

# INTERNATIONAL STANDARD

**Communication networks and systems for power utility automation –  
Part 9-3: Precision time protocol profile for power utility automation**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2016 IEC, Geneva, Switzerland

Copyright © 2016 IEEE

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing being secured. Requests for permission to reproduce should be addressed to either IEC at the address below or IEC's member National Committee in the country of the requester or from IEEE.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland  
Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

Institute of Electrical and Electronics Engineers, Inc.  
3 Park Avenue  
New York, NY 10016-5997  
United States of America  
[stds.ipr@ieee.org](mailto:stds.ipr@ieee.org)  
[www.ieee.org](http://www.ieee.org)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About the IEEE

IEEE is the world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities.

### About IEC/IEEE publications

The technical content of IEC/IEEE publications is kept under constant review by the IEC and IEEE. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC Catalogue - [webstore.iec.ch/catalogue](http://webstore.iec.ch/catalogue)

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

#### IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).

# INTERNATIONAL STANDARD

---

**Communication networks and systems for power utility automation –  
Part 9-3: Precision time protocol profile for power utility automation**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 33.200

IEEE ISBN 978-1-5044-2017-4; STD20937

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

FOREWORD.....	3
INTRODUCTION.....	5
1 Scope.....	6
2 Normative references.....	6
3 Terms, definitions, abbreviations, acronyms, and conventions .....	6
3.1 Terms and definitions .....	6
3.2 Abbreviations and acronyms.....	8
4 Identification.....	8
5 Clock types .....	8
6 Protocol specifications .....	9
7 Requirements .....	9
7.1 Measurement conditions.....	9
7.2 Network time inaccuracy .....	9
7.3 Network elements .....	10
7.4 Requirements for grandmasters.....	10
7.4.1 Grandmaster time inaccuracy .....	10
7.4.2 Grandmaster holdover.....	10
7.4.3 Grandmaster clockQuality in start-up, holdover and recovery .....	10
7.4.4 Grandmaster traceable flags .....	10
7.5 Requirements for TCs .....	10
7.6 Requirements for BCs .....	11
7.6.1 BC time inaccuracy .....	11
7.6.2 BC as free-running grandmaster.....	11
7.6.3 BC as master in holdover .....	11
7.7 Requirements for media converters .....	11
7.8 Requirements for links.....	11
7.9 Network engineering .....	12
8 Default settings .....	13
9 Redundant clock handling .....	13
10 Protocol Implementation Conformance Statement (PICS) .....	13
10.1 Conventions.....	13
10.2 PICS.....	14
Table 1 – PTP attributes for the power utility automation profile .....	13
Table 2 – PICS for clocks.....	14

## COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

### Part 9-3: Precision time protocol profile for power utility automation

#### 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.

IEEE Standards documents are developed within IEEE Societies and Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of IEEE and serve without compensation. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards. Use of IEEE Standards documents is wholly voluntary. *IEEE documents are made available for use subject to important notices and legal disclaimers (see <http://standards.ieee.org/IPR/disclaimers.html> for more information).*

IEC collaborates closely with IEEE in accordance with conditions determined by agreement between the two organizations. This Dual Logo International Standard was jointly developed by the IEC and IEEE under the terms of that agreement.

- 2) The formal decisions of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees. The formal decisions of IEEE on technical matters, once consensus within IEEE Societies and Standards Coordinating Committees has been reached, is determined by a balanced ballot of materially interested parties who indicate interest in reviewing the proposed standard. Final approval of the IEEE standards document is given by the IEEE Standards Association (IEEE-SA) Standards Board.
- 3) IEC/IEEE Publications have the form of recommendations for international use and are accepted by IEC National Committees/IEEE Societies in that sense. While all reasonable efforts are made to ensure that the technical content of IEC/IEEE Publications is accurate, IEC or IEEE cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications (including IEC/IEEE Publications) transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC/IEEE Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC and IEEE do not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC and IEEE are not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or IEEE or their directors, employees, servants or agents including individual experts and members of technical committees and IEC National Committees, or volunteers of IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board, for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC/IEEE Publication or any other IEC or IEEE Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that implementation of this IEC/IEEE Publication may require use of material covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. IEC or IEEE shall not be held responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patent Claims or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

International Standard IEC IEEE 61850-9-3 has been prepared by IEC Technical Committee 57, Power systems management and associated information exchange, in cooperation with

IEC subcommittee 65C, Industrial networks, and with IEEE Power Systems Relaying Committee Working Group H24/Substation Committee Working Group C7, of the Power & Energy Society<sup>1</sup> of the IEEE, under the IEC/IEEE Dual Logo Agreement.

