Timing Challenges in the Smart Grid

Cuong Nguyen1, Marc Weiss1, Ya-Shian Li-Baboud1, Dhananjay Anand1, Allen Goldstein1, Jason Allnutt2, Ravi Subramaniam2, Aaron Martin3, Bob Noseworthy4, and Doug Arnold5

Fundamental time scales in power systems

In the Fall of 2016, NIST and IEEE held a workshop to gather stakeholders to discuss application requirements, key timing challenges in the smart grid and identify research priorities. Stakeholders participating in the workshop coordination identified the wide area precision timing requirements necessary in measurement, protection and control applications.

Table 1 – Grid timing uses and timing requirements

<table>
<thead>
<tr>
<th>Application</th>
<th>Time Accuracy Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traveling Wave Fault Detection and Location</td>
<td>100 to 500 μs</td>
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<tr>
<td>Synchronometry (synchrophasors)</td>
<td>Better than 1 μs</td>
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<tr>
<td>Wide Area Protection Frequency Event Detection</td>
<td>10 to 20 μs</td>
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<tr>
<td>Anti-islanding</td>
<td>50 μs to ms</td>
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<tr>
<td>Droop Control</td>
<td>1 ms</td>
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<tr>
<td>Wide Area Power Oscillation Damping (WAPOD)</td>
<td>100 μs to 1 ms</td>
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<tr>
<td>Sequence of Events Recording</td>
<td>100 μs to 1 ms</td>
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<tr>
<td>Digital Fault Recorder</td>
<td>1 μs</td>
</tr>
<tr>
<td>Communication Events</td>
<td></td>
</tr>
<tr>
<td>Substation Local Area Networks (IEC 61850 GOOSE)</td>
<td></td>
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<tr>
<td>Substation Local Area Networks (IEC 61850 Sample Values)</td>
<td></td>
</tr>
</tbody>
</table>

Distributed measurement systems (Fig. 1)

- Phase and time of day alignment to synchronize the system’s real-time clock (RTC) to a traceable reference to time-stamp data for merging data and establishing a clear sequence of events
- Phase and/or time of day alignment to trigger a measurement event (e.g. start recording)
- Provide a frequency reference for driving the analog digital converter (ADC) sampling at consistently spaced time intervals
- Measurement message latency

Impact of timing errors on measurement uncertainty

Phasor Data Concentrators: Phasor data concentrators (PDCs) aggregate and time-align the phasor data from multiple PMUs. Since the data are time-aligned, they can be used to calculate real-time phase angles, oscillations, and dynamic grid events. This time-aligned, wide-area data is useful for monitoring and visualization, alarms and alerts, and off-line analysis.

A phasor is a representation of a voltage or current sinusoidal waveform used in alternating current (ac) power system analysis, where T represents an instant in time, ω0 is the angular frequency, X0 is the magnitude of the waveform, 110 volts for example, and ϕ depends on the time scale as shown in Equation 1 (IEEE C37.118.1-2011).

Equation 1: \[ x(t) = X_0 \cos(\omega_0 t + \phi) \]

PMUs must be capable of receiving time signals synchronized to a traceable reference (UTC) with an accuracy of ± 1 μs.

Phasor technology uses phasor measurement units (PMUs) synchronized to UTC to measure voltage and current waveforms, calculate, time-stamp, and send data at 10 to 120 reports per second to data concentrators and archives. In 2015, there were about 1800 PMUs in North America.

A PMU outputs time-stamped, estimated phasor representations to allow analysis of the electrical waveforms in downstream applications. Comparing other phasors in the electrical system must be done with the same time scale and frequency. Therefore, a synchrophasor is defined as the instantaneous magnitude, X0, and phase angle, ϕ, relative to a cosine function at 60 Hz, the nominal frequency in North American systems, synchronized to the Universal Time Coordinated (UTC) time scale (IEEE C37.118.1-2011).

Equation 2: \[ X = \left(\frac{X_0}{\sqrt{2}}\right) e^{j\phi} = \left(\frac{X_0}{\sqrt{2}}\right) (\cos(\phi + j \sin \phi)) X_0 + jX_0 \]

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Industry Priorities

Achieving Resilient and Assured Timing

Standards

- IEEE P802 and IEC TC 57 standards and guidance efforts in timing, including plug-fests and interoperability testing events
- IEC 61850-9-3 PTP Utility automation profile and UCA International Users Group Interoperability Test Event
- IEEE C37.238 PTP Power Profile and CASC
- IEEE C37.237 Draft standards requirements for time tags created by Intelligent Electronic Devices (IEDs)
- Certification Program (IEEE Conformity Assessment Program)

Industry Guidance

- PNNL/NASPI guidance for synchrophasor applications through the Time Synchronization Task Force (TSTF)
- Secure and resilient time distribution (DHS, NIST)
- Leap second guidance (DHS, NASPI, NIST)
- Power Systems Applications Hardware/Software Standards Interoperability (PNNL)
- Microgrid Standards Interoperability (NIST)
- Distributed CPS Timing Testbed (Arizona State University)

References: