

Security Guideline for the Electricity Sector: Time Stamping of Operational Data Logs

Preamble:

It is in the public interest for NERC to develop guidelines that are useful for improving the reliability of the bulk power system. Guidelines provide suggested guidance on a particular topic for use by bulk power system entities according to each entity's facts and circumstances and not to provide binding norms, establish mandatory reliability standards, or be used to monitor or enforce compliance.

Purpose:

The purpose of this guideline is to describe minimum recommendations for maintaining accurate time stamp indications for logged events on the bulk power system.

Applicability:

This guideline is focused on all computer or microprocessor-based operational devices used to monitor, control, or analyze the bulk power system where accurate timing has been deemed necessary. These devices include, but are not limited to, Power Plant Automation Systems, Substation Automation Systems, Programmable Logic Controllers (PLC), Intelligent Electronic Devices (IED), sequence of event recorders, digital fault recorders, intelligent protective relay devices, Energy Management Systems (EMS), Supervisory Control and Data Acquisition (SCADA) Systems, Plant Control Systems, routers, firewalls, Intrusion Detection Systems (IDS), remote access systems, physical security access control systems, telephone and voice recording systems, video surveillance systems, and log collection and analysis systems.

This guideline is applicable to anyone who owns, manages, or maintains devices, services and/or systems that support the North American bulk power system.

This guideline does not specify where time stamping recorders or telemetry equipment should be placed within the bulk power system. Rather, this guideline recommends the characteristics of the time stamps that are created by equipment that is selected and installed for other operational requirements.

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This guideline is not, by itself, intended to require equipment upgrades to existing implementations that do not support time stamping of operations. Rather, this guideline is intended to assist in the configuration of time synchronization features on equipment that either already exists or is in the planning stages for upgrades and deployments.

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This guideline describes recommended minimum configurations that should be used unless a specific application requires greater accuracy or resolution. Where more stringent requirements may exist (e.g., in other company specific requirements, regional or NERC requirements such as the PRC-018-1 Disturbance Monitoring Equipment Installation and Data Reporting Standard) they take precedence over the values specified in this guideline. This increased accuracy is beyond the scope of this document.

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Background:

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Proper time synchronization across interdependent power grids is a very important function for many reasons. As demands on the grid change, and the need for sophisticated information infrastructure increases, it will become more important than ever to ensure that events are accurately recorded and time-stamped consistently.

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The distributed nature of the North American power grid makes time synchronization between each interdependent system a challenging task. The most effective means of maintaining consistent time stamping is for each entity to synchronize all equipment with an internal clock to a recognized reference point. The reference point should be a government certified and supplied source. The US Global Positioning System (GPS) service is widely recognized as a good source for time synchronization and is available on the majority of the earth's surface. Other appropriate sources are the WWV and WWVB radio time sources provided by the US National Institute of Standards and Technology (NIST) or the CHU radio time service operated by the National Research Council of Canada.

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The distribution of time synchronization to applicable devices can be achieved in several ways; the most common distribution methods being IRIG-B signaling across coaxial cables and the use of the Network Time Protocol (NTP) over Ethernet networks. Both NTP and SNTP (Simple Network Time Protocol) implement the same network protocols; however, the algorithms implemented for the client and server software are less sophisticated for SNTP. (Refer to the RFC documentation for additional information.)

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The details included in this security guideline can generally be implemented with current technology. A new development, the Precision Timing Protocol (PTP), promises increased timing resolution over Ethernet. However, development is just beginning on the required companion standard that defines application of PTP to electric power, and therefore PTP remains an emerging technology. Numerous manufacturers of networking hardware are now including support for PTP in new devices and software. These considerations should be taken into account when procuring new hardware. Any recommendations that extend beyond current technologies are discussed under the Additional Considerations section of this guideline.

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Effective and accurate event logging is crucial to a reconstructed timeline following a disturbance event. Accurate time receiving devices are inexpensive, easy to configure, and require little

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maintenance. Lack of a coordinated accurate time stamp for recorded events makes any reconstruction of a timeline difficult and time consuming, if not impossible. In addition, the lack of coordinated time stamping of events may cause the recorded event data to be suspect when it is used to reconstruct a timeline of events among systems of different management or administrative domains.

