

IEEE Standard for Phasor Data Concentrators for Power Systems

IEEE Power and Energy Society

Developed by the
Power System Relaying and Control Committee

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Power System Relaying and Control Committee
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Abstract: A phasor data concentrator (PDC) is defined in this standard as a set of functions that may be performed on synchrophasor data. It describes the PMU measurement network and indicates the place of the PDC in it. The standard defines the minimum functions that a PDC should perform. The performance requirements for these functions are given, and the ways they can be tested are described. Cybersecurity is discussed, and while its importance is acknowledged in the overall system, it is beyond the scope of this standard, which is viewed as specific to PDC functions.

Keywords: IEEE C37.247™, PDC, phasor data concentrator, phasor measurement, phasor measurement unit, PMU, synchrophasor

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Introduction

This introduction is not part of IEEE Std C37.247-2019, IEEE Standard for Phasor Data Concentrators for Power Systems.

The present version of this standard is the first. It is unlikely that the requirements addressed in this standard will remain unchanged for long. Like most IEEE standards, it is expected that revisions will be needed to keep the standard in line with emerging technology.

The standard establishes requirements for a phasor data concentrator (PDC). A PDC is part of a communication system that extends from a phasor measurement unit (PMU) to a data center or control room. An overview of such a PMU measurement system is included in [Annex A](#). Such systems may transmit data in either direction. What might be called inbound data consist of the measurement results calculated at the PMU from the (usually three-phase) voltages and currents in the power system. Inbound data includes metadata indicating the origin of the results and the time at which they apply. Outbound data consist of settings and commands for the phasor measurement units.

A phasor data concentrator is a set of functions that combines PMU data from multiple sources for further processing. These functions may reside either in a standalone box, or as a software application on a server/computer.

The standard responds to other standards in terms of the format for the data. At present, IEEE Std C37.118.2™-2011 [\[B6\]](#) defines the method for the exchange of data. That standard is the latest in a series of IEEE standards that began in 1995 with IEEE Std 1344™ [\[B3\]](#) and has since been reaffirmed or revised about every five years. In the 2011 version, the topic of data transfer requirements was separated from that of measurement requirements, which became the subject of IEEE Std C37.118.1™-2011 and IEC/IEEE 60255-118-1:2018.

The functions that a PDC may perform are outlined in IEEE Std C37.244™-2013 [\[B8\]](#), IEEE Guide for Phasor Data Concentrator Requirements for Power System Protection, Control, and Monitoring. The requirements for all functions that a PDC may perform are described. This standard builds on that guide. In writing this standard, the approach was taken that not every PDC must be able to perform all of the functions listed in the guide.

This standard indicates only the minimum set of functions that every PDC must perform and specifies performance requirements that every PDC must meet in doing so. Manufacturers are free (and indeed encouraged) to add a wider range of functions to their products as enhancements, recognizing that new functions and features will arise for processing PMU data.

Users may consider some of these enhancements as essential to their intended use. Such needs may vary from one user to the next. In this respect, users should assess their needs and specify additional functions and requirements as necessary.

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IEEE Standard for Phasor Data Concentrators for Power Systems

1. Overview

This clause describes the scope, purpose, and the limitation of applicability of the IEEE Standard for Phasor Data Concentrators for Power Systems, hereafter referred to as “this standard.”

1.1 Scope

This standard specifies the requirements of phasor data concentrators (PDCs) for power systems.

It includes the following requirements:

- a) Data aggregation
- b) Processing of synchrophasors and other synchronized data
- c) Data interfaces with other systems
- d) Handling of commands, configuration, and other metadata
- e) Performance, including latency, environmental, throughput
- f) Testing

1.2 Purpose

The purpose is to improve interoperability of devices, systems, and applications that use synchrophasors and other synchronized data by standardizing requirements for PDCs.

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 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.

IEEE Std C37.118.1TM-2011, IEEE Standard for Synchrophasor Measurements for Power Systems.^{1,2}

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²IEEE publications are available from the Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

IEC/IEEE 60255-118-1:2018, Measuring relays and protection equipment—Part 118-1: Synchrophasor for power systems—Measurements.³

3. Definitions, abbreviations, and acronyms

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁴

3.1 Definitions

absent data tag: A substitute data inserted in a data frame, when the data is absent.

absolute wait time: The time interval added to the time corresponding to a given message time stamp. After this interval, the collection of data with that time stamp is terminated. (Adapted from IEEE Std C37.244-2013 [B8]⁵)

Coordinated Universal Time (UTC): An internationally agreed upon time scale maintained by the Bureau International des Poids et Mesures (BIPM) used as the time reference by nearly all commonly available time and frequency distribution systems (e.g., WWV, WWVH, LORAN-C, Transit, Omega, and GPS).

data aggregation: Forming a set of data from multiple inputs. (Adapted from IEEE Std C37.244-2013 [B8])

data forwarding: Forwarding a set of data from an input to an output with no intentional delay and without data aggregation. (Adapted from IEEE Std C37.244-2013 [B8])

data frame: A data frame is a set of synchrophasor, frequency, and rate-of-change-of-frequency measurements that corresponds to the same time stamp.

