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SOUTH AFRICAN NATIONAL STANDARD

Electromagnetic compatibility (EMC)

Part 4-30: Testing and measurement techniques — Power quality measurement methods

This national standard is the identical implementation of IEC 61000-4-30:2008, and is adopted with the permission of the International Electrotechnical Commission.

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Table of changes

Change No.	Date	Scope

National foreword

This South African standard was prepared by National Committee SABS/TC 073, *Electromagnetic compatibility*, in accordance with procedures of the South African Bureau of Standards, in compliance with annex 3 of the WTO/TBT agreement.

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This document is referenced in the Regulations of the Independent Communications Authority of South Africa Act, 2005 (Act No. 36 of 2005).

Compliance with this document cannot confer immunity from legal obligations.

Reaffirmed and reprinted in November 2019.
This document will be reviewed every five years
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Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods

Compatibilité électromagnétique (CEM) – Partie 4-30: Techniques d'essai et de mesure – Méthodes de mesure de la qualité de l'alimentation

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-30: Testing and measurement techniques – Power quality measurement methods

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61000-4-30 has been prepared by subcommittee 77A: Low-frequency phenomena, of IEC technical committee 77: Electromagnetic compatibility.

This standard forms part 4-30 of IEC 61000. It has the status of a basic EMC publication in accordance with IEC Guide 107.

This second edition cancels and replaces the first edition published in 2003. This edition includes the following significant technical changes with respect to the previous edition.

– Adjustments, clarifications, and corrections to class A and class B measurement methods.
– A new category, class S, intended for survey instruments, has been added.
– A new Annex C gives guidance on instruments.

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

FDIS	Report on voting
77A/660/FDIS	77A/666/RVD

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

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

A list of all parts of the IEC 61000 series, under the general title *Electromagnetic compatibility (EMC)*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

INTRODUCTION

IEC 61000 is published in separate parts according to the following structure:

Part 1: General

General considerations (introduction, fundamental principles)

Definitions, terminology

Part 2: Environment

Description of the environment

Classification of the environment

Compatibility levels

Part 3: Limits

Emission limits

Immunity limits (in so far as they do not fall under the responsibility of the product committees)

Part 4: Testing and measurement techniques

Measurement techniques

Testing techniques

Part 5: Installation and mitigation guidelines

Installation guidelines

Mitigation methods and devices

Part 6: Generic standards

Part 9: Miscellaneous

Each part is further subdivided into several parts, published either as International Standards or as Technical Specifications or Technical Reports, some of which have already been published as sections. Others will be published with the part number followed by a dash and completed by a second number identifying the subdivision (example: IEC 61000-6-1).

ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-30: Testing and measurement techniques – Power quality measurement methods

1 Scope

This part of IEC 61000-4 defines the methods for measurement and interpretation of results for power quality parameters in 50/60 Hz a.c. power supply systems.

Measurement methods are described for each relevant parameter in terms that give reliable and repeatable results, regardless of the method's implementation. This standard addresses measurement methods for *in situ* measurements.

Measurement of parameters covered by this standard is limited to voltage phenomena that can be conducted in a power system. The power quality parameters considered in this standard are power frequency, magnitude of the supply voltage, flicker, supply voltage dips and swells, voltage interruptions, transient voltages, supply voltage unbalance, voltage harmonics and interharmonics, mains signalling on the supply voltage and rapid voltage changes. Depending on the purpose of the measurement, all or a subset of the phenomena on this list may be measured.

NOTE 1 Information about current parameters may be found in A.3 and A.5.

This standard gives measurement methods and appropriate performance requirements, but does not set thresholds.

The effects of transducers inserted between the power system and the instrument are acknowledged but not addressed in detail in this standard. Precautions on installing monitors on live circuits are addressed.

NOTE 2 Some guidance about effects of transducers may be found in IEC 61557-12.

2 Normative references

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

IEC 60050-161, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 61000-2-2:2002, *Electromagnetic compatibility (EMC) – Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signalling in public low-voltage power supply systems*

IEC 61000-2-4, *Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances*

IEC 61000-3-8, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 8: Signalling on low-voltage electrical installations – Emission levels, frequency bands and electromagnetic disturbance levels*

IEC 61000-4-4:2004, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-7:2002, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*
Amendment 1 (2008)

IEC 61000-4-15, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 15: Flickermeter – Functional and design specifications*

IEC 61180 (all parts), *High-voltage test techniques for low voltage equipment*

3 Terms and definitions

For the purpose of this document, the definitions of IEC 60050-161, as well as the following, apply.

3.1
channel
individual measurement path through an instrument

NOTE “Channel” and “phase” are not the same. A voltage channel is by definition the difference in potential between 2 conductors. Phase refers to a single conductor. On polyphase systems, a channel may be between 2 phases, or between a phase and neutral, or between a phase and earth, or between neutral and earth.

3.2
Coordinated Universal Time
UTC
time scale which forms the basis of a coordinated radio dissemination of standard frequencies and time signals. It corresponds exactly in rate with international atomic time, but differs from it by an integral number of seconds.

NOTE 1 Coordinated universal time is established by the International Bureau of Weights and Measures (BIPM) and the International Earth Rotation Service (IERS).

NOTE 2 The UTC scale is adjusted by the insertion or deletion of seconds, so called positive or negative leap seconds, to ensure approximate agreement with UT1.

[IEV 713-05-20]

3.3
declared input voltage
$\boldsymbol{U_{din}}$
value obtained from the declared supply voltage by a transducer ratio

3.4
declared supply voltage
$\boldsymbol{U_c}$
declared supply voltage U_c is normally the nominal voltage U_n of the system. If, by agreement between the supplier and the customer, a voltage different from the nominal voltage is applied to the terminal, then this voltage is the declared supply voltage U_c

3.5
dip threshold
voltage magnitude specified for the purpose of detecting the start and the end of a voltage dip

3.6
flagged data
data that has been marked to indicate that its measurement or its aggregation may have been affected by interruptions, dips, or swells

NOTE Flagging enables other methods that may prevent a single event from being counted as several different types of events. Flagging is supplemental information about a measurement or aggregation. Flagged data is not removed from the data set. In some applications, flagged data may be excluded from further analysis but in other applications, the fact that data was flagged may be unimportant. The user, application, regulation, or other standards determine the use of flagged data. See 4.7 for further explanation.

3.7
flicker
impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time

[IEV 161-08-13]

3.8
fundamental component
component whose frequency is the fundamental frequency

[IEV 101-14-49, modified]

3.9
fundamental frequency
frequency in the spectrum obtained from a Fourier transform of a time function, to which all the frequencies of the spectrum are referred

[IEV 101-14-50, modified]

NOTE In case of any remaining risk of ambiguity, the fundamental frequency may be derived from the number of poles and speed of rotation of the synchronous generator(s) feeding the system.

3.10
harmonic component
any of the components having a harmonic frequency

[IEC 61000-2-2:2002, 3.2.4, modified]

NOTE Its value is normally expressed as an r.m.s. value. For brevity, such component may be referred to simply as a harmonic.

3.11
harmonic frequency
frequency which is an integer multiple of the fundamental frequency

NOTE The ratio of the harmonic frequency to the fundamental frequency is the *harmonic order* (notation: h).

3.12
hysteresis
difference in magnitude between the start and end thresholds

NOTE 1 This definition of hysteresis is relevant to Power Quality (PQ) measurement parameters and is different from the IEV definition which is relevant to iron core saturation.

NOTE 2 The purpose of hysteresis in the context of PQ measurements is to avoid counting multiple events when the magnitude of the parameter oscillates about the threshold level.

3.13
influence quantity
any quantity which may affect the working performance of a measuring equipment

[IEV 311-06-01, modified]

NOTE This quantity is generally external to the measurement equipment.

3.14
interharmonic component
component having an interharmonic frequency

[IEC 61000-2-2:2002, 3.2.6]

NOTE Its value is normally expressed as an r.m.s. value. For brevity, such a component may be referred to simply as an *interharmonic*.

3.15
interharmonic frequency
any frequency which is not an integer multiple of the fundamental frequency

[IEC 61000-2-2:2002, 3.2.5]

3.16
interruption
reduction of the voltage at a point in the electrical system below the interruption threshold

3.17
interruption threshold
voltage magnitude specified for the purpose of detecting the start and the end of a voltage interruption

3.18
measurement uncertainty
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[IEV 311-01-02]

3.19
nominal voltage
U_n
voltage by which a system is designated or identified

3.20
overdeviation
absolute value of the difference between the measured value and the nominal value of a parameter, only when the measured value of the parameter is greater than the nominal value

3.21
power quality
characteristics of the electricity at a given point on an electrical system, evaluated against a set of reference technical parameters

NOTE These parameters might, in some cases, relate to the compatibility between electricity supplied on a network and the loads connected to that network.

3.22
Real-Time Clock
RTC
local timekeeping device used for implementing certain methods in this standard.

NOTE The relationship between the real-time clock and UTC is defined in 4.6.

3.23
r.m.s. (root-mean-square) value
square root of the arithmetic mean of the squares of the instantaneous values of a quantity taken over a specified time interval and a specified bandwidth

[IEV 101-14-16, modified]

3.24
r.m.s. voltage refreshed each half-cycle
$U_{\mathbf{rms}(1/2)}$
value of the r.m.s. voltage measured over 1 cycle, commencing at a fundamental zero crossing, and refreshed each half-cycle

NOTE 1 This technique is independent for each channel and will produce r.m.s. values at successive times on different channels for polyphase systems.

NOTE 2 This value is used only for voltage dip, voltage swell and interruption detection and evaluation, in Class A.

NOTE 3 This r.m.s. voltage value may be a phase-to-phase value or a phase-to-neutral value.

3.25
r.m.s. voltage refreshed each cycle
$U_{\mathbf{rms}(1)}$
value of the r.m.s. voltage measured over 1 cycle and refreshed each cycle

NOTE 1 In contrast to $U_{\text{rms}(1/2)}$, this technique does not define when a cycle commences.

NOTE 2 This value is used only for voltage dip, voltage swell and interruption detection and evaluation, in Class S.

NOTE 3 This r.m.s. voltage value can be a phase-to-phase value or a phase-to-neutral value.

3.26
range of influence quantities
range of values of a single influence quantity

3.27
reference channel
one of the voltage measurement channels designated as the reference channel for polyphase measurements

3.28
residual voltage
$U_{\mathbf{res}}$
minimum value of $U_{\text{rms}(1/2)}$ or $U_{\text{rms}(1)}$ recorded during a voltage dip or interruption

NOTE The residual voltage is expressed as a value in volts, or as a percentage or per unit value of U_{din}. $U_{\text{rms}(1/2)}$ is used for Class A. Either $U_{\text{rms}(1/2)}$ or $U_{\text{rms}(1)}$ may be used for Class S. See 5.4.1.

3.29
sliding reference voltage
$U_{\mathbf{sr}}$
voltage magnitude averaged over a specified time interval, representing the voltage preceding a voltage-change type of event (e.g. voltage dips and swells, rapid voltage changes)

3.30
swell threshold
voltage magnitude specified for the purpose of detecting the start and the end of a swell

3.31
time aggregation
combination of several sequential values of a given parameter (each determined over identical time intervals) to provide a value for a longer time interval

NOTE Aggregation in this standard always refers to time aggregation.

3.32
underdeviation
the absolute value of the difference between the measured value and the nominal value of a parameter, only when the value of the parameter is lower than the nominal value

3.33
voltage dip
temporary reduction of the voltage magnitude at a point in the electrical system below a threshold

NOTE 1 Interruptions are a special case of a voltage dip. Post-processing may be used to distinguish between voltage dips and interruptions.

NOTE 2 A voltage dip is also referred to as sag. The two terms are considered interchangeable; however, this standard will only use the term voltage dip.

3.34
voltage swell
temporary increase of the voltage magnitude at a point in the electrical system above a threshold

3.35
voltage unbalance
condition in a polyphase system in which the r.m.s. values of the line voltages (fundamental component), and/or the phase angles between consecutive line voltages, are not all equal

[IEV 161-08-09, modified]

NOTE 1 The degree of the inequality is usually expressed as the ratios of the negative- and zero-sequence components to the positive-sequence component.

NOTE 2 In this standard, voltage unbalance is considered in relation to 3-phase systems.

4 General

4.1 Classes of measurement methods

For each parameter measured, three classes (A, S and B) are defined. For each class, measurement methods and appropriate performance requirements are included.

– **Class A**

  This class is used where precise measurements are necessary, for example, for contractual applications that may require resolving disputes, verifying compliance with standards, etc. Any measurements of a parameter carried out with two different instruments complying with the requirements of Class A, when measuring the same signals, will produce matching results within the specified uncertainty for that parameter.

– **Class S**

This class is used for statistical applications such as surveys or power quality assessment, possibly with a limited subset of parameters. Although it uses equivalent intervals of measurement as class A, the class S processing requirements are lower.

– **Class B**

This class is defined in order to avoid making many existing instruments designs obsolete.

NOTE Class B methods are not recommended for new designs. Readers are advised that Class B may be removed in a future Edition of this standard.

For each class, the range of influencing factors that shall be complied with is specified in Clause 6. Users shall select the class that they require, based on their application(s).

NOTE 1 The instrument manufacturer should declare influence quantities which are not expressly given and which may degrade performance of the instrument. Guidance can be found, for example, in IEC 61557-12.

NOTE 2 An instrument may measure some or all of the parameters identified in this standard, and preferably uses the same class for all parameters.

NOTE 3 The instrument manufacturer should declare which parameters are measured, which class is used for each parameter, the range of U_{din} for which each class is fulfilled, and all the necessary requirements and accessories (synchronization, probes, calibration period, temperature ranges, etc.) to meet each class.

NOTE 4 In this standard, "A" stands for "Advanced", and "S" stands for "Surveys". ("B" or "Basic" methods are not recommended for new designs, because Class B may be removed in a future Edition of this standard.)

4.2 Organization of the measurements

The electrical quantity to be measured may be either directly accessible, as is generally the case in low-voltage systems, or accessible via measurement transducers.

The whole measurement chain is shown in Figure 1.

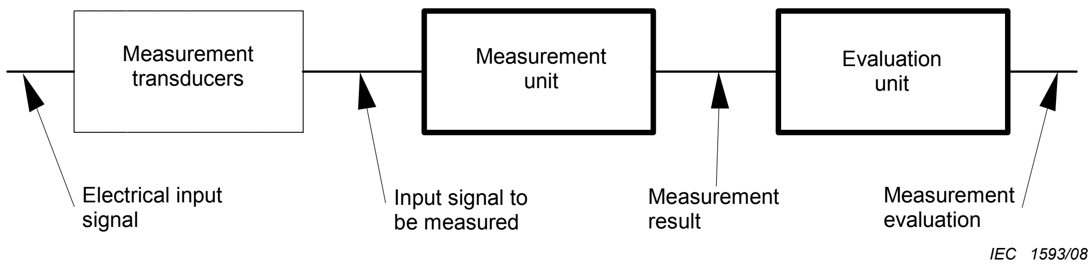

Figure 1 – Measurement chain

An instrument may include the whole measurement chain (see Figure 1). In this standard, the normative part does not consider the measurement transducers external to the instrument and their associated uncertainty, but Clause A.3 gives guidance.

4.3 Electrical values to be measured

Measurements can be performed on single-phase or polyphase supply systems. Depending on the context, it may be necessary to measure voltages between phase conductors and neutral (line-to-neutral) or between phase conductors (line-to-line) or between phase conductors or neutral and earth (phase-to-earth, neutral-to-earth). It is not the purpose of this standard to impose the choice of the electrical values to be measured. Moreover, except for the measurement of voltage unbalance, which is intrinsically polyphase, the measurement methods specified in this standard are such that independent results can be produced on each measurement channel.

Phase-to-phase instantaneous values can be measured directly or derived from instantaneous phase-to-neutral measured values.

Current measurements can be performed on each conductor of supply systems, including the neutral conductor and the protective earth conductor.

