Overcoming Technical Challenges of SynchroPhasors

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“The best way to predict the future is to create it.”

-Peter Drucker
Outline

- Architecture Changes
  - Current
  - Planned
- Data Storage
  - Constraints
    - Historian Responsiveness
    - Data Retention
- Data Integrity/Analysis Problems
Hardware & Software (Current)

PMUs
- SEL-421
- Ametek TR-2000

Data Concentration & Storage
- SEL-3306
- TVA SPDC

Clients
- RTDMS
- OSI OpenPMU
- Microsoft SQL Database
- OG&E PhasorView

openPDC
GRID PROTECTION ALLIANCE

OG&E
Hardware & Software (Planned)
Outline

- Architecture Changes
  - Current
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- Data Storage
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- Data Integrity/Analysis Problems
Constraint #1
Historian Responsiveness
Constraint #2
Data Retention Policy

- Problem
  - Hard to tell what is important

- Some Considerations
  - Fixed Duration
  - Multi-tier Storage

- Solution
  - Keep all data, indefinitely
Why?

- The rate of storage growth will soon outpace the rate of SynchroPhasor growth
- The challenge is not long term, the challenge is the next 3 years
- Based on these projections, we feel there is not a good reason to discard data
Getting over the hump (Lossless Compression)

- Problem:
  - Growing at 9 TB/Year
  - Up to 2.01 Trillion Data Samples

- Solution:
  - Developed Custom High Speed Compression
  - Reduced data storage requirement from 24.7GB/day to 7.4GB/day

<table>
<thead>
<tr>
<th>Method</th>
<th>Compress Rate</th>
<th>Decompress Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>QuickLZ</td>
<td>6.5MB/sec</td>
<td>56.7MB/sec</td>
</tr>
<tr>
<td>LZMA</td>
<td>184KB/sec</td>
<td>5.76MB/sec</td>
</tr>
<tr>
<td>OGE's</td>
<td>644MB/sec</td>
<td>792MB/sec</td>
</tr>
</tbody>
</table>
## Varying Data Requirements

<table>
<thead>
<tr>
<th>Historian Method</th>
<th>2 Trillion Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Data</td>
<td>32 TB</td>
</tr>
<tr>
<td>OGE's Uncompressed</td>
<td>18 TB</td>
</tr>
<tr>
<td>OGE's Compressed</td>
<td>5.4 TB</td>
</tr>
<tr>
<td>openHistorian 1.0</td>
<td>19 TB</td>
</tr>
<tr>
<td>openHistorian 2.0 Lossless</td>
<td>~5.2 TB</td>
</tr>
<tr>
<td>Expected Minimum Lossless</td>
<td>~3.6 TB</td>
</tr>
</tbody>
</table>
Recap – Storage Growth

- Data is more valuable than storage cost - Keep indefinitely
- Implemented Lossless Compression in August 2011
- Historian is Faster
- Reduced data storage requirement by 70%
Outline

- Architecture Changes
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- Data Integrity/Analysis Problems
Data Analysis

- Use of automated analysis routines to support advanced synchrophasor applications:
  - Oscillation detection (FFT emailer)
  - Failing equipment detection
  - Event detection

- These routines need to work around known data problems
CT/PT Measurement Error

- Five PMUs on the same ring bus don’t agree
- CCVT Accuracy is typically 0.6% for the relaying class
- Calibration needed
Discovery of Failing Equipment

- Discovered many loose connections in the potential circuits at fuses or terminal blocks
- This has caused misoperations in the past (relays get confused)
- Proactively finding these helps prevent future outages and misoperations
Our daily PT Problem report performs a dV/dT to help identify abnormal voltage fluctuations.

Failing analog input

(2 weeks)
Beware of Relay Testing

- 8/18/2011 – 345kV line from Sunnyside to Lawton went dead
- 260 high current event were experienced
- Detection algorithms need to know how to handle relay testing

[Graph showing current magnitude over time]

(75 Minutes)
Identifying GPS Problems

- A 3G data radio antenna mounted adjacent to the GPS antenna will very effectively jam the GPS signal!
Wrap Up

- Security: Preconcentrated PMUs with SEL appliances to ease security requirements
- Storage: Implemented custom compression to be available in GPA’s openHistorian 2.0 in order to maintain all of our data until 1TB floppies are released in 2020
- Data Analysis: Developed tools to automatically detect oscillations, failing equipment and system disturbances
Questions?

- Thanks! Feel free to contact us if you have any questions.
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