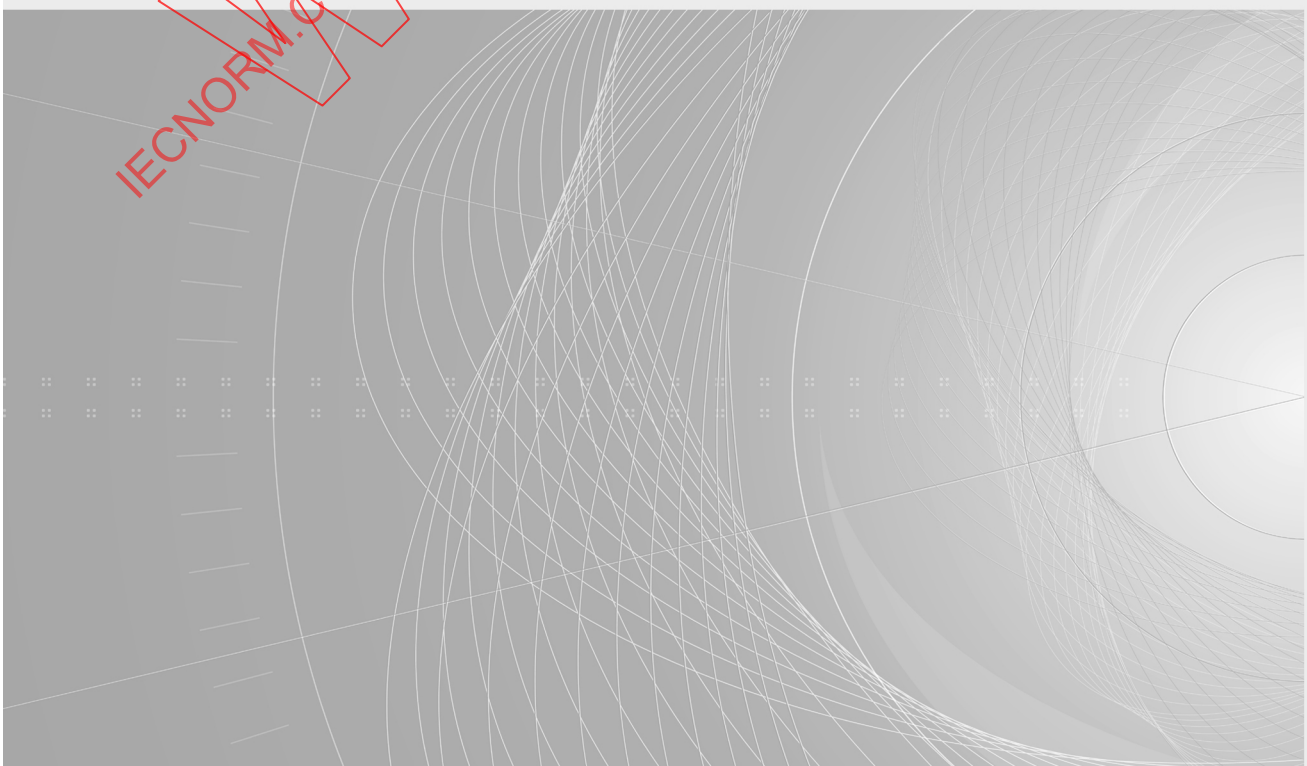
IEC PAS 61850-9-3

Edition 1.0 2015-06

PUBLICLY AVAILABLE SPECIFICATION

PRE-STANDARD

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



IEC PAS 61850-9-3:2015-06(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.200

ISBN 978-2-8322-2725-1

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

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

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The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
57/1551/PAS	57/1575/RVD

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

INTRODUCTION

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

This PAS applies Layer 2 communication according to IEC 61588:2009, Annex F, and uses peer-to-peer delay measurement according to the IEC 61588:2009, Annex J.4, default profile with restricted range values.

When clocks have a single attachment, this profile is a subset of IEC 61588:2009 with the above restrictions.

When clocks have an optional double attachment, this profile extends the BMCA of IEC 61588:2009 as IEC 62439-3:2015, Annex A, specifies.

COMMUNICATION NETWORKS AND SYSTEMS FOR POWER UTILITY AUTOMATION –

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

1 Scope

This PAS specifies a precision time protocol (PTP) profile of IEC 61588:2009 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*

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

IEC 62439-3:2015, *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 and acronyms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61588:2009 and IEC 62439-3:2015, as well as the following, apply:

3.1.1
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 time source.

3.1.2
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)

3.1.3
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 σ = 99,7%) or no more than 3 points outside the specified interval, out of 1 000 total points evaluated.

3.1.4
network time inaccuracy
time inaccuracy evaluated or measured between a particular slave clock and the time reference signal of its grandmaster clock(s), considering the worst network topology

3.2 Abbreviations and acronyms

For the purposes of this document, the abbreviations and acronyms given in IEC 61588:2009 and IEC 62439-3:2015, as well as the following, apply:

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, 19.3.3, are:

profileName: IEC 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 61850-9-3 can be obtained from the International Electrotechnical Commission (http://www.iec.ch)

NOTE The OUI defined in IEC 61588:2009, Annex J.4, does not apply.