NOTE It is often useful to measure current simultaneously with voltage and to associate the current measurements in one conductor with voltage measurements between that conductor and a reference conductor, such as an earth conductor or a neutral conductor.

4.4 Measurement aggregation over time intervals

The following measurement aggregations apply:

– **Class A**

The basic measurement time interval for parameter magnitudes (supply voltage, harmonics, interharmonics and unbalance) shall be a 10-cycle time interval for a 50 Hz power system or 12-cycle time interval for a 60 Hz power system.

The 10/12-cycle measurement shall be re-synchronized at every RTC 10 min tick. See Figure 2.

NOTE 1 The uncertainty of this measurement is included in the uncertainty measurement protocol of each parameter.

The 10/12-cycle values are then aggregated over 3 additional intervals:

– 150/180-cycle interval (150 cycles for 50 Hz nominal or 180 cycles for 60 Hz nominal),
– 10 min interval,
– 2 h interval.

NOTE 2 In some applications, other time intervals (e.g. 1 min) may be useful. These other time intervals, if used, should be implemented with an aggregation method that is analogous to a method defined in this standard (e.g. a 1 min time interval, if used, should be implemented using a method that is analogous to the 10 minute aggregation method).

NOTE 3 Clauses B.1 and B.2 discuss some applications of these aggregation time intervals.

– **Class S**

Same time intervals as Class A. The 10/12-cycle measurement shall be re-synchronized as described in Figure 3 and Figure 4.

– **Class B**

The manufacturer shall specify the number and duration of aggregation time intervals.

4.5 Measurement aggregation algorithm

4.5.1 Requirements

Aggregations shall be performed using the square root of the arithmetic mean of the squared input values.

NOTE For flicker measurements, the aggregation algorithm is different (see IEC 61000-4-15).

4.5.2 150/180 cycle aggregation

– **Class A**

The data for the 150/180-cycle time interval shall be aggregated without gap from fifteen 10/12-cycle time intervals.

The 150/180-cycle time interval is resynchronized upon the 10 min tick as shown in Figure 2.

When a 10 min tick occurs, a new 150/180-cycle time interval begins, and the pending 150/180-cycle time interval also continues until it is completed. This may create an overlap between these two 150/180-cycles intervals (overlap 2 in Figure 2).

– **Class S**

The data for the 150/180-cycle time interval shall be aggregated from 10/12-cycle time intervals. Resynchronization with the 10 min tick is permitted but not required. (See Figure 3).

Gaps are permitted but not required for harmonics, interharmonics, mains signalling voltage and unbalance. A minimum of three 10/12-cycle values shall be used each 150/180-cycle time interval, furthermore at least one 10/12-cycle value shall be used each 50/60 cycles (See Figure 4). For all other parameters, the data for the 150/180-cycle time interval shall be aggregated without gap from fifteen 10/12-cycle time intervals.

– **Class B**

The manufacturer shall specify the method of aggregation.

4.5.3 10 min aggregation

– **Class A**

The 10 min aggregated value shall be tagged with the absolute time (for example, 01H10.00). The time tag is the time at the conclusion of the 10 min aggregation.

The data for the 10 min time interval shall be aggregated without gaps from 10/12-cycle time intervals.

Each 10 min interval shall begin on an RTC 10 min tick. The 10 min tick is also used to re-synchronize the 10/12-cycle intervals and the 150/180-cycle intervals. See Figure 2.

The final 10/12-cycle interval(s) in a 10 min aggregation period will typically overlap in time with the RTC 10 min clock tick. Any overlapping 10/12-cycle interval (overlap 1 in Figure 2) is included in the aggregation of the previous 10 min interval.

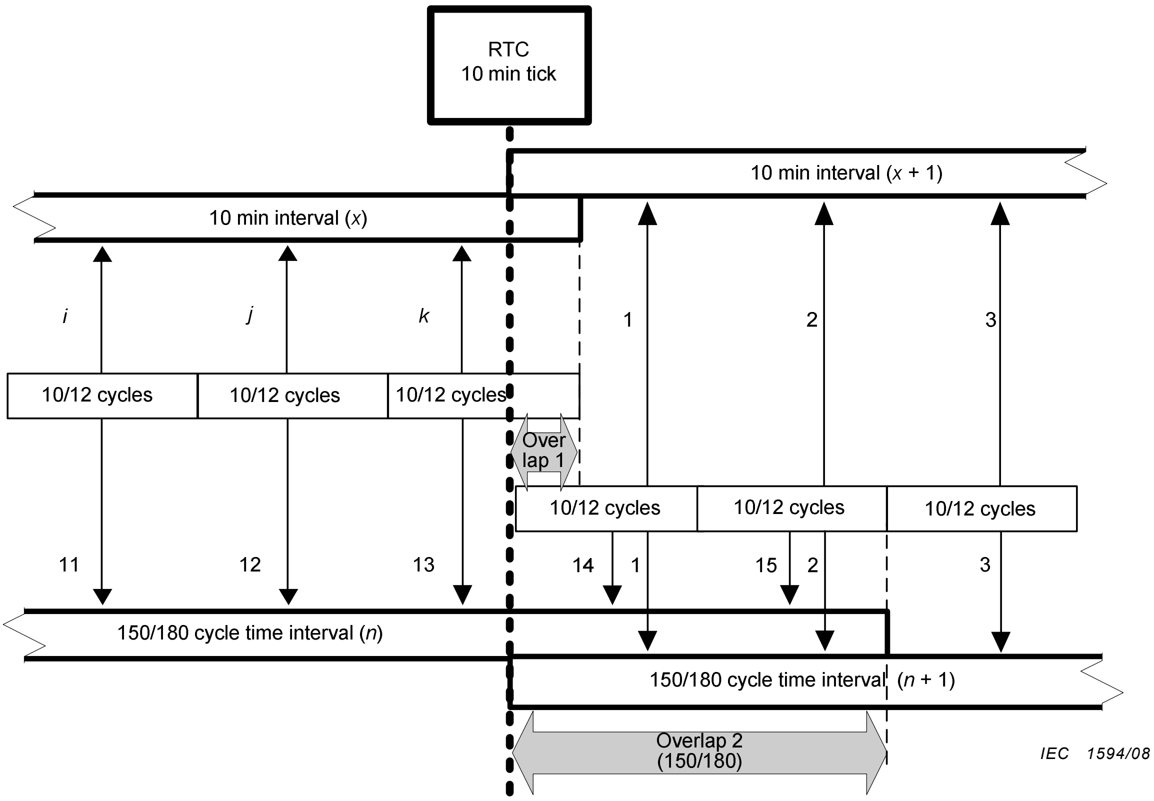

Figure 2 – Synchronization of aggregation intervals for Class A

– **Class S**

The 10 min aggregation method used for class S shall be either the class A method, or the following simplified method.

A new 10 min time interval shall commence after a 10 min tick occurs, at the beginning of the next 10/12 cycle time interval.

The data for the 10 min time interval shall be aggregated from 10/12-cycle time intervals. There is no resynchronization on the 10 min tick. The 10 min intervals are free running.

The 10 min aggregated value shall be tagged with the absolute time. The time tag is the time at the conclusion of the 10 min interval.

There will be no overlap, as illustrated in Figure 3 and Figure 4.

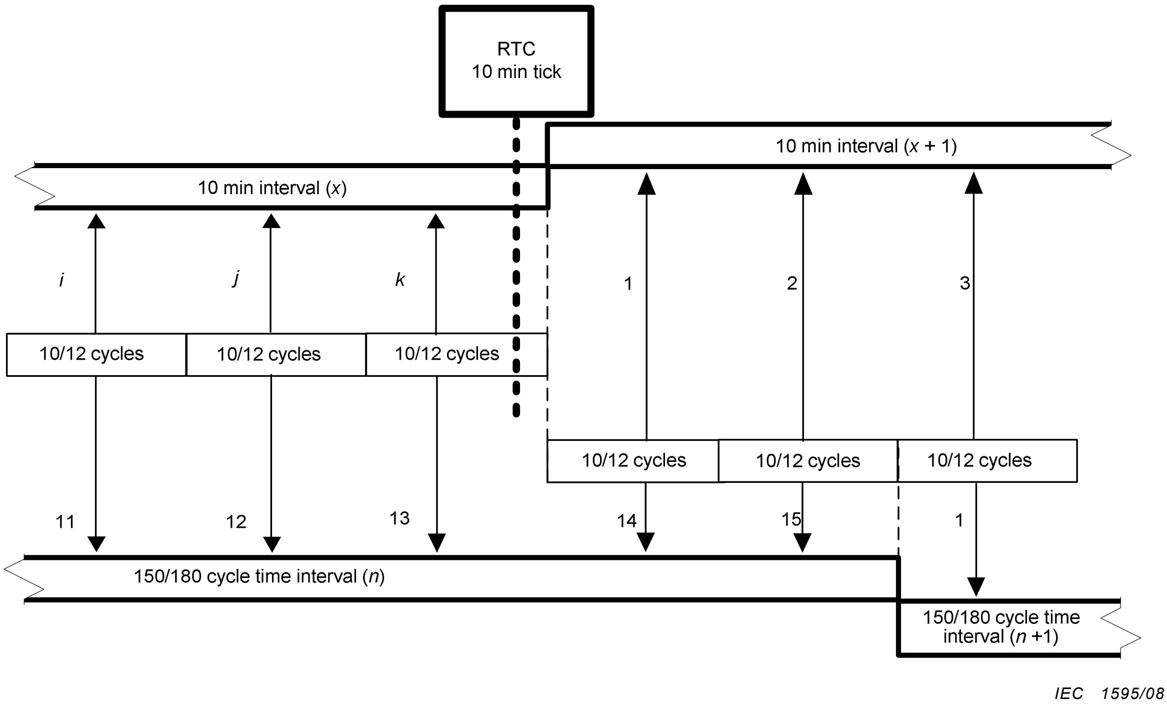

Figure 3 – Synchronization of aggregation intervals for class S: parameters for which gaps are not permitted

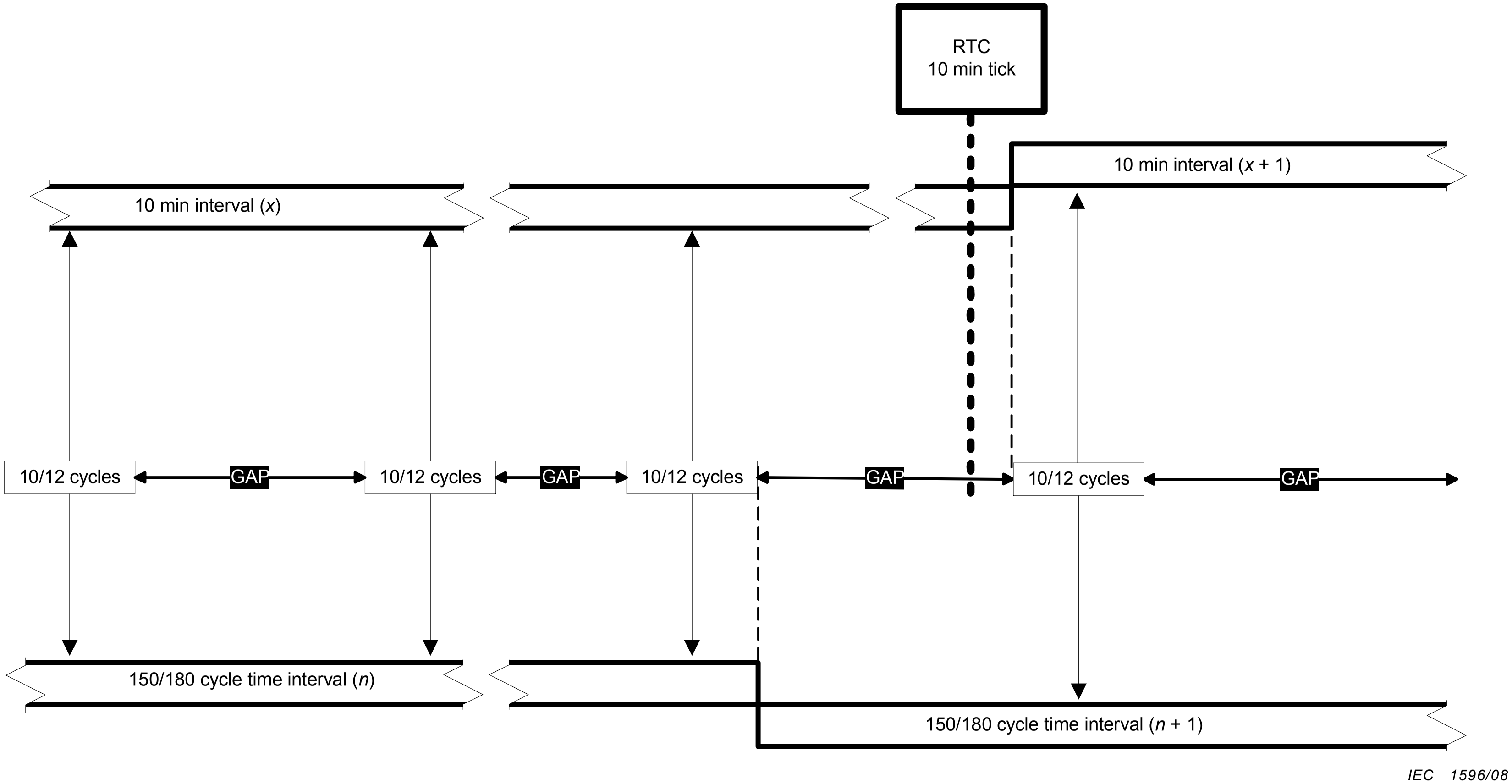

Figure 4 – Synchronization of aggregation intervals for class S: parameters for which gaps are permitted (see 4.5.2)

NOTE The mains frequency may be either higher or lower than expected. In the example shown in Figure 3, the frequency is lower than expected, so the 150/180 cycle interval continues beyond the 10 min tick. In the example shown in Figure 4, the frequency is higher than expected and/or there are gaps, so the 150/180 cycle interval concludes before the 10 min tick.

– **Class B**

The manufacturer shall specify the method of aggregation.

4.5.4 2 hour aggregation

– **Class A**

The data for the 2 h interval shall be aggregated from twelve 10 min intervals. The 2 h interval shall be gapless and not overlap. 2 h intervals commence at even-numbered 2 h RTC intervals.

– **Class S**

Same as class A.

– **Class B**

The manufacturer shall specify the method of aggregation.

4.6 Real time clock (RTC) uncertainty

RTC uncertainty is defined relative to Coordinated Universal Time (UTC).

– **Class A**

The RTC uncertainty shall not exceed ±20 ms for 50 Hz or ±16,7 ms for 60 Hz, regardless of the total time interval. This performance can be achieved, for example, through a synchronization procedure applied periodically during a measurement campaign, or through a GPS receiver, or through reception of transmitted radio timing signals. When synchronization by an external signal becomes unavailable, the RTC tolerance shall be better than ±1 s per 24 h period; however, this exception does not eliminate the requirement for compliance with the first part of this paragraph.

NOTE This performance is necessary to ensure that two instruments using class A methods produce the same 10 min and 2 h aggregation results when connected to the same signal. This performance is also necessary when it is required to use simultaneously more than one instrument using Class A methods, possibly placed at different locations.

– **Class S**

The RTC uncertainty shall not exceed ±5 s per 24 h period.

– **Class B**

The manufacturer shall specify the RTC uncertainty and the method to determine aggregation intervals, if any.

4.7 Flagging concept

During a dip, swell, or interruption, the measurement algorithm for other parameters (for example, frequency measurement) might produce an unreliable value. The flagging concept therefore avoids counting a single event more than once in different parameters (for example, counting a single dip as both a dip and a frequency variation), and indicates that an aggregated value might be unreliable.

Flagging is only triggered by dips, swells, and interruptions. The detection of dips and swells is dependent on the threshold selected by the user, and this selection will influence which data are flagged.

The flagging concept is applicable for class A and class S during measurement of power frequency, voltage magnitude, flicker, supply voltage unbalance, voltage harmonics, voltage interharmonics, mains signalling and measurement of underdeviation and overdeviation parameters.