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Of specific interest when collecting, storing and analyzing time stamp information is the concept of telemetry skew. Telemetry skew happens when communication delays or scan rates cause the receipt of information to not occur strictly in “real time”. For example, in a system where the time stamp is not propagated, when a breaker in a substation opens, internal logging functions in the breaker controller or other monitoring equipment in the substation should capture the time associated with the operation. At some point later, perhaps several hundred milliseconds, the RTU may detect the breaker operation, and capture the time. Later, the SCADA central server will poll the RTU, and detect that the status point associated with the breaker has changed, and store an updated point value in the database, optionally with a time stamp. Then, the SCADA alarm subsystem will generate an uncommanded operation alarm, with an alarm time associated, and present it to the SCADA system operator. Even later, the breaker status may be communicated to an ISO or RTO, and upon receipt of the status point, the updated value will be stored, timestamped, and perhaps alarmed at the ISO or RTO.

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Each of these reported times will be different due to scanning rates, communication delays, and system processor loads and message queue lengths. It is conceivable that the total time skew resulting from a telemetry sequence may exceed a minute. Of prime importance to the analysis of an event is the initial time stamp, which should be preserved for later analysis. Other time stamps may be used to determine when the succeeding systems found out that the point value was changed, but they will not be of primary use in developing an accurate electric system sequence of event timeline. Requirements for which events require stored time stamps is beyond the scope of this document.

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Time stamping requirements of critical events have been a responsibility of electric utilities for many years. Initially, these installations were very expensive primarily due to the cost of establishing a timing signal at the site with the required accuracy. Now, with the GPS in place, the cost has been mitigated considerably by deriving actual time (traceable to a government standard) with an accuracy measured in microseconds from GPS signals. Today a utility can install a commercially available GPS time code receiver producing either a modulated IRIG B, IEEE 1588 and/or NTP/SNTP output for approximately \$500 - \$7000 and one day’s labor cost from a reasonably trained person. The IRIG B modulated signal produced by the time code receiver can be distributed to the equipment requiring the time signal by using coaxial cable or fiber optics. Most if not all equipment that would actually time stamp data or events (e.g. protective relays, sequence of events recorders, SCADA Remote Terminal Units, etc.) are equipped to accept the modulated IRIG B signal. Alternately, newer time code receivers producing IRIG B unmodulated signals have become more widely accepted as new products require higher time accuracy. Unmodulated signal accuracy on average can reach the level of 100 nanoseconds while a modulated signal can reach an accuracy of 50-100 microseconds at best. For applications requiring ultimate accuracy, the use of direct coaxial connections and termination at either the source or the load of the line is recommended. While both modulated and unmodulated IRIG B signals can be distributed using coaxial cable, unmodulated signals

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require shorter cable lengths to maintain higher accuracy. NTP/SNTP output is required for all network connected devices such as routers, firewalls, servers, IDS, etc.

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When utilities implement time stamping, they need to consider the capabilities of the time stamping functions and protocols, depending on the application.

Definitions:

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Accuracy: The amount of conformity to which a measured value is to its actual value. Inaccuracy is an indication of the amount of error in a measurement or quantity.

Accurate: Free from error; conforming exactly to a standard.

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ACTS: NIST Automated Computer Time Service: An inexpensive service provided by NIST in Colorado (and Hawaii) for users who need to synchronize computer clocks to the correct time. When a computer connects to ACTS by analog telephone, it receives an ASCII time code. The information in the time code is then used to set the computer's clock.

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Availability: The degree to which a system, subsystem, or component is operable and in a useable state when needed.

CHU: Radio time service run and maintained by the National Research Council of Canada.

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Clock: The internal hardware and software that maintains time in a computer or intelligent microprocessor device.

Coordinated Time Synchronization Service: A hardware component or other device, generally local to control center, plant, or substation, that maintains a traceable, accurate time; and provides a time signal that can be used to synchronize the remaining devices at that location.

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GPS: Global Positioning System: provides a time service in addition to location information operated by the US Government Department of Defense.

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In-service device: A device that: is capable of processing and storing accurate time as specified in this guideline; has had its internal clock automatically or manually set to be within one second of the coordinated time; and, has established a permanent communication link with the coordinated time synchronization service.