This standard cancels and replaces IEC/PAS 61850-9-3 published in 2015.

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

FDIS	Report on voting
57/1679/FDIS	57/1713/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.

International standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61850 series, published under the general title *Communication networks and systems for power utility automation*, can be found on the IEC website.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website 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.

A bilingual version of this publication may be issued at a later date.

---

<sup>1</sup> A list of IEEE participants can be found at the following URL: [http://standards.ieee.org/downloads/61850-9-3/61850-9-3-2016/61850-9-3-2016\\_wg-participants.pdf](http://standards.ieee.org/downloads/61850-9-3/61850-9-3-2016/61850-9-3-2016_wg-participants.pdf)

## INTRODUCTION

### General

This part of IEC 61850 specifies a precision time protocol (PTP) profile of IEC 61588:2009 | IEEE Std 1588-2008 applicable to power utility automation, which allows compliance with the highest synchronization classes of IEC 61850-5 and IEC 61869-9.

This part of IEC 61850 applies Layer 2 communication according to IEC 61588:2009 | IEEE Std 1588-2008, Annex F, and uses peer-to-peer delay measurement according to the default profile of IEC 61588:2009 | IEEE Std 1588-2008, Annex J.4, with restricted range of values.

When clocks are singly attached, this profile is a subset of IEC 61588:2009 | IEEE Std 1588-2008 with above restrictions.

When clocks are doubly attached, this profile extends the BMCA of IEC 61588:2009 | IEEE Std 1588-2008 as IEC 62439-3:2016, Annex A, specifies.

NOTE IEC 62439-3:2016, Annex B is identical to this part of IEC 61850, except that doubly attached clocks are mandatory, while this part of IEC 61850 leaves them optional.

## COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

### Part 9-3: Precision time protocol profile for power utility automation

## 1 Scope

This part of IEC 61850 specifies a precision time protocol (PTP) profile of IEC 61588:2009 | IEEE Std 1588-2008 applicable to power utility automation, which allows compliance with the highest synchronization classes of IEC 61850-5 and IEC 61869-9.

## 2 Normative references

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

IEC 61588:2009, *Precision clock synchronization protocol for networked measurement and control systems* | IEEE Std 1588-2008, *IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems*<sup>2</sup>

IEC TR 61850-90-4:2013, *Communication networks and systems for power utility automation – Part 90-4: Network engineering guidelines*

IEC 62439-3:2016, *Industrial communication networks – High availability automation networks – Part 3: Parallel Redundancy Protocol (PRP) and High availability Seamless Redundancy (HSR)*

ISO/IEC 9646-7, *Open systems interconnection – Conformance testing methodology and framework – Part 7: Implementation conformance statements*

## 3 Terms, definitions, abbreviations, acronyms, and conventions

### 3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61588:2009 | IEEE Std 1588-2008 and IEC 62439-3:2016, as well as the following, apply:

#### 3.1.1

##### **device time inaccuracy**

time inaccuracy evaluated or measured between the time signal at the input of a device and the time signal that this device generates

Note 1 to entry: This definition applies to TCs, BCs and media converters.

Note 2 to entry: Device time inaccuracy includes the uncertainties in the computation of the path delay assuming an ideal Pdelay\_Resp from an upstream neighbour, and the uncertainty introduced in responding to an ideal Pdelay\_Req from a downstream neighbour.

---

<sup>2</sup> IEEE Std 1588-2008 was adopted as IEC 61588:2009.



### 3.1.2

#### **grandmaster-capable**

ordinary clock or boundary clock that is able to take the role of a grandmaster

Note 1 to entry: A grandmaster-capable clock is not necessarily connected to a recognized standard time source.

### 3.1.3

#### **grandmaster time inaccuracy**

time inaccuracy evaluated or measured between the reference time signal at the input of a grandmaster clock and the time signal(s) that the grandmaster generates

Note 1 to entry: Grandmaster time inaccuracy includes the uncertainty introduced in responding to an ideal Pdelay\_Req from a downstream neighbour.

