

# GPA Proposal Discussion – Part 1

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- Opening Remarks
- Application Demonstration



*VISUALIZATION SOFTWARE SYSTEM for  
WIDE AREA SITUATIONAL AWARENESS*

Russell Robertson & Ritchie Carroll  
November 28, 2017

# GPA Proposal – Opening Remarks

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- About GPA & T&D Consulting
- Proposal Technical Approach
- Proposal Business Approach

# Grid Protection Alliance

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GPA is a not-for-profit corporation formed to facilitate the development of comprehensive electric energy solutions.

- Mission – to improve the reliability and resiliency of the electric grid
- Purpose – to advance the technology of the electric grid by providing software and software services that create lasting value for electric energy producers, transmission & distribution companies, and consumers.

<https://gridprotectionalliance.org>

# Key GPA Staff



Grid Protection Alliance, Inc., specializes in the development and support of **innovative software solutions** for the **electric industry**.

GPA has a track record of innovation and **has led major software development projects** with client utilities and the Federal Government.

In addition to **custom application development**, GPA offers services for installation, set-up, integration, and on-going **maintenance of its open-source software**.



**Russell Robertson**  
Vice President, Grid Solutions

**ROLE: Overall Project Oversight**

- Founded GPA's open-source software and consulting-service business.
- 30+ years at the Tennessee Valley Authority, last 10 leading TVA OT – including all information systems that support RC, BA, IA, TOPs and TO functions.
- Expertise in grid operations, IT/OT architecture, information management, and control systems.
- Concurrently with GPA responsibilities, Director of Grid Data Management in 2014 for the CURENT center at the University of Tennessee.



**Ritchie Carroll**  
Senior Solutions Architect

**ROLE: Lead Developer / Architect**

- Oversees GPA software development and provides software system design and development services to utilities.
- 25+ years' expertise in high-performance software system design, development, and delivery. Has lead numerous large software development projects.
- 10 years at the Tennessee Valley Authority leading synchrophasor software development among other operational systems
- Active participant in NASPI and other industry efforts to improve synchrophasor data systems.



**Richard Driggans**  
Senior Project Manager

**ROLE: Project Management Support**

- Provides project management and technical writing support.
- 30+ years at the Tennessee Valley Authority, serving in a variety of roles including the management of R&D projects, developing corporate performance metrics, and participating in corporate power system planning and corporate strategy efforts.
- Expertise in project management, strategic planning, and environmental, energy, and natural resource management.



**Stephen Wills**  
Senior Systems Analyst

**ROLE: Senior Developer**

- Major contributor to GPA software solutions and provides system support and integration services to utilities.
- 10 years' experience in developing .NET solutions, much of that time contributing significantly to GPA's core code base – the Grid Solutions Framework.
- Specialize in the management of data from substation devices – PMUs, DFRs, power quality meters, and relays.
- Prior to joining GPA, 2 years' experience at the Tennessee Valley Authority in development of synchrophasor data software.



**Billy Ernest**  
System Analyst

**ROLE: Developer**

- Specializes in user interfaces/user experience, data storage, data visualization, and full-stack Web development.
- Experienced with numerous front end development JavaScript APIs including AngularJS, ReactJS, KnockoutJS, among others
- Lead developer on the Open PQ Dashboard with two years of experience at GPA developing .NET and web-based solutions

# T&D Consulting Engineers

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T&D Consulting Engineers is a small consultancy with domain expertise in synchrophasor deployments and power system dynamics, and with knowledge of western grid policies, procedures and issues.

## ■ Role:

- To actively participate in the specification/initial development stage to ensure ease-of-use and ability to interpret results for the proposed WASA system;
- To provide guidance in specifying, and quality control in fulfilling, the desired outcomes in each of the 24 specific use cases identified in Appendix C of the RFP;
- To generally augment the core GPA software team with additional domain expertise and guidance.

# T&D Consulting Engineers' Subject Matter Experts

## T&D CONSULTING ENGINEERS

TDCE provides domain expertise in measurement systems and signal processing, synchrophasor applications, and power system operations.

