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IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications

IEEE Power and Energy Society

Sponsored by the
Power System Relaying Committee

and the

Substations Committee

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IEEE Std C37.238™-2017
(Revision of
IEEE Std C37.238-2011)

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Abstract: An extended profile is specified for the use of Precision Time Protocol of IEEE Std 1588-2008 in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

Keywords: grandmaster clock, IEEE 1588™, IEEE C37.238™, power substation, precise time synchronization, Precision Time Protocol, PTP, sample synchronization, slave-only clock, synchrophasors, transparent clock

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When the IEEE-SA Standards Board approved this standard on 23 March 2017, it had the following membership:

Introduction

This introduction is not part of IEEE Std C37.238-2017, IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications.

This standard specifies a profile that extends the capabilities of IEC/IEEE 61850-9-3 profile for the use of the IEEE 1588 Precision Time Protocol (PTP) in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

This revision was generated to respond in a timely manner to comments brought forward by IEC Technical Committee 57 Working Group 10 and others after publication of IEEE Std C37.238-2011, as a result of first implementations.

To provide base-level interoperability, IEEE Std C37.238-2011 was divided into a base profile specified in IEC/IEEE 61850-9-3:2016 and the profile that extends the capabilities of the IEC/IEEE 61850-9-3 profile, which is specified in this standard. As a result, this standard is compliant with the IEC/IEEE 61850-9-3:2016 standard.

The following main changes are incorporated into this revision:

- PTP parameters and performance specifications that are part of the base profile were replaced with references to IEC/IEEE 61850-9-3:2016. Refer to 5.2 to 5.11 and Annex B of IEEE Std C37.238-2011.
- Definitions were revisited; some definitions were removed and replaced with references. Refer to 3.1.
- New Clause 5 was added to explain the relationship between different standards, namely IEEE Std 1588-2008, IEC/IEEE 61850-9-3:2016, and this standard.
- The Best Master Clock Algorithm (BMCA) requirement to check for the presence of profile-specific type, length, and value (TLV) was removed, to keep the BMCA as specified in 9.3 of IEEE Std 1588-2008. Refer to 5.12 of IEEE Std C37.238-2011 and new subclause 6.2 of this standard.
  - The field definition in the IEEE_C37_238_TLV was modified while keeping backwards compatibility with the previous version's data fields. Refer to 5.12.2 of IEEE Std C37.238-2011 and new subclause 6.2.1 of this standard.
    - organizationSubType has been changed from 1 to 2.
    - GrandmasterTimeInaccuracy is replaced with Total time inaccuracy.
    - grandmasterID field field's range restriction has been removed (all 16 bits are now usable), for the following reasons:
      - IEC 61850 applications will now be using the 64-bit grandmaster clock identity, so they do not require a short grandmasterID.
      - For applications that use Inter-Range Instrumentation Group B (IRIG-B), keeping this field, with an expansion to 16 bits, provides compatibility with IEEE Std C37.238-2011, a user-settable ID that does not change when the clock's hardware is replaced (see C.4, C.4.2, and D.3.3), and the use of grandmasterID field is now optional (zero if unused).
- The fields of the IEEE 1588 Alternate Time Offset Indicator TLV are clarified for providing the local time. TLV support is mandatory and use is optional. Refer to 6.2.2.
- Description of TimeInaccuracy concept is expanded and terms are redefined for clarity. Refer to 5.13 of IEEE Std C37.238-2011, new subclause 6.3 of this standard, and Clause 3 of IEC/IEEE 61850-9-3:2016.

- Guidance on compatibility with the previous version of this standard is provided in new Annex B.
- Additional guidance is provided on mapping between IEEE Std C37.238 and IRIG-B formats (see Annex C).
- Appropriate changes are made to Annex C and Annex D to include a new profile-specific TLV format.
- Guidance on the use of multiple PTP profiles in a single timing network, particularly, using IEC/IEEE 61850-9-3 slave devices in an IEEE C37.238 network, can be found in Annex E.