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IDS: Intrusion Detection System: a computer device used in both physical and cyber security that detects and reports on unauthorized access attempts to a physical space (physical IDS), or a computer system or network (cyber IDS).

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IRIG: Inter Range Instrumentation Group: A Department of Defense organization which developed a specification for transmission of time synchronization over wide areas.

ISO: Independent System Operator: An organization that coordinates controls and monitors the operation of the bulk power system..

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Leap Second: A second that is added to Coordinated Universal Time (UTC) to make it agree with astronomical time to within 0.9 second. UTC is an atomic time scale, based on the performance of atomic clocks. Astronomical time is based on the rate of rotation of the earth. Since atomic clocks are more stable than the rate at which the earth rotates, leap seconds are occasionally needed to keep the two time scales in agreement.

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NTP: Network Time Protocol: A protocol used to accurately synchronize computer clocks via a network connection. NTPv4 can usually maintain time to within 10 milliseconds (1/100 s) over the public Internet, and can achieve accuracies of 200 microseconds (1/5000 s) or better in local area networks under ideal conditions.

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Precision: The degree of mutual agreement among a series of individual measurements or values; the ability to independently reproduce the same result under the same conditions.

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PTP: Precision Timing Protocol: A protocol designed to increase timing accuracy over traditional Ethernet based protocols. Where it has advantages over traditional protocols there are limitations that prevent it from readily replacing existing installations. This is now superseded by IEEE 1588.

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Resolution: The smallest increment of time to which the measurement can be distinguished.

RTO: Regional Transmission Organization: a regional organization that is established to control and manage the transportation (at high voltage) and flows of electricity on the bulk power system over an area that is generally larger than the footprint typical power company's transmission system.

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SNTP: Simple Network Time Protocol: A protocol used to accurately synchronize computer clocks via a network connection. SNTP can be used when the ultimate performance of the full NTP implementation is not needed or justified. SNTP is a simpler protocol than NTP that does not require storing information about previous communications. It is used in some embedded devices and in applications where high accuracy timing is not required.

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SCADA: Supervisory Control and Data Acquisition: A computer control system or systems used for gathering, and displaying real-time data related to electric systems, power plants, etc and performing control at the supervisory level. Generally these systems span large areas.

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Time Client: A computer-based end-device which depends on a time server to provide a source for time. Time clients are generally application devices requiring accurate time for their application, but rely on a Time Server to provide that accurate time. Example time clients include: EMS / SCADA systems, IEDs, synchrophasors, Intrusion Detection Systems, firewalls, authentication servers, routers, and video recording systems.

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Time Server: A computer-based source of accurate time. Time Servers will typically access GPS, WWV, WWVB, or CHU time signals, and produce a locally distributable time signal (such as IRIG-B, NTP, SNTP, or PTP) for use by the local Time Clients.

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UTC: Coordinated Universal Time: Sometimes called Greenwich Mean Time, UTC nominally reflects the mean solar time along the Earth's prime meridian.

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WWV: Radio time service run and maintained by the US National Institute of Standards and Technology (NIST) at Ft. Collins (US) Radio 2.5, 5, 10, 15, 20 MHz.

WWVB: Radio time service run and maintained by the US National Institute of Standards and Technology (NIST) at Boulder (US) Radio 60 kHz.

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Guideline Statement:

Internal clocks on all affected devices at all affected functional organizations should maintain an accurate coordinated time, and that time should be similarly coordinated with accepted government time sources.

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Guideline Detail:

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1.1. All specific geographic sites containing applicable devices (e.g., control center, power plant, substation) should include a coordinated time synchronization service. This coordinated service should have a demonstrated availability appropriate to the application. For example, an availability of 99.9% is achievable using commercially available equipment and services.

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1.2. The coordinated time synchronization service should be directly traceable to the international time standard maintained in the United States by the US Naval Observatory on behalf of the US Government, or the equivalent Canadian or Mexican government entity, and should have an accuracy of 1 ms. Common services providing such a time signal include GPS, WWV, WWVB, and CHU.

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1.2.1. Applications such as the logging of human actions which require time stamping only accurate to approximately 10 ms may use the NIST Automated Computer Time Service (ACTS).