### 3.1.4

#### **network time inaccuracy**

time inaccuracy evaluated or measured between the reference time signal at the input of a grandmaster clock and the time signal at the input of a given slave clock, considering the worst path between the grandmaster(s) and the slave

Note 1 to entry: Network time inaccuracy varies depending on the path the time signals take.

### 3.1.5

#### **reference time inaccuracy**

time inaccuracy evaluated or measured between the time maintained by the international standards laboratories that form the basis for the International Atomic Time (TAI) and Coordinated Universal Time (UTC) timescales and the reference time signal at the input of a grandmaster

Note 1 to entry: Reference time inaccuracy considers e.g. the GPS or the DCF77 time inaccuracy as received at a particular geographical location, at the output of the receiver.

### 3.1.6

#### **subdomain**

region of a time domain delimited by Boundary Clocks, each subdomain having exactly one selected master (Boundary Clock or grandmaster)

### 3.1.7

#### **time error**

deviation from the time reference used for measurement or synchronization caused by a network element, evaluated over a short time span (a few Sync intervals)

### 3.1.8

#### **time inaccuracy**

time error not exceeded by 99,7 % of the measurements, evaluated over a series of 1 000 measurements (about 20 minutes) in steady state

Note 1 to entry: Assuming a Gaussian distribution, this corresponds to three sigma ( $3\sigma = 99,7\%$ ) or no more than 3 points outside the specified interval, out of 1 000 total points evaluated.

### 3.1.9

#### **total time inaccuracy**

time inaccuracy evaluated or measured between the time maintained by the international standards laboratories that form the basis for the International Atomic Time (TAI) and Universal Coordinated Time (UTC) timescales and the time signal at the input of a slave clock

Note 1 to entry: The TimeAccuracy attribute of IEC 61850-7-2 sums the total time inaccuracy and the time inaccuracy of the sampling. Therefore, the mapping from total time inaccuracy to TimeAccuracy is implementation-dependent.

### 3.2 Abbreviations and acronyms

For the purposes of this document, the abbreviations and acronyms given in IEC 61588:2009 | IEEE Std 1588-2008 and IEC 62439-3:2016, as well as the following, apply:

ATOI	Alternate Time Offset Indicator (IEC 61588:2009   IEEE Std 1588-2008, 16.3)
MIB	Management Information Base (RFC 1157)
PICS	Protocol Implementation Conformance Statement (ISO/IEC 9646-7)
SNMP	Simple Network Management Protocol (RFC 1157)

## 4 Identification

The identification values for this profile according to IEC 61588:2009 | IEEE Std 1588-2008, 19.3.3 are:

profileName: IEC/IEEE 61850-9-3 "Precision time protocol profile for power utility automation"  
 profileVersion: 1.0  
 profileIdentifier: 00-0C-CD-00-01-xy

Whereas the first nibble of the sixth octet is a bitfield:

- x = 0 for a singly-attached clock
- x = 1 for PRP redundancy
- x = 2 for HSR redundancy
- x = 3 for both PRP and HSR (configurable) redundancy
- y = 0 (minor revision: profileVersion 1.0)

organizationName: IEC Technical Committee 57 Working Group 10  
 sourceIdentification: A copy of IEC/IEEE 61850-9-3 can either be obtained from the International Electrotechnical Commission (<http://www.iec.ch>) or from the Institute of Electrical and Electronics Engineers (<http://standards.ieee.org>).

NOTE The OUI defined in IEC 61588:2009 | IEEE Std 1588-2008, Annex J.4, does not apply.

## 5 Clock types

This specification distinguishes clocks by their capabilities:

- Ordinary Clocks (OCs) implement one of the following capabilities:
  - Slave-only (defaultDS.slaveOnly = true)  
no port can be in the MASTER state.
  - Grandmaster-capable (defaultDS.slaveOnly = false)  
the port (or the port pair in redundancy) can be in the MASTER state.
  - Grandmaster-only (defaultDS.slaveOnly = false and clockClass = 6 or 7)  
no port can be in the SLAVE state.
- Transparent Clocks (TCs) correct and forward PTP messages:  
their ports do not have states in IEC 61588:2009 | IEEE Std 1588-2008.
- Boundary Clocks (BCs) are never slave-only and can have either:
  - exactly one port in the SLAVE state and all other in the MASTER or PASSIVE state;
  - all ports in the MASTER state, in which case the BC is the grandmaster.