NOTE—The term “frame” is used to differentiate it from samples, which are understood as points on an analog waveform.⁶

duplicate data: Multiple copies of the same synchrophasor data received by a phasor data concentrator, with all identical values, names, and time stamps. (Adapted from IEEE Std C37.244-2013 [B8])

egress time: Egress time is the time when the data becomes available at the output (denoted by the first transition of the first bit of the output message at the communication interface point).

leap second: A positive or negative one-second adjustment to the Coordinated Universal Time that keeps it close to mean solar time.

phasor: A complex equivalent of a sinusoidal wave quantity such that the complex modulus is the cosine wave amplitude and the complex angle (in polar form) is the cosine wave phase angle. (Adapted from IEC/IEEE 60255-118-1:2018)

phasor data concentrator (PDC): A function that collects phasor data, and discrete event data from phasor measurement units and possibly from other PDCs, and transmits data to other applications.

³IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

⁴*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

⁵The numbers in brackets correspond to those of the bibliography in Annex G.

⁶Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

phasor data concentrator (PDC) latency: The time difference between the arrival time of the first complete data message with a given time stamp and its egress time from the PDC. (Adapted from IEEE Std C37.244-2013 [B8])

phasor data concentrator (PDC) processing time: The time interval a PDC uses to complete the production of an output stream. It starts when all data to be processed is received or wait times were reached, and ends at the data egress time from the PDC. (Adapted from IEEE Std C37.244-2013 [B8])

phasor measurement unit (PMU): A device or a function in a multifunction device that produces synchronized phasor, frequency, and rate of change of frequency estimates from voltage and/or current signals and a time synchronizing signal. (Adapted from IEC/IEEE 60255-118-1-2018)

relative wait time: The time interval added to the arrival time of the first message with a given time stamp. After this interval, the collection of data with that time stamp is terminated. (Adapted from IEEE Std C37.244-2013 [B8])

reliability: The ability of a component or system to perform required functions under stated conditions for a stated period of time.

synchronized phasor: *See:* **synchrophasor**.

synchrophasor: Phasor representing the fundamental of an ac signal whose magnitude is the RMS value of the fundamental amplitude and angle is the difference between the signal fundamental angle and the phase angle of a cosine at the nominal signal frequency that is synchronized to Coordinated Universal Time. (Adapted from IEC/IEEE 60255-118-1-2018) *Syn:* **synchronized phasor**.

total vector error (TVE): The normalized value of the difference between the measured synchrophasor and the reference synchrophasor, both at the same time. (Adapted from IEC/IEEE 60255-118-1-2018)

valid time stamp: A time stamp that is in the set defined by the synchrophasor protocol and data rate in use. (For example, IEEE C37.118.2 synchrophasor protocol requires data rates to be restricted to integer multiples or submultiples of nominal line frequency [30, 120, etc., for 60 Hz systems], and time stamps to be restricted to that number of equidistant values between top of two consecutive seconds.)

wait time: The maximum time interval during which the phasor data concentrator collects data for a particular output from one or more inputs. It is the time interval added to a message time stamp time or message-arrival time after which no more data with that time stamp is accepted. (Adapted from IEEE Std C37.244-2013 [B8])

3.2 Abbreviations and acronyms

CRC	cyclic redundancy check
DFR	digital fault recorder
GPS	Global Positioning System
IP	Internet Protocol (see IETF RFC 791 [B10])
NaN	not a number
PDC	phasor data concentrator
PMU	phasor measurement unit
ROCOF	rate of change of frequency
TCP	Transmission Control Protocol (see IETF RFC 793 [B11])
TCP/IP	Transmission Control Protocol/Internet Protocol
TVE	total vector error

UDP	User Datagram Protocol (see IETF RFC 768 [B9])
UDP/IP	User Datagram Protocol/Internet Protocol
UTC	Coordinated Universal Time (initials are ordered based on French language)

4. Phasor data concentrator (PDC) functional requirements

4.1 Time alignment of data

4.1.1 General description

This function is used to aggregate time synchronized data with identical time stamps from multiple phasor measurement units (PMUs) or PDCs. This time aligned data may be sent as an output data stream to an external device/application or to a local function/application such as archiving, visualization, monitoring, protection, or control.

