registers, any decimal fraction drum shall be marked differently.

The indicating device shall not be significantly affected by exposure to normal operating conditions over the maximum duration of the meter lifetime.

The indicating device shall be able to display all data relevant for billing purposes. In the case of multiple values presented by a single indicating device it shall be possible to display the content of all relevant memories. For automatic sequencing displays, each display of register for billing purposes shall be retained for a minimum of 5 s.

For multi-tariff meters, the register which reflects the active tariff shall be indicated. It shall be possible to read each tariff register locally and each register shall be clearly identified.

Electronic registers shall be non-volatile so that they retain stored values upon loss of power. Stored values shall not be overwritten and shall be capable of being retrieved upon restoration of power. The register shall be capable of storing and displaying an amount of energy that corresponds to the meter running at $P = U_{nom} \times I_{max} \times n$ for at least 4000 h, where n is the number of phases. This capability for storage and display applies to all registers relevant for billing including positive and negative flow registers for bi-directional meters and tariff registers for multi-tariff meters.

Note: The National Authority may change the minimum time required for register rollover.

In the case of electronic registers, the minimum retention time for results is one year for a disconnected meter. Electronic indicating devices shall be provided with a display test that switches all the display segments on then off for the purpose of determining whether all display segments are working.

7.4.2 Testability

7.4.2.1 Test output

The meter shall be equipped with a test output for efficient testing, such as a rotor with a mark or a test pulse output. The manufacturer shall declare the necessary number of pulses to ensure a standard deviation of measurement less than 0.1 base mpe, at Imax, Itr and Imin.

For meters with the accuracy class of E / 0.1, this number of pulses to ensure a standard deviation of measurement may be larger than 0.1 base mpe, but shall not exceed ± 0.02 %.

The relation between the measured energy given by the test output and the measured energy given by the indicating device shall comply with the meter constant marking on the name-plate.

If the meter is capable of supporting multiple meters constants, or a range of meter constants, all shall correctly express the relation between the measured energy given by the test output and the measured energy given by the indicating device.

Note: The test output may also be used for other functions.

The wavelength of the radiated signals for light emitting systems shall be between 550 nm and 1 000 nm. The output device in the meter shall generate a signal with a radiation strength E_T over a defined reference surface (optically active area) at a distance of 10 mm ± 1 mm from the surface of the meter, with the following limiting values:

ON-condition: $50\ \mu W/cm^2 \leq E_T \leq 7500\ \mu W/cm^2$

OFF-condition: $E_T \leq 2\ \mu W/cm^2$

7.4.2.2 Test mode for demand meters

Demand meter may be equipped with a test mode. Demand meters equipped with a test mode shall comply with the following requirements:

a) The meter design shall ensure there are no internal or external factors which can cause a difference between the measured values obtained via the test mode and normal operating modes.

b) The error differential between the test results in normal mode and those in test mode shall not exceed 0.2 %.

7.5 Categories of meters

Meters shall comprise the following components:

- Measuring element(s)
- Register(s)
- Indicating device(s)
- Test output(s).

Measuring elements include voltage circuit(s) and current circuit(s) and processing unit(s).

Meters shall be either direct connected or transformer-operated.

Meters may include the following components:

- Internal clock – synchronous and/or crystal controlled
- Auxiliary devices.

Meters shall fall into one or more of the following categories:

- Active energy meter or watt hour meter
- Reactive energy meter or var hour meter
- Volt ampere hour meter

Meters may be interval meters.

Meters may be multi-tariff (multi-rate) meters.

Meters shall, at minimum, be capable of measuring energy in one direction (positive direction). The meters may be capable of measuring energy in both positive and negative directions (bi-directional).

7.6 Direction of energy flow

7.6.1 General

Where a manufacturer has specified that a meter is capable of bidirectional energy flow, the meter shall correctly handle both positive and negative mean energy flow and the meter shall fulfil the requirement of this Recommendation for energy flow in both directions. The polarity of energy flow shall be defined by the manufacturer's connection instructions for the meter. Mean energy flow refers to the power integrated over at least one cycle of the nominal frequency.

Where a manufacturer has specified that a bi-directional, poly-phase meter is capable of concurrent energy flow in the positive and negative direction on different phases, the meter shall correctly register this energy flow and fulfil the requirements of this Recommendation.

A meter shall fall into at least one of the following categories:

- single-register, bi-directional:
  where the meter is specified as capable of measuring both positive and negative mean energy flow, and where the net result will be placed in a single register;

- two-register, bi-directional:
  where the meter is specified as capable of measuring both positive and negative mean energy flow, as defined by the connection of the meter, and where the positive result and negative result are placed in different registers;

- single-register, positive direction only:
  where the meter is specified as capable of measuring and registering only positive mean energy flow. It may inherently, by its design, register only positive mean energy flow or it may be equipped with a reverse running detent;

- single-register, uni-directional:
  where the meter is specified as capable of measuring and registering the absolute value of the mean energy flow. Normally such a meter will register all energy as consumed energy independent of the true direction of the energy flow or of how the meter is connected.

For bi-directional meters, energy registration shall occur in the correct register when the direction of flow changes.

Note 1: The terms “single-register” and “two-register” in the list above refer to the basic energy register(s) only. A meter may have other registers, e.g. for storage of tariff and/or phase information.

Note 2: The national authority may determine what meter types and calculation methods are appropriate.

7.6.2 Performance requirements for apparent energy meters

Apparent energy recorded by the meter shall be allocated into a register identified as VAH_{del} where that apparent energy was measured concurrently with watt hours delivered. In addition, the var energy used to calculate VAH_{del} shall also be coincident with watt hours delivered.

Apparent energy recorded by the meter shall be allocated into a register identified as VAH_{rec} where that apparent energy was applied concurrently with watt hours received. In addition, the var energy used to calculate VAH_{rec} shall also be coincident with watt hours received.

No apparent energy concurrent with watt hours delivered shall be recorded in a VAH_{rec} register and no apparent energy concurrent with watt hour received shall be recorded in a VAH_{del} register.