NOTE 1 Within a time domain, a BC has a port in the SLAVE state in the upper subdomain and one or several ports in the MASTER state in the lower subdomain(s) (see IEC TR 61850-90-4).

NOTE 2 A BC filters the messages that are forwarded from one subdomain to the other(s). A BC does not propagate event messages, but does propagate management messages. A BC propagates selected TLVs such as ALTERNATE\_TIME\_OFFSET\_INDICATOR (ATOI) from one subdomain to the next, but these TLVs are attached to different Announce messages.

## 6 Protocol specifications

All clocks shall transmit PTP messages according to IEC 61588:2009 | IEEE Std 1588-2008, Annex F (Transport of PTP over IEEE 802.3 /Ethernet).

All clocks shall support the delay measurement defined in IEC 61588:2009 | IEEE Std 1588-2008, 10.3 and 11.4 (Peer delay mechanism).

All clocks shall support the PTP timescale defined in IEC 61588:2009 | IEEE Std 1588-2008, 7.2.2 (based on TAI).

All singly attached clocks shall support the default best master clock algorithm in IEC 61588:2009 | IEEE Std 1588-2008, 9.3.2, 9.3.3 and 9.3.4.

All doubly attached clocks according to IEC 62439-3:2016 shall support in addition the extension to the best master clock algorithm defined in IEC 62439-3:2016, Annex A.

All clocks shall support both 1-step and 2-step synchronization on ingress, they may use 1-step or 2-step synchronization on egress.

All clocks shall support at least one of the three management mechanisms, as stated in IEC 61588:2009 | IEEE Std 1588-2008, 15.1.1:

- 1) the alternate management mechanism using the SNMP MIB specified in IEC 62439-3:2016, Annex E, and/or
- 2) the alternate management mechanism using the management objects defined in IEC TR 61850-90-4:2013, 19.3 and 19.4, and/or
- 3) the manufacturer-defined fixed values and/or the manufacturer-specific implementation means to address all configurable values.

For testing purposes, it is recommended to equip clocks with a 1 PPS output, see 7.9.

## 7 Requirements

### 7.1 Measurement conditions

Steady state is defined as 30 s after a single master starts to send synchronization messages and 16 s after a change of master, with no change to the environment temperature.

This definition applies only to clocks that have been energized for 30 minutes to accommodate, for instance, temperature-controlled oscillators.

### 7.2 Network time inaccuracy

The following requirements on the network elements aim at achieving a network time inaccuracy better than  $\pm 1 \mu\text{s}$  after crossing approximately 15 TCs or 3 BCs.

### 7.3 Network elements

All network elements shall be clocks according to this part of IEC 61850, conformant media converters and/or conformant links.

### 7.4 Requirements for grandmasters

#### 7.4.1 Grandmaster time inaccuracy

A grandmaster-capable clock shall have a time inaccuracy measured between its applied time reference signal and the produced synchronization messages that is smaller than 250 ns.

NOTE This value corresponds to an IEC 61588:2009 | IEEE Std 1588-2008 clockAccuracy of 22 hex.

In case the grandmaster-capable clock has no time reference signal, IEC 61588:2009 | IEEE Std 1588-2008, J.4.4.1 shall apply.

#### 7.4.2 Grandmaster holdover

A grandmaster shall remain within the time inaccuracy of 7.4.1 for a holdover time of at least 5 s after losing its time reference signal, given that it was in steady state.

#### 7.4.3 Grandmaster clockQuality in start-up, holdover and recovery

A grandmaster clock shall adjust its clockClass according to IEC 61588:2009 | IEEE Std 1588-2008, Table 5 with the values:

- 6 while synchronized to its time reference signal and in steady state;
- 7 after loss of its time reference signal, while in holdover;
- 52 after loss of its time reference signal, when its time error exceeds 7.4.1;
- 187 after loss of its time reference signal, when its time error exceeds 1  $\mu$ s;
- 6 after recovering the time reference signal and in steady state.

NOTE 1 This modifies IEC 61588:2009 | IEEE Std 1588-2008, Table 5 with the timing requirements of this profile.

NOTE 2 The clockClass 6 appears twice in this list, once before loss of time reference signal, and once after recovery thereof.

NOTE 3 A grandmaster clock adjusts its clockAccuracy and offsetScaledLogVariance according to IEC 61588:2009 | IEEE Std 1588-2008, 7.6.2.5 and 7.6.3.

