# GPS Timing Challenges and Robustness Needs for Critical Infrastructures: *Examples from Telecom, Broadcast and Power Delivery Industries*

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# Overview

- Who we are
- What is our PNT problem?
- Potential remedies
- What we’re doing about it

# We represent your PNT customers

- Net Insight provides time transfer solutions as part of network services to the telecom and broadcast industries.
- NASPI is working to advance the use of synchrophasor (time-synched) technology to improve power system reliability and economics.
  - Many North American power sector participants
  - International membership
  - Partnerships with federal agencies, national labs, research organizations

# Here’s what we know about PNT:

- There are many ways for existing PNT systems to fail, whether from error, accident, or attack.
  - We’ll show you some of those failures and consequences from our PNT users’ perspective.
- We need PNT to fail less – but that’s beyond our scope and pay grade….
- Users need to prevent and mitigate against failure -- whatever the cause – using better prevention, detection, redundancy and resiliency measures.

# How telecom and broadcast use PNT

- Both telecom and broadcast are critical infrastructures and must be robust and resilient
- Telecom needs stable frequency
  - Modern telecom & mobile networks are phase-aligned
  - GPS receivers cheaper than cesium clocks
- Broadcast networks need stable frequency
  - Broadcast transmitters need UTC
  - GPS receivers allow SFN transmission

# Typical GPS clock used for telecom and broadcast

- GPS L1 C/A code phase signal, UTC timescale
  - Sufficient for most uses
  - Cheap OEM module for time
- Basic time interface
  - 10 MHz, PPS, NMEA
- Additional output signals feasible
  - IRIG-B, NTP, PTP, 2.048 MHz, 1.544 MHz
- Receiver monitoring is needed to identify potential problems and alert user

# Consequences of recent GPS problems for European telecom & broadcast

- 26 January 2016 GPS event – SVN 23 removed from constellation, 15 of 31 satellites had 13.7 us UTC time-error; GPS clocks fluctuated wildly, shifting between satellites
  - Telecom PTP long-term test failed in Berlin
  - Broadcasters had DVB-T and DAB SFN failure (noted in BBC press release)
- 1024 week wrap-around affected older GPS receiver – stopped a financial market
- PRN31/SVN52 launch – affected some GPS receivers
- PRN32 launch – killed a national telecom network

# Other experiences

- Leap seconds
  - Have affected several networks
  - But each new leap second has less impact
- GPS jammers
  - Have closed ports and airports
  - Used for crimes such as stealing cars
- GPS receiver installation problems including snow, ice, water, steam, lightning, other transmitters and Christmas tree
  - Have caused time transmittal problems

# PNT from the electric grid perspective

- Power systems today use mostly GPS for locational purposes, not for timing.
  - Also heavy telecom and IT network dependence, which rely on timing delivery services
- Synchrophasor technology does high-speed grid monitoring, time-synchronized to UTC with microsecond accuracy. When networks and timing become more reliable, synchrophasor technology can become a mission-critical tool.
  - GPS is the dominant timing delivery service today for Phasor Measurement Units (PMUs)
  - Still telecom and IT network dependence…