Note: Refer to 5.2.4 for more information on the apparent energy quantities.

7.7 Demand meters

7.7.1 Maximum demand register

The meter shall record and store the value of maximum demand in the maximum demand register. The value shall be subsequent of the most recent maximum demand reset. The meter shall be capable of displaying maximum demand either on demand, via a regular scroll sequence or continuously.

7.7.2 Maximum demand reset device

Demand meters with maximum demand register(s) shall have a maximum demand reset device. The reset device may be mechanical or electronic.

A mechanical reset device in its normal position shall not affect the values stored in maximum demand registers and/or displayed by them. Means shall be provided for sealing the reset device in this position. Resetting of any maximum demand register shall only be possible either after breaking the seal or with a special tool. Activation of a mechanical reset device shall have the effect of resetting demand values stored any maximum demand register to zero.

For an electronic reset device, resetting of the maximum demand register shall be performed through an on-board device or a remote mechanism. Activation of an electronic reset device may have the effect of resetting demand values stored in any maximum demand register to zero, or to the current demand value.

7.7.3 Demand interval

The demand interval shall be 15, 20, 30 or 60 minutes, using either a sliding window or block demand response.

Sliding window responding meters shall be comprised of consecutive 5-minute demand subintervals.

Demand intervals shall not deviate from the nominal demand interval by more than 0.2 % (e.g. 1.8 s for nominal 15-minute demand interval).

7.7.4 Demand interval indication

Demand meters shall be equipped with a demand interval indication to be used to assess the accuracy of the demand intervals and subintervals.

The demand interval indication shall provide a means for indicating the start and end of each demand interval (for block) or subinterval (for sliding window). The indication may be a pulse output or other form of discrete indication such as a display annunciator, relay output or light output. If the indication is on the display or in the form of a light output, it shall be capable of being detected by conventional optical pick up means.

7.7.5 Demand interval changes

In the case of meters that establish demand using a demand interval length other than that programmed, the demand registration will be deemed acceptable on condition that:

a) the meter discards any demand measurement which is established on the basis of energy data accumulated over an interval which is either shorter or longer than the programmed interval length or;

b) where the energy data is accumulated over an interval of less than the programmed interval length, the demand value is calculated using the energy data as if it was registered over the programmed interval length.

In the case of meters that establish demand on the basis of sliding window algorithms, the provisions of a) and/or b) above, shall apply to the subinterval. In addition, the calculation for sliding window demand shall be based on contiguous running time subinterval data. Demand measurements subsequent to a power outage lasting greater than a complete subinterval shall be determined as if the previous two subintervals contained no energy data.

In the case of meters that have multiple programmable time references, which could impact an energized meters demand calculation:

a) The requirements for demand intervals shall apply to each time reference available on the meter.

b) The meter shall be capable of locking out and preventing the use of any time reference that is not verified when the meter is sealed.

Note: For a meter which has an internal clock time reference which is only used during a power outage, there is no impact on the demand calculation.

7.7.6 Calculation of Demand

All demand quantities shall be established on the basis of energy registration measured over integration periods defined by the demand interval.

All demand quantities shall be established from corresponding energy values that are established in accordance with the requirements of energy meters established in this Recommendation.

Meters shall acquire any energy data used in establishing the demand registration either continuously or at a rate of at least once per minute.

7.7.7 Allocation of demand

Demand quantities shall be appropriately allocated to demand registers. In particular:

a) Demand derived from active energy measured in the positive direction shall only be allocated into a demand register associated with the positive direction.

b) Demand derived from active energy measured in the negative direction (where applicable) shall only be allocated into a demand register associated with the negative direction.

Corresponding requirements shall apply for demand associated with reactive energy and apparent energy (where applicable).

7.7.8 Performance Requirements

Performance requirements apply to all demand values provided by the meter via the display and any data output.

There shall be no significant registration at no load. Demand values shall not exceed 0.1 % of the maximum demand rating.

7.8 Requirements for interval and multi-tariff meters

Manufacturers shall specify the interval data storage capabilities of the meters (e.g.: 200 days for 30-minute interval data).The minimum storage period for stored data shall be determined by national authorities. The specified storage capabilities shall be listed on the certificates of approval. For interval meters, the summation of interval data shall equate to the energy accumulation register value over the same period.

For multi-tariff meters, only a single tariff register (in addition to the energy accumulation register) shall be active at any time. The summation of values recorded in each multi-tariff register shall equate to the value recorded in the energy accumulation register.

7.9 Requirements for internal clocks

The internal clocks of meters shall meet the relevant timekeeping accuracy requirements specified in the IEC 62054-21:2004-05 [11], clause 7.5 “Functional requirements and tests - accuracy”.

7.10 Requirement for remote display units

[To be added]

7.11 Requirements for modular components

[To be added].

8 Requirements for kinds of meters

8.1 Requirements for multi-branch meters

Requirements for multi-branch meters are provided in Annex A.

8.2 Requirements for street light metering

[To be added].

Annex A
Requirements for multi-branch meters
(Mandatory)

A.1 Overview

This annex contains additional requirements that apply for multi-branch meters.

A.2 Type Approval

A.2.1 General

The following requirements are applicable for the type approval of multi-branch meters.

a) Meters shall be designed so that every channel is identical.

b) For testing purposes only, every branch shall include an individual pulse output or the registers shall have sufficient resolution to detect a single pulse, with a minimum resolution of 1 Wh.

c) If the meter is designed to measure single-phase connections, the meter shall comply with the base maximum permissible errors for the accuracy class on the single-phase connections. This shall be assessed by testing one or more single-phase channel (randomly selected).

d) If the meter is designed to measure three phase connections, the meter shall comply with the base maximum permissible errors for the accuracy class for all three connections. This shall be assessed by testing one group of three channels (randomly selected).

e) Cross-channel influences: For any channel, it shall comply with the base maximum permissible errors for the accuracy class, and comply with requirements under conditions of no load, while energy is flowing in all other channels.

f) For all other requirements for type approval, the meter shall meet the requirements in each configuration. It is not necessary to test every possible configuration provided the testing of specific configurations is representative of all configurations.

g) Requirements for self-heating shall be met applying maximum current and voltage to all branches.

h) If the meter is designed to operate with a family of LPITs, with identical characteristics, but different primary current values, each additional type shall comply with the base maximum permissible errors (initial intrinsic error), no load and starting requirements.