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1.3. All applicable in-service devices co-located at a specific geographic site should maintain constant communication to either a local coordinated time synchronization service, or a remote coordinated time synchronization service as defined in guideline detail 1.2.

1.4. Time Zones

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1.4.1. All applicable in-service devices should internally store time using the UTC time zone.

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1.4.2. Operational events that are logged to hard copy or screens, or events that are presented to operators may be displayed using the local time zone, and may be represented to any resolution needed to properly operate the system, so long as

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the internal time stamps are maintained with the specified time zone and resolution as defined in preceding guideline details

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1.4.3. All operational events should be communicated and stored with time stamps. The time stamps should use the UTC time zone. In the event use of UTC is impractical, the time zone employed should be clearly stated. If multiple time stamps are available for a given event, other standards or guidelines should determine which time stamp (or time stamps) should be stored for the event.

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1.5. Utilities should use the most accurate protocols to implement time stamping capabilities suitable for the application. Specific standards exist for different classes of application and should be referenced. Some examples include PRC-018-1 or IEEE C37.118

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1.6. The objective is for all applicable devices in an Interconnection to have an internal time that does not deviate from any other applicable device within the same Interconnection by more than 128 ms. Accordingly, since 2 individual devices may each be up to 128 ms different then 2 time 'clients' may differ from one another by no more than 256 ms. The rationale for this is to keep the maximum deviation between an in-specification slow clock and an in-specification fast clock to less than approximately one quarter second.

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1.6.1. In situations where the end time 'clients' are unable to contact a time source, an accuracy within 256 ms should be maintained for up to 4 hours or until contact with the time source is restored.

1.6.2. Testing should be performed to ensure that these recommendations are met.

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1.7. Timestamp resolution should be appropriate for the application. Some applications may need to support a resolution of better than 0.1 ms. Sources of time uncertainty should be known and recorded.

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1.7.1. Accuracy of clocks in devices generating time stamps should be known and recorded. Some applications may require greater accuracy.

1.7.2. When replaced, clock accuracy should be analyzed to ensure that the accuracy required by the application is achieved. It may be necessary for replacement devices to have a accuracy of better than 1 ms.

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Additional Considerations:

Time Stamping Functionality – Standard Protocols & Formats

10 Some time stamping formats have been standardized, and others are in the process of
development and standardization. Relevant formats are included in standards such as the IEEE
Synchrophasor standard (C37.118) and the IEC-61850 Utility Automation standard, and in
reports such as the IEEE Power System Relaying Committee (PSRC) Working Group's report on
a Common Format for IED Event Data. Also referenced are IEC-60870 and DNP3 used for
15 SCADA telemetry, and ISO-8601 for the presentation of timestamps.

20 Within IEC-61850, the time stamp formats are defined in IEC-61850-7-2, clause 5.5.3.7, and in
IEC-61850-8-1, clause 8.1.3.6. Note that IEC-61850 defines both a time stamp format (for data
objects) and a separate entry time format (for event log entries and similar purposes). The
Specific Communications Service Mapping in IEC-61850-8-1 defines different formats for time
stamp and entry time. The Specific Communications Service Mapping in IEC-61850-9-2
references the timestamp and entry time definitions in IEC-61850-8-1. IEC-61850 time
referenced to UTC based on seconds and fractions of seconds since 01/01/1970 (similar to
DNP3). The resolution of IEC-61850 timestamps is to 1 part in 2^{24} of a second (binary fraction
of a second) or about 60 ns. The IEC-61850 timestamps also indicate if they include leap seconds
25 or not.

30 Within IEC-60870, time is defined in clause 6.8 of IEC-60870-5-4 and is used in IEC-60870-5-
101, IEC-60870-5-102, IEC-60870-5-103 and IEC-60870-5-104. There are two absolute time
formats, one of which is legacy and now rarely used, and a relative time format used for defining
intervals. The IEC 60870 time stamps are "recommended" to be UTC time, but they also allow
for the use of local time and the representation of "summer time" (i.e., Daylight Savings Time)
with a flag that indicates the time reported is "summer time". The resolution of IEC-60870 for
both clocks and time tags is one millisecond.

