Synchrophasor technology, power systems and timing
-- NASPI Time Sync Task Force

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NASPI Time Sync Task Force

• Goals
  – Explain how power systems (not just synchrophasor technology) use precise timing
  – Figure out & explain what happens if we lose accurate timing
  – Review remedies and options to improve delivery, resilience and use of accurate timing
  – Deliver work products that educate and help electric industry colleagues and others help us meet our timing needs

• TSTF members
  – TOs – Dominion Virginia Power, BPA,
  – Researchers & national labs – EPRI, NIST, PNNL, ORNL
  – Agencies – DHS & DOE
  – Vendors and consultants – MITRE, SWRI, National Instruments, Schweitzer
NASPI TSTF scope

• How the power system uses precise timing
• Document problems of current Positioning, Navigation & Timing (PNT) solutions
• Identify specific, near-term solutions and mitigations that can address multiple failure causes (redundant timing sources, better installation and maintenance, detection of bad or anomalous time signals, specs for good-quality equipment, etc.)
• Develop and share how-to information for these solutions
• Recommendations for longer-term research needs (timing problem detection, equipment interoperability, standards updates, etc.) within grid sector and beyond
Key grid timing use technologies

Most grid time-using devices use GPS antennas as the timing source, and distribute time within the substation primarily using copper cabling (IRIG-B), with growing use of Ethernet (IEC 1588).

• Relays – system protection workhorse. Monitors local grid conditions down to the microsecond, and actuates control operations (including breaker operation) for line trips and other system protection measures. Time-synchronized with GPS (mostly) or SONET over fiber.

• Synchrophasor technology – Phasor Measurement Units (PMUs) do high-speed grid monitoring, time-synchronized to UTC with microsecond accuracy. Used mostly at transmission level. Now sampling at 30 to 120 samples/sec; timing must be accurate within 1 μs. When timing delivery mechanisms become more reliable, synchrophasor technology can become a mission-critical tool.

• Micro-PMUs being developed for distribution system monitoring, analysis & control.

• PS – telecom and it rely on accurate timing
Power system uses of time-dependent data

On-line, real-time uses
(current and emerging uses)

Relative time (to event = time 0)
- Fault detection & location (100 ns)*
- Fault clearing
- Lightning correlation (1 ms)

Synchronized time
- Frequency management
- Voltage management*
- Wide-area situational awareness
- Automatic event detection & notification*
- Oscillation detection
- Islanding control
- Synchronize generator to grid
- Black-start system restoration
- Integrate distributed resources, including rooftop PV and EVs*
- Dynamic line management*
- Remedial action schemes (<50 ms)*

Off-line uses

- Power system modeling
  - Generators
  - Loads
  - System model
- Event reconstruction and analysis (1 ms)
- Equipment mis-operations identification and diagnosis
- Baselining (statistical event characterization) to develop operator decision support tools*
- Disaggregate distributed generation from loads behind the meter*

* = emerging uses
Some of the ways timing goes bad from the grid user’s perspective

- From space
  - Ionospheric problems – sunspots, geomagnetic disturbances
  - Events – leap seconds, satellite constellation changes
- On-site
  - GPS receiver – poor quality, software bugs, no firmware updates, bad location, local jamming or spoofing or other radio interference, lost wire to the PMU, no correction for PNT broadcast problems
  - PMU – poor interoperability with GPS receiver, slow firmware patches, lost wire to GPS receiver, sloppy program for time-handling, no detection of timing problems, no back-up time source
  - In substation timing delivery (rare) – problems with cabling or Ethernet distribution of time signal to slave clocks
- Phasor Data Concentrator and applications – inadequate detection of timing anomalies or gaps and computational errors resulting from those problems. Also sometimes inadequate timing standards and protocols...
What happens to synchrophasor measurements if GPS goes bad?

• If there is an error or spoof of the time signal to a phasor measurement unit (PMU), that error will cause false calculations of phase angle and mis-alignment of measured grid conditions relative to other PMUs.