Note: The test procedures for multi-branch meters are specified in OIML R 46-2, 2.5 and Annex B.

A.2.2 Channel configuration and sealing for multi-branch meters

The configuration of the channels for multi-branch meters is considered to be a metrologically relevant parameter. The configuration of the channels includes which channels are grouped together to measure poly-phase circuits.

For multi-branch meters, the metrological seal(s) shall also secure the meter along with the connected LPITs.

Annex B
Requirements for software-controlled meters (Mandatory)

B.1 Introduction

These requirements are based on OIML D 31:20XX *General requirements for software-controlled measuring instruments* [13]. The requirements specified in this Annex apply:

- Only to the legally relevant parts of an electricity meter, e.g. software, parameters, the measured quantity value, measurement result and measurement data; and
- Equally to non-dynamic and dynamic modules of legally relevant software.

The manufacturer is responsible for producing electricity meters and legally relevant software that conforms to the approved type and the documentation submitted for type evaluation.

National authorities shall determine what are considered to be: an authorised modification, loading or changes for software securing and protection (B.2.3), an authorised person for support of fault and defect detection (B.2.6) and an authorised person for a verified update (B.4.2) and a traced update (B.4.3)

Means described in B.2.1and B.3.1B.2.1 shall be provided to allow for the evaluation of conformity.

The terms used in this Annex conform to the terms and definitions specified in OIML D 31:20XX. For convenience some of the terms and definitions are reproduced below:

dynamic module of legally relevant software

software module whose functional behaviour depends on predefined device-specific parameters that may change over time during use

Note: Such dynamic modules may be considered to incorporate or utilise machine learning or artificial intelligence characteristics and processes.

measurement data

data used during the measurement process

Note: Measurement data includes the measured quantity value, measurement result relevant data and measurement process data.

measurement result

set of quantity values being attributed to a measurand together with any other available relevant data

Note 1: The measurement result relevant data may consist of e.g. measurement uncertainty, date and time of measurement, number of measurement, identification of sensor and in the case where price calculation is part of the legally relevant software, unit price and price to pay.

Note 2: The measurement result (including the measured quantity value according to V 2:200:2012) is used for the legally relevant purpose, e.g. conclusion of a transaction.

significant defect

incident that has an undesirable impact on the compliance of the measuring instrument or a fault

Note: Examples of significant defect include: a) deletion of the audit trail; b) inadmissible parameter changes; c) unauthorised updates d) accidental software changes due to physical effects.

B.2 General Requirements

B.2.1 Software identification

Legally relevant software modules of an electricity meter and/or its components shall be clearly and uniquely identified with the software version. The identification may consist of more than one part, but at least one part shall be dedicated to the legal purpose.

The identification shall be inextricably linked to the software itself and shall be displayed or printed either:

a) on command; and/or

b) during operation.

If an electronic sub-assembly/device has neither a display nor a printer, the identification shall be sent via a communication interface in order to be displayed/printed on another electronic sub-assembly/device.

As an exception, an imprint of the software identification on the instrument/electronic device shall be an acceptable solution if it satisfies all of the following conditions:

1) the user interface does not have any control capability to activate the indication of the software identification on the display, or the display does not technically allow the identification of the software to be shown (analogue indicating device or electromechanical counter);

2) the instrument/electronic device does not have an interface to communicate the software identification; and

3) after production of the instrument/electronic device, a change of the software is not possible, or only possible if the hardware or a hardware component is also changed.

In this case, the manufacturer of the hardware component is responsible for ensuring that the software identification is correctly marked on the concerned instrument/electronic device. If the software is modified in any way, a new software identification is required.

The software identification and the means of identification shall be stated in the type approval certificate. Instructions on how to display or print the software identification shall be in the type approval certificate.

Each electricity meter in use shall conform to the approved type. The software identification enables surveillance personnel and persons affected by the measurement to determine whether the electricity meter under consideration conforms to the approved type.

B.2.2 Correctness of metrological algorithms and functions

The measuring algorithms and functions of the electricity meter and/or its components shall be appropriate and functionally correct.

It shall be possible to evaluate algorithms and functions by:

a) Analysis of the documentation and validation of the design (AD)

b) Verification by functional testing of metrological functions (VFTM); and/or

c) Verification by functional testing of software functions (VFTSw).

All legally relevant metrological algorithms, functions and parameters shall be documented. No hidden or undocumented functions or parameters shall exist.

B.2.3 Software securing and protection

Software shall be protected in such a way that evidence of any intervention (e.g. software updates, parameters changes) shall be available (e.g. in an audit trail, see B.2.4). Software shall be secured against unauthorised modification, loading, or changes by swapping the memory device.

Mechanical sealing or other technical means may be necessary to secure measuring instruments. Audit trails are considered to be part of the legally relevant software and should be protected as such.

Only clearly documented functions (see B.2.5) may be activated by the user interface, which do not influence the metrological characteristics of the instrument.

Parameters that fix the legally relevant characteristics of the electricity meter shall be protected against unauthorised modification. Legally relevant parameters shall be secured and protected in such a way that evidence of an intervention shall be available.

In the case of dynamic software modules of legally relevant software with predefined parameters, these shall be considered as a part of the software and treated as such. This entails logging of all parameter changes in an audit trail.

For the purpose of verification, it shall be possible to display or print the current parameter settings as well as data containing evidence of interventions. If applicable it shall also be possible to transmit the current parameter settings and data containing evidence of interventions to the verification software.