5 Clock types

This PAS 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.
- Boundary Clocks (BC) are never slave-only and can have either:
  - exactly one port in the SLAVE state and all other in the MASTER state;
  - all ports in the MASTER state, in which case the BC is the grandmaster.

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

Atomic clocks are not considered in this specification.

6 Protocol specifications

All clocks shall transmit PTP messages on Ethernet layer 2 according to IEC 61588:2009, Annex F.

All clocks shall use multicast communication using the addresses specified in IEC 61588:2009, F.1.

All clocks shall support the peer-to-peer delay measurement defined in IEC 61588:2009, 10.3 and 11.4.

All clocks shall support the PTP time scale (based on TAI).

All singly attached clocks shall support the default best master clock algorithm in IEC 61588:2009, 9.3.2, 9.3.3 and 9.3.4.

All doubly attached clocks according to IEC 62439-3 shall support in addition the extension to the best master clock algorithm defined in IEC 62439,3:2015, 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:

1) The alternate management mechanism using the SNMP MIB specified in IEC 62439-3:2015, Annex E and/or
2) The alternate management mechanism using the management objects defined in IEC 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 as stated in IEC 61588:2009, 15.1.1.

7 Requirements

7.1 Measurement conditions

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

This requirement 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 ±1 μs after crossing approximately 15 TCs or 3 BCs.

7.3 Network elements

All network elements shall be clocks according to this standard, 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 clockAccuracy of 22 hex; IEC 61588 defines clockAccuracy.

In case the grandmaster-capable clock has no time reference signal, IEC 61588:2009, 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 clockClass in holdover and recovery

A grandmaster clock shall have an IEC 61588:2009 clockClass of:

6 while connected to its time reference signal and in steady state;

7 after loss of time reference signal, while in holdover;

52 when its time error exceeds 7.4.1;

187 when its time error exceeds 1 μs;

6 after recovering the time reference signal and in steady state.

NOTE 1 This modifies IEC 61588:2009, Table 5, for the timing requirements of this profile.

NOTE 2 The timeTraceable bit of the flagField indicates if the grandmaster is currently locked to a recognized standard time source or has a stated uncertainty to a recognized standard time source. The clockClass = 6 indicates that the grandmaster is currently locked to its time reference signal. The clock class 6 appears twice, once before loss of time reference signal, and once after recovery of that signal.

7.5 Requirements for TCs

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

NOTE This 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. This time inaccuracy may be measured using peer devices with known contribution of the peer delay measurement to time error 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

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

NOTE This 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. This time inaccuracy may be measured using peer devices with known contribution of the peer delay measurement to time error 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, 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 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 (e.g. fibre to copper) introduce a delay, considered in peer-to-peer delay measurement. This delay may suffer from a significant jitter and may be different in both directions. Network engineering should use only media converters with known behaviour to estimate the network time inaccuracy at every slave clock.

Media converters 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 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 network time inaccuracy of the time signal available at a given clock is computed at engineering time as:

$$\varepsilon_{GM} + N_{TC} \times \varepsilon_{TC} + N_{BC} \times \varepsilon_{BC}$$

where:

ε_{GM} = worst-case grandmaster time inaccuracy (see 7.4);

ε_{TC} = worst-case TC time inaccuracy (see 7.5);

ε_{BC} = worst-case BC time inaccuracy (see 7.6);

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.

The network engineering should consider the time error in the signal received from the recognized standard time source, e.g. the GNSS signal.

The network commissioner should check the time inaccuracy class 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. For this purpose, it is recommended to equip clocks with a 1 PPS output.

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
portDS.logAnnounceInterval	0	0 [a]
portDS.logSyncInterval	0	0 [a]
portDS.logMinPdelay_ReqInterval	0	0 [a]
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
τ (Allan deviation sample period)	1,0 s	1,0 s

[a] Although a master clock is not required to support any other value, it still can have a jitter as IEC 61588:2009, 9.5.9.2, specifies. A slave clock should have a capture range accordingly.

For each defined range, manufacturers are free to allow wider ranges, which are out of the scope of this profile and which conformance testing will not consider.

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 62439-3:2015, Annex A, that use peer-to-peer delay measurement.

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	True
CLOCK_TYPE_TC	clock is TC according to this base	True, False	m	c.1	
CLOCK_TYPE_BC	clock is BC according to this base	True, False	m	c.1	
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	True
TIME_TRACEABLE	connectable to a time reference outside of PTP (e.g. GPS)	True, False	m	c.3	
FREQ_TRACEABLE	connectable to a frequency reference outside of PTP (e.g. GPS)	True, False	m	c.3	
DAC	doubly attached OC	True, False	o	-	True
PORTS_PAIRED	paired clock ports for redundancy (e.g. {3-4})	identifier pair	o	c.4	{0,1}