#### 7.4.4 Grandmaster traceable flags

PTP messages carry a timeTraceable and a frequencyTraceable flag. A grandmaster that receives its reference signal e.g. through a GPS receiver would set the timeTraceable flag, while a grandmaster that e.g. only receives a 1PPS signal would set the frequencyTraceable flag. These flags are however not considered in the BMCA, so other means allow prioritizing a time source over a frequency source, when both exist in the same time domain, for instance configuring Priority1, see 7.9.

### 7.5 Requirements for TCs

The TC time inaccuracy cumulates the time errors in measuring the residence delay, measuring the peer delay in the ingress port and responding to the peer delay measurement from the downstream clocks in the egress port(s). It does not include time error due to asymmetry in either link, nor introduced by the upstream or downstream peer devices involved in the peer delay measurements.

A TC shall introduce less than 50 ns of device time inaccuracy, measured between the applied synchronization messages at any ingress port and the produced synchronization messages at any egress port, given it is in steady state.

A TC should forward Sync messages even if it is not yet in steady state.

NOTE 1 The TC's contribution to time inaccuracy is measurable using peer clocks with known contribution to time error in the peer delay measurement and using links with known or negligible asymmetry, and subtracting those amounts from the observed TC time error.

## **7.6 Requirements for BCs**

### **7.6.1 BC time inaccuracy**

The BC time inaccuracy cumulates the time errors in local clock adjustment, measuring the peer delay in the port in the SLAVE state and responding to the peer delay measurement from the downstream clocks in the port(s) in the MASTER state. It does not include time errors due to asymmetry in either link, nor introduced by the upstream or downstream peer devices involved in the peer delay measurements.

A BC shall introduce less than 200 ns of device time inaccuracy between the port in the SLAVE state and any port in the MASTER state, given it is in steady state.

A BC should send Announce and Sync messages even if it is not yet in steady state.

NOTE 1 The BC's contribution to time inaccuracy is measurable using peer clocks with known contribution to time error of the peer delay measurement and using links with known or negligible asymmetry, and subtracting those amounts from the observed BC time error.

### **7.6.2 BC as free-running grandmaster**

In case the BC has no port in the SLAVE state and no time reference signal, IEC 61588:2009 | IEEE Std 1588-2008, J.4.4.1 shall apply.

### **7.6.3 BC as master in holdover**

A BC shall remain within the time inaccuracy of 7.4.1 for a holdover time of at least 5 s after losing its time reference signal or PTP synchronization, given that it was in steady state.

## **7.7 Requirements for media converters**

Media converters (e.g. fibre to copper) introduce a delay, considered in the peer-to-peer delay measurement. This delay suffers from a significant jitter and could be different in both directions.

Media converters that support IEC 61588 are considered as TCs or BCs and are subject to the requirements of 7.5 and 7.6, respectively.

Media converters that do not support IEC 61588 shall present a jitter of less than 50 ns and an asymmetry of less than 25 ns.

## **7.8 Requirements for links**

Links present a predictable and nearly constant link propagation delay (about 5 µs/km for fibre or copper), whose average value is regularly calculated by peer-to-peer delay measurement.

NOTE Radio links are not considered.

Since delay asymmetry is not measurable, network engineering must know it to compensate for it.

Links shall present a propagation asymmetry of less than 25 ns or shall have a known propagation asymmetry with an asymmetry variation of less than 25 ns.

## 7.9 Network engineering

To achieve the required network time inaccuracy, careful network design is required, considering the placement of masters and redundant masters and possible network topology changes because of reconfigurations, so as not to exceed the number of allowed TCs and BCs.

The network designer should only select network elements knowing their contribution to network time inaccuracy and dependencies on the operating conditions. The network designer should estimate the network time inaccuracy for all slave clocks.

The network designer should use network elements with stricter specifications in more demanding applications or larger networks.

