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

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Agenda

1. Precise time in Power Systems
2. Introduction the Precision Time Protocol
3. Profile for PTP in Power Systems
4. Summary
Why are Synchrophasors Needed?

High-speed precision measurements provide information that SCADA data cannot provide.

SCADA → Synchrophasor
= X-Ray → MRI

SCADA - Supervisory Control and Data Acquisition
Why are Synchrophasors Needed?

If the data can be transformed into information that enables operators to make faster more accurate decisions, the benefits to reliability are tremendous.

Precise time synchronized measurements are essential to transforming the data into information.
IEC 61850 Smart Substation: Industrial Ethernet Infrastructure With PTP

- Control Center
- HMI Station Controller
- Substation Clocks
- Communication Bus
- Bay Controller
- Intelligent Switchgear
- Next Generation CT/PT (VT)
- Merging Unit
- Process Bus
- Station Bus
- Gateway
- NO INDEPENDENT TIMING DISTRIBUTION

IEEE C37.238-2011 Timing (PTP Power Profile)

- Communication Bus
- Switchgear
- CT/PT (VT)

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Synchrophaser Timing Requirements


A phase error of 0.57 degrees (0.01 radian) will by itself cause 1% Total Vector Error (TVE) ... This corresponds to a time error of ±26 μs for a 60 Hz system and ±31 μs for a 50 Hz system.

A time source that reliably provides time, frequency, and frequency stability at least 10 times better than these values corresponding to 1% TVE is highly recommended.

Bottom line: ±2.6 μs for 60 Hz and ±3.1 μs for 50 Hz
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# Time Transfer Technologies

<table>
<thead>
<tr>
<th></th>
<th>IRIG-B</th>
<th>(S)NTP</th>
<th>PTP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy (typical)</strong></td>
<td>1-10µs</td>
<td>1ms – 10 ms</td>
<td>100ns-1µs</td>
</tr>
<tr>
<td><strong>Transport media</strong></td>
<td>Dedicated cables</td>
<td>Ethernet cables</td>
<td>Ethernet cables</td>
</tr>
<tr>
<td><strong>Protocol style</strong></td>
<td>Master-slave</td>
<td>Client-server</td>
<td>Master-slave</td>
</tr>
<tr>
<td><strong>Built in latency correction</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Set-up</strong></td>
<td>Configured</td>
<td>Configured</td>
<td>Self-organizing, or configured</td>
</tr>
<tr>
<td><strong>Update intervals</strong></td>
<td>1 second</td>
<td>Minutes</td>
<td>1 second</td>
</tr>
<tr>
<td><strong>Specialized hardware</strong></td>
<td>Required</td>
<td>No</td>
<td>Required</td>
</tr>
<tr>
<td><strong>Redundant masters for N-1 contingency</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
What a network looks like to PTP
An Ordinary Clock Wakes Up

Initialize

Listening

Announce Message from better master

Master

Slave

Announce Message from better master

No better Master before time out

Master disappears and no better master before time out

No better Master before time out

Announce Message from better master
National Football League Division Champion Tie Breakers

1. Head-to-head (best won-lost-tied percentage in games between the clubs).
2. Best won-lost-tied percentage in games played within the division.
3. Best won-lost-tied percentage in common games.

... 

10. Best net points in all games.
11. Best net touchdowns in all games.
12. Coin toss

Best Master Clock in PTP

1. Priority 1 Field
   • User configurable
2. Clock Class
   • Got GPS?
3. Clock Accuracy
   • E.g. 100 ns
4. Clock Variance
   • Frequency Stability
5. Priority 2 Field
   • User Configurable
6. Clock ID
   • Must be unique
   • Often MAC address
Total delay = cable delays + switch residence time
PTP Profiles

• PTP options
  – Many optional features
  – Works over many network types
  – Used in several different industries
  – Interoperability between PTP enabled devices is not guaranteed!

• Profiles
  – More restrictive set of rules for specific application
  – Specifies:
    • Required options
    • Allowed options
    • Forbidden options
    • Network topology limitations
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IEEE 1588 Power Profile Standard 2011

• IEEE C37.238-2011 Standard
  - Profile for IEEE 1588 Precision Time Protocol in power system applications

• Profile Characteristics:
  - LAN (Layer 2 Ethernet Mapping)
  - Multicast addressing only
  - Peer-to-peer delay measurement
  - Switches are Transparent Clocks
  - Time transfer accuracy and holdover time defined

• IEC 61850 will add C37.238-2011 as a requirement in the future.

PTP Power Profile delivers microsecond timing in the Smart Substation
The Rules

• Required:
  – Ethernet Layer 2
    • HSR, PRP allowed
  – All switches support peer to peer timing mechanism
    • Usually transparent clocks
  – Priority fields set to 128 for GM capable devices
  – Power Profile TLV
  – SNMP MIB for GM capable devices
  – 802.1Q VLAN tags

• Allowed:
  – Clock types
    • Preferred Master clocks
    • Ordinary clocks
    • Slave only clocks
    • Transparent clocks
    • Boundary clocks
  – One step and two step clocks

• Forbidden:
  – Internet Protocol (Layer 3)
  – End to end delay measurement
  – Alternative time scales
### Message Rates

<table>
<thead>
<tr>
<th>Message</th>
<th>Interval or trigger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Announce</td>
<td>1 second</td>
</tr>
<tr>
<td>Sync</td>
<td>1 second</td>
</tr>
<tr>
<td>Follow-up (2-step clocks only)</td>
<td>Triggered by Sync Message</td>
</tr>
<tr>
<td>Peer Delay Request</td>
<td>1 second</td>
</tr>
<tr>
<td>Peer Delay Response</td>
<td>Triggered by Peer Delay Request</td>
</tr>
<tr>
<td>Peer Delay Response Follow-up</td>
<td>Triggered by Peer Delay Response Follow-up</td>
</tr>
</tbody>
</table>

(2-step clocks only)
Inaccuracy
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Future of Power Profile

• IEEE 1588
  – Study Group formed to craft requirements for revision
  – New optional features
  – New network mappings
    • Explicit support for HSR and PRP?

• C37.238 Addendum
  – Clean up minor errors
  – SNMP MIB and VLAN tags optional?

• Significant investment by equipment manufacturers and silicon vendors means that maintaining backwards compatibility will be top priority
Take Aways

• PTP Power profile designed to meet the time synchronization needs of PMUs and other IEDs
  – 1 us over 16 switches.
• Key benefits of PTP (IEEE 1588)
  – Time over the data network
  – Cable delays automatically calibrated
  – Self-organizing
  – Fault tolerant
• Power Profile
  – Switches are Transparent clocks
    • Using peer to peer delay measurements
  – Message rates of once per second
  – Message carry 802.1Q Ethernet tags
  – Announce message carries maximum inaccuracy information
SGC-1500 Smart Grid Clock

- Multiple GigE ports
- GPS timing receiver
- PTP Power Profile GM
- PTP Telecom Profile slave*
- Secure management
- NERC CIP compliance

- IRIG-B, DCF-77, pulse rates, 10MPPS output timing ports
- T1/E1, Fiber optic, Open collector outputs
- Rubidium oscillator option
- IEC 61850-3, IEEE 1613 hardened

*Additional information on the PTP Telecom Profile is available on the Symmetricom website (recorded webinar and white paper.)
Thank you.

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