If, during a given time interval, any value is flagged, the aggregated value which includes that value shall also be flagged. The flagged value shall be stored and also included in the aggregation process. For example, if during a given time interval, any value is flagged, then the aggregated value that includes this value shall also be flagged and stored.

NOTE The flag may be made available with the data. The user, application, regulation, or other standards determine the use of flagged data. The fact that data have been flagged is an alert that there are possible problems in the data.

5 Power quality parameters

5.1 Power frequency

5.1.1 Measurement method

– **Class A**

The frequency reading shall be obtained every 10 s. As power frequency may not be exactly 50 Hz or 60 Hz within the 10 s time clock interval, the number of cycles may not be an integer number. The fundamental frequency output is the ratio of the number of integral cycles counted during the 10 s time clock interval, divided by the cumulative duration of the integer cycles. Before each assessment, harmonics and interharmonics shall be attenuated to minimize the effects of multiple zero crossings.

The measurement time intervals shall be non-overlapping. Individual cycles that overlap the 10 s time clock are discarded. Each 10 s interval shall begin on an absolute 10 s time clock, with uncertainty as defined in 4.6.

Other techniques that provide equivalent results, such as convolution, are acceptable.

– **Class S**

Same as class A.

– **Class B**

The manufacturer shall specify the process used for frequency measurement.

5.1.2 Measurement uncertainty and measuring range

– **Class A**

Under the conditions described in 6.1, the measurement uncertainty shall not exceed ±10 mHz over the measuring ranges 42,5 Hz ~ 57,5 Hz / 51 Hz ~ 69 Hz.

– **Class S**

Under the conditions described in 6.1, the measurement uncertainty shall not exceed ±50 mHz over the measuring ranges 42,5 Hz ~ 57,5 Hz / 51 Hz ~ 69 Hz.

– **Class B**

The manufacturer shall specify the uncertainty over the measuring ranges 42,5 Hz ~ 57,5 Hz / 51 Hz ~ 69 Hz.

5.1.3 Measurement evaluation

– **Class A**

The frequency measurement shall be made on the reference channel.

NOTE The manufacturer should specify the behaviour of frequency measurement whenever the reference channel loses voltage.

– **Class S**

Same as class A.

– **Class B**

The manufacturer shall indicate the process used for frequency measurement.

5.1.4 Aggregation

Aggregation is not required.

5.2 Magnitude of the supply voltage

5.2.1 Measurement method

– **Class A**

The measurement shall be the r.m.s. value of the voltage magnitude over a 10-cycle time interval for 50 Hz power systems or 12-cycle time interval for 60 Hz power system. Every 10/12-cycle interval shall be contiguous, and not overlapping with adjacent 10/12-cycle intervals except as shown as overlap 1 in Figure 2.

NOTE 1 This specific measurement method is used for quasi-stationary signals, and is not used for the detection and measurement of disturbances: dips, swells, voltage interruptions and transients.

NOTE 2 The r.m.s. value includes, by definition, harmonics, interharmonics, mains signalling, etc.

– **Class S**

Same as class A.

– **Class B**

The measurement shall be the r.m.s. value of the voltage over a period specified by the manufacturer.

5.2.2 Measurement uncertainty and measuring range

– **Class A**

Under the conditions described in 6.1, the measurement uncertainty shall not exceed ±0,1 % of U_{din}, over the range of 10 % ~ 150 % of U_{din}.

– **Class S**

Under the conditions described in 6.1, the measurement uncertainty shall not exceed ±0,5 % of U_{din} , over the range of 20 % ~ 120 % of U_{din}.

– **Class B**

Under the conditions described in 6.1, the measurement uncertainty shall be specified by the manufacturer, in such a way as not to exceed ±1 % of U_{din} , over a range specified by the manufacturer.

5.2.3 Measurement evaluation

No requirements.

5.2.4 Aggregation

Aggregation shall be performed according to 4.4 and 4.5.

5.3 Flicker

5.3.1 Measurement method

– **Class A**

IEC 61000-4-15 applies.

– **Class S**

IEC 61000-4-15 applies.

– **Class B**

Not applicable.

NOTE In IEC 61000-4-15, measurements are defined only at 120 V / 60 Hz and 230 V / 50 Hz. At present, an extension of the flicker definition to other voltages is being considered.

5.3.2 Measurement uncertainty and measuring range

– **Class A**

See IEC 61000-4-15. Under the conditions described in 6.1, the measurement uncertainty required by IEC 61000-4-15 shall be met over the measuring range of 0,2 ~ 10 P_{st}.

– **Class S**

See IEC 61000-4-15. Under the conditions described in 6.1, twice the permitted measurement uncertainty required by IEC 61000-4-15 shall be met over the measuring range of 0,4 ~ 4 P_{st}.

– **Class B**

Not applicable.

5.3.3 Measurement evaluation

– **Class A**

IEC 61000-4-15 applies.

The 10 min time interval for P_{st} shall commence on an RTC 10 min tick, and shall be tagged with the absolute time (see 4.5.3).

Voltage dips, swells, and interruptions shall cause P_{st} and P_{lt} output values (see IEC 61000-4-15) to be flagged.

– **Class S**

Same as class A.

– **Class B**

Not applicable.

5.3.4 Aggregation

– **Class A**

Aggregation shall be performed according to IEC 61000-4-15. For P_{lt}, aggregation shall be performed according to IEC 61000-4-15 over 2 h periods, as per 4.5.4 of this standard.

– **Class S**

Same as class A.

– **Class B**

Not applicable.

5.4 Supply voltage dips and swells

5.4.1 Measurement method

– **Class A**

The basic measurement U_{rms} of a voltage dip and swell shall be the $U_{rms(1/2)}$ on each measurement channel (see 3.24).

The cycle duration for $U_{rms(1/2)}$ depends on the frequency. The frequency might be determined by the last non-flagged power frequency measurement (see 4.7 and 5.1), or by any other method that yields the uncertainty requirements of 6.2.

NOTE 1 The $U_{rms(1/2)}$ value includes, by definition, harmonics, interharmonics, mains signalling voltage, etc.

– **Class S**

The basic measurement U_{rms} of a voltage dip and swell shall be either the $U_{rms(1/2)}$ on each measurement channel (see 3.24), or the $U_{rms(1)}$ on each measurement channel (see 3.25). The manufacturer shall specify which measurement is used.

NOTE 2 The $U_{rms(1)}$ value includes, by definition, harmonics, interharmonics, mains signalling voltage, etc.

– **Class B**

The manufacturer shall specify the method used for U_{rms}.

5.4.2 Detection and evaluation of a voltage dip

5.4.2.1 Voltage dip detection

The dip threshold is a percentage of either U_{din} or the sliding voltage reference U_{sr} (see 5.4.4). The user shall declare the reference voltage in use.

NOTE Sliding voltage reference U_{sr} is generally not used in LV systems. See IEC 61000-2-8 for further information and advice.

– On single-phase systems, a voltage dip begins when the U_{rms} voltage falls below the dip threshold, and ends when the U_{rms} voltage is equal to or above the dip threshold plus the hysteresis voltage.
– On polyphase systems, a dip begins when the U_{rms} voltage of one or more channels is below the dip threshold and ends when the U_{rms} voltage on all measured channels is equal to or above the dip threshold plus the hysteresis voltage.

The dip threshold and the hysteresis voltage are both set by the user according to the use.

5.4.2.2 Voltage dip evaluation

A voltage dip is characterized by a pair of data: either residual voltage (U_{res}) or depth, and duration:

– the residual voltage is the lowest U_{rms} value measured on any channel during the dip;
– the depth is the difference between the reference voltage (either U_{din} or U_{sr}) and the residual voltage. It is generally expressed in percentage of the reference voltage.

The start time of a dip shall be time stamped with the time of the end of the U_{rms} of the channel that initiated the event and the end time of the dip shall be time stamped with the time of the end of the U_{rms} that ended the event, as defined by the threshold plus the hysteresis.

The duration of a voltage dip is the time difference between the start time and the end time of the voltage dip.

NOTE 1 For polyphase measurements, the dip duration may start on one channel and terminate on a different channel.

NOTE 2 Voltage dip envelopes are not necessarily rectangular. As a consequence, for a given voltage dip, the measured duration is dependent on the selected dip threshold value. The shape of the envelope may be assessed using several dip thresholds set within the range of voltage dip and voltage interruption thresholds.

NOTE 3 Typically, the hysteresis is equal to 2 % of U_{din}.

NOTE 4 Dip thresholds are typically in the range 85 % to 90 % of the fixed voltage reference for troubleshooting or statistical applications.

NOTE 5 Residual voltage is often useful to end-users, and may be preferred because it is referenced to zero volts. In contrast, depth is often useful to electric suppliers, especially on HV systems or in cases when a sliding reference voltage is used.

NOTE 6 Phase shift may occur during voltage dips. See A.7.5.

NOTE 7 When a threshold is crossed, a time stamp may be recorded.

5.4.3 Detection and evaluation of a voltage swell

5.4.3.1 Voltage swell detection

The swell threshold is a percentage of either U_{din} or the sliding reference voltage U_{sr} (see 5.4.4). The user shall declare the reference voltage in use.

NOTE Sliding reference voltage U_{sr} is generally not used in LV systems. See IEC 61000-2-8 for further information and advice.

– On single-phase systems, a swell begins when the U_{rms} voltage rises above the swell threshold, and ends when the U_{rms} voltage is equal to or below the swell threshold minus the hysteresis voltage.
– On polyphase systems, a swell begins when the U_{rms} voltage of one or more channels is above the swell threshold and ends when the U_{rms} voltage on all measured channels is equal to or below the swell threshold minus the hysteresis voltage.

The swell threshold and the hysteresis voltage are both set by the user according to the use.

5.4.3.2 Voltage swell evaluation

A voltage swell is characterized by a pair of data; maximum swell voltage magnitude and duration.

– The maximum swell magnitude voltage is the largest U_{rms} value measured on any channel during the swell.
– The start time of a swell shall be time stamped with the time of the end of the U_{rms} of the channel that initiated the event and the end time of the swell shall be time stamped with the time of the end of the U_{rms} that ended the event, as defined by the threshold minus the hysteresis.
– The duration of a voltage swell is the time difference between the beginning and the end of the swell.

NOTE 1 For polyphase measurements, the swell duration measurement may start on one channel and terminate on a different channel.

NOTE 2 Voltage swell envelope may not be rectangular. As a consequence, for a given swell, the measured duration is dependent on the swell threshold value.

NOTE 3 Typically, the hysteresis is equal to 2 % of U_{din}.

NOTE 4 Typically, the swell threshold is equal to or greater than 110 % of U_{din}.

NOTE 5 Phase shift may also occur during voltage swells.

NOTE 6 When a threshold is crossed, a time stamp may be recorded.

5.4.4 Calculation of a sliding reference voltage

The sliding reference voltage implementation is optional, not required. If a sliding reference is chosen for voltage dip or swell detection, this shall be calculated using a first-order filter with a 1 min time constant. This filter is given by:

$$U_{sr(n)} = 0{,}996\,7 \times U_{sr(n-1)} + 0{,}003\,3 \times U_{(10/12)rms}$$

where

$U_{sr(n)}$ is the present value of the sliding reference voltage;

$U_{sr(n-1)}$ is the previous value of the sliding reference voltage; and

$U_{(10/12)rms}$ is the most recent 10/12-cycle r.m.s. value.

When the measurement is started, the initial value of the sliding reference voltage is set to the declared input voltage. The sliding reference voltage is updated every 10/12-cycles. If a 10/12-cycle value is flagged, the sliding reference voltage is not updated and the previous value is used.

5.4.5 Measurement uncertainty and measuring range

5.4.5.1 Residual voltage and swell voltage magnitude measurement uncertainty

– **Class A**

The measurement uncertainty shall not exceed ±0,2 % of U_{din}.

– **Class S**

The measurement uncertainty shall not exceed ±1,0 % of U_{din}.

– **Class B**

The manufacturer shall specify the uncertainty which shall not exceed ±2,0 % of U_{din}.

5.4.5.2 Duration measurement uncertainty

– **Class A**

The uncertainty of a dip or swell duration is equal to the dip or swell commencement uncertainty (half a cycle) plus the dip or swell conclusion uncertainty (half a cycle).

– **Class S**

If $U_{rms(1/2)}$ is used, then the uncertainty of a dip or swell duration is equal to the dip or swell commencement uncertainty (half a cycle) plus the dip or swell conclusion uncertainty (half a cycle). If $U_{rms(1)}$ is used, then the uncertainty of a dip or swell duration is equal to the dip or swell commencement uncertainty (one cycle) plus the dip or swell conclusion uncertainty (one cycle).

– **Class B**

The manufacturer shall specify the duration measurement uncertainty.

5.4.6 Aggregation

Aggregation is not applicable for triggered events.

5.5 Voltage interruptions

5.5.1 Measurement method

The basic measurement of the voltage shall be as defined in 5.4.1 for each class.

5.5.2 Evaluation of a voltage interruption

On single-phase systems, a voltage interruption begins when the U_{rms} voltage falls below the voltage interruption threshold and ends when the U_{rms} value is equal to, or greater than, the voltage interruption threshold plus the hysteresis.

On polyphase systems, a voltage interruption begins when the U_{rms} voltages of all channels fall below the voltage interruption threshold and ends when the U_{rms} voltage on any one channel is equal to, or greater than, the voltage interruption threshold plus the hysteresis.

The voltage interruption threshold and the hysteresis voltage are both set by the user according to the use. The voltage interruption threshold shall not be set below the uncertainty of residual voltage measurement plus the value of the hysteresis. Typically, the hysteresis is equal to 2 % of U_{din}.

The start time of a voltage interruption shall be time stamped with the time of the end of the U_{rms} of the channel that initiated the event and the end time of the voltage interruption shall be time stamped with the time of the end of the U_{rms} that ended the event, as defined by the threshold plus the hysteresis.

The duration of a voltage interruption is the time difference between the beginning and the end of the voltage interruption.

NOTE 1 The voltage interruption threshold can, for example, be set to 5 % or to 10% of U_{din}.

NOTE 2 IEV 161-08-20 considers an interruption to have occurred when the voltage magnitude is less than 1 % of the nominal voltage. However, it is difficult to correctly measure voltages below 1 % of the nominal voltage. Therefore, this standard recommends that the user set an appropriate voltage interruption threshold.

NOTE 3 The interruption of one or more phases on a polyphase system can be seen as an interruption of the supply to single-phase customers connected to that system, even though this would not be classified as an interruption in a polyphase measurement.

5.5.3 Measurement uncertainty and measuring range

For duration measurement uncertainty, see 5.4.5.2.

5.5.4 Aggregation

Aggregation is not applicable for triggered events.

5.6 Transient voltages

Clause A.4 provides some information on the significant parameters necessary to characterize transient voltages and currents.

5.7 Supply voltage unbalance

5.7.1 Measurement method

Unbalance measurements apply only to 3-phase systems.

– **Class A**

The supply voltage unbalance is evaluated using the method of symmetrical components. In addition to the positive sequence component U_1, under unbalanced conditions there also exists at least one of the following components: negative sequence component U_2 and/or zero sequence component U_0.

The fundamental component of the voltage input signal is measured over a 10-cycle time interval for 50 Hz power systems or a 12-cycle time interval for 60 Hz power systems.

NOTE 1 The effect of harmonics is minimized by the use of a filter or by using a DFT algorithm.

NOTE 2 Algorithms that use only the r.m.s. values to calculate unbalance fail to take into account the contributions of angular displacement to unbalance, and cause unpredictable results when harmonic voltages are present. The negative sequence unbalance and zero sequence unbalance provide more precise and more directly useful values.