35 DNP3 specifies time in "DNP3 Specification Volume 6: DNP3 Data Object Library." There are
two DNP time formats, one absolute and one expressed as relative to an absolute time. The
DNP3 time is defined as clock-face time in UTC, represented as a count of milliseconds since
00:00:00.000 01-Jan-1970, using the assumption of every second having 1000 milliseconds,
every minute 60 seconds, every hour 60 minutes and every day 24 hours. This specifically means
that it does not allow time stamping WITHIN the occasional leap second that is "added in" to
keep the clock face and solar system in step: When that happens the minute has 61 seconds, but
40 DNP3 calculates times as 60 seconds per minute every time. The resolution DNP3 for both
clocks and time tags is one millisecond.

The PSRC WG report uses the Synchrophasor format for its time stamp.

45 ISO Standard 8601 defines the international standard for the presentation of time. It describes
how time is to be presented to a human, and includes provision for sub-second decimal
presentation (e.g., to a tenth, hundredth, thousandth of a second).

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Leap Seconds

With the advent of highly accurate atomic clocks it was noticed that the atomic clocks did not exactly correlate with the observed time based on the position of the Earth relative to the Sun.

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To make adjustments in the clock, a particular minute would contain either 61 or 59 seconds instead of the conventional 60 seconds. The particular minute, therefore, either have a positive or a negative leap second. It was expected and proved true that this would normally occur once a year.

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The first leap second was added on June 30, 1972. Since then, they have occurred at an average rate of less than one per year. Although it is possible to have a negative leap second (a second removed from UTC), so far, all leap seconds have been positive (an extra second has been added to UTC). Based on what we know about the earth's rotation, it seems unlikely that we will ever have a negative leap second.

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By international agreement, UTC is maintained within 9/10 of a second of "solar" time. Thus, the introduction of leap seconds will permit a good clock to keep approximate step with Earth's rotation relative to the sun. Since the rotation of the earth is not uniform we cannot exactly predict when leap seconds will be added or deleted. When a leap second is necessary, an announcement is made at least several months in advance, and all leap seconds so far have been implemented on either June 30th or December 31st.

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For example, a leap second was added on July 1, 1997. Coordinated Universal Time (UTC) was retarded by 1.0s so that the sequence of dates of the UTC markers was:

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1997 June 30 23h 59m 59s
1997 June 30 23h 59m 60s
1997 July 01 0h 0m 0s

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We should keep in mind that the advantage we gain by using the UTC system prevents us from simply subtracting the dates of two events to get the time difference between them. We must in fact, take into account any leap seconds that were added or deleted.

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Global Positioning System (GPS) time, is the atomic time scale implemented by the atomic clocks in the GPS ground control stations and the GPS satellites themselves. GPS time was set to zero at 0h 6-Jan-1980 and does not include leap seconds. The GPS protocol includes a correction which can be applied to the GPS time to produce UTC time. This correction is automatically transmitted by the GPS satellites once every 12 ½ minutes. Most GPS Time Servers apply this correction factor and provide a source of UTC time to their time clients.

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Leap seconds can be problematic for the electric industry disturbance event correlation and sequence of events processing since, in theory, the leap second could be either negative or positive, causing the timestamp of two events not correctly indicate the order of the events, or the time difference between two events to be incorrect.

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NIST ACTS

The ACTS dial-up time service provided by NIST only works with analog modems that use ordinary telephone lines. Digital modems, such as Digital Subscriber Line (DSL), cable and wireless modems cannot synchronize using ACTS. When a client computer connects to ACTS by analog telephone, it receives an ASCII time code. The information in the time code is then used to set the computer's clock. The ASCII time code contains an on-time marker (OTM) code. Since the OTM is delayed as it travels from NIST to the client computer, ACTS sends it out 45 milliseconds early. This always removes some of the delay. Better results are possible if the user's software returns the OTM to ACTS after it is received. Each time the OTM is returned, ACTS measures the amount of time it took for the OTM to go from ACTS to the user and back to ACTS. This quantity (the round-trip path delay) is divided by 2 to get the one-way path delay. ACTS then advances the OTM by the one-way path delay and the OTM changes from an asterisk to a pound sign (#). When the # sign appears, the time code is synchronized within a few milliseconds of UTC at NIST.