B.2.4 Audit trails

Audit trails and event counters are part of the legally relevant software and shall be secured and protected as such. It shall not be possible to delete or inadmissibly change the data of the audit trail or event counter and it shall not be possible to exchange the audit trails or the value of the event counter when the software is updated.

The audit trail shall contain at minimum the following information:

a) timestamp of the event or intervention;

b) the nature of the event or intervention;

c) the success/failure of the intervention or update;

d) in the case of a software update:

  i. software identification of the installed version;

  ii. software identification of the previous installed version;

e) in the case of a parameter change:

  i. identification of the changed parameter;

  ii. the old and new values of the changed parameter; and

f) the identification of the downloading party if available.

The audit trail or value of the event counter shall be displayed or printed on command and, if applicable, transmitted to the verification software. The OIML certificate / type approval certificate shall describe how the audit trail or the value of the event counter may be displayed or printed and specify if the audit trail or event counter is part of a remote verification procedure.

The storage device for the audit trail shall have a sufficient capacity to ensure that the information is available for the life of the meter. If the audit trail has no more capacity an appropriate response is required i.e., either the oldest entry may be deleted, or no other update or parameter change shall be possible without breaking a metrological seal.

B.2.5 Prevention of misuse

An electricity meter shall be constructed in such a way that possibilities for unintentional, accidental, or intentional misuse are minimal. Only clearly documented functions are allowed to be activated by the user and communication interfaces, which shall be realised in such a way that it does not facilitate fraudulent use.

All inputs from the user interface shall be handled by a protective interface. Any function that can be activated by the user interface shall:

a) be clearly documented; and

b) not be able to inadmissibly influence the legally relevant characteristics of the electricity meter.

All inputs from communication interfaces shall be handled by a protective interface. Any function that can be activated through a communication interface shall:

a) be clearly documented; and

b) not be able to influence the legally relevant characteristics of the electricity meter remotely such as through a remote verification procedure or a software download.

The presentation of the measurement result shall be accessible and unambiguous for all parties affected by the measurement result.

B.2.6 Support of fault and defect detection

Software may be involved in the checking facilities used for the detection of faults and defects and to act upon significant faults and significant defects or to prevent them from occurring. In such a case, this software is considered legally relevant.

If software is involved in the detection of significant faults or significant defects, the software-controlled electricity meter shall be made inoperative automatically, or automatically raise an alarm. The alarm may be visual, audible or transmittable to the person in control of the electricity meter (e.g. the utility company). The alarm shall continue until such time as an authorised person takes action to resolve the fault or defect, the electricity meter acts upon the fault or defect, or it is otherwise resolved.

The documentation to be submitted for type evaluation shall contain a list of parameters and their valid and controlled ranges which may generate faults and which will be detected by the software including the expected reaction and, if necessary for understanding the detection algorithm, its description.

B.3 Requirements specific for configurations

B.3.1 Specification and separation of legally relevant components and interfaces

B.3.1.1 General

This requirement applies if the electricity meter and/or its components or software modules have interfaces for communicating with other electronic devices, with the user, or with other (non-legally relevant) software modules next to the legally-relevant components/modules.

Legally-relevant components of an electricity meter – whether software or hardware – shall not be inadmissibly influenced by other components of the measuring system.

B.3.1.2 Separation of constituents of a measuring system

Components of an electricity meter that perform functions which are legally relevant shall be identified, clearly defined, and documented. These form the legally relevant part of the measuring system.

It shall be demonstrated that the legally-relevant functions and data of components cannot be inadmissibly influenced by commands received via an interface. This implies that there is an unambiguous assignment of each command to all initiated functions or data changes in the component.

B.3.1.3 Separation of software modules

All software modules (programs, subroutines, objects, etc.) that perform legally relevant functions or that contain legally relevant data domains form the legally relevant software part of an electricity meter. This part shall be made identifiable as described in B.2.1.

If the separation of the software modules is not possible, the software is legally-relevant as a whole.

If the legally relevant software part communicates with other software parts, a software interface shall be defined and implemented. All communication shall be performed exclusively via this interface. The legally relevant software part and the interface shall be clearly documented. All legally relevant functions and data domains of the software shall be described to enable a type approval authority to decide on correct software separation.

The interface consists of program code and dedicated data domains. Defined coded commands or data are exchanged between the software parts by storing to the dedicated data domain by one software part and reading from it by the other. Reading and writing program code is part of the software interface.

The data domain forming the software interface, including the code that exports from the legally-relevant part to the interface data domain and the code that imports from the interface to the legally relevant part, shall be clearly defined and documented. The declared software interface shall not be circumvented.

There shall be an unambiguous assignment of each command to all initiated functions or data changes in the legally relevant part of the software. Commands that communicate through the software interface shall be declared and documented. Only documented commands are allowed to be activated through the software interface. The manufacturer shall state the completeness of the documentation of commands.

Where legally relevant software has been separated from non-relevant software, the legally relevant software shall have priority using the resources over non-relevant software. The measurement task (realised by the legally relevant software part) shall not be delayed or blocked by other tasks.

When dynamic modules of legally relevant software have facilities for continuous learning that allow dynamic parameter changes during use, the manufacturer shall clarify the facilities and its priorities to the whole legally relevant software, especially in reference to the measuring functions.

B.3.2 Shared indications

Software that realises the indication of measurement values and other legally-relevant information belongs to the legally-relevant part.

A display or printout may be employed for presenting both information from the legally relevant part of the software and other information. The information generated by the legally relevant information shall always be readable, and clearly distinguishable from other information.

B.3.3 Data storage

B.3.3.1 General

Hardware and software, whether incorporated into the electricity meter or connected to it externally, that is intended to be used for the storage of measurement results and/or measurement data shall be subject to the requirements specified in B.3.3.2 to B.3.3.4.

The measurement result and measurement data includes all associated data necessary for future legally relevant use.

B.3.3.2 Protection of stored data

Stored measurement results and measurement data shall be protected to guarantee the authenticity, integrity and, if necessary, correctness of the information concerning the time of measurement. Where timestamps are required, they shall be read from an internal clock. The setting of the time and date shall be secured.