The negative sequence ratio u_2 , expressed as a percentage, is evaluated by

$$u_2 = \frac{U_2}{U_1} \times 100 = \frac{\text{negative sequence}}{\text{positive sequence}} \times 100 \tag{1}$$

For 3-phase systems considering only phase-to-phase voltages, and only fundamental voltages, this can be written (with $U_{\text{ij fund}}$ = phase *i* to phase *j* fundamental voltage)

$$u_2 = \sqrt{\frac{1-\sqrt{3-6\beta}}{1+\sqrt{3-6\beta}}} \times 100 \text{ with } \beta = \frac{U_{12\text{ fund}}^4 + U_{23\text{ fund}}^4 + U_{31\text{ fund}}^4}{\left(U_{12\text{ fund}}^2 + U_{23\text{ fund}}^2 + U_{31\text{ fund}}^2\right)^2} \tag{2}$$

The zero-sequence ratio u_0 expressed as a percentage is evaluated by

$$u_0 = \frac{U_0}{U_1} \times 100 = \frac{\text{zero sequence}}{\text{positive sequence}} \times 100 \tag{3}$$

NOTE 3 The zero sequence unbalance by definition is zero when phase-to-phase voltages are measured. However, the phase-to-neutral or phase-to-earth voltages may still contain the zero sequence component in that case.

– **Class S**

The negative sequence ratio is evaluated in the same way as for Class A. The evaluation of the zero-sequence unbalance ratio is optional, not mandatory.

– **Class B**

The manufacturer shall specify the algorithms and methods used to calculate unbalance.

5.7.2 Measurement uncertainty and measuring range

– **Class A**

When a 3-phase a.c. voltage that fulfils the requirements of "testing state 1" conditions (see Table 2), except for negative- and zero-sequence unbalance in the measuring range 1 % to 5 % of U_1, is applied at the input, then the instrument shall present an uncertainty less than ±0,15 % for both u_2 and u_0. For example, an instrument presented with a 1,0 % negative sequence shall provide a reading x such that 0,85 % ≤ x ≤ 1,15 %. See Figure 5.

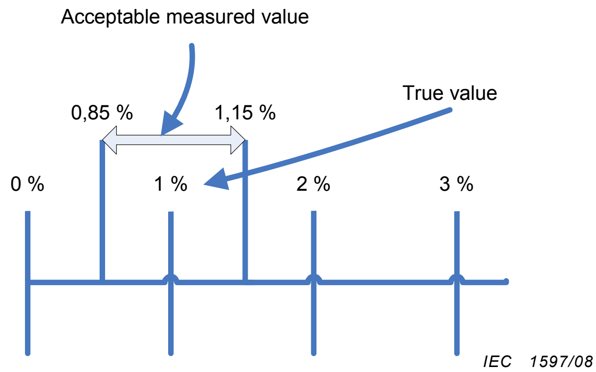

Figure 5 – Example of supply voltage unbalance uncertainty

– **Class S**

Same as class A, except for the uncertainty, which is less than ±0,3% for u_2 (and for u_0 if it is evaluated).

– **Class B**

Same as class A, except for the uncertainty, which is less than ±0,3% for any unbalance parameter that is evaluated.

5.7.3 Measurement evaluation

No requirements.

NOTE The uncertainty of measurement transformers, if present, may have a large impact on the calculation of unbalance.

5.7.4 Aggregation

Aggregation shall be performed according to 4.4 and 4.5.

5.8 Voltage harmonics

5.8.1 Measurement method

– **Class A**

The basic measurement of voltage harmonics, for class A, is defined in IEC 61000-4-7 class I. That standard shall be used to determine a 10/12-cycle gapless harmonic subgroup measurement, denoted $U_{sg,h}$ in IEC 61000-4-7.

NOTE 1 Other methods, including analogue and frequency domain methods, may be preferred in special cases (see, for example, IEC 61000-3-8).

NOTE 2 Current harmonic measurements are considered in Clause A.6.

Measurements shall be made at least up to the 50th order.

If the total harmonic distortion is calculated, then it shall be calculated as the subgroup total harmonic distortion (*THDS*), defined in IEC 61000-4-7.

– **Class S**

The basic measurement of voltage harmonics, for class S, is defined in IEC 61000-4-7, class II. Gaps are permitted (see 4.5). The manufacturer shall select either a 10/12-cycle harmonic group designated $U_{g,h}$ in IEC 61000-4-7, or a 10/12-cycle subgroup measurement designated $U_{sg,h}$ in IEC 61000-4-7. The manufacturer shall specify which has been selected.

Measurements shall be made at least up to the 40th order.

NOTE 3 EN 50160 assessment requires the 40th order.

If the total harmonic distortion is calculated, then it shall be calculated either as the total harmonic distortion (*THD*) if $U_{g,h}$ is selected, or the subgroup total harmonic distortion (*THDS*) if $U_{sg,h}$ is selected, both defined in IEC 61000-4-7.

– **Class B**

The manufacturer shall specify the measurement method.

5.8.2 Measurement uncertainty and measuring range

– **Class A**

The maximum uncertainty shall be the levels specified in IEC 61000-4-7 class I.

The measuring range shall be 10 % to 200 % of class 3 compatibility level in IEC 61000-2-4.

– **Class S**

The maximum uncertainty shall be twice the levels specified in IEC 61000-4-7 class II. The anti-aliasing low-pass filter specified in IEC 61000-4-7, 5.3 shall be optional. The ±0,03 % maximum permissible error for time between leading edges requirement as specified in IEC 61000-4-7, 4.4.1 shall be optional, but the maximum uncertainty requirement shall still be met over the range of influence quantities specified in Clause 6 of this standard.

The measuring range shall be 10 % to 100 % of class 3 compatibility level in IEC 61000-2-4.

– **Class B**

The manufacturer shall specify measurement uncertainty and measuring range.

5.8.3 Measurement evaluation

No requirements.

5.8.4 Aggregation

Aggregation shall be performed according to 4.4 and 4.5.

5.9 Voltage interharmonics

5.9.1 Measurement method

– **Class A**

The basic measurement of voltage interharmonics, for the purpose of this standard, is defined in IEC 61000-4-7, class I. This standard shall be used to determine a 10/12-cycle gapless centred interharmonic subgroup measurement, denoted $U_{isg,h}$ in IEC 61000-4-7.

NOTE Current interharmonic measurements are considered in Clause A.6.

Measurements shall be made at least up to the 50th order.

– **Class S**

The manufacturer shall specify the measurement method.

– **Class B**

The manufacturer shall specify the measurement method.

5.9.2 Measurement uncertainty and measuring range

– **Class A**

The maximum uncertainty shall be the levels specified in IEC 61000-4-7 class I .

Measuring range shall be 10 % to 200 % of class 3 compatibility level in IEC 61000-2-4.

– **Class S**

The manufacturer shall specify measurement uncertainty and measuring range.

– **Class B**

The manufacturer shall specify measurement uncertainty and measuring range.

5.9.3 Measurement evaluation

No requirements.

5.9.4 Aggregation

Aggregation shall be performed according to 4.4 and 4.5.

5.10 Mains signalling voltage on the supply voltage

Mains signalling voltage, called ripple control signal in certain applications, is a burst of signals, often applied at a non-harmonic frequency, that remotely control industrial equipment, revenue meters, and other devices.

5.10.1 Measurement method

– **Class A**

The method described here shall be used for mains signalling frequencies below 3 kHz. For mains signalling, frequencies above 3 kHz, see IEC 61000-3-8.

This method measures the level of the signal voltage for a user-specified carrier frequency.

NOTE The purpose of this method is to measure the maximum level of the signal voltage, and not to diagnose mains signalling difficulties.

Mains signalling voltage measurement shall be based on:

- either the corresponding 10/12-cycle r.m.s. value interharmonic bin;
- or the root of the sum of the squares of the 4 nearest 10/12-cycle r.m.s. value interharmonic bins (for example, a 316,67 Hz ripple control signal in a 50 Hz power system shall be approximated by a root of the sum of the squares of 310 Hz, 315 Hz, 320 Hz and 325 Hz bins, available from the DFT performed on a 10/12 cycle time interval).

The first method is preferred if the user-specified frequency is in the center of an DFT bin. The second method is preferred if the frequency is not in the center of a bin.

The user shall select a detection threshold above 0,3 % U_{din} as well as the length of the recording period up to 120 s. The beginning of a signalling emission shall be detected when the measured value of the concerned interharmonic exceeds the detection threshold. The measured values are recorded during a period of time specified by the user, in order to give the maximum level of the signal voltage.

– **Class S**

The manufacturer shall specify the measurement technique.

– **Class B**

The manufacturer shall specify the measurement technique.

5.10.2 Measurement uncertainty and measuring range

– **Class A**

The measurement range shall be at least 0 % to 15 % of U_{din}.

For the mains signalling voltage between 3 % and 15 % of U_{din}, the uncertainty shall not exceed ±5 % of the measured value. For the mains signalling voltage between 1 % and 3 % of U_{din}, the uncertainty shall not exceed ±0,15 % of U_{din}. For the mains signalling voltage less than 1 % of U_{din}, no uncertainty requirement is given.

– **Class S**

The manufacturer shall specify the uncertainty and the measuring range.

– **Class B**

The manufacturer shall specify the uncertainty and the measuring range.

5.10.3 Measurement evaluation

No requirements.

5.10.4 Aggregation

Aggregation is not required.

5.11 Rapid Voltage Changes (RVC)

NOTE Clause A.5 provides some information on the significant parameters necessary to characterize a rapid voltage change. Further information regarding loads in low voltage networks can be found in IEC 61000-3-3 and IEC 61000-3-11. This further information is not necessarily applicable to the networks themselves.

5.12 Measurement of underdeviation and overdeviation parameters

5.12.1 Measurement method

– **Class A**

The 10/12-cycle r.m.s. value $U_{rms\text{-}200ms}$ shall be used to assess the underdeviation and overdeviation parameters in per cent of U_{din}. The underdeviation $U_{rms\text{-}under}$ and overdeviation $U_{rms\text{-}over}$ parameters are determined by equations (4A), (4B), (5A), (5B), (6), and (7).

Underdeviation assessment:

the following rule (4) applies for the calculation of $U_{rms\text{-}under,i}$:

If $$U_{rms-200ms,i} > U_{din} \text{ then } U_{rms-under,i} = U_{din} \quad (4A)$$

If $$U_{rms-200ms,i} \leq U_{din} \text{ then } U_{rms-under,i} = U_{rms-200ms,i} \quad (4B)$$

Overdeviation assessment:

the following rule (5) applies for the calculation of $U_{rms\text{-}over,i}$:

If $$U_{rms-200ms,i} < U_{din} \text{ then } U_{rms-over,i} = U_{din} \quad (5A)$$

If $$U_{rms-200ms,i} \geq U_{din} \text{ then } U_{rms-over,i} = U_{rms-200ms,i} \quad (5B)$$

NOTE On single-phase systems, there is a single underdeviation assessment and overdeviation assessment value for each interval. On 3-phase 3-wire systems, there are 3 values for each interval. Either 6 values or 3 values may be measured on 4-wire systems.

– **Class S**

Not required.

– **Class B**

Not required.

5.12.2 Measurement uncertainty and measuring range

The underlying 10/12-cycles r.m.s. values shall be consistent with the requirements of 5.2.2.

5.12.3 Aggregation

– **Class A**

Underdeviation assessment:

$$U_{under} = \frac{U_{din} - \sqrt{\dfrac{\sum_{i=1}^{n} U^2_{rms-under,i}}{n}}}{U_{din}} \quad [\%] \qquad (6)$$

where n = number of 10/12-cycle r.m.s. values for under- or overdeviation during the aggregation interval

and $U_{rms-under,i}$ is the i[th] 10/12-cycle r.m.s. value.

Overdeviation assessment:

$$U_{over} = \frac{\sqrt{\dfrac{\sum_{i=1}^{n} U^2_{rms-over,i}}{n}} - U_{din}}{U_{din}} \quad [\%] \qquad (7)$$

where

$U_{rms-over,i}$ is the i[th] 10/12-cycle r.m.s. value.

NOTE Both underdeviation and overdeviation parameter equations (4) and (5) give positive values.

Aggregation shall be performed according to 4.4 and 4.5.

– **Class S**

Not required.

– **Class B**

Not required.

6 Range of influence quantities and steady-state verification

6.1 Range of influence quantities

The measurement of a specific characteristic can be adversely affected by the application of a disturbing influence (influence quantity) on the electrical input signal. For example, the measurement of supply voltage unbalance might be adversely affected if the voltage waveform is at the same time subject to a harmonic disturbance.

The result of a parameter measurement shall be within the specified measurement uncertainty given in Clause 5 when all other parameters are within their influence quantity range, given in the Table 1.

Table 1 – Influence quantity range

Section and parameter	Class	Influence quantity range
5.1 Frequency	A	42,5 Hz ~ 57,5 Hz, 51 Hz ~ 69 Hz
	S	42,5 Hz ~ 57,5 Hz, 51 Hz ~ 69 Hz
	B	42,5 Hz ~ 57,5 Hz, 51 Hz ~ 69 Hz
5.2 Magnitude of the supply	A	10 % ~ 200 % U_{din}
	S	10 % ~ 150 % U_{din}
	B	10 % ~ 150 % U_{din}
5.3 Flicker	A	0 ~ 20 P_{st}
	S	0 ~ 10 P_{st}
	B	N/A
5.4 Dips and swells	A	N/A
	S	N/A
	B	N/A
5.5 Interruptions	A	N/A
	S	N/A
	B	N/A
5.7 Unbalance	A	0 % ~ 5 % u_2, 0 % ~ 5 % u_0
	S	0 % ~ 5 % u_2
	B	SBM
5.8 Voltage harmonics	A	200 % of class 3 of IEC 61000-2-4
	S	200 % of class 3 of IEC 61000-2-4
	B	200 % of class 3 of IEC 61000-2-4
5.9 Voltage Interharmonics	A	200 % of class 3 of IEC 61000-2-4
	S	200 % of class 3 of IEC 61000-2-4
	B	200 % of class 3 of IEC 61000-2-4
5.10 Mains signalling voltage	A	0 % ~ 15 % U_{din}
	S	0 % ~ 15 % U_{din}
	B	0 % ~ 15 % U_{din}
5.12 Under/overdeviation	A	N/A
	S	N/A
	B	N/A
Transient voltages IEC 61180	A	6 kV peak
	S	N/R
	B	N/R
Fast transients IEC 61000-4-4	A	4 kV peak
	S	N/R
	B	N/R

SBM = Specified by manufacturer
N/R = no requirement
N/A = not applicable

NOTE For safety requirements, EMC requirements or climatic requirements, see product standards, for instance IEC 61557-12.

The instrument shall tolerate signals in the influence quantity range without shifting the measurement of other parameters out of their uncertainty requirement, and without instrument damage. The instrument may indicate overrange for signals greater than the measuring range, up to the influence quantity range (not including transients and fast transients).

For transient voltages and fast transients, there shall be no effect on any measurement after the transient. The transients are applied to the measuring terminals, not to the instrument power terminals.

6.2 Steady-state performance verification

The tests below confirm that steady-state signals are measured within their specified uncertainties, with influence quantities applied.

These tests are necessary but not sufficient to verify that an implementation meets the requirements of this standard. To fully verify that the measuring methods of Clause 5 have been implemented correctly, additional tests and/or validation may be necessary.

NOTE 1 See Annex C for guidance.

– **Class A**

To confirm that the steady-state performance of an instrument is correct, the tests below are applied.

NOTE 2 These tests are required as type tests, not as routine tests.

The uncertainty of an instrument shall be tested for each measured quantity as follows (see Table 2):

- select a measured quantity (for example, r.m.s. voltage magnitude);
- holding all other quantities in testing state 1, verify the uncertainty of the measured quantity to be tested at 5 approximately equally spaced points throughout the measurement range including the upper and lower limit (for example, 10 % of U_{din}, 45 % of U_{din}, 80 % of U_{din}, 115 % of U_{din}, 150 % of U_{din} for class A);
- holding all other quantities in testing state 2, repeat the test;
- holding all other quantities in testing state 3, repeat the test.

Other testing states may be used in addition to the testing states specified in Table 2. In this case, the values chosen for each influence quantity shall be within the range of variations for that influence quantity.

