HOW TO BUILD A SMARTER GRID

Tackling GPS vulnerabilities with microsecond timing

BY RON HOLM, Symmetricom

To ensure service continuity and effective, real-time control of today's power grid, operators require microsecond timing that is sufficiently robust to counter increasing GPS (global positioning system) vulnerabilities.

The emergence of real-time substation automation systems requires microsecond time stamping of key data—specifically sensor data from substation IEDs (intelligent electronic devices) such as phasor measurement units and merging units. Traditionally, substation timing was primarily for post-fault analysis where millisecond timing was sufficient. The newly standardized IEC 61850-based smart substations, published by the International Electrotechnical Commission (IEC), require microsecond timing to identify and mitigate a potential fault condition in real time. That requirement, in turn, means operators must be more selective in the types of timekeeping equipment they employ. That's especially true as GPS —the *de facto* time reference for substation timing—has shown increasing vulnerability to a number of space and Earth-based threats. A robust timekeeping system is one that can deliver microsecond timing accuracy for extended periods when a GPS system is unavailable.

WHY MICROSECOND TIMING MATTERS

Smart Grid monitoring and control technology improves the efficiency, reliability of power production and delivery. Generation and transmission equipment can operate closer to their operational limits with less risk of brownouts or blackouts, allowing more power to be delivered over existing infrastructure. Microsecond timing is a key enabler of modern control and monitoring.

Timing in a power grid refers to the ability of its various electronic devices—like intelligent relays, phasor measurement units, merging units, event recorders, fault detectors and control consoles—to stay precisely in sync with a common time reference. Precise synchronization to the microsecond is especially important for real-time operational control in two specific areas: phasor measurements and sampled values.

Phasor Measurements

As the Smart Grid enables more power to be delivered over existing infrastructure from alternative sources such as solar farms, wind farms and distant generation plants, challenges increase for maintaining grid balance and stability. Balance can be maintained and power quality increased by precisely measuring voltage and current waveforms at multiple points on the grid.

GPS-synchronized phasor measurement units (PMUs) distributed across the power grid measure voltage and current waveforms and compute the respective phasors.

Synchronous phasor measurements, called synchrophasors, provide early identification of grid instabilities that could lead to an outage. Monitoring phasors simultaneously on both ends of the line allows reactive/capacitive components to be added in real time to keep the circuit in balance and mitigate blackouts.

Modern PMUs generate up to 120 synchrophasor measurements per second. To ensure accurate analysis and computations of the grid-wide synchrophasor data, the time stamps must be accurate to within one microsecond of Coordinated Universal Time (UTC).

Sample Values

Sample values have traditionally been measured via hardwired analog connections from instrument transformers to IEDs (intelligent

electronic devices). Digitizing sampled values with microsecond time stamping at merging units per the IEC 61850-9 standard for electrical substation design (specific communication service mapping) improves reliability and lowers costs. Time-based protection schemes ensure that the sampled data can be acted on in the order sampled rather than the order received. Cost is reduced as the data can be shared amongst other devices for protection, control, recording and monitoring. Microsecond timing is once again the key enabler to align and process the samples.

WHAT "MICROSECOND TIMING" MEANS

There are five measures grid operators should use to determine whether their timekeeping equipment meets operational requirements:

#1

Precision: Refers to the resolution of the clock that is providing the timestamps. For example, for a clock to provide microsecond level time stamping per the new smart substation requirements, its clock must have a resolution of at least a microsecond. Traditional substation IED clocks have a resolution of one millisecond as required by post-event fault analysis applications.

#2

Accuracy: The accuracy of a clock to a common time standard is paramount to sharing data between grid wide systems. The international time standard is Coordinated Universal Time (UTC) and all substation devices must be synchronized to it. GPS-based time and frequency instruments can routinely provide less than fifty nanosecond synchronization to UTC when locked to a GPS system.

#3

Clock Drift: The accuracy of a clock is based upon its internal oscillator whose frequency can be impacted by temperature and aging. When a clock is locked to a time reference such as GPS, the temperature and aging effects are essentially removed. When the time reference is lost, however, clock performance will be based on the oscillator characteristics where aging and temperature sensitivity determine how accurately the clock will continue to "holdover" and maintain time. The oscillator with the lowest drift will remain accurate for a longer period when the time reference is not available.

#4

Robustness: It is almost universally accepted that grid operators maintain N-1 redundancy for all substation components including timekeeping equipment. N-1 redundancy is achieved when a second clock is continuously available to substation devices should the first clock fail.

#5

Latency: This parameter is how long it takes for data to get from sender to receiver across a network. The more time it takes, the greater the network latency. Highly precise and accurate time is of no value if it is not delivered to where it's needed while it is still needed. The substation's time distribution protocols and network must ensure that the delay between the master clock and IEDs is compensated for to ensure microsecond timing.

MICROSECOND TIMING TECHNOLOGY

Three key pieces of technology are involved in providing accurate and precise time stamps where and when they are needed both in the substation and across the grid:

Substation Master Clocks

These master clocks typically receive time from GPS satellites and deliver it over IP networks via the Network Time Protocol (NTP) and Precision Time Protocol (PTP) to IEDs. PMUs and merging units synchronize to the substation master clock and apply the time stamps to the phasor measurements and sampled values. NTP and PTP automatically compensate for transmission path latency to provide millisecond and microsecond timing respectively. Having multiple substation master clocks provides N-1 redundancy.