The software that displays or further processes measurement results and measurement data shall check the authenticity and integrity of the data after having read them from storage.

Software modules that prepare measurement results and measurement data for storage, or that check data after reading are considered part of the legally relevant software.

If a modification or corruption is detected, the stored measurement results and measurement data shall be discarded or marked unusable.

B.3.3.3 Automatic storage

Measurement results and measurement data shall be stored automatically.

The storage device shall have sufficient permanency to ensure that measurement results and measurement data are not corrupted under normal storage conditions. There shall be sufficient memory storage for the intended application.

B.3.3.4 Deletion of stored data

Stored data may be deleted if either:

- the transaction is settled, or
- the data are printed by a printing device subject to legal control.

This shall not apply to the energy accumulation register(s) and audit trail.

It shall not be possible to zero (reset) the register(s) that stores the total energy metered without breaking a metrological seal.

B.3.4 Data transmission

B.3.4.1 General

If applicable, hardware and software, whether incorporated into the electricity meter or connected to it externally, that is intended to be used for the transmission of measurement results and/or measurement data shall be subject to the requirements specified in B.3.4.2 and B.3.4.3.

The measurement result and measurement data includes all associated data necessary for future legally relevant use.

Requirements concerning the transmission of measurement results and/or measurement data via communication networks are subject to national regulations.

Note: In some jurisdictions transmission of data via communication networks is not subject to legal metrology requirements. National regulations may instead specify compliance with data transmissions standards such as EN 13757 Communication systems for meters.

B.3.4.2 Protection of transmitted data

Transmitted measurement results and measurement data shall be protected to guarantee the authenticity, integrity and, if necessary, correctness of the information concerning the time of measurement. Where timestamps are required, they shall be read from an internal clock. The setting of the time and date shall be secured.

The software that displays or further processes measurement results and measurement data shall check the authenticity and integrity of the data after having received them from a transmission channel.

Software modules that prepare measurement results and measurement data for transmission, or that check data after reading or receiving are considered part of the legally relevant software.

If a modification or corruption is detected, the transmitted measurement results and measurement data shall be discarded or marked unusable.

When transferring measurement results and measurement data through an open network, it is necessary to apply cryptographic methods. Confidentiality keys employed for this purpose shall be kept secret and secured in the electricity meter, electronic devices, or sub-assemblies involved in the transmission. Means shall be provided whereby these keys can only be input or read if a seal is broken.

Transmitted measurement results and measurement data shall be traceable back to the measurement process and electricity meter (or component) that generated them.

B.3.4.3 Transmission delay or interruption

Measurement results and measurement data shall not be inadmissibly influenced by a transmission delay or interruption. If network services become unreliable or unavailable, no measurement results and measurement data shall be lost.

B.3.5 Indications from dynamic modules of legally relevant software

Where electricity meters incorporate or are dependent upon dynamic modules of legally relevant software, this information shall be indicated and made available to any parties interested in the measurement result(s) produced by that electricity meter.

Where a measurement result is the product of a measurement process that incorporates or is dependent upon dynamic modules of legally relevant software, the indication of the measurement result shall include information regarding the use of those modules in the measurement process. This may be achieved by the use of a short statement, clearly understood markings, symbols or other indications.

Where measurement data is produced as a result of algorithms of dynamic modules of legally relevant software, the measurement data shall be marked or indicated as such.

B.4 Maintenance and reconfiguration

B.4.1 General

Only versions of legally-relevant software that conform to the approved type are allowed for use.

In addition, download and installation of legally relevant software is allowed if the requirements in the download procedures described in either B.4.2 or B.4.3 are met.

The used of verified updates, traced updates and required download procedure(s) are subject to national regulation.

B.4.2 Verified update

A verified update is the procedure of changing software (i.e. exchange with another approved version or re-installation of an existing version) in a verified device or component, after which the subsequent verification by an authorised person is necessary.

The software to be updated can be loaded locally, i.e. directly on the electricity meter, or remotely via a network. A metrological seal needs to be broken for the update to take effect.

Loading and installation may be two different steps or combined into one, depending on the needs of the technical solution.

Means shall be implemented to check the effectiveness of the update (e.g. in-person inspection).

After the update of the legally-relevant software of an electricity meter, the electricity meter is not allowed to be employed for legal purposes before a verification of the electricity meter has been performed and the securing means have been renewed.

B.4.3 Traced update

A traced update is the procedure of changing software in a verified device or component after which the subsequent verification by a responsible person on site is not necessary. This means the traced update shall not affect existing parameters or the accuracy of the measurement. The following conditions shall apply:

a) Traced update of software shall be automatic. Upon completion of the update procedure, the software protection environment shall be at the same level as required by the OIML certificate / type approval certificate.

b) Technical means shall be employed to guarantee the authenticity of the loaded software.

c) Technical means shall be employed to ensure the integrity of the loaded software, i.e. that it has not been inadmissibly changed before loading.

d) Appropriate technical means shall be employed to ensure that traced updates are adequately traceable within the electricity meter.

e) If the loaded software fails the authenticity check, the electricity meter shall discard it and use the previous version of the software or switch to an inoperable mode.

f) The electricity meter shall have a sub-assembly/electronic device for the user or owner to express his/her consent. It shall be possible to enable and disable this sub-assembly/electronic device, e.g. by means of a switch that can be sealed or by a parameter. If the sub-assembly/electronic device is enabled, each download must be initiated by the user or owner. If it is disabled, no activity by the user or owner is necessary to perform a download.

g) If the requirements of a) through f) cannot be fulfilled, it is still possible to update the legally non-relevant software part. In this case, the following requirements shall be met:

  - there is a distinct separation between the legally relevant and non-relevant software according to B.3.1;
  - the whole legally-relevant software part cannot be updated without breaking a seal; and
  - it is stated in the OIML certificate / type approval certificate that updating of the legally non-relevant part is acceptable.