Staffed by highly qualified technical professionals, TDCE brings an in-depth understanding of signals and systems applied to power engineering along with the ability to effectively communicate this knowledge through documentation and training.



**Dan Trudnowski, PhD, PE**  
**Managing Partner**  
**ROLE: Engineering SME**

- IEEE Fellow “for contributions to algorithms for characterizing power-system small-signal stability properties.”
- Over 90 refereed publications over entire career; IEEE PES prize paper awards, 2009, 2013.
- 25+ years investigating the dynamics of the western North American power grid; regular contributor to JSIS subcommittee of WECC.
- Acting Dean of the College of Engineering at Montana Tech.



**Matt Donnelly, PhD, PE**  
**Managing Partner**  
**ROLE: Engineering SME**

- 30+ years in power systems and power engineering with special expertise in measurement systems.
- Convener of NASPI predecessor and contributor to NASPI, JSIS and SMS efforts.
- Active participant in NASPI and other industry efforts to improve synchrophasor data systems.



**Josh Wold, PhD**  
**Staff Engineer**  
**ROLE: Engineering SME**

- Expert in mathematical modeling with current research interest in power plant model validation (conventional and renewable).
- Hardware engineer at Schweitzer Engineering Lab prior to joining TDCE and Montana Tech.

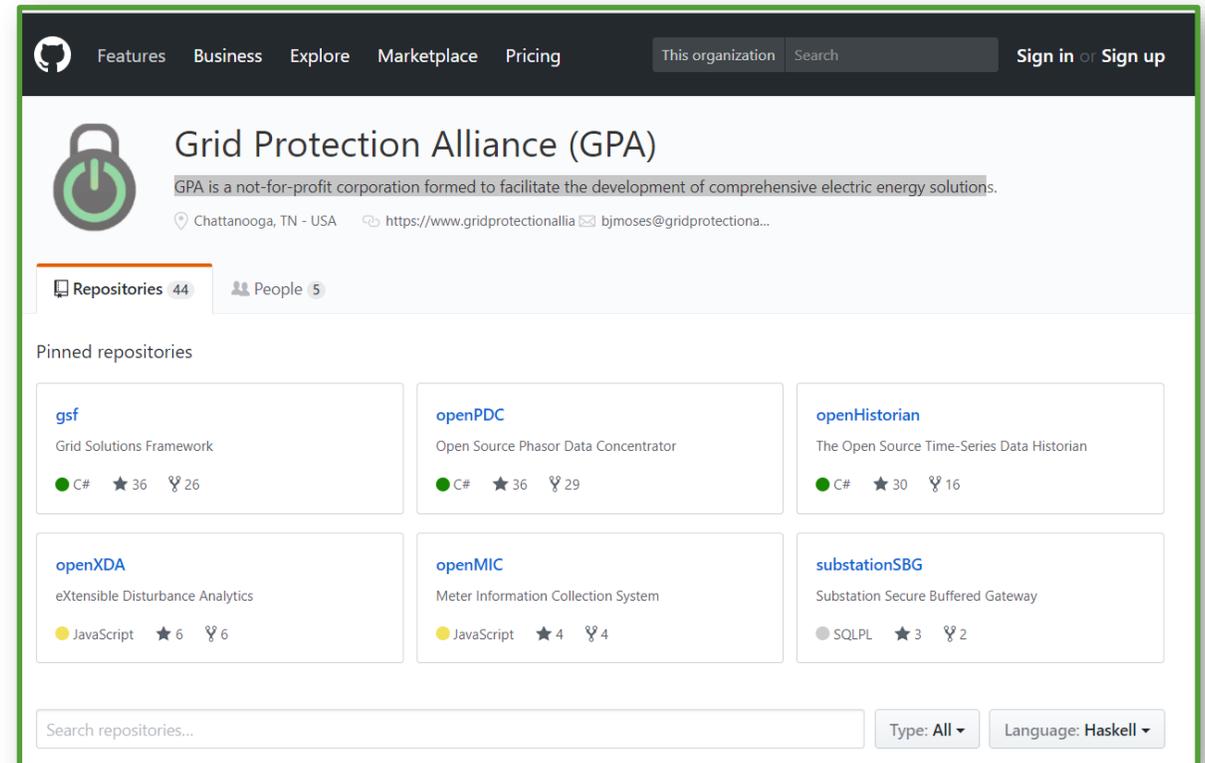
# An Architecture of Component Reuse

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- GPA products are light weight and leverage the functionality provided by the GSF – which contains the large majority of GPA's open source code.
- GPA quickly incorporates the latest updates/revisions from Microsoft to take advantage of performance and security improvements. (Now using .NET 4.6.1)
- GPA libraries are tested on multiple platforms (Windows, Linux, Mac) to assure wide use

