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

Alison Silverstein,
NASPI Project Manager
alisonsilverstein@mac.com

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NASPI North American SynchroPhasor Initiative

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**

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Some of the ways timing goes bad from the grid user's perspective

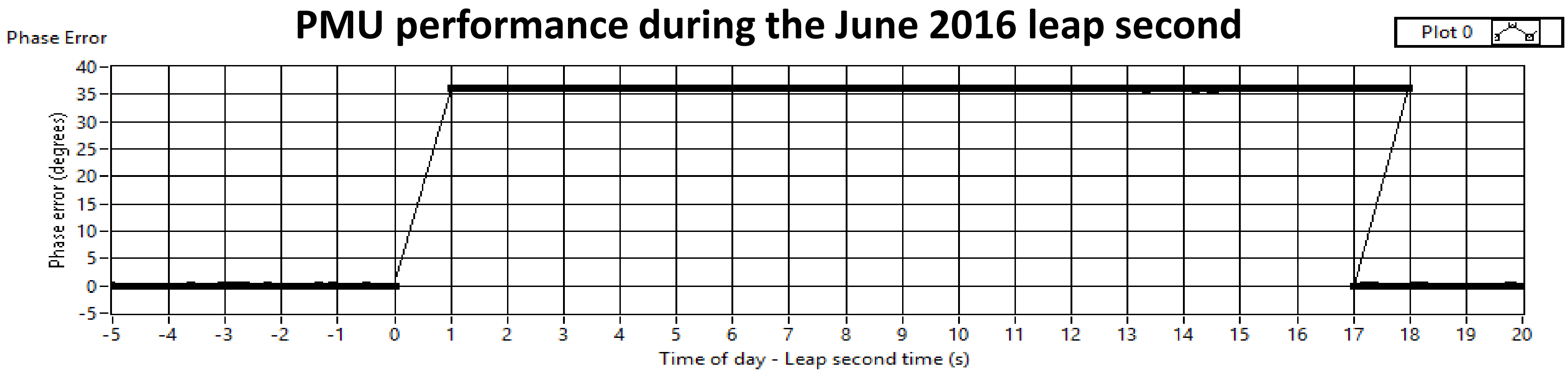
- From space
  - Ionospheric problems – sunspots, geomagnetic disturbances
  - Events – leap seconds, satellite constellation changes
- On-site
  - GPS receiver – poor quality, software bugs, no firmware updates, bad location, local jamming or spoofing or other radio interference, lost wire to the PMU, 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

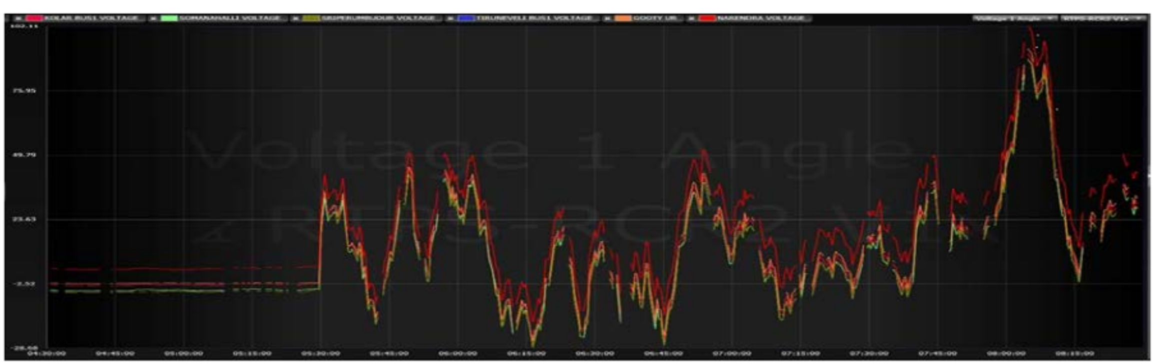
*** These are all PMU or clock problems, not GPS problems – but the user doesn’t recognize that…

Calculating phase angle with a time error



- 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.

Source: "2015 NIST Investigation of PMU Response to Leap Second", Allen Goldstein, DJ Anand & Ya-Shian Li-Baboud, NIST, March 2016



Source: POSOCO, P.K. Agarwal, "Encounter with the Leap Second," NASPI Work Group, March 23, 2016

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 <u>all</u> 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:

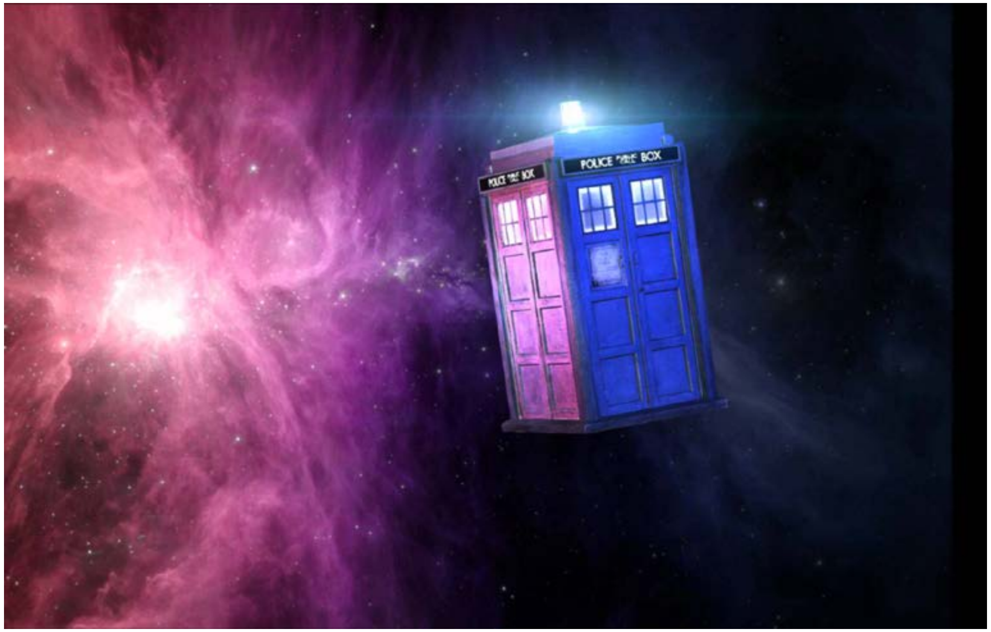
- Telecom network is capable of time transfer -- avoids dependence on satellites and transmitter sites and requirement for large receiver network installation and maintenance
- Network-distributed time can receive accurate time from multiple sources (GPS, NTP, CDMA, PTP), some IRIG-B
- Distributed clock 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?

Alison Silverstein
NASPI Project Manager
alisonsilverstein@mac.com
www.naspi.org



Source: BBC