An audit trail shall be employed to ensure that traced updates of legally relevant software are adequately recorded and traceable within the electricity meter for subsequent verification and surveillance or inspection. The electricity meter shall be capable of presenting the recorded data upon request from an authorised person. The traceability means and records are part of the legally-relevant software and shall be protected as such. See clauses B.2.4 and B.2.5 for specific requirements.

B.5 Software documentation

All program functions shall be explained in the documentation of the electricity meter, including relevant data structures and software interfaces of the legally relevant part of the software that is implemented in the electricity meter. All commands and their effects shall be completely described in the software documentation.

The manufacturer shall submit all such documentation to allow for a reasonable evaluation of the legally relevant software. The documentation shall include:

a) a description of the legally-relevant software and how the requirements are met;

b) a list of the software modules that belong to the legally-relevant part;

c) a declaration that all legally relevant functions are included in the description;

d) a description of the software interfaces of the legally-relevant software part and of the commands and data flows via this interface, including a statement of completeness;

e) a description of the generation of the software identification;

f) the software identification and instructions for obtaining it from a electricity meter in use;

g) a list of parameters to be protected and a description of protection means;

h) a description of suitable system configuration and minimal required resources;

i) a description of security means of the operating system (password, etc. if applicable);

j) a description of the (software) protection method(s);

k) an overview of the system hardware, e.g. topology block diagram, type of computer(s), type of network, etc. Where a hardware component is deemed legally-relevant or where it performs legally relevant functions, this should also be identified;

l) a description of the user interface, menus, and dialogues;

m) a list of commands of each hardware interface of the electricity meter / electronic device(s) / sub-assembly(ies), including a statement of completeness;

n) a description of the accuracy of the algorithms (e.g. volume calculation, rounding algorithms, etc.);

o) if realised in the software:

- a description of the audit trail and instructions on how to access the audit trail;
- a list of durability errors that are detected by the software and a description of the detecting algorithms;
- a list of faults and/or defects that are detected and a description of the detecting algorithm;

p) a description of data sets stored or transmitted; and

q) the operating manual.

Annex C
Estimation of combined errors
(Informative)

C.1 Estimate of combined maximum permissible error based on the requirements of this Recommendation

This Recommendation permits a base maximum permissible error plus an error shift caused by influence quantities. The actual error of a complying meter when in use could therefore exceed the base maximum permissible error. There is a need to estimate an overall maximum permissible error that indicates the largest error that can reasonably be attributed to a meter type that complies with this Recommendation. This entails estimating the errors of a measurement of an arbitrary meter within the rated operating conditions.

However, adding the base maximum permissible error and all error shifts algebraically would give a much too pessimistic estimate of the metering uncertainty, for two reasons. For an arbitrary set of influence factor values, some of the error shifts will be low and some will probably have opposite signs, tending to cancel each other out. Furthermore, the electricity meter is an integrating device, thus the errors caused by influence quantities will average out to some extent as the values of the influence factors vary over time.

If we make the following assumptions:

a) the integrating effect may be ignored,

b) none of the effects of the influence factors are correlated;,

c) the values of the influence quantities are more likely to be close to the reference values than to limits of the rated operated conditions,

d) the influence quantities, and the effects of the influence factors, can be treated as Gaussian distributions, and thus a value of half the maximum permissible error shift can be used for the standard uncertainty,

then the combined maximum permissible error (assuming a coverage factor of two corresponding to a coverage probability of approximately 95 %) can be estimated using the formula(1):

$$v = 2 \times \sqrt{\frac{v_{base}^2}{4} + \frac{v_{voltage}^2}{4} + \frac{v_{frequency}^2}{4} + \frac{v_{unbalance}^2}{4} + \frac{v_{harmonic}^2}{4} + \frac{v_{temperature}^2}{4}}$$

where:

v_{base} is the base maximum permissible error;

$v_{voltage}$ is the maximum error shift permitted for voltage variation;

$v_{frequncy}$ is the maximum error shift permitted for frequency variation;

$v_{unbalance}$ is the maximum error shift permitted for unbalance variation;

$v_{harmonics}$ is the maximum error shift permitted for the variation of harmonic content;

$v_{temperature}$ is the maximum error shift permitted for temperature variation.

Note (1): This is line with the ISO *Guide to the expression of uncertainty of measurement* (GUM).

C.2 Estimation of combined error based on type test results and specific conditions

C.2.1 Method 1

The combined maximum error can also be estimated for a particular meter type using type test results. Type test results can often show a smaller variation than that required by this Recommendation, leading to an assured smaller value for the overall maximum error.

Keeping the assumption of a Gaussian distribution being valid the combined maximum error can then be estimated from a combination of test results using the formula [(3)]:

$$e_{c(p,i)} = \sqrt{\left(e^2(PF_p, I_i\right) + \delta e_{p,i}^2(T) + \delta e_{p,i}^2(U) + \delta e_{p,i}^2(f)}$$

where:

For each current I_i and each power factor PF_p

- $e(PF_p, I_i)$ is the intrinsic error of the meter measured in the course of the tests, at current I_i and power factor PF_p;
- $\delta e_{p,i}(T)$, $\delta e_{p,i}(U)$, and $\delta e_{p,i}(f)$ are the maximum additional errors measured in the course the test, when the temperature, the voltage and the frequency are respectively varied over the whole range specified in the rated operated conditions, at current I_i and power factor PF_p.

C.2.2 Method 2

When assuming that a Gaussian distribution may no longer be valid, instead a rectangular distribution should be assumed for the effects of influence factors.