The total time inaccuracy  $\varepsilon_T$  of the time signal available at the input of a given clock is computed at engineering time as:

$$\varepsilon_T = \varepsilon_{RF} + \varepsilon_{GM} + (N_{TC} \times \varepsilon_{TC}) + (N_{BC} \times \varepsilon_{BC}) + (N_{MC} \times \varepsilon_{MC})$$

The network time inaccuracy  $\varepsilon_N$  of the time signal available at the input of a given clock is computed at engineering time as:

$$\varepsilon_N = \varepsilon_{GM} + (N_{TC} \times \varepsilon_{TC}) + (N_{BC} \times \varepsilon_{BC}) + (N_{MC} \times \varepsilon_{MC})$$

where:

- $\varepsilon_T$  = total time inaccuracy;
- $\varepsilon_N$  = network time inaccuracy;
- $\varepsilon_{RF}$  = reference time inaccuracy;
- $\varepsilon_{GM}$  = grandmaster time inaccuracy (see 7.4);
- $\varepsilon_{TC}$  = TC time inaccuracy (see 7.5);
- $\varepsilon_{BC}$  = BC time inaccuracy (see 7.6);
- $\varepsilon_{MC}$  = media converter time inaccuracy (see 7.7);
- $N_{TC}$  = number of TCs in series on the longest path to this clock;
- $N_{BC}$  = number of BCs in the path on the longest path to this clock;
- $N_{MC}$  = number of media converters in the path on the longest path to this clock.

NOTE 1 Medium asymmetry is considered negligible in a properly engineered substation.

NOTE 2 The fields in the Announce message, especially timeSource, clockQuality and stepsRemoved provide an estimation of the actual time inaccuracy.

The network commissioner should check the time inaccuracy of the installed network components and verify the topology (e.g. using the management mechanism, if such is provided) and then perform a calibration for the network time inaccuracy of all slave clocks, e.g. using their 1 PPS output.

Network engineers should configure the Priority1 field to give preference to grandmasters that are time-traceable over grandmasters that are frequency-traceable in the same time domain, see 7.4.4.

The network engineer should ensure that all clocks participating in the PTP time distribution are set to the same time domain. To avoid conflict with another PTP time distribution that occupies time domain 0 on the same network, time domain 93 is recommended as an alternative to time domain 0. This also applies to the primary domain of TCs.

## 8 Default settings

All clocks shall be initially configured with the default settings and shall be able to support the ranges (if specified) of Table 1.

**Table 1 – PTP attributes for the power utility automation profile**

PTP attribute	Default value	Range
defaultDS.domainNumber	0	As specified in Table 2 of IEC 61588:2009 ; IEEE Std 1588-2008 <sup>1)</sup>
portDS.logAnnounceInterval	0	0 <sup>2)</sup>
portDS.logSyncInterval	0	0 <sup>2)</sup>
portDS.logMinPdelay_ReqInterval	0	0 <sup>2)</sup>
portDS.announceReceiptTimeout	3	3
defaultDS.priority1	255 for slave-only clocks, 128 otherwise	0.. 255 255 for slave-only clocks
defaultDS.priority2	255 for slave-only clocks, 128 otherwise	0..255 255 for slave-only clocks
defaultDS.slaveOnly	False (if this parameter is configurable)	True, False
transparentClockdefaultDS.primaryDomain	0	As specified in Table 2 of IEC 61588:2009 ; IEEE Std 1588-2008 <sup>1)</sup>
$\tau$ (Allan deviation sample period)	1,0 s	1,0 s

<sup>1)</sup> A clock is settable to any domainNumber {0 to 255} even if this value is reserved. Default domain is 0, but domainNumber 93 is recommended to prevent conflict with another PTP time distribution that is using domain 0.

<sup>2)</sup> Although the value of the interval between messages is nominally fixed, this interval is allowed to vary in accordance with IEC 61588:2009 ; IEEE Std 1588-2008, 7.7.2.1 (general), 9.5.9.2 (Sync messages), 9.5.8 (Announce messages), and 9.5.13.2 (Pdelay\_Req messages). The Packet Delay Variation in the local area network (in the order of ms) is assumed to be negligible compared with the allowed variation (hundreds of ms).

Clocks are expected to operate correctly over the allowed interval variation and to rely on the indicated interval in the message header rather than on a predefined value of that interval. Testing is limited to the values given in Table 1, plus or minus the allowed interval variation.

## 9 Redundant clock handling

NOTE This Clause does not apply to clocks with only one port.

Clocks may implement any of the doubly attached clock models of IEC 62439-3:2016, Annex A that use peer-to-peer delay measurement at the exclusion of other methods.

To express that the double attachment of clocks is mandatory rather than optional, IEC 62439-3:2016, Annex B should be used.