NOTE 3 In interpreting this subclause, it is intended that 15 series of testing states will be selected for each measured parameter. For parameters that have multiple sub-parameters (for example, voltage harmonics have fifty individual harmonics), select one representative sub-parameter.

NOTE 4 Some influence quantities should not influence the value of the measured parameter (for example, harmonics should not influence the value of unbalance). Other influence quantities should influence the value of the measured parameter (for example, harmonics should influence the value of r.m.s.). The uncertainty requirements should be met in both cases.

Table 2 – Uncertainty steady-state verification for class A and class S

Influence quantities	Testing state 1	Testing state 2	Testing state 3
Frequency	$f_{nom} \pm 0{,}5$ Hz	$f_{nom} - 1$ Hz $\pm 0{,}5$ Hz	$f_{nom} + 1$ Hz $\pm 0{,}5$ Hz
Voltage magnitude	$U_{din} \pm 1$ %	Determined by flicker, unbalance, harmonics, interharmonics (below)	Determined by flicker, unbalance, harmonics, interharmonics (below)
Flicker	$P_{st} < 0{,}1$	$P_{st} = 1 \pm 0{,}1$ – rectangular modulation at 39 changes per minute	$P_{st} = 4 \pm 0{,}1$ – rectangular modulation at 110 changes per minute
Unbalance	100% ± 0,5 % of U_{din} on all channels. All phase angles 120° (equivalent to u_0 = 0 %, u_2 = 0 %)	73 % ± 0,5 % of U_{din} Channel 1 80 % ± 0,5 % of U_{din} Channel 2 87 % ± 0,5 % of U_{din} Channel 3 all phase angles 120° (equivalent to u_0 = 5,05 %, u_2 = 5,05 %)	152 % ± 0,5 % of U_{din} Channel 1 140 % ± 0,5 % of U_{din} Channel 2 128 % ± 0,5 % of U_{din} Channel 3 all phase angles 120° (equivalent to u_0 = 4,95 %, u_2 = 4,95 %)
Harmonics	0 % to 3 % of U_{din}	10 % ± 3 % of U_{din} 3rd at 0° 5 % ± 3 % of U_{din} 5th at 0° 5 % ± 3 % of U_{din} 29th at 0°	10 % ± 3 % of U_{din} 7th at 180° 5 % ± 3 % of U_{din} 13th at 0° 5 % ± 3 % of U_{din} 25th at 0°
Interharmonics	0 % to 0,5 % of U_{din}	1 % ± 0,5 % of U_{din} at 7,5 f_{nom}	1 % ± 0,5 % of U_{din} at 3,5 f_{nom}

When verifying magnitude of supply voltage performance, replace U_{din} in Table 2 with the magnitude of supply voltage value that has been selected for the test.

– **Class S**

Same as class A.

– **Class B**

No steady-state uncertainty testing requirements are specified.

Annex A
(informative)

Power quality measurements – Issues and guidelines

A.1 General

This annex is provided as an informative complement to the normative part of this standard.

The following two clauses address general concerns and procedures for implementation of power quality measurements regardless of the purpose of the measurements.

– A.2 – Installation precautions
– A.3 – Transducers

The following clauses are pre-normative measurement methods:

– A.4 – Transient voltages and currents
– A.5 – Rapid voltage changes
– A.6 – Current
– A.7 – Voltage dip characteristics

A.2 Installation precautions

A.2.1 Installation

During installation of power quality (PQ) measurement instruments, the safety of the installer and others, the integrity of the system being monitored and the integrity of the instrument itself shall be ensured.

While many installations are temporary in nature and consequently may not utilize the same practices as for permanent installations, local codes shall never be compromised. Local codes, regulations and safety practices will cover most of the items below and will always take precedence over the precautions listed here. All local and national safety requirements shall be followed (for example, personal protective equipment requirements).

A.2.2 Test leads

A.2.2.1 Test lead connections

For safety, IEC 61010, which gives the safety requirements for electrical equipment for measurement, control and laboratory use, applies.

Test lead connections made in load centre panel boards or junction boxes will be attached in a manner that does not violate the listed use of the devices to which they are attached. This generally includes returning doors, cover plates and access panels to their in-use position (i.e., closed, mounted with a full set of screws, etc.). If panels remain open during monitoring, adequate means will be provided to limit access to the area and inform others about the monitoring set-up and the responsible on-site contact.

It is for most cases recommended that the PQ measurement instrument be attached to a point in the system specifically designed for measurements or metering.

Test leads will be routed away from exposed conductors, sharp objects, low- and high-frequency electromagnetic fields, and other adverse environments. If possible, they will be strapped or tied to a solid object to prevent inadvertent disconnection.

A.2.2.2 Voltage test leads

Leads that are fused at the probe end, i.e. the end connected to the system being monitored, increase the safety of the connection. The instrument manufacturer shall specify the fuse size; this will be low enough to protect the test lead against overload conditions. Furthermore, the interrupting capacity of the fuse will be consistent with the available power-frequency fault current at the point of connection.

Voltage sense leads shall not be casually twisted around existing wires or inserted in circuit-breaker connectors that are designed to receive a single conductor. Instead, a properly rated and installed mechanical connection should be used. Where clips are used for temporary installations, they shall comply with IEC 61010. It is essential to ensure both that the clip is rated for the maximum voltage that may be present and that it is installed in a mechanically secure manner. During installation, the installer will consider what will happen if the clip is inadvertently dislodged, for example, by an abrupt tug on the cable.

Some test leads have insulated plugs capable of being stacked one on top of the other. Caution should be exercised so that when stacking, only intentional connections are made rather than creating an inadvertent short circuit. Always double-check the leads to ensure that short circuits have not been introduced. Also, connect the sense leads to the monitored circuit only after the leads have been connected to the PQ instrument and checked for correctness.

A.2.2.3 Current test leads

Care should be taken that the secondaries of current transformers, if used, do not become open circuit, i.e. there shall be no fuse in the secondaries of such circuits, and the connection to the burden shall be mechanically secure.

Clamp-on current transducers and associated leads, used for temporary installations, shall be designed according to IEC 61010-2-032.

A.2.3 Guarding of live parts

Often panel covers are removed for installation, or during the monitoring period. If so, all live parts will be adequately protected and the area will be kept inaccessible. If screw terminals are used in the measurement instrument, appropriate covers will be used to insulate the terminations. All attachments to terminations will be made in accordance with the specifications and intent of the terminations. For example, multiple wires shall not be connected to a screw terminal designed for a single wire.

A.2.4 Monitor placement

The PQ measurement instrument needs to be placed securely to minimize the risk of the instrument moving or loosening connections. If a paper printer is used for reporting disturbances, adequate precautions should be taken to ensure that accumulating paper does not present a hazard. Measurement instruments will not be left where excessive heat, moisture or dust may damage the instrument, or jeopardize the data collection process.

The measurement instrument will be placed so that it does not pose a hazard to those working in the area. A protective enclosure or barrier can sometimes be used to alleviate this concern. If possible, the measurement instrument will not be placed in a location where it will be exposed to many people, for example, in a heavily travelled hallway.

In addition, the location should not pose an undue hazard to the person installing the PQ measurement instrument. There are many locations that are too cramped, or in other ways physically constrained, to allow suitable connection of instrument leads. In these situations, an alternative location will be selected.

A number of external environmental factors can affect the performance of a PQ measurement instrument. These environmental factors include temperature, humidity, low- and high-frequency electromagnetic fields, static discharge, mechanical shock and vibration.

A.2.5 Earthing

All instruments are capable of developing internal faults. The instruments power supply will be properly connected to a protective earth if declared necessary by the manufacturer. Many safety regulations also require an earth connection associated with the voltage test leads. Instruments with two or more earth connections (for example, one earth connection for the power supply, and another for the test leads) can create ground loops if the earth connections are made to different physical points outside the instrument. The risk from ground loops on the measurements and on the system being measured will need to be carefully considered.

There is also a need to consider the potential hazard to personnel and the instrument due to high potentials between different points in the grounding system. The use of isolating transformers for the power supply of the instrument is in most cases useful.

In all cases, safety considerations will take the highest priority.

A.2.6 Interference

If the PQ measurement instrument is connected to a mobile phone or other radio transmitter, one should take care that the transmitter antenna is sufficiently far away from devices that could be sensitive to interference. Such sensitive devices can include protection devices, medical monitors, scientific instruments, etc.

A.3 Transducers

A.3.1 General

Power quality measurement instruments, especially those in portable packages, are generally provided with inputs designed for low-voltage applications. Some permanently installed PQ measurement instruments are mounted at a distance from the point of the circuit where the parameters are to be measured. In both cases, a suitable transducer might be needed, to step down the voltage, to isolate the input circuits from the system voltage, or to transmit the signals over some distance. To accomplish any of these functions, a transducer may be used, provided that its characteristics are suitable for the parameter of interest.

In low-voltage systems, PQ measurement instruments are generally connected direct to the voltage point of interest, but transducers are often used for current measurements.

In medium- and high-voltage systems, transducers are used for both voltage and current PQ measurements.

There are two important concerns using transducers:

– signal levels: signals levels should use the full scale of the instrument without distorting or clipping the desired signal;
– frequency and phase response: these characteristics are particularly important for transient and harmonic measurements.

In order to avoid incorrect measurements, the full-scale rating, linearity, frequency and phase response, and burden characteristics of the transducer should be carefully considered.

NOTE Current transducers designed for protection purposes may be less accurate than metering transducers.

A.3.2 Signal levels

A.3.2.1 Voltage transducers

The most common voltage transducer is the voltage transformer. Two types of voltage transformers can be considered: those used by protective relay circuits, and those used by metering circuits. The first type is sized so as to provide a correct response even in the case of overvoltages due to an unbalanced short circuit. The second, in contrast, is designed to protect meters from network overvoltages. In the latter category, in case of saturation, distortion of the delivered signal will occur.

Where monitoring is attached to a voltage transformer which is also used for other functions (for example, metering), one shall be careful that the additional burden do not affect the calibration or uncertainty of such other functions.

One should be careful when making connections to the secondary circuit of a transformer used for a protective relay. Connection errors might cause the relay to inadvertently trip.

NOTE For further details of the uncertainty of voltage transformers, see IEC 60044-2.

A.3.2.2 Current transducers

In the operation on the power system network, the value of the current can range from 0 to the short-circuit level of the network being monitored. The short-circuit current value can be well above the nominal current level. A value of 20 times nominal is not unusual.

The most common type of current transducer is the current transformer.

Some current transformers are equipped with two or more cores and/or two secondary windings: one for large current flows (20 to 30 times nominal current), typically for protection relays, and a second for nominal current flows. The correct secondary should be selected for the intended measurement. With direct connections, it is possible to damage the measuring instrument during faults if the wrong secondary has been selected. This damage can inadvertently provide an open circuit on the transformer secondary. Open circuits on the secondary winding of current transformers can give rise to dangerously high (and destructive) voltages.

Other considerations may affect the uncertainty of clamp-on current transducers, such as the centring and angle of the conductor as it passes through the window of the transducer.

NOTE For further details of the uncertainty of current transformers, see IEC 60044-1.

Measurements of transients can be performed with shunts or current transformers designed for high-frequency response.

Coaxial shunts are routinely used in laboratory environments but have the disadvantage of requiring insertion into the current-carrying conductors, and the fact that the output signal of the shunt is not isolated from the power circuit. On the other hand, they are not susceptible to the saturation and residual magnetization that can affect measurements made with current transformers.

Current transformers operating with a suitable resistive burden deliver a voltage signal proportional to the primary current. In general, the primary consists of one or a few turns of the primary circuit fed through an opening in the core. The major advantage of these current transducers is to provide isolation from the power circuits, and a wide range of ampere-to-volt ratios. Another advantage is that some (but not all) current transformers do not require the disconnection of the power conductor from its load during installation.

Other types of current transducers are sometimes used, including optical polarization detectors and Hall-effect transducers.

A.3.3 Frequency response of transducers

A.3.3.1 Frequency and phase response of voltage transducers

In general, transformer-type electromagnetic voltage transducers have frequency and transient responses suitable up to typically 1 kHz; but the frequency range may sometimes be limited to well below 1 kHz, and sometimes may extend to a few kilohertz.

Simple capacitor dividers can have frequency and phase responses that are suitable up to hundreds of kilohertz or even higher; however, in many applications, a resonant circuit is intentionally added, making the frequency response of the capacitive divider unsuitable for measurements at any frequency other than the fundamental.

Resistive voltage dividers may have frequency and phase response suitable up to hundreds of kilohertz. However, they may introduce other problems, for example, the capacitive load of the measurement instrument can influence the frequency and phase response of the resistive voltage dividers.

A.3.3.2 Frequency and phase response of current transducers

As current transformers are wound electromagnetic devices, the frequency response varies according to the uncertainty class, type (manufacturer), turns ratio, core material and cross-section, and the secondary circuit load.

Usually, the cut-off frequency of a current transducer ranges from 1 kHz to a few kilohertz, and the phase response degrades as the cut-off frequency is approached.

NOTE New concepts of current transducers with higher cut-off frequency and better linearity are being developed (optical and Hall-effect transducers). Insulation coordination, noise issues, full-scale capability, and safety conditions should be carefully considered.

A.3.4 Transducers for measuring transients

There are two important concerns that shall be addressed when selecting transducers for a.c. mains transients. Firstly, signal levels should use the full scale of the instrument without distorting or clipping the desired signal. Secondly, the frequency response (both amplitude and phase) of the transducer should be adequate for the expected signal.

- **Voltage Transducers (VTs)**
  - VTs should be sized to prevent measured disturbances from inducing saturation. For low-frequency transients, this requires that the knee point of the transducer saturation curve be at least 200 % of the nominal system voltage.
  - The frequency response of a standard metering class VT depends on its type and the burden applied. With a high impedance burden, the response is usually adequate to at least 2 kHz, but it can be less.
  - Capacitively coupled voltage transformers generally do not provide accurate representation of any higher frequency components.
  - High-frequency transient measurements require a capacitor divider or pure resistive divider. Special purpose capacitor dividers can be obtained for measurements requiring accurate characterization of transients up to at least 1 MHz.
- **Current Transducers (CTs)**
  - Selecting the proper transducer for currents is more difficult. The current in a distribution feeder changes more often and with greater magnitude than the voltage.
  - Standard metering-class CTs are generally adequate for frequencies up to 2 kHz (phase error can start to become significant before this limit). For higher frequencies, window

type CTs with a high turns ratio (doughnut, split core, bar type, and clamp-on) should be used.

– Additional desirable attributes for CTs are: a large turns ratio, for example, 2000:5; less than 5 turns in the primary; small remnant flux, for example, 10 % of core saturation; large core area; minimal secondary winding resistance and leakage impedance. When using a CT to measure transients, there are 2 key parameters that need to be considered, current-time product (*I*·*t* max) and rise time/droop. Typical values of the rise time (10 % to 90 %) are in the range of 2 ns to 200 ns. Typical droop values range from 0,1 %/µs to 0,5 %/ms.

NOTE In HV systems, high-frequency and transient voltage measurements may be performed using capacitive taps often available on CTs and transformer bushings.

A.4 Transient voltages and currents

A.4.1 General

This clause is primarily focused on transients occurring in LV systems and does not cover transients from GIS[1] installations or HV systems.

Transients can occur on all a.c. power systems. Traditionally, they have been characterized as "transient voltages"; however, in many cases, the transient current may be more important. The detection, classification, and characterization of transient voltages are challenging subjects.

A.4.2 Terms and definitions

A.4.2.1
transient
pertaining to or designating a phenomenon or a quantity which varies between 2 consecutive steady states during a time interval short when compared with the timescale of interest

[IEV 161-02-01]

A.4.2.2
surge
transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage

[IEV 161-08-11]

A.4.3 Frequency and amplitude characteristics of a.c. mains transients

Transients in a.c. power circuits occur over a wide range of waveforms, amplitudes, and duration. It is difficult to describe these by a simple set of parameters, but obtaining their signatures allows them to be classified into a few typical waveforms that are used for test purposes. Figure A.1 shows the frequency spectrum of several representative test waveforms in general use. This information is useful in developing algorithms that will be necessary for appropriate reduction of the analogue signals into the digital recordings and data processing of these events.