Thus, the combined maximum error can then be estimated from a combination of test results using the formula[(3)]:

$$e_c = 2 \times \sqrt{\frac{e_{base}^2}{3} + \frac{e_{voltage}^2}{3} + \frac{e_{frequency}^2}{3} + \frac{e_{unbalance}^2}{3} + \frac{e_{harmonic}^2}{3} + \frac{e_{temperature}^2}{3}}$$

where:

e_{base}	is the maximum error obtained in the test for base maximum error, taking into account the measurement uncertainty of the type test[(2)];
$e_{voltage}$	is the maximum error shift obtained in the test for voltage variation, taking into account the measurement uncertainty of the type test;
$e_{frequncy}$	is the maximum error shift obtained in the test for frequency variation, taking into account the measurement uncertainty of the type test;
$e_{unbalance}$	is the maximum error shift obtained in the test for unbalance variation, taking into account the measurement uncertainty of the type test;
$e_{harmonics}$	is the maximum error shift obtained in the test for variation of harmonic content, taking into account the measurement uncertainty of the type test;
$e_{temperature}$	is the maximum error shift obtained in the test for temperature variation, taking into account the measurement uncertainty of the type test.

Note (2): The measurement uncertainty must be included in each component e_i of the overall error. Since one term is a known value and the other an uncertainty they cannot be treated as two uncorrelated statistical distributions, and must hence be added algebraically.

Note (3): Components contributing to the combined error may be selected by national or regional authorities and should at least comprise: e_{base}, $e_{frequency}$, $e_{temperature}$ and $e_{voltage}$.

The effects of correlations between factors such as load profiles and ambient temperature variation on meter accuracy have not been included in the above calculations, but could be modelled in situations where appropriate.

Annex D
Legislative Matters
(Informative)

D.1 Legislative considerations

It would be impractical to develop this Recommendation to fit each and every one of the wide variety of situations and meter applications which exist around the world. It is therefore inevitable that some issues may need to be addressed by national authorities or at a regional level.

One way in which this Recommendation seeks to provide an appropriate balance between flexibility and uniformity is by the provision of options for a number of conditions, such as:

a) Nominal voltage;

b) Nominal frequency;

c) Rated temperature;

d) Level of protection from water and humidity;

e) Level of protection from impulse voltages;

f) Handling of energy flow direction.

It should be noted that in some countries or regions, local legislation may also include specific requirements relating to matters such as:

g) Electrical interface;

h) Mechanical interface and housing.

It should also be noted that, while the maximum current is most often specified by the characteristics of the installation, the value of the transitional current and/or the ratio between the maximum current and the transitional current are important for end customers with low power consumption, since these customers could experience large relative metering errors if the load current is lower than the transitional current for a large part of the time. It is thus recommended that the values of I_{tr} and I_{max} be chosen from Table 7.

Table 7 – Preferred current ranges

Type of meter connection	Preferred values of I_{tr} and I_{max} (Amperes)	Other values of I_{tr} and I_{max} (Amperes)
Direct connection	Standard I_{tr} values: 0.125, 0.25, 0.5, 1, 2, 3. Standard I_{max} values: 10, 20, 40, 60, 80, 100, 120, 200, 320	Other I_{tr} values: 0.75, 1.5, 2.5, 4, 5 Other I_{max} values:30, 50, 160
Connection through current transformer(s)	Standard I_{tr} values: 0.05, 0.1, 0.25 Standard I_{max} values: 1.2, 1.5, 2, 2.4, 3, 4, 6, 7.5, 10, 20	Other I_{tr} values: 0.125 Other I_{max} values 3.75, 5

Note 1: The current range of transformer-operated meters should be compatible with the current range of current transformers.

Note 2: The legislator may prescribe the maximum permissible I_{tr} value, prescribe a minimum current range, or a minimum ratio between I_{max} and I_{tr}. These can be prescribed as absolute values or values based on the typical power demand for certain types of customers etc.

D.1.1 Choice of accuracy class

More accurate meters should be used when metering large flows of electricity in order to minimize the economic impact of unavoidable measurement errors. While class A meters may be acceptable for situations involving low energy consumption, higher class indices should be used when higher rates of energy consumption are involved.

The accuracy of the meter will be independent of the power grid characteristics for most meter connection modes; however, there may be a need to evaluate the influence of grid characteristics, especially for meters with higher class indices, in cases where there are underlying assumptions of grid symmetry and/or lack of leakage currents. It is possible that contributions to the overall meter error due to grid characteristics in such situations may be larger than contributions from the meter itself, especially at higher accuracy; it may therefore be appropriate to limit the use of connection modes of this type.

D.1.2 Matters not covered by the scope of this Recommendation

This Recommendation is limited to describing the relevant metrological requirements of an electricity meter and therefore does not cover certain matters which may or should be regulated by legislation, such as:

a) EMC emissions;

b) Electrical safety and personal safety;

c) Security of communication protocols and further handling of measurement results.

Annex E
Accuracy classes and current values
(Informative)

E.1 General

This Annex provides information about the different terms for accuracy classes and current values in international and regional standards and regulations.

E.2 Accuracy classes

Some standards and regulations designate accuracy classes with letters and others use numbers. Table 8 provides a comparison of accuracy classes for active energy.

The correspondence of accuracy classes between different standards and regulations is not direct. For instance, accuracy classes may be based on meter performance at reference conditions, whereas others may be based on combined error. See Annex C for more details on this.

Table 8 – Accuracy classes for active energy in different standards and regulations

Standard or regulation	Designations (lowest accuracy to highest accuracy)				
This Recommendation	A/2	B/1	C/0.5	D/0.2	E/0.1
OIML R 46:2012	A	B	C	D	–
IEC 62053.21:2020, IEC 62053.22:2020	2	1	0.5S	0.2S	–
IEC 62053.21, IEC 62053.22	2	1	0.5S	0.2S	0.1S
ANSI C12.20:2010	–	–	0.5	0.2	0.1
Directive 2014/32/EU "Measuring Instrument Directive"	A	B	C	–	–

E.3 Current values

Related to accuracy classes, different standards and regulations use different terms for current values and specifications. A summary of these and their relationship to each other is provided in Table 9.