## 10 Protocol Implementation Conformance Statement (PICS)

### 10.1 Conventions

The "Base" column reflects the definitions and specifications in the base standard. Each entry in this column is chosen from the following list:

- **mandatory (m):** the base standard mandates this capability and it is implemented;
- **optional (o):** the base standard leaves this capability optional, but it is implemented.



The "Condition" column reflects the condition(s) for the capability. Each entry in this column is chosen from the following list:

- **conditionally supported (c):** this capability is supported under the conditions specified in the corresponding index in the PICS Table;
- **unconditionally supported (–):** this capability is not constrained.

The "Support" column is to be filled by the manufacturer.

## 10.2 PICS

The manufacturer shall list the capabilities and options supported by its clock in the PICS according to Table 2. The "Base" of this PICS are Clauses 5, 6, 7, 8 and 9 of this document.

**Table 2 – PICS for clocks**

PICS proforma reference	Capability	Value range	Base	Condition	Support (see Note)
CLOCK_TYPE_OC	clock is OC according to this base	True, False	m	c.1	<i>True</i>
CLOCK_TYPE_TC	clock is TC according to this base	True, False	m	c.1	<i>False</i>
CLOCK_TYPE_BC	clock is BC according to this base	True, False	m	c.1	<i>False</i>
NR_PORTS	number of clock ports (total)	integer > 0	m	–	2
PORTS_STEP	1: all ports support 1-step on egress 2: all ports support 2-step on egress 3: all ports support both 1-step and 2.	1..3	m	–	{1}
SLAVE_ONLY	all ports of the clock are slave-only	True, False	m	c.2	<i>True</i>
TIME_TRACEABLE	connectable to a time reference outside of PTP (e.g. GPS)	True, False	m	c.3	<i>N/A</i>
FREQ_TRACEABLE	connectable to a frequency reference outside of PTP (e.g. GPS)	True, False	m	c.3	<i>N/A</i>
DAC	doubly attached OC	True, False	o	–	<i>True</i>
PORTS_PAISED	paired clock ports for redundancy (e.g. {3-4})	identifier pair	o	c.4	{0,1}
REDBOX_DATC	Redbox as TC	True, False	o	c.5	<i>N/A</i>
REDBOX_SLTC	Redbox as Stateless TC	True, False	o	c.5	<i>N/A</i>
REDBOX_TWBC	Redbox as three-way BC	True, False	o	c.6	<i>N/A</i>
REDBOX_DABC	Redbox as DAC BC	True, False	o	c.6	<i>N/A</i>
MIB_SNMP	supports MIB of IEC 62439-3:2016, Annex E	True, False	m	c.7	<i>False</i>
MIB_61850	supports IEC TR 61850-90-4 Clock Objects	True, False	m	c.7	<i>False</i>
MIB_OTHER	clock supports fixed values or a mechanism defined by the manufacturer (if True, this list is appended to this PICS)	True, False	m	c.7	<i>True, void list.</i>
ATOI	supports ATOI TLV as specified in IEC 61588:2009   IEEE Std 1588-2008, 16.3	True, False	o	–	<i>False</i>
PPS	clock has a 1 PPS output	True, False	o	–	<i>True</i>
ACCURACY	Design value of clockAccuracy	nanoseconds	o	–	<i>1000 ns</i>
DEVIATION	Design value of Allan deviation	nanoseconds	o	–	<i>4 ns</i>
HOLDOVER	The length of time the clock is expected to stay in clockClass 7, if it is the grandmaster and no longer synchronized to its time reference signal.	seconds	o	–	<i>N/A</i>
c.1: at least one shall be supported (CLOCK_TYPE_OC and CLOCK_TYPE_TC may be both True) c.2: only if CLOCK_TYPE_OC = True c.3: only if SLAVE_ONLY = False c.4: shall be "m" (>1) if DAC = True c.5: support shall only be declared if CLOCK_TYPE_TC = True and DAC=True c.6: support shall only be declared if CLOCK_TYPE_BC = True and DAC=True c.7: at least one shall be supported					
NOTE The values in the "Support" column are an example of an IED that is doubly attached over ports 0 and 1, uses 1-step Pdelay_Req, has no master capability, does not support a MIB and does not implement the ATOI option.					





INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

3, rue de Varembe  
PO Box 131  
CH-1211 Geneva 20  
Switzerland

Tel: + 41 22 919 02 11  
Fax: + 41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)