RTDS Technologies Inc.

GTSYNC and PMU Testing Development

Real time digital simulation for the power industry
Presentation Outline

- Definitions and acronyms
- GTSYNC
  - Applications
  - Connectivity and synchronization modes
  - Performance and accuracy
- PMU Testing
  - Capabilities and development timeline
- Questions and answers
Definitions:

• First a few definitions and acronyms…
  • 1PPS – 1 Pulse Per Second
  • IEEE 1588 PTP – IEEE Precision Time Protocol
  • DUT – Device under test
  • IED – Intelligent Electronic Device
  • SV – IEC 61850-9-2 Sampled Values
  • PMU – Phasor Measurement Unit
  • PDC – Phasor Data Concentrator
  • TVE – Total vector error
GTSYNC

Real time digital simulation for the power industry
Applications:
IEEE C37.118 Synchrophasors
- PMUs measure voltage and current phasors and transmit the measurements to central location for monitoring and control
- Synchrophasors are calculated relative to a global time reference and timestamped prior to transmission

Real time digital simulation for the power industry
Applications (cont):

IEEE C37.118 Synchrophasors

- PMU error specification is 1% TVE (total vector error) which includes both magnitude and time error components
  - In absence of magnitude error, maximum time error would be 26 usec for 60Hz systems
  - When testing a PMU, minimizing the time error in the applied signals increases the accuracy testing of TVE
Applications (cont):
IEC 61850-9-2

- Requires sampling to be synchronized to an external time reference and time-stamped because samples are transmitted over Ethernet
- 61850-9-2 LE spec specifies sampling synchronization limits of +/- 4 usec
- The GTSYNC allows synchronization of the simulation time-step which allows the GPC to produce higher fidelity and higher sample rate SV messages compared to the GTNET 1PPS synchronization mechanism

GTSYNC

Real time digital simulation for the power industry
Connectivity and Synchronization Modes:
Connection to the RTDS Simulator
- Connects to GTWIF port 7
- Uses same LC-LC GT fibre cables as GTIO cards and IRC Switch
- 1 GTSYNC for the master rack of multi-rack simulations
- Enabled via the parameters dialog in Draft
Connectivity and Synchronization Modes (cont):

3 modes available for the GTSYNC

- Synchronize RTDS to external 1PPS (copper or fibre)
- Synchronize RTDS to external IEEE 1588 v2 clock (100BASE-TX or 100BASE-FX via ST connector)
- Generate 1PPS internally to synchronize RTDS and DUT

Notes:

- IRIG-B may be added in the future
- No support for direct connection of a GPS antenna
Connectivity and Synchronization Modes (cont):

Synchronize to external 1PPS

- BNC copper 5V TTL input
- ST Fiber (820nm multi-mode 62.5/125um)
Connectivity and Synchronization Modes (cont):
Synchronize to external IEEE 1588 clock
• 100BASE-TX (copper RJ45)
• 100BASE-FX (optical mm 820nm 62.5/125um, ST connector)
• Based on IXXAT IEEE 1588 v2 software (IEEE Power Profile will be supported once finalized)
• Uses hardware assisted timestamping via National Semiconductor DP83640 PHY
Connectivity and Synchronization Modes (cont):
Generate 1PPS internally
- Synchronizes simulator and DUT
- BNC 1PPS output 5V TTL
- 4 ST optical 1PPS outputs

Real time digital simulation for the power industry
Performance and Accuracy:

- Overall simulation synchronization accuracy consists of 2 main components:
  - Synchronization accuracy of the time-step
  - Effects due to the simulation algorithms and input/output latency (e.g. Dommel V/I delay, I/O cards)
Performance and Accuracy (cont):

- Time-step synchronization
  - Synchronized specified to better than +/- 1 usec, typically better than +/- 250 nsec
  - Performance is dependent on quality of time reference signal
  - System delays (e.g. cable delays or other known latencies) can be calibrated out using correction parameters entered through the PER menu of the GTWIF
    - Time ref -> GTSYNC correction
    - GTSYNC -> GTWIF skew
Performance and Accuracy (cont):

- Time-step synchronization example
  - nTSTEP output from GTWIF sync’d with IEEE 1588 to Tekron TTM01-E shows synchronization jitter in the range of +/- 250 nsec
Performance and Accuracy (cont):

- Algorithm and I/O latency and jitter
  - Latencies and jitter are a well understood concept in real-time simulation. The significance and/or mitigation strategy depends on the type of testing being performed. (e.g. closed loop testing vs open loop PMU accuracy testing)
Performance and Accuracy (cont):

- Example GTAO square wave output with IEEE 1588 sync to Tekron TTM01-E (no oversampling and no phase advance enabled in GTAO)
Performance and Accuracy (cont):

- Example of sync with GTAO sinusoidal output and 2 different timescales
- Difficult to see the change in the sinusoid when scope is at 2 us/div
- Square wave jitter is not discernable at 1 ms/div timescale
Summary and review:

• Synchronizes time-step of the simulator
• Can synchronize to external time references such as satellite clocks using 1PPS signals or IEEE 1588 PTP
• Mechanical specs are similar to other GT cards
  • DIN rail mount card
  • 24V power supply
  • GT fibre cables, but connects to GTWIF not GPC
• Initially targeted for IEC 61850-9-2 SV and IEEE C37.118 Synchrophasor applications
PMU Testing

Introduction:

IEEE 37.118 – Synchrophasors

Real time digital simulation for the power industry
PMU Testing

PMU Testing Capabilities:

- Benchmark testing of PMU for steady state and dynamic response
- Provide a simulated PMU for PDC/controller design and testing
- GTNET-PMU to allow hardware in-the loop testing of PDC (future)

Real time digital simulation for the power industry
PMU Testing

PMU Testing Capabilities (cont):

Development Timeline

<table>
<thead>
<tr>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMU Model development</td>
<td>GSYNC hardware development</td>
<td>GTNET-PMU release</td>
</tr>
<tr>
<td>Development of GTWIF time-step synchronization mechanism</td>
<td>In-house PMU Testing</td>
<td>GTNET-PMU development</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Real time digital simulation for the power industry
PMU Testing Capabilities (cont):
Benchmark testing of PMUs

- Can provide the necessary waveforms for static and dynamic testing of PMUs for validation of TVE
- Testing performed:
  - In-house checkout of GE D60 and D90plus UR Relays
  - In-house checkout of SEL 421-1 relay
  - Joint testing of ERLPhase Tesla DFR/PMU
  - Used TVA PDC software to evaluate PMU data
PMU Testing

PMU Testing Capabilities (cont):
Simulated PMU

- Provides PMU metering function
- Up to 8 PMUs per component
- An sample pulse indicates when a new set of samples is available
- Can be used to develop PDC control algorithms
PMU Testing Capabilities (cont):
GTNET-PMU

- Full development will be underway shortly
- Release planned for Q4 2011
  - Preliminary specs
    - 8 PMUs per GTNET
    - Reporting rates from 1/sec to 60/sec
    - Floating point or integer
    - Polar or rectangular format
    - TCP or UDP

Note: transmits PMU data only – it can not receive PMU data messages
Questions?

Real time digital simulation for the power industry