# GPA Software is Open Source

- Posted on Github
  - 44 Repositories
- Permissive Licensing
- Nightly builds available on-line from GPA
- GPA is an active code steward
- Code Security
  - Checked at development time
  - Checked nightly using SolarQube



The screenshot shows the GitHub organization page for the Grid Protection Alliance (GPA). The page header includes navigation links for Features, Business, Explore, Marketplace, and Pricing, along with a search bar and options to sign in or sign up. The organization's profile is displayed, featuring the GPA logo (a green padlock with a power button symbol) and the text: "Grid Protection Alliance (GPA)", "GPA is a not-for-profit corporation formed to facilitate the development of comprehensive electric energy solutions.", "Chattanooga, TN - USA", and "https://www.gridprotectionallia.com". Below the profile, there are tabs for "Repositories 44" and "People 5". The "Pinned repositories" section lists six repositories:

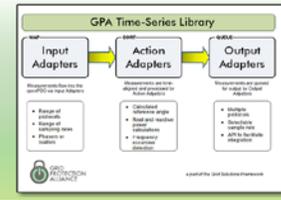
Repository Name	Description	Language	Stars	Forks
gsf	Grid Solutions Framework	C#	36	26
openPDC	Open Source Phasor Data Concentrator	C#	36	29
openHistorian	The Open Source Time-Series Data Historian	C#	30	16
openXDA	eXtensible Disturbance Analytics	JavaScript	6	6
openMIC	Meter Information Collection System	JavaScript	4	4
substationSBG	Substation Secure Buffered Gateway	SQLPL	3	2

At the bottom of the repository list, there is a search bar labeled "Search repositories..." and filters for "Type: All" and "Language: Haskell".

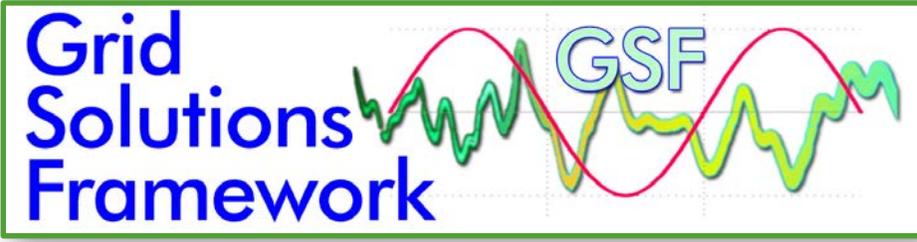
# GPA Core Technology

Version 2.2.144

- Grid Solutions Framework
- Time-Series Library



**SNAPdb Library**  
Serialized, NoSQL, ACID Compliant, highly Performant  
Included in the Grid Solutions Framework from the Grid Protection Alliance