Necessary definitions are provided. Typical Ethernet-based time distribution architecture consists of a reference clock, bridges, and end devices. Bridges with boundary clock functionality may also be used at interconnection points between different PTP domains or PTP profiles.

In addition to distributing global time that is traceable to a recognized standard time source, for the cases when connectivity to recognized standard time sources is lost, a timing island is formed. The master clock is now in holdover mode and continues to distribute its time to the local area (all devices receiving the same time can be construed as being on a timing island), with the master clock's ID (64-bit globally unique and 16-bit user-configurable choices are available) allowing verification of which subsequent timestamps may be correctly compared.

The profile can be used for precise time synchronization of the devices in a substation, and between substations in a larger geographical area, if performance requirements of this standard are met.

The use of different physical layer communication technologies to carry Ethernet frames, including SONET/SDH and wireless technologies, is not precluded if they can meet performance requirements of this standard.

Time distribution specified in this standard is based on the following basic assumptions:

- All devices that participate in time distribution support this standard (except that slave devices may be IEC/IEEE 61850-9-3).
- All devices are in the same time distribution domain.
- All devices have point-to-point connections to their neighbors.
- Transmit and receive cable delay for each point-to-point connection is assumed to be symmetrical. Known asymmetry in cable delay can be configured and corrected.

Cyber security is important in power system design. The scope of this standard does not include that topic. However, other standards and works in progress do address these concerns. For instance, the IEEE 1588 Revision Working Group at the time of this publication was actively investigating methods to secure PTP. Other standards regarding this subject include IEEE Std C37.240™, IEEE Std 1686™-2013, and IEC 62351-6.

Redundancy is an important consideration; some applications recommend or mandate support for different time distribution technologies, e.g., Global Positioning System (GPS) and IRIG-B. Support for multiple time distribution technologies at the same time is out of scope for this standard. Redundancy may be provided using this standard (multiple grandmasters and/or diverse network paths) using domains.

Specific environmental requirements are out of scope for this profile. However, devices conforming to this profile may also follow environmental standards such as IEEE Std 1613™ and IEC 61850-3. Vendors are encouraged to provide information regarding the effect of environmental influences on device performance, perhaps including the pass/fail criteria used when determining environmental compliance.

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IEEE Standard Profile for Use of IEEE 1588™ Precision Time Protocol in Power System Applications

1. Overview

1.1 Scope

This standard specifies an extended profile for the use of IEEE Std 1588-2008[1] in power system protection, control, automation, and data communication applications utilizing an Ethernet communications architecture.

The profile specifies a well-defined subset of IEEE 1588 mechanisms and settings aimed at enabling device interoperability, robust response to network failures, and deterministic control of delivered time quality. It is compliant with IEC/IEEE 61850-9-3:2016, which specifies the preferred physical layer, Ethernet; the higher level protocol used for message exchange, Precision Time Protocol (PTP); and the PTP protocol configuration parameters. Special attention is given to ensuring consistent and reliable time distribution within substations, between substations, and across wide geographic areas. As such, this profile extends IEC/IEEE 61850-9-3:2016 with continuous monitoring of time inaccuracy, and optionally local time based on Coordinated Universal Time (UTC).

1.2 Purpose

The purpose of this standard is to facilitate adoption of IEEE Std 1588-2008 for power system applications requiring high-precision time synchronization. IEC/IEEE 61850-9-3:2016 and this standard specify a common subset of PTP parameters and options to provide global time availability, device interoperability, and failure management. This set of PTP parameters and options allows IEEE 1588-based time synchronization to be used in mission critical power system protection, control, automation, and data communication applications.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in the text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC/IEEE 61850-9-3:2016, Communication networks and systems for power utility automation – Part 9-3: Precision time protocol profile for power utility automation.[2]

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[1]Information on references can be found in Clause 2.

[2]IEC/IEEE publications are available from the International Electrotechnical Commission (http://www.iec.ch) and The Institute of Electrical and Electronics Engineers (http://standards.ieee.org).