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1 Gas-insulated switchgear.

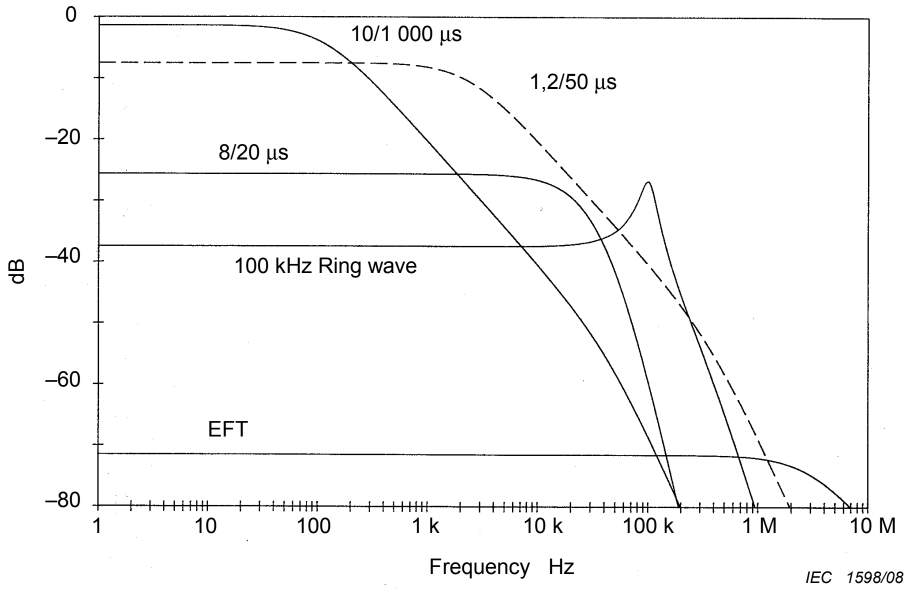

Figure A.1 – Frequency spectrum of typical representative transient test waveforms

For both voltage and current, the spectra of common test waveforms for a.c. mains transients contain frequencies that range up to approximately 10 MHz (lasting for 200 µs), with large amplitudes up to 1 MHz (lasting for 2 ms). For end-use a.c. mains connections, the amplitudes of common test waveforms range up to 6 kV, and up to 5 kA.

The sampling rate shall therefore be at least twice the maximum frequency of the waveform; in addition, the corresponding anti-alias filter shall have appropriate characteristics. See also A.2.4 for further information related to transient measurement.

A.4.4 Transient voltage detection

The results of a transient measurement depend both on the actual nature of the transient, and on the parameters selected by the user and reported by the instrument. When insulation is the main concern, transient measurements are generally made from phase to earth. When instrument damage is the primary concern, transient measurements are generally made from phase to phase or from phase to neutral.

Some of the detection methods and examples of application include:

– comparative method: when a fixed, absolute threshold is exceeded, a transient is detected, for example, Surge Protective Devices (SPDs) that are sensitive to the total voltage;

– envelope method: similar to comparative method, but with the fundamental removed prior to analysis, for example, for instances of capacitive coupled transients;

– sliding-window method: the instantaneous values are compared to the corresponding values on the previous cycle, for example, low-frequency switching transients associated with capacitive banks used for power factor correction;

– d*v*/d*t* method: when a fixed, absolute threshold of d*v*/d*t* is exceeded, for example, mistrigger of power electronics circuits or non-linear distribution on inductor winding;

– r.m.s. value: using very rapid sampling, the r.m.s. value is computed for intervals much less than one fundamental period, and compared to a threshold, for example, when further computations are desirable such as energy deposition in an SPD or charge transfer;

– other methods include frequency versus amplitude measurements (Discrete or Fast Fourier transform, wavelet, etc.).

A.4.5 Transient voltage evaluation

Once the transient has been detected using the methods above, it can be classified. Some classification methods and parameters include

- the peak voltage and/or current. Note that the peak value is also influenced by the measurement interval;
- the overshoot voltage;
- the rate of rise (dv/dt or di/dt), of the leading edge;
- frequency parameters;
- the duration. This is a difficult parameter to define, due to damping, irregularity of wave-forms, etc.;
- damping coefficient;
- frequency of occurrence;
- energy and power, available or conveyed;
- continuous (every cycle, such as notches) or single-shot (unpredictable) transients.

All of these numerical parameters are helpful in developing a classification system to describe the transient environment in statistical terms.

On the other hand, especially when troubleshooting, a signature can describe in one graphic representation several of these hard-to-quantify parameters.

A.4.6 Effect of surge protective devices on transient measurements

Surge protective devices (SPDs) are shunt-connected components that conduct when a threshold voltage is exceeded. They are commonly used to limit transient voltages. They may be found in plug-in mains filtering devices, and are often included as part of a sensitive electronic device, such as a personal computer.

Because all SPDs on a mains circuit are effectively connected in parallel, the one with the lowest limiting voltage will (within its performance capabilities) limit all transient voltages to its limiting voltage and divert the largest portion of the transient current impinging on the facility. Consequently, measuring transient voltages in many environments – offices, labs, factories, etc. – is of limited of use: one is simply measuring the threshold voltage of one of the many SPDs that are present.

For this reason, the transient current is often a better measure of the severity of a.c. system transients than the transient voltage.

A.5 Rapid Voltage Changes (RVC)

A rapid voltage change is a quick transition in r.m.s. voltage between two steady-state conditions.

To measure rapid voltage changes, thresholds may be defined for each of the following: the minimum rate of change, the minimum duration of the steady-state conditions, the minimum difference in voltage between the two steady state conditions, the maximum voltage change during the transition period (voltage change characteristic) and the steadiness of the steady-state conditions.

The voltage during a rapid voltage change shall not exceed the voltage dip and/or the voltage swell threshold, as it would otherwise be considered as a voltage dip or swell.

The characteristic parameter of the rapid voltage change is the difference between the steady-state value reached after the change and the initial steady-state value.

A.6 Current

A.6.1 General

In a power quality context, current measurements are useful as a supplement to voltage measurements, especially when trying to determine the causes of events such as voltage magnitude change, dip, interruption, or unbalance.

The current waveform can further help associate the recorded event with a particular device and an action, such as a motor being started, a transformer being energized or a capacitor being switched.

Linked with voltage harmonics and interharmonics, the current harmonics and interharmonics can be useful to characterize the load connected to the network.

Note that this annex does not consider the measurement transducers.

A.6.2 Term and definitions

$I_{\text{half cycle rms}}$

value of the r.m.s. current measured over each half-period

A.6.3 Magnitude of current

A.6.3.1 Measurement

The manufacturer or the user should specify a full-scale r.m.s. current, including a maximum crest-factor value.

NOTE Harmonics, interharmonics and ripple control signals are included in the evaluation.

– **Class A**

  The measurement should be the r.m.s. value (defined in 3.23) of the current magnitude over a 10-cycle time interval for a 50 Hz power system or 12-cycle time interval for a 60 Hz power system. Each 10/12-cycle interval should be contiguous and non-overlapping.

– **Class S**

  The manufacturer should specify the measurement time interval used.

– **Class B**

  Same as class S.

A.6.3.2 Measurement uncertainty

– **Class A**

  Over the specified influence quantity conditions described in 6.1, the measurement uncertainty ΔI should not exceed ±0,1 % of full scale.

– **Class S**

  The manufacturer should specify the uncertainty ΔI over the specified influence quantity conditions described in 6.1. In all cases, the measurement uncertainty should not exceed ±1,0 % of full scale.

– **Class B**

  The manufacturer should specify the uncertainty ΔI over the specified influence quantity conditions described in 6.1. In all cases, the measurement uncertainty should not exceed ±2,0 % of full scale.

A.6.3.3 Measurement evaluation

For single-phase systems, there is a single r.m.s. current value. For 3-phase 3-wire systems, there are typically 3 r.m.s. current values; for 3-phase 4-wire systems, there are typically 4 current values. It is optional to measure the current in the earth conductor as well.

– **Class A**

Aggregation intervals as described in 4.4 and 4.5 should be used, but additional aggregation techniques might be used for smoothing, for example with a digital filter as specified in IEC 61000-4-7.

If any of the 10/12-cycle r.m.s. values are greater than the full-scale current specified, the 10/12-cycle r.m.s. current value for that interval should be "flagged".

– **Class S**

The manufacturer and/or the user should specify the measurement intervals.

– **Class B**

Same as class S.

A.6.4 Inrush current

A.6.4.1 Measurement

– **Class A**

The inrush current begins when the $I_{\text{half cycle rms}}$ current rises above the inrush threshold, and ends when the $I_{\text{half cycle rms}}$ current is equal to or below the inrush threshold minus a user-selected hysteresis value.

The measurement should be the $I_{\text{half cycle rms}}$ values. Each half-cycle interval should be contiguous and non-overlapping.

NOTE 1 The inrush threshold is set by the user. Typically, the inrush threshold is greater than 120 % of the nominal current.

NOTE 2 For a full understanding of the inrush phenomena it is recommended that the user obtain a signature of all currents and voltages relating to the inrush current (see B.7.2).

– **Class S**

The measurement should be the r.m.s. value of the current over a short time interval specified by the manufacturer.

– **Class B**

Same as class S.

A.6.4.2 Measurement evaluation

– **Class A**

The inrush current can be further characterized by:

- the time duration between the beginning and the end of the inrush current;
- the maximum value of inrush current measured $I_{\text{half cycle rms}}$ value;
- the square root of the mean of the squared $I_{\text{half cycle rms}}$ values measured during the inrush duration.

– **Class S**

No requirement.

– **Class B**

Same as class S.

A.6.4.3 Measurement uncertainty

– **Class A**

Over the range of influence quantities described in 6.1. the measurement uncertainty should not exceed ±0,5 % of reading. The uncertainty of the duration measured is 1 half-cycle.

– **Class S**

The manufacturer should specify:

- the uncertainty over the specified influence quantities conditions described in 6.1,
- the range of current.

– **Class B**

Same as class S.

In all cases, the measurement uncertainty should not exceed ±5,0 % of reading.

A.6.5 Harmonic currents

– **Class A**

The basic measurement of current harmonics, for the purpose of this standard, is defined in IEC 61000-4-7. Use that standard to determine a 10/12-cycle gapless harmonic sub-group measurement, denoted $I_{sg,h}$.

Aggregation intervals as described in 4.4 and 4.5 should be used.

A 10/12-cycle current harmonic measurement is marked "flagged" if either a voltage dip or voltage swell (see 5.4) or a voltage interruption (see 5.5) occurs during this time interval.

– **Class S**

The manufacturer should specify measurement and aggregation methods.

– **Class B**

Same as class S.

A.6.6 Interharmonic currents

– **Class A**

The basic measurement of current interharmonics, for the purpose of this standard, is defined in 61000-4-7. Use that standard to determine a 10/12-cycle gapless centred interharmonic sub-group measurements, denoted $I_{isg,h}$.

Aggregation intervals as described in Clause 4.4 and Clause 4.5 should be used.

A 10/12-cycle interharmonic current measurement is marked "flagged" if either a voltage dip or a voltage swell (see Clause 5.4), or a voltage interruption (see Clause 5.5) occurs during this time interval.

– **Class S**

The manufacturer should specify measurement and aggregation methods.

– **For Class B**

Same as class S.

A.7 Voltage dip characteristics

A.7.1 General

Voltage dips are generally acknowledged to be a common power quality event.

The normative part of this standard characterizes voltage dips by two characteristics, depth (or residual voltage) and duration. It derives these characteristics from one-cycle r.m.s. values that are updated each half-cycle.

However, voltage dips are rarely rectangular, i.e. the U_{rms} value often varies during the dip, and limiting the characteristics to depth and duration can obscure useful information. As an example, in the case of voltage dips due to motor-starting or due to transformer energizing where there is a smooth transition between the dip and normal operation.

Ultimately, the greatest amount of information is available in waveforms recorded during the voltage dip. But characteristics are a useful way of reducing data, interpreting and categorizing events.

Multiple dips may occur, for example, during a failed attempt to auto-reclose and re-energize a faulty line section. Events that occur at approximately the same time may be counted as a single event.

Depending on the purpose of the measurement, other characteristics in addition to depth and duration should be considered.

A.7.2 Rapidly updated r.m.s values

During a voltage dip, it may be useful to calculate 1-cycle r.m.s values that are updated more frequently than every half-cycle (as specified in the normative part of standard). For example, it may be useful to update the 1-cycle r.m.s. value 128 times each cycle. This approach allows more precise identification of the beginning and end of the voltage dip, using simple thresholds. The drawbacks are increased data and processing and introducing a possibly misleading sliding filter.

RMS voltage values correctly reflect the available power into a resistive load. However, electronic loads are not directly sensitive to r.m.s. voltage, instead, they are generally sensitive to voltage near the peak of the waveform, and are insensitive to other parts of the waveform. Algorithms other than r.m.s. may be useful to evaluate the effects of a voltage dip on electronic loads.

A.7.3 Phase angle/point-on-wave

For some applications, for example, electro-mechanical contactor drop-outs, the phase angle at which a voltage dip begins is an important characteristic, which is sometimes called point-on-wave.

This phase angle can be determined by capturing the pre-dip and during-dip waveforms, then examining them for the point at which the waveform deviates from the ideal by, for example, 10 %, then backing up along the waveform with a narrower threshold, for example, 5 %, to the beginning of the dip. This algorithm is highly sensitive for finding the exact beginning of a voltage dip, without triggering on minor non-dip variations.

A similar algorithm may be used to find the end of the dip. In addition to phase-angle information, this approach also permits the dip duration to be calculated precisely, with a resolution much finer than 1-cycle.

Also, advanced signal-processing techniques are capable of detecting the exact beginning of a voltage dip.

A.7.4 Voltage dip unbalance

Even very brief unbalance can damage 3-phase rectified loads, or cause over-current devices to trip. Three-phase dips are often unbalanced. With the rapidly updated r.m.s values described in A.7.2, it is often useful to calculate 3-phase unbalance during a dip. The unbalance often varies during a dip, so the unbalance might be presented in a graphic form, or the maximum unbalance during a dip might be presented.

It may be useful to analyse separately the zero sequence, negative sequence, and positive sequence of the fundamental frequency during an unbalanced dip. This approach yields information about how the dip propagates through the network and can be useful in understanding simultaneous dips and swells on different phases.

A.7.5 Phase shift during voltage dip

In some applications, for example, 3-phase rectifiers, the phase shift of the voltage dip can be important. Such a phase shift may be measured by, for example, a DFT applied to the cycle prior to commencement of the dip, and another cycle after the commencement of the dip. If this approach is taken throughout the dip, a maximum phase shift during the dip may be calculated. The phase shift at the conclusion of the dip may also be useful. In some applications, for example, phase-locked-loop stability, it may be useful to calculate the maximum slew rate ($d\Theta/dt$) of the phase angle during the dip.

The calculation of phase shift during a voltage dip may be combined with voltage dip unbalance by calculating the magnitude and phase angle of zero-sequence, negative-sequence and positive-sequence components during an unbalanced dip.

A.7.6 Missing voltage

This characteristic of a voltage dip may be calculated by subtracting the dip waveform from an ideal waveform, with amplitude, phase, and frequency based on the pre-dip data. This characteristic can be useful for analysing the effect of the dip on voltage restoration devices, for example.

A.7.7 Distortion during voltage dip

The voltage during a dip is often distorted, and the distortion may be important for understanding the effect of the dip on electronic devices. Traditional methods such as THD may be considered for describing this distortion, but THD compares the distortion to the fundamental which, by definition, is rapidly varying during a dip. For this reason, it may be more useful to evaluate distortion during a dip simply as the r.m.s. value of the non-fundamental components.

The presence of even harmonics during or after the dip may point to transformer saturation.