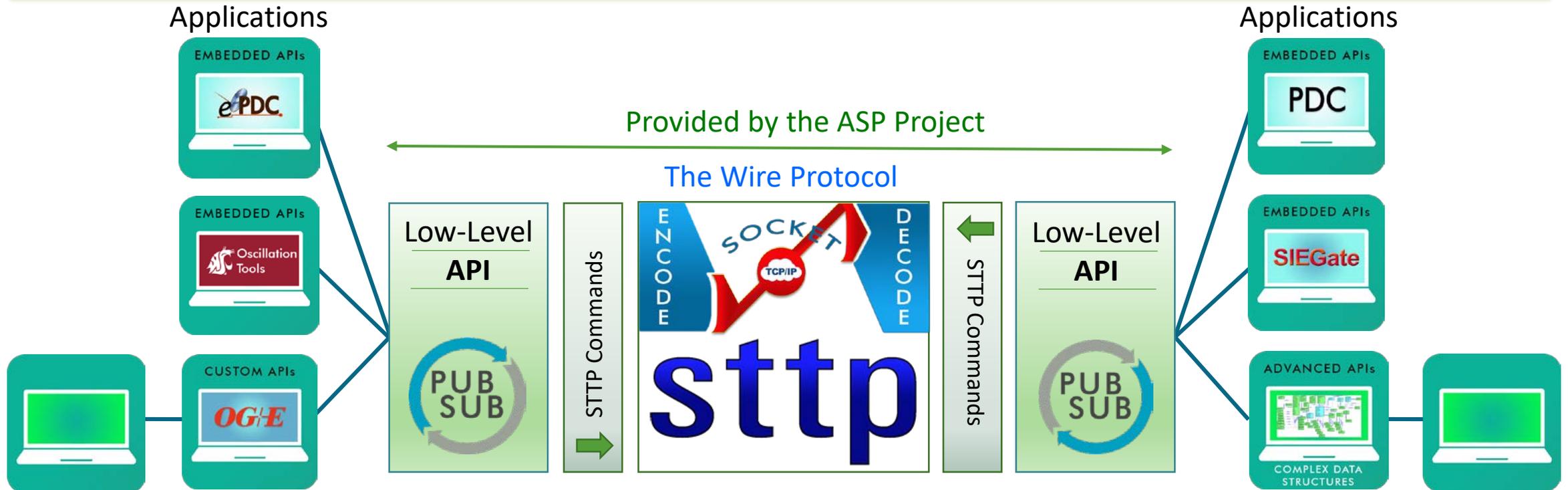
- A comprehensive collection of classes and methods useful for any project
- Foundational code library for all GPA products with 100's of class libraries
- 860,000 lines of code and more than 225,000 lines of comments spanning more than 75 assemblies

Grid Solutions Framework  
GRID PROTECTION ALLIANCE  
<https://gsf.codeplex.com/>

GSF-Core.dll  
GSF-Communicator.dll  
GSF-Net.dll  
GSF-ServiceProcess.dll  
GSF-Web.dll  
GSF-Wireless.dll  
GSF-PhasorProtocols.dll  
GSF-Bus.dll  
GSF-ServiceModel.dll  
GSF-Imagines.dll  
Other GSF Assemblies