• In the case of the leap second:
  – Where the GPS clocks skipped the second or were early/late, PMU measurements were too early or too late, causing PDCs to ignore the PMU measurements.
  – Where there were duplicate time stamps, there were “duplicate” PMU measurements.
  – Phase angle error depends on accurate time information; bad time stamps mean erroneous phase angle calculation.

*** These are all PMU or clock problems, not GPS problems – but the user doesn’t recognize that...
Calculating phase angle with a time error

PMU performance during the June 2016 leap second

Above -- for 17 seconds, it appears that the phase has a 36 degree error (at 59.9Hz)

Note that there are no reports for the second immediately following the leap second, and there are two sets of reports for the second between 17 and 18 seconds after.

And different PMU models handled the leap second differently.

Due to inconsistent time-determination methods (below), some PMUs in India reported wildly fluctuating phase angles.


Leap second alert!

• Next leap second will be at midnight on 12/31/16
• We’ve seen many different ways that numerous synchrophasor systems failed or mis-performed on the last leap second (6/26/15)
  – Poor time-stamping of grid measurements
  – Duplicative &/or missing grid measurements
  – Erroneous interpretation of PMU data
  – PMU or clock failures from seconds to hours long
  – Dropped PMU measurements at the PDC
  – Mis-match between PMU and PDC times
• Consequences of these failures varied by utility
• Some problems caused by individual components (PMUs or clocks or PDCs) and some due to poor interoperability across the components
TSTF leap second paper

• New NASPI TSTF paper points out recent synchrophasor leap second handling problems and offers recommendations for user and vendor action and longer-term action.
• Leap second handling problems are not GPS’ fault – it’s users’ and vendors’ responsibility to manage the event correctly
• Some recommendations
  – Anticipate the problem and know what systems might be affected by the leap second (synchrophasors, relays, IT (anything running Windows!), other?)
  – Update all firmware (PMUs, clocks, receivers, PDCs)
  – Tell your vendors how you expect their equipment to perform
  – Know what to look for and monitor your timing uses before (up to a week before!), during and after the leap second event
  – Have a plan for what to do if you spot a leap second glitch
  – Longer-term opportunities in standards modification, device certification, and more
• Leap second paper will be posted on www.naspi.org and distributed by NASPI, NERC SMS, WECC JSIS, and EPRI
Power system punchlines

• Timing errors from the time source can cause incorrect synchrophasor data
  – Such errors can create false analytical conclusions and in the future could drive undesirable and possibly dangerous automated grid operations with synchrophasor-based controls

• The power sector needs to protect future grid operations with better timing tools and practices to improve robustness and resilience
  – We need to assume that PNT could be unreliable at both source and receiving points
  – We need to start implementing measures to assure accurate, reliable time stamps against multiple failure modes
Some timing remedies and options

At the PNT level:
• Improved signal robustness checks
• Multi-frequency – L1 C/A, L2C, L5 (but multi-frequency receivers are expensive)
• Multi-system receivers – GPS, GLONASS, GALILEO, eLoran, good internal oscillators
• Multiple receivers
• Jamming, spoofing and interference detection and/or prevention

GPS-independent networks:
• Telecom network is capable of time transfer -- avoids dependence on satellites and transmitter sites and requirement for large receiver network installation and maintenance
• Network-distributed time can receive accurate time from multiple sources (GPS, NTP, CDMA, PTP), some IRIG-B
• Distributed clock networks, some IEEE 1588
• Hold-over clocks in key devices for short-term back-up
TSTF work products and timing

- Leap second paper (10/16)
- Minimum GPS receiver & clock specs (3/17)
- TSTF definitions, details & guidance paper (3/17)
- Recommendations for future work (including spoofing and jamming)
- TSTF focus session in March 2017 NASPI WG meeting
- Other technical guidance as appropriate
- Outreach to timing organizations and stakeholders
  - Federal PNT Advisory Board (4/16)
  - Civil GPS Service Interface Committee (9/16)
  - IEEE/NIST Timing Challenges in the Smart Grid technical workshop (10/16)
  - Precise Time & Time Interval International Technical Meeting (1/17)
  - NIST timing workshops (3/17)
Questions?

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