GPS Timing In Substations: Past, Present, & Future

NASPI Working Group

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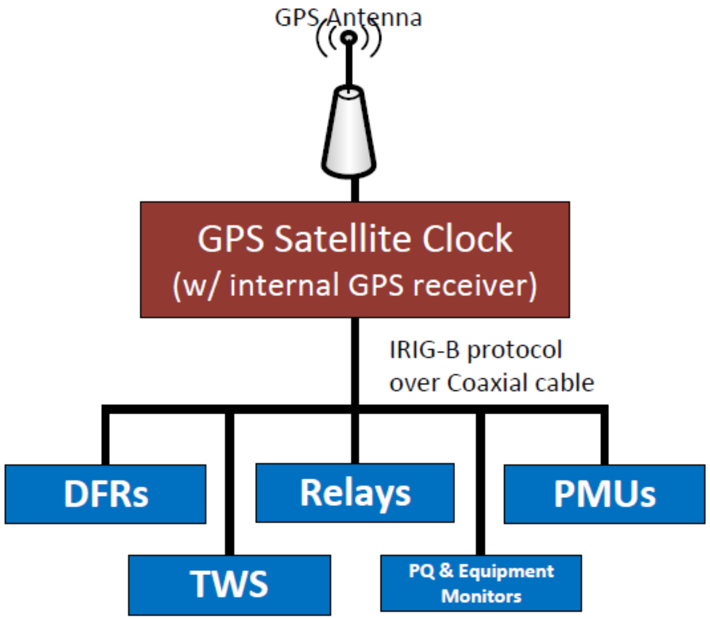
Current Timing

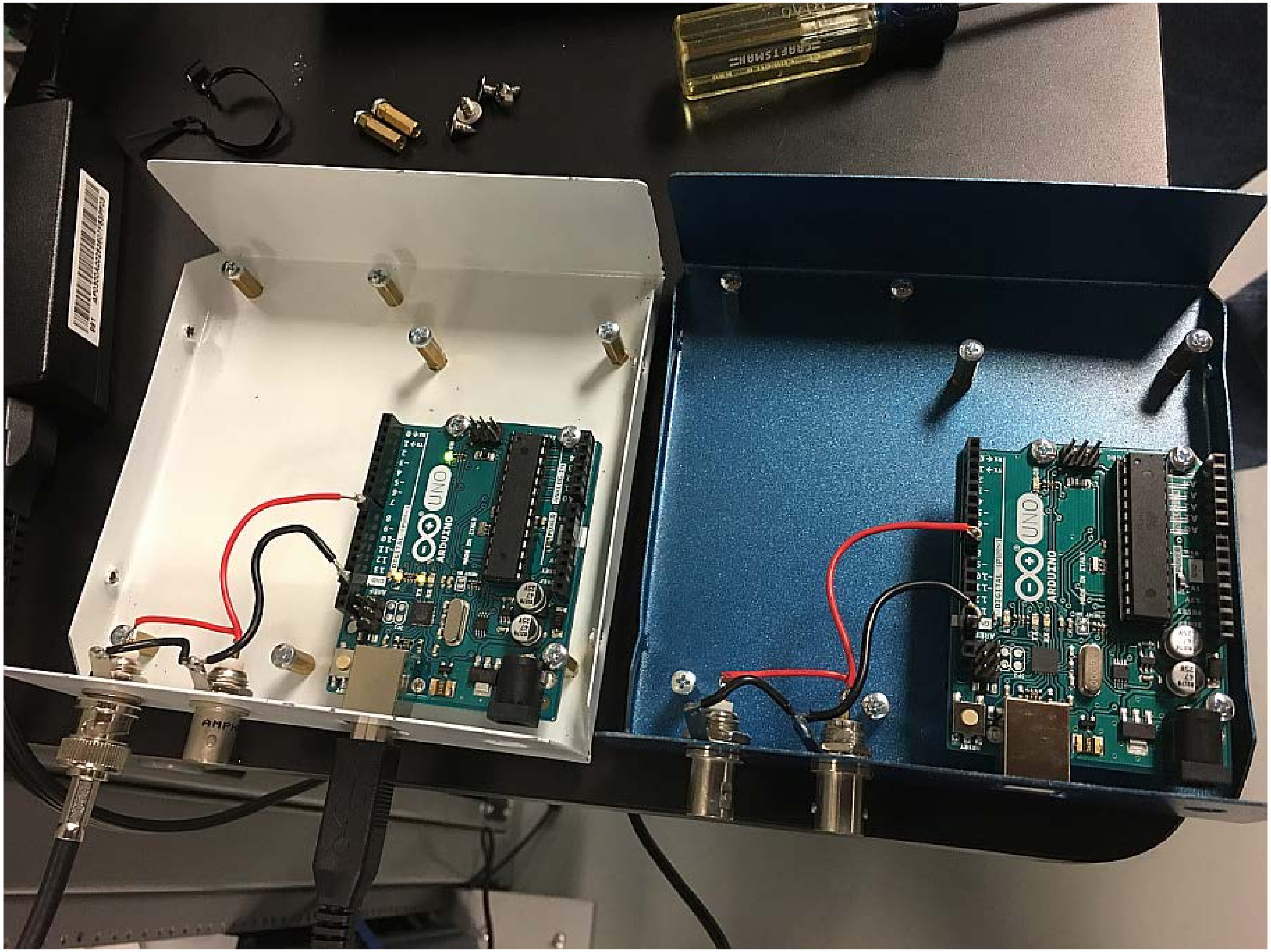
- A GPS satellite clock installed at all Dominion transmission substations (100kV and above) and many distribution substations.
  - Located inside substation control houses, these are stand-alone GPS clocks, which have an internal GPS receiver chip
- Time synchronization is provided to many substation devices from the GPS clock via IRIG-B over coaxial cable
  - Includes Digital Fault Recorders (DFRs), protective relays, Phasor Measurement Units (PMUs), Traveling Wave fault locators (TWS), meters, and more