Reporting of Time Quality and Time Error

Within time stamp formats there are issues of how to report time quality. Factors include whether the clock itself is working, whether the device is synchronized to the clock, an indication of the time accuracy, and treatment of leap seconds. Examples of time accuracy reporting include providing an estimate of the error and providing an estimate of the time at which the device was last synchronized to the clock. For example, in the IEEE Synchrophasor standard, the time of last synchronization is used, with a range of up to about 10 seconds.

PTP – IEEE 1588

Precision Time Protocol is a time-transfer protocol defined in the IEEE 1588 standard. It has been developed to improve precision over current Ethernet protocols. Where the pervasive NTP can synchronize to within tens of milliseconds PTP has the ability to synchronize within tens of microseconds offering a significant increase in precision. The protocol functions autonomously discovering other PTP devices automatically thus maintaining synchronization even in a dynamic environment.

Although the protocol adds significant advantages, there are several factors that prevent wide adoption of PTP over NTP in Ethernet networks. The Precision Timing protocol also has limitations over Wide Area Networks (WAN's) and does not currently support encapsulation or authentication as is available with the Network Time Protocol. It is important to note that future versions of NTP could theoretically use the same hardware stamping techniques utilized in PTP to increase timing resolution but would have the same requirement for supporting hardware.

PTP is designed for *precision*, not necessarily *accuracy* (refer to the Wikipedia article included in the Related Documents and Links section). This distinction is one of the factors referenced above for adoption of PTP over wide-area links. A highly deterministic link may provide for precision, but not for accuracy; a non-deterministic link doesn't provide for either precision or accuracy.

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The structure of PTP requires that for its use in any specific application, such as electric power, a companion standard called a "profile" must be developed. Work on such a "profile" (or companion standard) for application of PTP to electric power is just starting within IEEE. Benefits and limitations of PTP for use in substations will depend on the issues identified and addressed in developing that standard. In addition, it is clear that new hardware would be required for supporting PTP, because most existing hardware does not contain that capability.

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Possible Issues for GPS Based Time Reference Sources

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It should be noted that almost all GPS based time reference sources operate on the Standard Positioning Service encoded signal that is available to the general public. There are two known issues:

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- a) A possibility exists that this signal may become purposely disabled under certain circumstances (see document reference "White House wants plans for GPS shutdown").
- b) A possibility exists that this signal may be maliciously "spoofed"

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Certain GPS time reference sources are able to receive the Precise Positioning Service encoded signal (see document reference "USNO NAVSTAR Global Positioning System") with a Selective Availability/Anti-Spoofing Module (SAASM). The SAASM ensures that received GPS signal is genuine. This service is only available to select users.

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While there is a possibility that a GPS satellite signal may be maliciously "spoofed", some GPS based time reference receivers will perform "sanity" checking and will reject a signal that falls outside certain parameters.

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GPS users are advised to discuss the available options with their equipment manufacturer should operation under the above conditions be desired. GPS users are also advised to have a suitable procedure available to manually override the time being produced as required. In the event that the GPS signal is lost or if the time reference is manually overridden, the accuracy of the time reference should remain as specified in Section 1.6.

Related Documents and Links:

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Note: Documents listed herein with hypertext links are publically available at the time of publication by following the indicated links. All other documents are available by requesting them from the respective organizations.

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- ✓ RFC1305 and RFC4330 Network Time Protocol (NTP) and Simple Network Time Protocol (SNTP) <http://www.ietf.org>
- ✓ August 14, 2003 Blackout: NERC Actions to Prevent and Mitigate the Impacts of Future Cascading Blackouts, February 10, 2004 at http://www.nerc.com/docs/docs/blackout/BOARD_APPROVED_BLACKOUT_RECOMMENDATIONS_021004.pdf

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- ✓ "Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations," U.S.-Canada Power System Outage Task Force, April 5, 2004 at <http://www.nerc.com/filez/blackout.html>

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- ✓ IRIG standards are issued by the Inter Range Instrumentation Group of the Range Commanders Council under the authority of the US Department of Defense at <https://wsmrc2vger.wsmr.army.mil/rcc/manuals/200-04/TT-45.pdf>

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- ✓ IEEE 1588TM-2002 Standard for A Precision Clock Synchronization Protocol for Networked Measurement and Control Systems at <http://iee1588.nist.gov/>