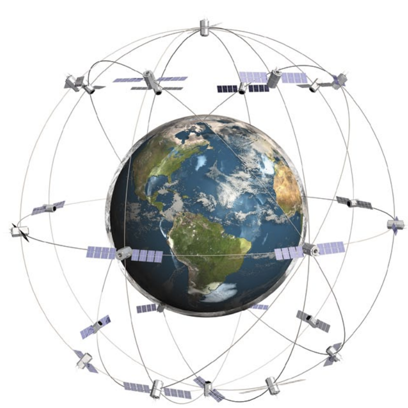

Photo Credit: Jef Bettens

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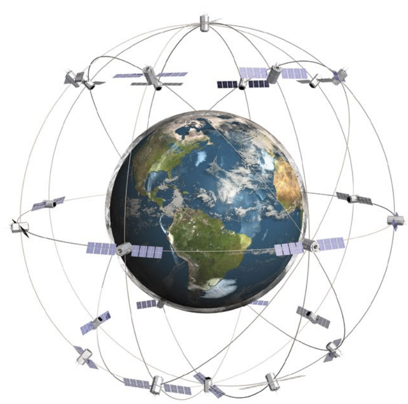

Photo Credit: Jef Bettens

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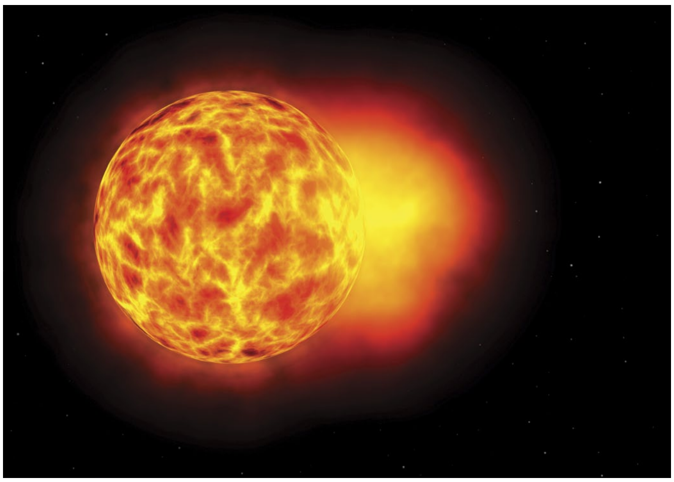
But what about the GPS? If the GPS signal becomes unavailable, then the substation clock accuracy is dependent upon its oscillator until the GPS signal is restored. An oscillator with the highest holdover performance drifts less and can maintain microsecond time for longer periods allowing substation operations to continue.

Uninterrupted GPS service cannot be assured. Antennas come down in storms; wires accidentally get cut; connections come loose; and other mishaps occur here on Earth. But recent developments show that GPS signals can be disrupted due to solar events (solar flares) and Earth-based signals—intentional and unintentional—operating in or near the GPS band.

We are currently in the most intense phase of an 11-year solar flare cycle that will last for several years. January 2012, in fact, saw the largest solar radiation storm since 2005. The storm, which scientists call a coronal mass ejection, sent billions of tons of electrically-charged matter crashing into the Earth's atmosphere at millions of miles per hour. The resulting electromagnetic radiation can disrupt GPS navigation and radio communications. With the recent January solar storm, some international airlines diverted planes from polar routes in order to ensure contact with ground controllers.

PLAYING WITH FIRE



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The proposed LightSquared 4G LTE satellite-based wireless broadband service (pending approval from the Federal Communications Commission with the waiver request rejected in February 2012) is an example of an Earth-based signal that could interfere with GPS signal reception. 4G represents the fourth generation of cellular wireless standards.

The proposed system planned to use an array of 40,000 ground stations broadcasting in the spectrum adjacent to the GPS L-band at approximately one billion times the power of the GPS signals. If this system became operational, there is real concern that the high-powered ground station signals would disrupt reception of the far weaker GPS signals.

WHAT IS THE RIGHT OPTION?

Power grid operators need to weigh how much protection they want against GPS interruptions by deciding how much holdover performance to provide in their substation master clocks. The greater the holdover performance of the internal oscillator, the longer the period of extended GPS signal loss before microsecond timing is lost.

In making that decision, three types of oscillators are available: a TCXO (temperature compensated crystal oscillator), OCXO (oven compensated crystal oscillator) or rubidium atomic oscillator. Here is how long each oscillator can maintain microsecond timing without a GPS reference:

- TCXO: About one minute
- OCXO: About 10 minutes
- Rubidium: About eight hours

The TCXO is the least expensive option and rubidium is the most. However, the rubidium option assures the substation will maintain microsecond timing for several hours. Such robust microsecond timing at substation IEDs, PMUs and merging units means grid operators can continue to maintain effective monitoring and control of their power grids when it counts most—in real time. ■

Ron Holm is a product marketing manager for Symmetricom responsible for GPS Time and Frequency Instrumentation product line solutions for the power industry.