A.7.8 Other characteristics and references

This list of voltage dip characteristics is not exhaustive. Other characteristics, not identified here, may be useful for analysing the effects of voltage dips on various types of loads, control devices, and correction devices. For further details and examples, it is recommended to refer to the following publications: IEC 61000-2-8 and IEEE 1159.

Annex B
(informative)

Power quality measurement –
Guidance for applications

B.1 Contractual applications of power quality measurements

B.1.1 General

This clause provides guidance on the measurement of Power Quality (PQ) for contractual purposes. It highlights factors that should be considered by the concerned parties.

NOTE The description of voltage quality parameters is discussed below.

It is recommended that B.1.2 should be consulted prior to entering into a PQ contract, whilst B.1.3 should be consulted prior to performing PQ measurements to test compliance with the contract terms.

B.1.2 General considerations

The terms specified in the contract will need to be both achievable by one party and acceptable to the other. The starting point for a PQ contract should be a PQ standard or specification. Consideration should be given to the planning and indicative values in the relevant IEC standards, for example, IEC 61000-2-2, IEC 61000-2-4, IEC 61000-2-12 and parts of IEC 61000-3-6 and IEC 61000-3-7.

In order to ensure that the results are representative of normal system operating conditions, the PQ measurement survey may discount but not discard data at times when the supply network is subject to severe disturbance resulting from

– exceptional weather conditions;
– third-party interference;
– acts by public authorities;
– industrial action;
– force majeure;
– power shortages resulting from external events.

The contract should specify whether flagged data, as described in the normative part (see 4.7) in this standard, should be excluded from the analysis when assessing the results for contract compliance. If flagged data are excluded, the measurement results will generally be mutually independent for each parameter, and each parameter may be more easily compared directly to a contractual value. If flagged data is included, the measurement results will generally be more directly related to the effects of power quality on sensitive loads, but will be far more difficult or even impossible to compare to any contractual values.

NOTE Flagged data indicate that a disturbance might have influenced the measurement and that consequently a single disturbance might have affected multiple parameters.

When PQ measurements are considered necessary to assess compliance of the supply against contract terms, it is the responsibility of the party that considers the measurements necessary to arrange for them to be performed, if permanent monitoring is not already available. However, this should not preclude the contract from detailing who should perform the measurements. There might be a need to consult third parties.

The contract should indicate how the financial cost of the measurements is to be borne by the concerned parties. This can be dependent upon the measurement results.

The terms of this contract should specify the duration of the contract, the measurement time interval, the PQ parameters to be measured and the electrical location of the measuring instrument(s). See B.1.3 for examples of measurement time interval and PQ parameters.

The choice of the connection mode of the measuring device (i.e. phase-to-neutral or phase-to-phase) should be coherent with the type of supply connection or should result from a common decision between the concerned parties. It should be explicitly mentioned in the contract.

The terms of the contract should specify the use of the measurement methods and the uncertainty described in the normative part of this standard.

The contract should specify the method for determining compensation, in the event of one party failing to honour the terms of the contract.

The contract may contain provisions for the resolution of disputes regarding interpretation of measurements.

The contract will need to address the subject of data access and confidentiality, for example, the party carrying out the PQ measurements might not be the same party that has to analyse the data and assess contract conformity.

B.1.3 Specific considerations

B.1.3.1 General

Power quality (PQ) is assessed by a comparison between the results of measured PQ parameters, and the limits (contractual values) given in a PQ contract. These limits are beyond the scope of this standard.

In a contract, the description of each PQ parameter may include: contractual value(s), time interval to be considered, duration of the assessment time interval(s), and possibly special procedures regarding “flagged” measurements.

Many PQ parameters (voltage, harmonics, flicker) can show variations between weekday and weekends. For these, the assessment period should be for a week minimum (or an integer number of weeks).

B.1.3.2 Power frequency

Measurement interval: 1 week minimum assessment period.

Evaluation techniques: 10 s values are considered. The following techniques are suggested, but other evaluation techniques might be agreed between the parties:

- the number, or per cent, of values during the measurement interval that exceed high or low contractual values might be counted;
- the worst-case values might be compared to high and/or low contractual values (the measurement interval might be different for this possibility);
- one or more 95 % (or other percentage) probability weekly values, expressed in hertz, might be compared to high and/or low contractual values;
- the number of consecutive values that exceed high and/or low contractual values might be counted;
- the integration over the measurement interval, of value that deviate from nominal frequency might be compared to contractual values.

B.1.3.3 Magnitude of the supply voltage

Measurement interval: 1 week minimum assessment period.

Evaluation techniques: 10 min values should be considered. The following techniques are suggested, but other evaluation techniques might be agreed between the parties:

- the number, or per cent, of values during the measurement interval that exceed high or low contractual values might be counted;
- the worst-case values might be compared to high and/or low contractual values (the measurement interval might be different for this possibility);
- one or more 95 % (or other percentage) probability weekly values, expressed in volts, might be compared to high and/or low contractual values;
- the number of consecutive values that exceed high and/or low contractual values might be counted.

B.1.3.4 Flicker

Measurement interval: 1 week minimum assessment period.

Evaluation techniques: 10 min values (P_{st}) and/or 2 hour values (P_{lt}) might be considered. The following techniques are suggested for both values, but other evaluation techniques might be agreed between the parties:

- the number, or per cent, of values during the measurement interval that exceed contractual values might be counted;
- a 99 % (or other percentage) probability weekly values for P_{st}, or 95 % (or other percentage) probability weekly value for P_{lt}, might be compared to contractual values.

B.1.3.5 Voltage dips/swells

Measurement interval: 1 year minimum assessment period.

Evaluation techniques: the parties to the contract should agree on the declared input voltage U_{din}.

NOTE For LV customers, the declared voltage is usually equal to the nominal voltage of the supply system. For MV or HV customers, the declared voltage may be different from the nominal voltage.

The parties to the contract should agree on

- the dip and swell detection thresholds;
- time aggregation techniques;
- location aggregation techniques if more than one location is measured;
- reporting techniques such as residual voltage/duration tables,
- any other evaluation techniques that might be relevant.

B.1.3.6 Voltage interruptions

Measurement interval: 1 year minimum assessment period.

Evaluation techniques: the parties might agree on a duration that defines the borderline between "short" and "long" voltage interruptions. The count of the voltage interruptions, and the total duration of the "long" voltage interruptions during the measurement interval, might be considered. Other evaluation techniques might be agreed between the parties.

Interruptions for which the customer is informed in advance (for example, minimum 24 h) could be counted separately from interruptions for which the customer is not informed in advance.

B.1.3.7 Supply voltage unbalance

Measurement interval: 1 week minimum assessment period.

Evaluation techniques: 10 min values and/or 2 h values might be considered. The following techniques are suggested for both values, but other evaluation techniques might be agreed between the parties:

– the number, or per cent, of values during the measurement interval that exceed contractual values might be counted;

– the worst-case values might be compared to contractual values (the measurement interval might be different for this possibility, for example one year);

– one or more 95 % (or other percentage) probability weekly values, expressed in per cent, might be compared to contractual values.

B.1.3.8 Harmonic voltages

Measurement interval: 1 week minimum assessment period for 10 min values, and daily assessment of 150/180-cycle values for at least 1 week.

Evaluation techniques: 150/180-cycle time interval and/or 10 min values might be considered. Contractual values may be applied to individual harmonics, or range of harmonics, or other groupings, for example, even and odd harmonics, according to agreement between the parties to the contract. The following techniques are suggested for all values, but other evaluation techniques might be agreed between the parties:

– the number, or per cent, of values during the measurement interval that exceed contractual values might be counted;

– the worst-case values might be compared to contractual values (the measurement interval might be different for this possibility, for example one year);

– one or more 95 % (or other percentage) probability weekly values for 10 min values, and/or 95 % (or other percentage) probability daily values for 150/180-cycle time interval values, expressed in per cent, might be compared to contractual values.

B.1.3.9 Interharmonic voltages

Measurement interval: 1 week minimum assessment period for 10 min values, and daily assessment of 150/180-cycle values for at least 1 week.

Evaluation techniques: 150/180-cycle time interval and/or 10 min values might be considered. Contractual values may be applied to a range of interharmonics, or other groupings, according to agreement between the parties to the contract. The following techniques are suggested for all values, but other evaluation techniques might be agreed between the parties:

– the number, or per cent, of values during the measurement interval that exceed contractual values might be counted;

– the worst-case values might be compared to contractual values (the measurement interval might be different for this possibility, for example one year);

– one or more 95 % (or other percentage) probability weekly values for 10 min values, and/or 95 % (or other percentage) probability daily values for 150/180-cycle time interval values, expressed in per cent, might be compared to contractual values.

B.1.3.10 Mains signalling voltage on the supply voltage

Measurement interval: 1 week minimum assessment period.

Evaluation techniques: the following techniques are suggested for all values, but other evaluation techniques might be agreed between the parties:

– the number, or per cent, of values during the measurement interval that exceed contractual values might be counted;
– the worst-case values might be compared to contractual values (the measurement interval might be different for this possibility).

B.2 Statistical survey applications

B.2.1 General

These provide guidance for designing and performing statistical power quality surveys (including permanent monitoring) in support of:

a) Consumer requirements, where the aim of such surveys is to provide the consumer with information on the power quality parameters seen by the consumer referenced against a set of recognized power quality indices. These indices may relate to recognized standards, or a pre-defined set of requirements specified for a particular installation or item of equipment (e.g. contracts or equipment specifications).
b) Network operator requirements for assessing existing levels of distortion/disturbance on the network (e.g. in the assessment required for the connection of new loads).

Historically, networks have been designed and operated differently in different countries and any attempt to normalize the outputs of different national power quality surveys will be extremely complex and open to misinterpretation.

This clause explains the aim of power quality statistics and gives some guidelines.

The first objective of these techniques is to compress a large number of measured values.

The second objective is to compute power quality indices for benchmarking, either on one specific point or for a whole network in order to:

– verify the compliance with contractual agreement (see Clause B.1),
– monitor the performance evolution of a network during long periods,
– compare different networks during the same interval.

B.2.2 Considerations

A statistical analysis shall be done with homogeneous values: same measurement time interval, same measurement data, same network, etc.

Statistics computation is based on a classification of the measured values.

For each parameter, the user defines a "normal range" of variation and may choose to include or not, flagged data (see 4.7), since this data by definition can be irrelevant.

The normal range of variation is then divided into several classes of equal width. The number of classes determines the confidence interval – 100 classes seem adequate. Classes remain constant over a measurement period – 1 day, 1 week, 1 year, etc. – and are ordered from the lowest to the greatest class value within the normal range of variation.

The number of measured values within each class is counted. These counts may be used to determine cumulative curves, which in turn may be used to determine percentiles.

The statistics formula with the confidence level, for example 95 %, should be used to determine the confidence interval. When the number of statistical values is small, one should be careful about the confidence interval.

B.2.3 Power quality indices

B.2.3.1 Characterizing a single point on the network

One single measurement point may be characterized by two kinds of power quality indices depending on the phenomena concerned:

– statistical indices like percentiles, maximum or mean values over a period of time (see IEC 61000-3-6 for harmonics, IEC 61000-3-7 for flicker, or IEC 61000-3-13 for unbalance);

– event counting and tabulating.

Examples of power quality indices are given for each parameter in B.1.3.

B.2.3.2 Characterizing an entire network

An entire network is a collection of single points classified by type of network or customers. Weighting rules might be defined in order to get global results. Weighting rules might apply both to statistical indices and events.

B.2.4 Monitoring objectives

Power quality monitoring is necessary to characterize electromagnetic phenomena at a particular location on an electric power circuit.

The objective may be as simple as verifying steady state voltage regulation at a service entrance, or may be as complex as analyzing the harmonic current flows within a distribution network.

Generally speaking, power quality monitoring is carried out for one of three reasons.

a) Troubleshooting: To diagnose incompatibilities between the electric power source and existing equipment connected within an installation.
b) PQ evaluation: To evaluate the electrical environment at a particular location to refine modelling techniques or to develop a power quality baseline.
c) Planning the connection of new equipment: To predict future performance of equipment or power quality mitigating devices that are planned to be connected within an installation. In any event, the most important task in any monitoring project is to define clearly the objectives of monitoring.

The procedure for defining monitoring objectives will depend upon the reason for carrying out the monitoring. From this will come the parameters to be measured, the duration of the monitoring and the thresholds against which the parameters will be evaluated.

B.2.5 Economic aspects of power quality surveys

There are several elements that impact on the cost and overall economics of a measurement campaign. These elements include:

- measurement equipment;
- transducers;
- installation, including connection access;

- labour;
- communications;
- data management (database, etc.);
- data processing and analysis;
- survey duration.

Of these elements, the measurement equipment cost itself is rarely the most expensive item. In electric utility substation and feeder applications, the installation and labour costs usually dominate the measurement equipment costs by a significant margin. When the total life cycle of a long term measurement campaign is considered, the communication and data analysis costs begin to dominate. It is wise therefore to choose instrumentation that is easy to install, has many communication options, and provide the data in a form that simplifies the analysis task (e.g. the data are available in a standardized format).

An obvious multiplier of measurement campaign cost, is related to the duration of a survey. This is applicable to compliance measurement campaigns such as those associated with standards such as EN 50160. The guidance in this regard is to first, comply with national standards requirements for survey durations and then second, take into consideration the context of the measurement when the duration is not explicitly mandated in a national standard. The duration of the measurement campaign should be tailored to the situation in such way that the survey duration can be minimized whilst obtaining enough information to properly conduct the assessment. Factors that influence the selection of the duration of a measurement campaign include:

- customer type (e.g. residential, commercial, industrial);
- reason for monitoring (see above);
- variability of the load and time frame over which that variability is expected to be experienced.

Prior to installing a permanent power quality monitoring system, a business case often has to be developed. Typical business cases include both tangible and intangible benefits. Direct, tangible benefits include:

- identification by signature analysis of failing equipment before total failure (e.g. tap changers, capacitor banks and their switches, transformers);
- reduction of system restoration time (e.g. fault finding);
- contract compliance;
- connection requirements for new equipment.

Intangible benefits include:

- identifying problem feeders to help improve reliability indices;
- customer feedback to improve customer relations.

The economics of a power quality measurement campaign can be improved by augmenting the system with information gathered by other equipment not specifically designed for power quality measurement. Sharing resources in this manner allows the cost of measurement to be shared with the primary cost of the device: reclosers, capacitor switch controllers, etc.

B.3 Locations and types of surveys

B.3.1 Monitoring locations

The choice of locations to install power quality monitors will be dependent upon the objective of the survey. If the monitoring objective is to diagnose an equipment performance problem, then the monitor should be placed as close to the load as possible. This applies to performance problems with both sensitive electronic loads such as computers and adjustable speed drives, and electrical distribution equipment such as circuit breakers and capacitors. After the voltage fluctuations are detected, the monitor may be moved upstream on the circuit to determine the source of the disturbance.

Monitoring location may also be determined by cost and convenience as long as it does not compromise the technical, regulatory or legal objectives. For example, it is less costly to monitor at low voltage than at high voltage. Measuring in a substation is generally less expensive than on a feeder or on a pole.

For compliance monitoring related to service contracts, a monitoring location shall be agreed to by all parties to the contract in advance. This is typically defined as the Point of Common Coupling (PCC) between the customer and the system. Where the PCC is defined as the point on a public power supply network, electrically nearest to a particular load, at which other loads are, or could be, connected.

B.3.2 Pre-monitoring site surveys

Prior to conducting a measurement campaign, it is recommended that information regarding the system environment be gathered to facilitate proper instrument placement, operation and analysis. Elements that are common to all surveys include among others:

- electrical system data (single-line diagrams, transformer specifications, transformer connection, short circuit levels, capacitor bank size and location, branch circuit data, load data, grounding, etc.);
- changes in installation topology over time (e.g. power factor capacitor status, loads, transformers in/out of service, etc.);
- known disturbing loads, rating and operating regime.