- ✓ "What time is it? The importance of time in networks" Cisco, October 2007 at http://www.cisco.com/en/US/prod/collateral/iosswrel/ps6537/ps6555/ps6602/prod_white_paper0900aecd806dab49.pdf

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- ✓ Internet Engineering Task Force NTP Working Group (NTPWG) Archives at <https://lists.ntp.org/pipermail/ntpwg/>

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- ✓ NERC Reliability Standard PRC-018-1 Disturbance Monitoring Equipment Standard Installation and Data Reporting Standard: at <http://www.nerc.com/files/PRC-018-1.pdf>

- ✓ NERC CIP Reliability Standards: <http://www.nerc.com/page.php?cid=2|20>. Refer to "Critical infrastructure Protection (CIP) " selection on page

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- ✓ IEC-61850 time synch format:

- IEC-61850-7-2:2003, Communication networks and systems in substations – Part 7-2: Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)

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- IEC-61850-8-1:2004, Communication networks and systems in substations – Part 8-1: Specific communication service mapping (SCSM) – Mappings to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2) and to ISO/IEC 8802-3

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- IEC-61850-9-2:2004, Communication networks and systems in substations – Part 9-2: Specific communication service mapping (SCSM) – Sampled values over ISO/IEC 8802-3

- ✓ IEC-60870:

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- IEC 60870-5-4:1993, Telecontrol equipment and systems – Part 5: Transmission protocols – Section 4: Definition and coding of application information elements

- IEC-60870-5-101:2003, Telecontrol equipment and systems – Part 5-101: Transmission protocols – Companion standard for basic telecontrol tasks

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- IEC-60870-5-102:1996, Telecontrol equipment and systems – Part 5: Transmission protocols – Section 102: Companion standard for the transmission of integrated totals in electric power systems

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- IEC-60870-5-103:1997, Telecontrol equipment and systems – Part 5-103: Transmission protocols – Companion standard for the informative interface of protection equipment

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- IEC-60870-5-104:2006, Telecontrol equipment and systems – Part 5-104: Transmission protocols – Network access for IEC 60870-5-101 using standard transport profiles

✓ DNP3 Technical Specification, Volume 6: DNP3 Data Object Library

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✓ IEEE Std C37.118-2005, IEEE Standard for Synchrophasors for Power Systems

✓ IEEE PSRC Working Group report to the Relay Communications Subcommittee, Report on a Common Data Format For IED Event Data at http://www.pes-psrc.org/h/H5-b_Report_IED_Sampled_Data_Draft4_1.pdf

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✓ Standard ISO8601:2004 Data elements and interchange formats – Information interchange – Representation of dates and times

✓ White House wants plans for GPS shutdown at <http://www.msnbc.msn.com/id/6720387/>

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✓ USNO NAVSTAR Global Positioning System at <http://tycho.usno.navy.mil/gpsinfo.html>

✓ Accuracy and Precision at http://en.wikipedia.org/wiki/Accuracy_and_precision

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Revision History:

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Date	Version Number	Reason/Comments
Sept 2003	Version – 0.0.1	Initial draft.
	Version – 0.0.2	Updates.
	Version – 0.0.3	Added Telemetry skew comments
	Version – 0.0.4	Added non-proscriptive comments
Oct 2003	Version – 0.0.5	Shall to should; explain 150ms vs. 250ms time; add definition for forensic
45 Nov 2003	Version – 0.0.6	Added more non-proscriptive clarifying language
	Version – 0.0.7	PCSS TF Review
	Version – 0.0.8	Additional Review by PCSS TF
	Version – 0.9	Additional Review by PCSS TF, addition of IRIG
50 April, 2004	Version 1.0	Comments from CIPC, WECC, and DEWG

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March, 2008	Version 1.01	Document Updated
June 1, 2008	Version 1.02	Document updated
July 8, 2008	Version 1.03	Additional Information added
July 28, 2008	Version 1.04	Additional information and clarification added
July 29, 2008	Version 1.05	Edits from Conference Call
August 4, 2008	Version 1.0.6	Post call edits – CSSWG Ballot version
August 13, 2008	Version 0.9	Final CSSWG Approved – sent to SGWG
November 7, 2008	Version 0.91	Updates based on CIP Review process

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