Table 9 – Current values in different standards and regulations

Standard or regulation	Current Values (lowest to highest)					
This Recommendation	I_{st}	I_{min}	I_{tr}	10 I_{tr}	20 I_{tr}	I_{max}
OIML R 46:2012	I_{st}	I_{min}	I_{tr}	–	–	I_{max}
IEC 62052.11:2016, 62053.21:2016, IEC 62053.22:2016	I_{st}	–	–	I_b (1)	I_n (2)	I_{max}
IEC 62052.11:2020, 62053.21:2020, IEC 62053.22:2020	I_{st}	–	–	I_n (2)		I_{max}
ANSI C12.20:2010 (3)	Starting current	–	Light load	Test Amps	–	Class Amps
Directive 2014/32/EU "Measuring Instrument Directive"	I_{st}	I_{min}	I_{tr}	I_b (4)	I_n (4)	I_{max}

(1) I_n is the nominal current. In the 2016 IEC standards it relates only to transformer-operated meters.

(2) I_b is the basic current and it relates only to direct connected meters.

(3) There is no direct correspondence of current values in ANSI, but there is a similar concept as described here.

(4) In Directive 2014/32/EU, the nominal current is defined to be 20 times the transitional current ($I_n = 20 \times I_{tr}$) for indirect connected meters. For direct connected meters, the basic current is not defined, but generally the basic current is taken to be 10 time the transitional current ($I_b = 10 \times I_{tr}$).

E.4 Acceptance of correspondence

The correspondence between accuracy classes is informative. For example, a meter that is considered to comply with IEC 62052.11:2016 with accuracy class 1 cannot automatically be assumed to comply with accuracy class B/1 under this recommendation. This is because conformance with the standard requires compliance with all of the metrological and technical requirements.

Correspondence between current values may be used to support acceptance of results from other international standards. For example, if an identical test is performed under a different international standard, the correspondence of current values (E.3) can be used to demonstrate the equivalence of current values.

Further, where an IEC standard specifies load points for a test that differs from this Recommendation, the alternative load points shall be considered acceptable under this Recommendation.

Annex F
Bibliography
(Informative)

Ref.	Standards and reference documents	Description
[1]	IEC 62052-11, Edition 2, 2020-06 Electricity metering equipment – General requirements, tests and test conditions – Part 11: Metering equipment	Specifies requirements and associated tests, with their appropriate conditions for type testing of AC and DC electricity meters.
[2]	IEC 62053-21, Edition 2, 2020-06 Electricity metering equipment – Particular requirements – Part 21: Static meters for AC active energy (classes 0.5, 1 and 2)	Applies only to static watt-hour meters of accuracy classes 0.5, 1 and 2 for the measurement of alternating current electrical active energy in 50 Hz or 60 Hz networks and it applies to their type tests only.
[3]	IEC 62053-22, Edition 2, 2020-06 Electricity metering equipment – Particular requirements – Part 22: Static meters for AC active energy (classes 0.1A, 0.2S and 0.5S)	Applies only to transformer operated static watt-hour meters of accuracy classes 0.1 S, 0.2 S and 0.5 S for the measurement of alternating current electrical active energy in 50 Hz or 60 Hz networks and it applies to their type tests only.
[4]	IEC 62053-23, Edition 2, 2020-06 Electricity metering equipment – Particular requirements – Part 23: Static meters for reactive energy (classes 2 and 3)	Applies only to static var-hour meters of accuracy classes 2 and 3 for the measurement of alternating current electrical reactive energy in 50 Hz or 60 Hz networks and it applies to their type tests only.
[5]	IEC 62053-24, Edition 2, 2020-06 Electricity metering equipment – Particular requirements – Part 24: Static meters for fundamental component reactive energy (classes 0.5S, 1S, 1, 2 and 3)	Applies only to static var-hour meters of accuracy classes 0.5 S, 1 S, 1, 2 and 3 for the measurement of alternating current electrical reactive energy in 50 Hz or 60 Hz networks and it applies to their type tests only. This document uses a conventional definition of reactive energy where the reactive power and energy is calculated from the fundamental frequency components of the currents and voltages only.
[6]	OIML V 2-200 (2012) International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM)	Vocabulary, prepared by a joint working group consisting of experts appointed by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML
[7]	OIML V 1 (2013) International vocabulary of terms in legal metrology (VIML)	The set of terms and definitions in this vocabulary is related to various aspects of legal metrology which are dealt with in OIML publications. However, this vocabulary was developed to be compatible with fundamental metrological publications, first of all the *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*, so it can be used not only within the OIML.
[8]	OIML D 11 (2013) General requirements for measuring instruments – Environmental conditions	Guidance for establishing appropriate metrological performance testing requirements for influence quantities which may affect the measuring instruments covered by OIML Recommendations.

[9]	OIML D 31 (2019), including Amendment 1 (2020) General requirements for software controlled measuring instruments	Guidance to OIML Technical Committees and Subcommittees for establishing appropriate requirements for software-related functionalities in measuring instruments covered by OIML Recommendations.
[10]	OIML G 1-100 (2008), (GUM) Evaluation of measurement data - Guide to the expression of uncertainty in measurement	This Guide establishes general rules for evaluating and expressing uncertainty in measurement that are intended to be applicable to a broad spectrum of measurements.
[11]	IEC 62054-21:2004-05 Electricity metering equipment (AC) – Tariff and load control – Part 21: Particular requirements for time switches	Specifies particular requirements for newly manufactured indoor time switches with operation reserve that are used to control electrical loads, multi-tariff registers and maximum demand devices of electricity metering equipment.
[12]	IEC 62053-52 (2005) Electricity metering equipment (AC) - Particular requirements - Part 52: Symbols	Applies to letter and graphical symbols intended for marking on and identifying the function of electromechanical or static a.c. electricity meters and their auxiliary devices. The symbols specified in this standard shall be marked on the name-plate, dial plate, external labels or accessories, or shown on the display of the meter as appropriate.
[13]	OIML D 31 (20XX) General requirements for software controlled measuring instruments	Guidance to OIML Technical Committees and Subcommittees for establishing appropriate requirements for software-related functionalities in measuring instruments covered by OIML Recommendations.