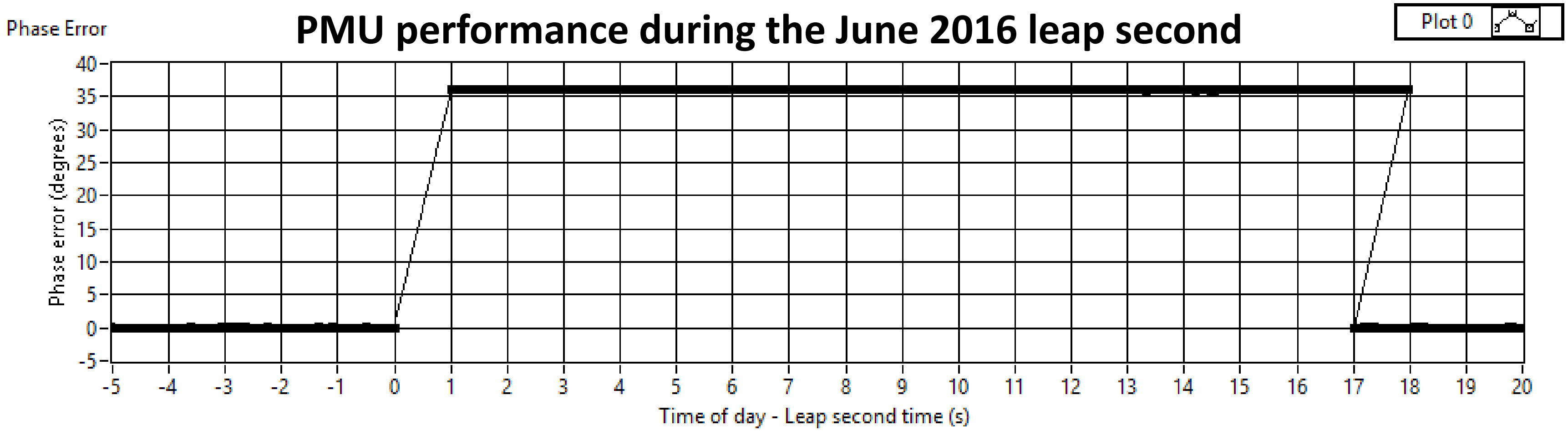
# Some of the ways timing goes bad from the grid user's perspective

- On-site
  - GPS receiver – poor quality, software bugs, no firmware updates, bad location, local jamming or spoofing, 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 Phasor Data Concentrator and applications – inadequate detection of timing anomalies or gaps and computational errors resulting from those problems

# 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

# Calculating phase angle with time error

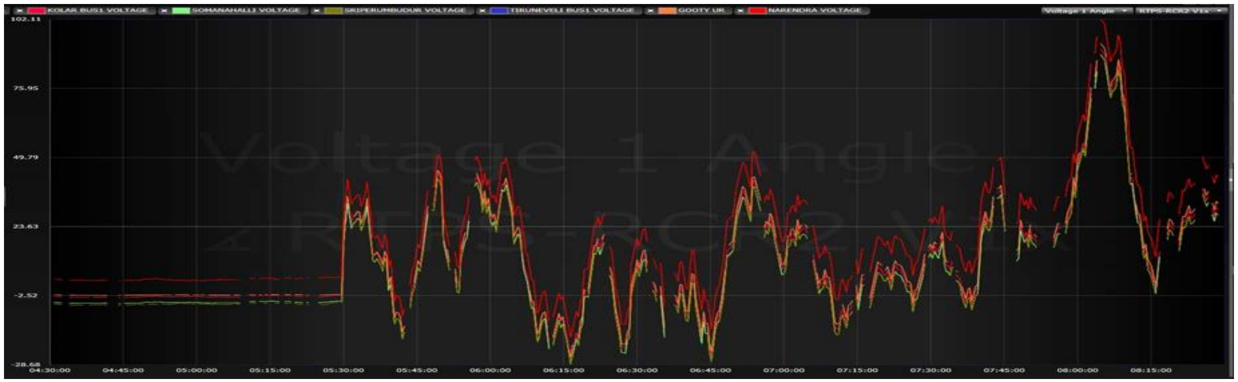



- For 17 seconds, it appears that the phase has a 36 degree error (at 59.9Hz)
- Note that there are no reports for the second immediately following the leap second
- And there are two sets of reports for the second between 17 and 18 seconds after.