Current Timing

- Until recently, substation timing has been taken for granted – it hasn’t been as carefully scrutinized as other equipment.
- That is changing with the advent of new devices that are able to make use of precise timing.
  - Starting to see more issues and alarms than previously
- Early 2015 we began setting up lab/procedures to thoroughly test our substation clocks as new firmware upgrades came out

$50 IRIG-B monitor



Discovering Timing Problems

- Monitoring and logging of the IRIG-B timing output is very insightful
  - Without monitoring IRIG-B output of clock, when time errors occur do not know if the problem is the clock or the end-device (PMU, DFR, etc.)
- By decoding the IRIG data stream we have learned a lot. This data was previously unavailable to us due to a lack of tools.
- New IRIG monitoring tools are now on the market

Timing Problems found to date

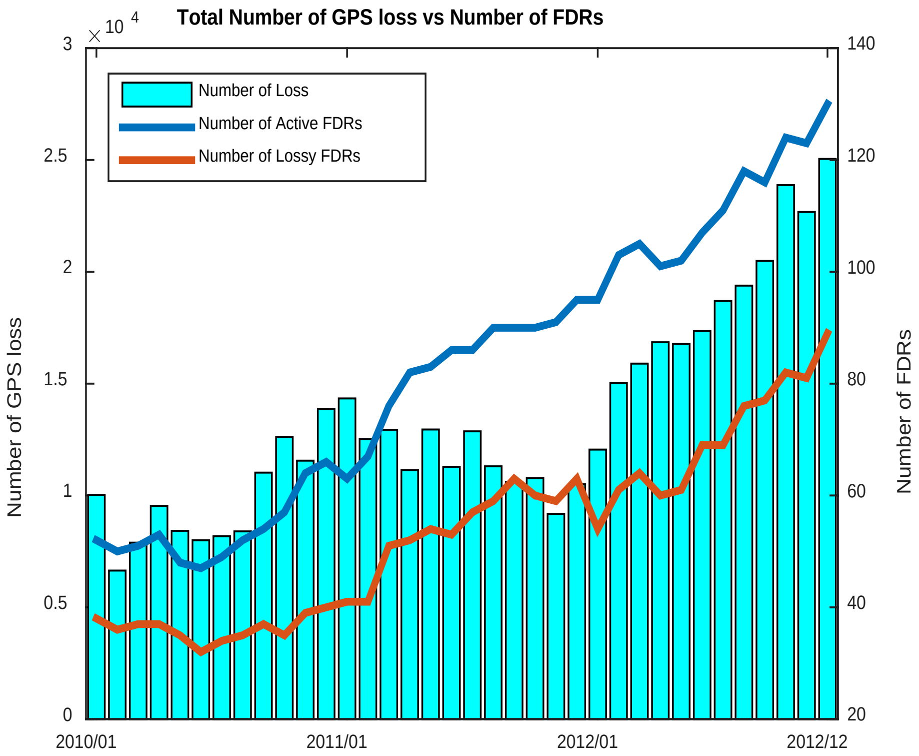
- Firmware/clock testing and monitoring
  - Problems surrounding the changeover from Standard time to Daylight time
  - Leap second handling
  - Year rollover issues
- Loss of signal/hardware issues
  - Cabling
  - Antenna mounting
  - Installation practices
  - Loss of GPS signal