B.3.3 Customer side site survey

For surveys within a customer's installation, in addition to the information mentioned above, it is useful to gather information on any encountered problems. For example the nature and characteristics of sensitive equipment, the time stamp of any events that coincide with a reduction in performance. These events should be checked for coincidence with operations within the installation and on the network.

B.3.4 Network side survey

Surveys of the supply network itself require that network specific information be gathered including:

- network protection equipment and settings
  - – if the settings are changed for any reason during the course of a survey, it can impact the statistics of voltage dips, for example,
  - – this permits evaluation of alternative protection scenarios based on survey results;
- existence and characteristics of ripple control (or other relevant telecontrol via power line carrier) that may impact measurements;
- load characteristics (e.g. industrial, commercial, residential or mixture);
- network operation protocol with regards to volt/var control – regulation.

B.4 Connections and quantities to measure

B.4.1 Equipment connection options

There are several decisions that need to be made related to connecting the measurement equipment. These decisions include:

- single-phase versus three-phase measurement;
- line-to-line versus line-to-neutral or line-to-ground connection;
- high side versus low side measurement near transformers.

These decisions will be heavily influenced by the reason for the survey. Sometimes, connection requirements may be specified inherently by a particular standard against which the survey is being conducted. Whatever the case, the connection should be made in a way that is consistent with the requirements or connection of the affected equipment, taking into account transformer connection issues.

A general observation can be made that when measuring steady state phenomena such as harmonics and flicker, single-phase measurements can often be made instead of three phase measurements. This is possible because these phenomena are often reasonably balanced. This assumption should be checked by performing a temporary three-phase measurement. When voltage dips and swells are the primary reason for monitoring, it is necessary to monitor all phases powering the affected equipment.

When general surveys are being performed with a three-phase connection and/or there are several voltage transformations downstream from the monitored location, connecting the measurement equipment from line-to-neutral on grounded systems is recommended because the line-to-line values can often be derived either in the instrument or off-line.

Where this is not the case, the connection mode of the monitoring instrument should be chosen taking into account both the connection mode of the potentially affected equipment and the successive voltage transformations downstream.

B.4.2 Priorities: Quantities to measure

The quantities to measure will generally be defined by the monitoring objectives, relevant compliance standards and other factors. For general surveys, it will be necessary, in order to conserve memory space, to identify a priority order for the quantities to monitor. For example:

a) power parameters (*V, I, P, Q, S, DPF, TPF*, etc.),
b) voltage dips/swells,
c) harmonic voltage,
d) harmonic current,
e) unbalance,
f) transients (e.g. capacitor switching – low frequency),
g) flicker,
h) interharmonic voltages and currents,
i) mains signalling.

NOTE DPF is the Displacement Power Factor, or the cosine of the angle between the fundamental voltage and the fundamental current. TPF is the true power factor, or the ratio between watts and volt-amperes.

This ordering is an example; the actual prioritization depends on the overall goals and objectives of a particular measurement campaign.

Once the priority is established and an instrument chosen based on those priorities, it is recommended that as much information as the instrument can provide be utilized. It is generally easier to discard data after a survey rather than to derive them when a quantity is desired later that was not directly measured. Generally, the only issues affecting this decision are instrument storage capabilities and communication time/cost impacts.

B.4.3 Current monitoring

In general, customers are responsible for the current that their equipment draws from or injects into the system and the supplier is responsible for the supply voltage. This fact can be used as the basis for deciding when to measure currents.

The measurement of current is important for the concept of emission assessment. The measurement of the magnitudes of the harmonic currents is normally sufficient for compliance tests. In other types of tests, knowledge of the phase angles of the harmonic currents is important, for example in studies to determine whether the harmonic currents of a planned new installation, when superimposed on the already existing harmonic currents, are acceptable or not. Moreover, the information on phase angles between harmonic currents and harmonic voltages helps to find unknown sources of possibly distorting harmonic currents. The accurate measurement of phase angles needs appropriate instrumentation, including voltage and current sensors, and may become increasingly difficult with increasing order of the harmonics.

The measurement of current can be invaluable in determining sources/causes of power quality events, since it can help to determine if the cause of the event is up stream or down stream of the measuring instrument. This is particularly true for voltage dips.

B.5 Selecting the monitoring thresholds and monitoring period

B.5.1 Monitoring thresholds

Monitoring thresholds may be determined by the power quality indices against which the results are to be compared, or may be determined by the load requirements. Once again, the reasons for performing the power quality survey shall be consulted.

The difference between thresholds used for disturbance capture, versus thresholds used for event characterization, counting and analysis, should be considered.

As a general recommendation, thresholds should be as tight as feasible (while avoiding continuous triggering). Wider thresholds can be effectively implemented subsequently on captured data, but data that was missed due to loose thresholds can never be recaptured.

Thresholds on sliding references should be used when measuring at an unregulated portion of the network. For example, monitors deployed on distribution feeders with load tap changers or capacitor bank based voltage regulation may be able to use fixed thresholds. Transmission systems or other portions of the network that are not directly regulated with regards to voltage should use the sliding reference method.

B.5.2 Monitoring period

The monitoring period will be determined by the reasons for performing the power quality survey. For example, if the results are to be compared against power quality indices, there may be guidance in those indices regarding the monitoring period.

It is often useful to compare power quality measurements over time, for example comparing one year to the previous year. If this type of comparison is useful, the monitoring period may be permanent.

Some standards may specify minimum measurement periods. In any case, event measurements such as voltage dips and swells generally require longer measurement periods in order to capture enough events to provide meaningful statistics (months). Rarer events such as interruptions may require even longer periods; in contrast, for harmonics and other steady state measurements, meaningful information may be captured in relatively short periods of time (minimum of one week).

For compliance monitoring, the monitoring period should already be specified in the relevant standard. For practical reasons, it may be necessary to interpret the standard - for example "do you need to measure for one year for EN 50160 compliance? Does it need to be continuous?"

B.6 Statistical analysis of the measured data

B.6.1 General

A suitable statistical analysis method shall be chosen for the data. Different statistical methods may be selected, depending on the power quality parameter and measurement objectives, but the methods can be roughly divided into:

- methods that count the number of events that exceed some threshold, and
- methods that summarize large numbers of quasi-steady-state measurements into a single number or a few numbers.

For the latter methods, various possible numbers may be chosen as the most useful summary value: maximum value, 99 % value, 95 % value, average value, minimum value, etc. In many references, the 95 % probability value has been found to be useful.

B.6.2 Indices

Prior to carrying out a measurement campaign, it is necessary to understand the indices against which the results of the campaign will be compared. This information will help to determine the duration of the campaign, trigger thresholds and statistical analysis of the results. In the absence of a recognized standard, it will be necessary to devise a specific set of indices for each measurement campaign.

There has been much work done by various professional bodies around the world on the subject of power quality indices. Some of the better known of these are listed under the bibliography.

B.7 Troubleshooting applications

B.7.1 General

Power-quality-related troubleshooting is generally performed in response to operational incidents or problems. Consequently, it is often desirable to produce results as quickly as possible, rather than producing data of archival or contractual value. Nevertheless, this need for fast diagnosis should not lead to premature or unfounded conclusions.

Typically, raw unaggregated samples are most useful for troubleshooting, as they permit any type of post-processing that may be desired, for example, signatures, wavelets, etc. However, to minimize the amount of data to be stored and reviewed for troubleshooting, it is useful for the instrument to record and present only data that were recorded just prior to, during, and after an event such as a voltage dip or transient.

B.7.2 Power quality signatures

Signatures are graphic presentations of power quality events, often accompanied by a short table of numeric characteristics.

The most common form is a time-domain plot of voltage and current. Other forms, such as histogram displays of harmonics, cumulative probability distributions, etc., may also be useful. Common timescales for signatures range from 100 µs to 30 day. Usually, an instrument determines the best timescale for presenting a power quality event based on the event's characteristics and duration.

It is generally agreed that useful signatures show the signal before, during, and after the power quality event (pre-trigger system). Typically, a quarter of the graph is allocated to the signal just prior to the event.

These power quality signatures are useful for troubleshooting problems throughout electrical networks, including customers' installations. Typically, they are used to identify and locate the source of a power quality event and to select an appropriate solution.

An expert might use the signature of a voltage dip, for example, to determine that the cause is a large motor starting downstream from the monitoring location, and to select an appropriate solution. Although this example deals with voltage dips, widely available reference books set out the typical signatures for hundreds of different power quality events: switching of power factor correction capacitors, lightning strikes, utility and customer faults, loose wiring, arcing contacts, radio transmission interference, electronic loads that share circuits with motors, etc.

Although many experts can identify common power quality events from their voltage signatures alone, having current signatures as well greatly increases the range and precision of statements that can be made about a power quality event. Moreover, current signatures can assist in identifying the direction of the cause of a disturbance.

Annex C
(informative)

Guidance on instruments

C.1 General

This standard is a basic EMC publication. Detailed guidance on instrument performance, performance verification methods, additional influence quantities and other similar information should, in general, be found in a product standard.

However, such product standards are not yet available, and it is recognized that users of this standard wish to design, specify, test or select a power quality instrument using this basic standard. This annex provides some informative guidance.

After complete product standards become available, this annex may be removed in a future edition.

C.2 Summary of requirements

Table C.1 provides an informative summary of the requirements for classes A and S. In case of any conflict between Table C.1 and the normative clauses of this standard, the normative clauses prevail.

Table C.1 – Summary of requirements

Section and Parameter	Class	Measurement Method	Uncertainty	Measuring range(1)	Influence Quantity range(2)	Aggregation method
5.1 Frequency	A	See 5.1.1	±10 mHz	42,5 Hz ~ 57,5 Hz, 51 Hz ~ 69 Hz	42,5 Hz ~ 57,5 Hz, 51 Hz ~ 69 Hz	N/R
	S	See 5.1.1	±50 mHz	42,5 Hz ~ 57.5 Hz, 51 Hz ~ 69 Hz	42,5 Hz ~ 57,5 Hz, 51 Hz ~ 69 Hz	N/R
5.2 Magnitude of the Supply	A	See 5.2.1	±0,1 % U_{din}	10 % ~ 150 % U_{din}	10 % ~ 200% U_{din}	See 4.4 and 4.5
	S	See 5.2.1	±0,5 % of U_{din}	20 % ~ 120 % U_{din}	10 % ~ 150% U_{din}	See 4.4 and 4.5
5.3 Flicker	A	IEC 61000-4-15	IEC 61000-4-15	0,2 ~ 10,0 P_{st}	0 ~ 20 P_{st}	IEC 61000-4-15
	S	IEC 61000-4-15	See 5.3.2	0,4 ~ 4,0 P_{st}	0 ~ 10 P_{st}	IEC 61000-4-15
5.4 Dips and Swells	A	$U_{rms(1/2)}$	Amplitude ±0,2 % U_{din} Duration +/- 1 cycle	N/A	N/A	N/R
	S	See 5.4.1	Amplitude ±1 % of U_{din} Duration +/- 1 cycle or +/-2 cycles	N/A	N/A	N/R
5.5 Interruptions	A	$U_{rms(1/2)}$	Duration +/- 1 cycle	N/A	N/A	N/R
	S	see 5.5.1	Duration +/- 1 cycle or +/-2 cycles	N/A	N/A	N/R
5.7 Unbalance	A	Symmetrical components: U_2 and U_0	±0,15 %	0,5 % ~ 5 % u_2 0,5 % ~ 5 % u_0	0 % ~ 5 % u_2 0 % ~ 5 % u_0	See 4.4 and 4.5
	S	Symmetrical components: U_2, and optionally U_0	±0,3 %	1 % ~ 5 % u_2 1 % ~ 5 % u_0 if implemented	0 % ~ 5 % u_2 0 % ~ 5 % u_0 if implemented	See 4.4 and 4.5
5.8 Voltage Harmonics	A	See 5.8.1	IEC 61000-4-7 Class I	10 % ~ 200 % of Class 3 of IEC 61000-2-4	200 % of Class 3 of IEC 61000-2-4	See 4.4 and 4.5
	S	See 5.8.1	200 % of IEC 61000-4-7 Class II	10 % ~ 100 % of Class 3 of IEC 61000-2-4	200 % of Class 3 of IEC 61000-2-4	See 4.4 and 4.5
5.9 Voltage Inter-harmonics	A	See 5.9.1	IEC 61000-4-7 Class I	10 % ~ 200 % of Class 3 of IEC 61000-2-4	200 % of Class 3 of IEC 61000-2-4	See 4.4 and 4.5
	S	SBM	SBM	SBM	200 % of Class 3 of IEC 61000-2-4	See 4.4 and 4.5
5.10 Mains Signalling Voltage	A	See 5.10.1	See 5.10.2	0 % ~ 15% U_{din}	0 % ~ 15% U_{din}	N/R
	S	SBM	SBM	SBM	0 % ~ 15% U_{din}	N/R
5.12 Under/over deviation	A	See 5.12.1	See 5.12.2	See 5.12.2	N/A	See 4.4 and 4.5
	S	N/R	N/R	N/R	N/A	N/R
Transient Voltages IEC 61180	A	N/R	N/R	N/R	6 kV peak see (3) below	N/A
	S	N/R	N/R	N/R	N/R	N/A
Fast Transients IEC 61000-4-4	A	N/R	N/R	N/R	4 kV peak see (3) below	N/A
	S	N/R	N/R	N/R	N/R	N/A

SBM = Specified by Manufacturer, **N/R** = no requirement, **N/A** = not applicable

(1) The instrument shall meet the uncertainty requirements for signals within the measuring range.

(2) The instrument shall tolerate signals in the influence quantity range without shifting the measurement of other parameters out of their uncertainty requirement, and without instrument damage. The instrument may indicate overrange for signals greater than the measuring range, up to the influence quantity range (not including transients and fast transients).

(3) For transient voltages and fast transients, there shall be no effect on any measurement after the transient. The transients are applied to the measuring terminals, not to the instrument power terminals.

NOTE Class B methods are not included in the table above because they are not recommended for new designs. Readers are advised that Class B may be removed in a future Edition of this standard.

C.3 Guidance on testing

The power quality parameters in this standard may be grouped into two categories: non-triggered and triggered. Non-triggered parameters, for example, include magnitude of the supply, frequency, harmonics, flicker, unbalance and related parameters. Triggered parameters, for example, include dips, swells and interruptions.

The steady-state tests given in Clause 6 are sufficient to verify the uncertainty, performance and influence quantity response of non-triggered parameters. However, the steady-state tests given in Clause 6 do not completely verify that all parameters have been implemented correctly.

For both triggered and non-triggered parameters, implementation according to Clause 5 may be verified with non-steady-state waveforms.

For example, to verify that an instrument's voltage dip measurement method is implemented according to 5.4, one non-steady-state waveform might be used to verify that voltage dips are measured using true RMS; and a second non-steady-state waveform might be used to verify that the true RMS is calculated every cycle; and a third non-steady-state waveform might be used to verify that the true RMS is updated every half-cycle; and a fourth non-steady-state waveform might be used to verify the half-cycle is independently synchronized to each channel, and a fifth non-steady-state signal might be used to verify that the depth and duration on poly-phase dips are correctly reported.

The example given in the preceding paragraph is intended only as an illustration for guidance. Full verification of all parameters might require testing with hundreds of non-steady-state waveforms. (Alternatively, method implementation verification might, in some cases, be performed with a detailed firmware validation.)

This standard does not provide a complete list of tests for verifying that measurement methods have been implemented correctly. Such a list may, in the future, be found in product standards.

Also, for certain parameters in some classes, there are requirements that certain items be "specified by the manufacturer". During performance verification, compliance with this type of requirement should be verified by examining the published specifications of the instrument.

C.4 Guidance on reporting

Reporting that an instrument complies with class A, B, or S is not sufficient.

At a minimum, the following items should also be reported:

– the acceptable range of U_{din} and its associated frequency;
– any accessories or options that may be necessary for compliance;
– a list of each of the parameters in this standard, with the verified class for each parameter.

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IEEE 1159:1995, *Recommended Practice for Monitoring Electric Power Quality*

EN 50160, *Voltage characteristics of electricity supplied by public distribution systems*

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