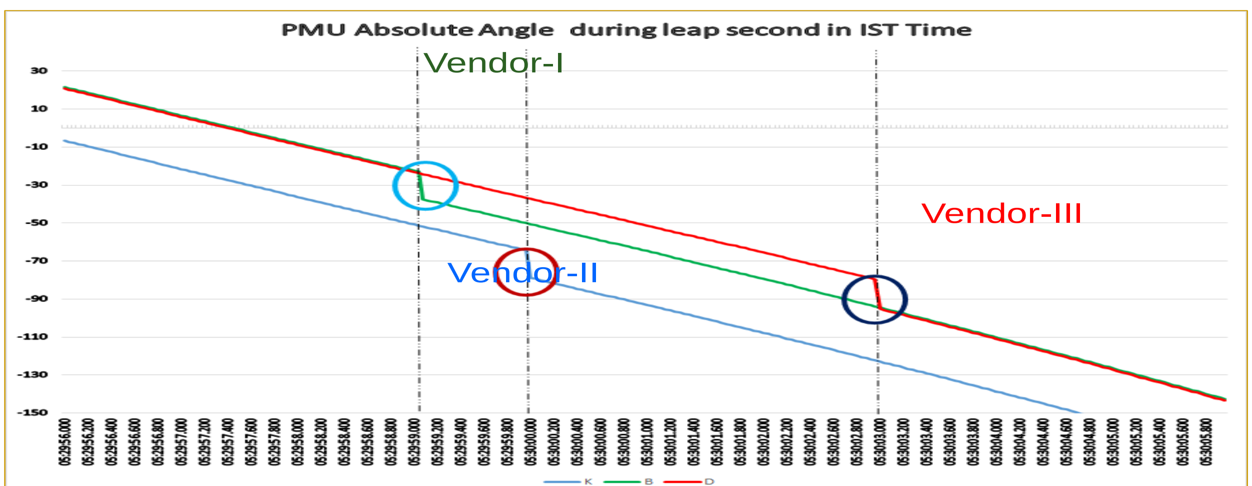
Source: "2015 NIST Investigation of PMU Response to Leap Second", Allen Goldstein, DJ Anand & Ya-Shian Li-Baboud, National Institute for Standards and Technology, March 2016

# Random changes in angular difference after the leap second

Random changes in angular differences observed in some PMUs after 23:29 in the POSOCO (India) control center




Different PMUs handled (mis-handled) the leap second differently




Sources: POSOCO, P.K. Agarwal, “Encounter with the Leap Second,” NASPI Work Group, March 23, 2016

# Power system punch lines

- Timing errors from the time source can cause incorrect synchrophasor data
  - Such errors can create false analytical conclusions and drive undesirable and possibly dangerous automated grid operations.
- 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 the receiving points
  - We need to start implementing measures to assure accurate, reliable time stamps against multiple failure modes

# Remedies at the PNT level

- Improved signal robustness checks
- Multi-frequency – L1 C/A, L2C, L5 (but multi-frequency receivers are expensive)
- Multi-system – GPS, GLONASS, GALILEO, eLoran – a few GPS + GLONASS receivers exist (mainly because Russian law prohibits dependence on GPS only)
- Multiple receivers – only addresses hardware failure
- Jamming and spoofing detection and/or prevention
- GPS-independent networks

# More remedies -- 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
- Holdover clocks for short-term back-up

# What we're doing about it – NASPI Time Synchronization Task Force

Scope – Time synchronization awareness and problem-solving for electric sector, with synchrophasor focus

- Document problems of current 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

# NASPI Time Synchronization Task Force (2)

- Participants
  - Power system representatives (BPA, Dominion, NERC)
  - National labs and research orgs (NIST, PNNL, ORNL, SWRI, EPRI, U.S. DOE)
  - Private sector experts (MITRE, Net Insight)
  - More volunteers welcome!
- Timing
  - Start in May 2016
  - Major product by March 2017
  - Follow-up to be determined

# Big picture NASPI TSTF goals

- Find ways for the power sector to improve timing delivery reliability and resilience for synchrophasor technology and grid operations
  - Coordinate, focus and share work and results within the power sector
  - Develop and deliver materials for non-expert use
- Leverage timing delivery expertise and resources available beyond the power sector
  - Help you understand our needs
  - Gain access to better equipment, software and practices – short- and long-term

# Thank you

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