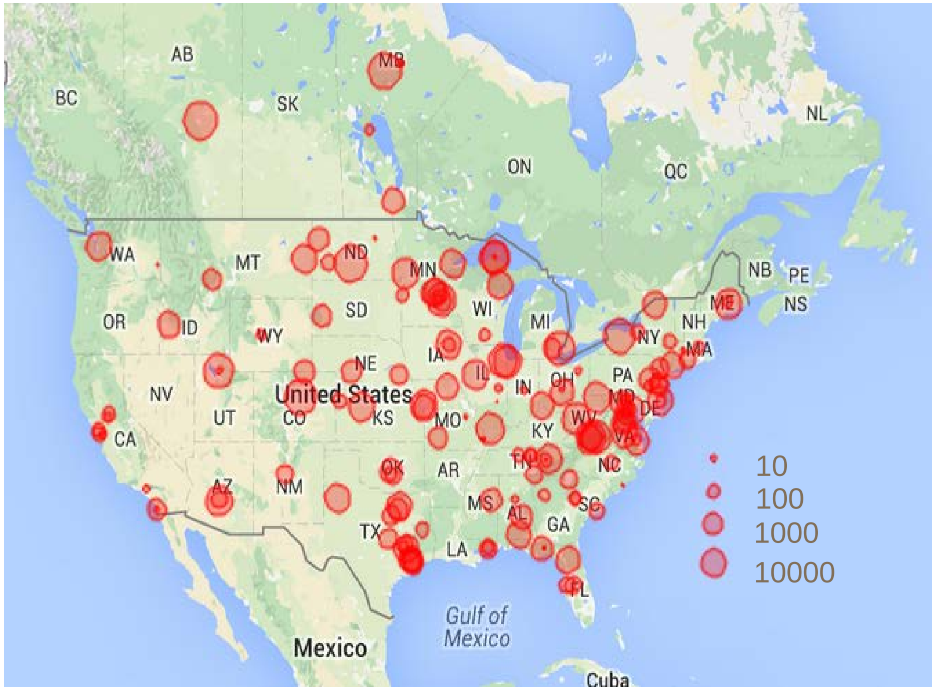
GPS Timing Loss with UTK FDRs

Total number of FDRs increased from 53 in Jan 2010 to 131 in Dec 2012

Over 50% of the FDRs suffer from GPS Timing loss. The average loss rate is about 6 to 10 times /unit /day

The following map shows the average GPS losses/month of FDRs from 2010-2012 vs location. No significant spatial pattern was observed