4.1.1.1 Wait times

Since data from different PMUs may not arrive at the same time, the function waits for data from all PMUs (and/or PDCs) to arrive before aggregating and transmitting output data. However, to prevent occasional loss of data from a PMU holding up the output indefinitely, this wait time is limited. Data arriving within a specified wait time is included in the output data stream, and data arriving beyond is excluded.

4.1.1.2 Time reference

Some PDCs are designed to make continuous use of a synchronized time signal such as Coordinated Universal Time (UTC). For these PDCs, the time alignment function uses this time to establish an “absolute” wait time. When that synchronization is lost, the PDC continues operation using an internal timer.

Other PDCs are designed to perform time alignment without an absolute time reference. They make use of the time stamps in the data, and/or an internal clock. These PDCs make use of a “relative” wait time.

Relative and absolute wait times are described in 4.1.2.3 and 4.1.2.4.

4.1.1.3 Egress times

For both absolute and relative wait times, if the PDC assembles and sends the output frame as soon as all the data arrive, the data egress will be correspondingly quicker, and will be determined by the last arriving PMU data. This uncertainty of the output timing will not exist if the PDC always waits for the end of the wait time before processing the input data.

There is an additional uncertainty for relative wait time. Variance in incoming communication delays will result in variance in start of the relative wait time and hence in the egress time.

4.1.1.4 Latency

Latency is a critical aspect of some applications for PMU data. PMU measurements not available quickly may be unusable for some such applications. Any function performed in the PDC will add to the latency. Different applications may have different latency and data requirements, creating the need for the function to furnish multiple data streams with independent, settable wait times. This is illustrated in the following three examples:

- a) A protection/remedial action application may require selected signals to be available with a short delay such as a few tens of milliseconds. If all the required signals are not available within this time, the control application may act on as many signals as are available, rather than wait longer and lose the window of opportunity for action.

- b) A visualization application may require only the signals selected for the display, and may be able to wait several seconds before using the data available.
- c) A long-term data archival application may be able to wait until the data is needed, which can be a very long time.

4.1.2 Functional requirements

4.1.2.1 Time alignment

The PDC shall collect PMU data from all its inputs and place data with valid and matching time stamps in a data frame and transmit to the designated destination. The destination can be an output stream or a local function/application. Time stamps that are identical within rounding error are considered matching. Refer to C.2 for more information. Validity of time stamps is defined by the synchrophasor data protocol in use.

Data collected from PMUs during the wait time shall be aggregated and made available to the designated destination either when all expected data frames have been received prior to the wait time, or when the wait time has elapsed.

4.1.2.2 Wait times

Wait time is defined by its start time, and a duration. There are two types of wait times, defined by different start times. The start time is governed either by time relative to the time of arrival of the data or by reference to absolute time, as described in 4.1.2.3 and 4.1.2.4. A PDC shall include time alignment by relative wait time. Absolute wait time is optional. Both require an accurate clock to be available, though the latter requires a UTC synchronized clock. Examples of wait time implementations are shown in [Annex D](#).

4.1.2.3 Relative wait time

Relative wait time shall begin at the arrival time of the first data for each expected time stamp.⁷ When relative wait time is used, the PDC shall wait no longer than the specified duration after the arrival of the first data for the time stamp time before aggregating and transmitting the data. Time alignment with relative wait time shall be used when a clock synchronized to UTC is not available, or not practical.

4.1.2.4 Absolute wait time

Absolute wait time shall begin at each valid time stamp time. This requires that a UTC synchronized clock be available to the time alignment function. When absolute wait time is used, the PDC shall wait no longer than the specified duration after the time stamp time before aggregating and transmitting the data.

4.1.2.5 Switching between absolute and relative wait times

If a PDC using absolute wait time and a synchronized clock loses the synchronized clock, it shall switch to relative wait time after a user-settable duration.

After UTC synchronization has been regained, the PDC shall switch back to absolute wait times without user intervention. There shall be no data loss when either switching occurs.

4.1.2.6 Sort-by-arrival function

The sort-by-arrival function allows inclusion of data in a transmission if its time stamp does not match the time stamp for that transmission. The method uses a time stamp assigned by the PDC locally based on when the data is received. The PDC shall allow users to enable the sort-by-arrival function for each separate output stream. An output stream that uses the sort-by-arrival function shall allow inclusion of valid input data with locally assigned time stamps.

⁷The question of the validity of the timestamp is crucial. Refer to [Annex E](#) for further information.