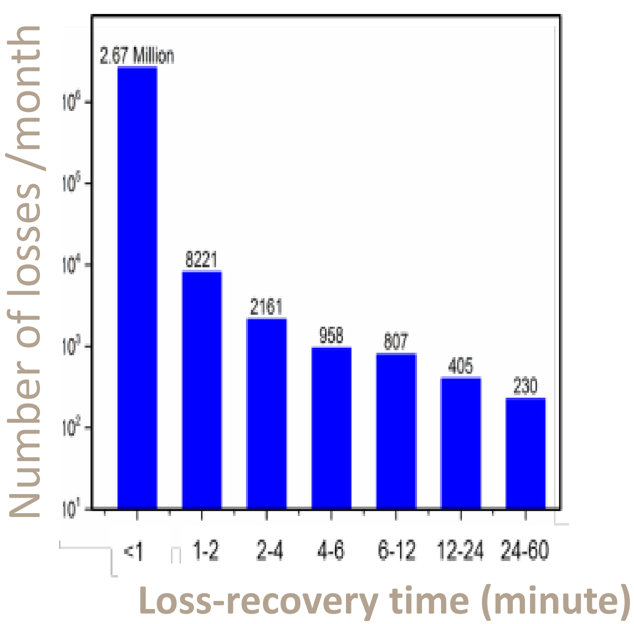
GPS Timing Loss-Recovery Time

The monthly average number of losses decreases exponentially as recovery time increases

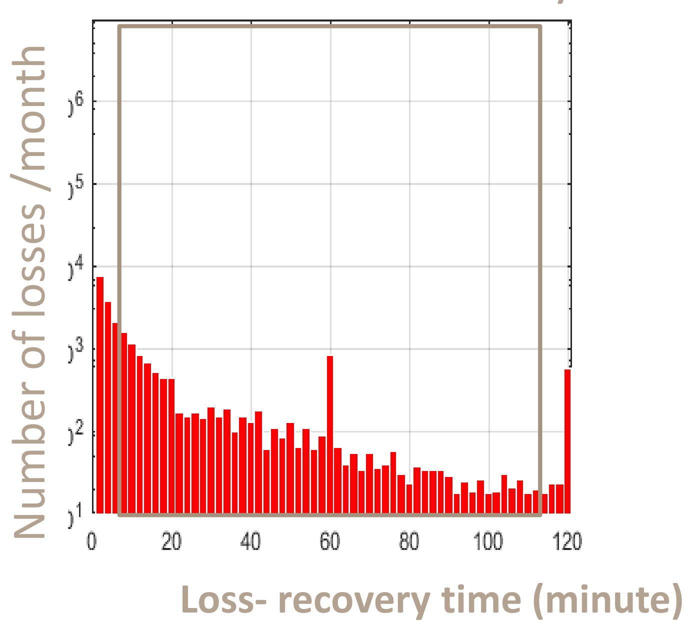
Most of GPS losses recovers with in 20 minutes

FDRs are set to coast running without GPS for 1 or 2 hours

PMU loss-recovery time



FDR loss-recovery time



Impacts of Timing Problems

June 2015 Leap Second Event

- Discovered all our substation clocks had a firmware bug that performed the leap second late (5 seconds or longer)
- All PMU data rejected as “late” data by the PDC due to wait-time setting
- No operational impact to protection functions. Data records did have inaccurate timestamps until clocks did the leap second

Time should have progressed as:

19:59:58
19:59:59
19:59:60
20:00:00
20:00:01
20:00:02
20:00:03
20:00:04
20:00:05

SCADA data transfer with Comm. Processor

- Due to year roll over bug in clocks, relays set with incorrect year.
- New Comm. Processor had time checks, began filtering out SCADA traffic from relays with wrong date/time

Time actually progressed as:

Year	Day	Time	LSP	LS
2015	181	19:59:58	1	0
2015	181	19:59:59	1	0
2015	181	20:00:00	0	0
2015	181	20:00:01	0	0
2015	181	20:00:02	0	0
2015	181	20:00:03	0	0
2015	181	20:00:04	0	0
2015	181	20:00:05	0	0
2015	181	20:00:05	0	0
2015	181	20:00:06	0	0

Conclusions

- Timing in electric substations is becoming more important as more technologies become available that rely on accurate time.
  - With increased PMU deployment and the move towards operator decisions from PMU data and PMU-based control applications, timing becoming as critical as the PMU, relay, etc.
- Treat the timing system with the same thoroughness given to other substation systems.
- Need to keep up to date with industry developments in timing and the state of GNSS.

Future Timing Initiatives

- Evaluating new clocks and technologies. Our current clock model is >10 years old.
- Timing has been an afterthought
  - Not treated with the same importance as other substation equipment
- More rigorous testing of timing equipment. We have purchased a GPS simulator to test clocks and firmware updates.
- Improving timing architecture and products to ensure high availability of precise timing sources