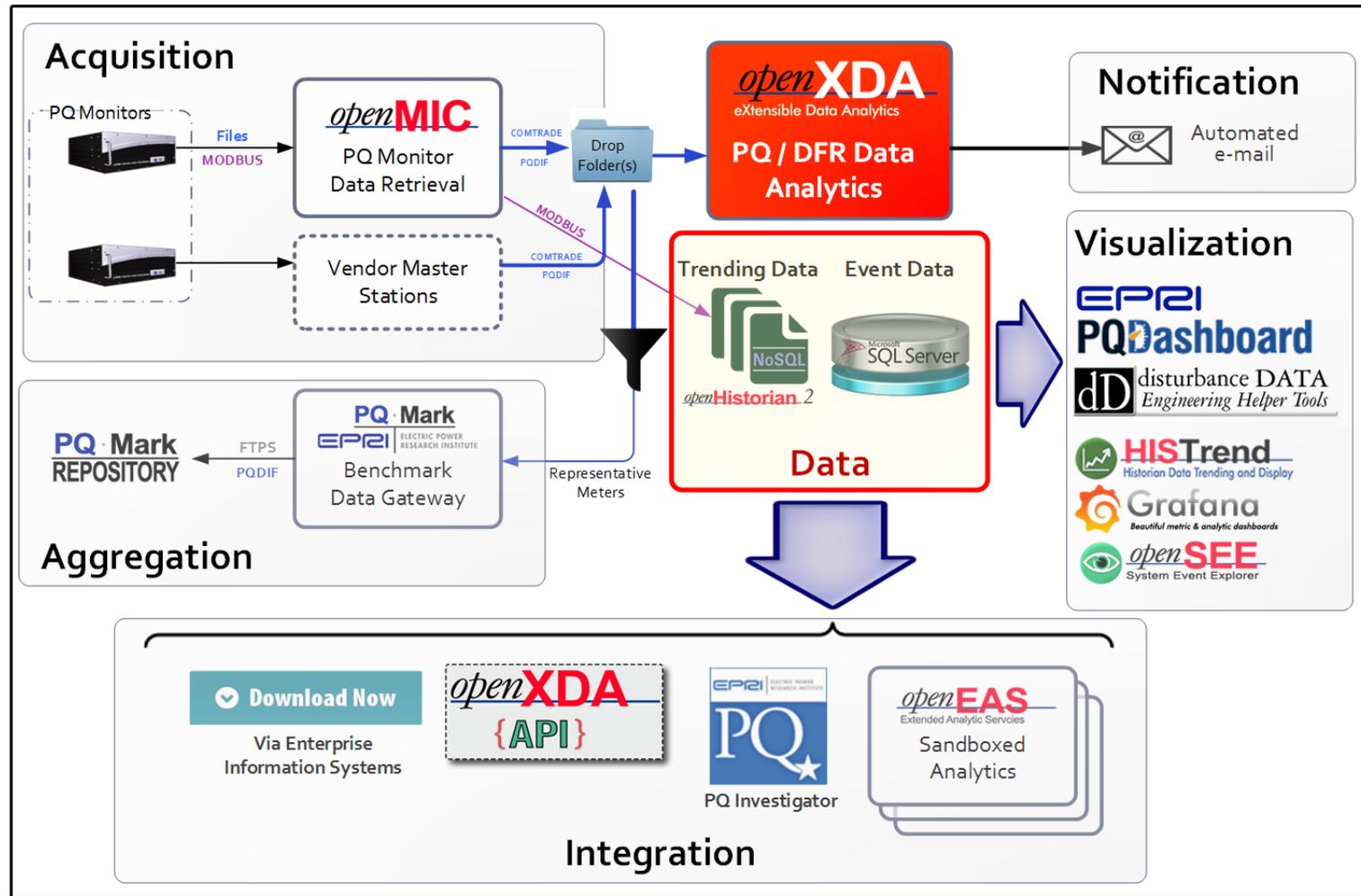


# SDG&E is a Participant in the DOE ASP Project Lead by GPA



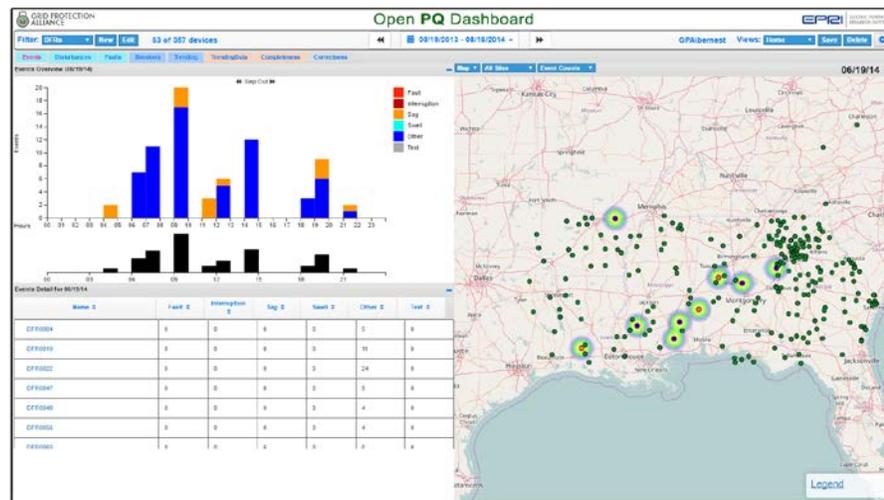
- Performant Data Exchange at Scale
- Extensible Metadata
- Access Control and Security
- Bidirectional Connectivity

# GPA's Disturbance Monitoring Tool Suite



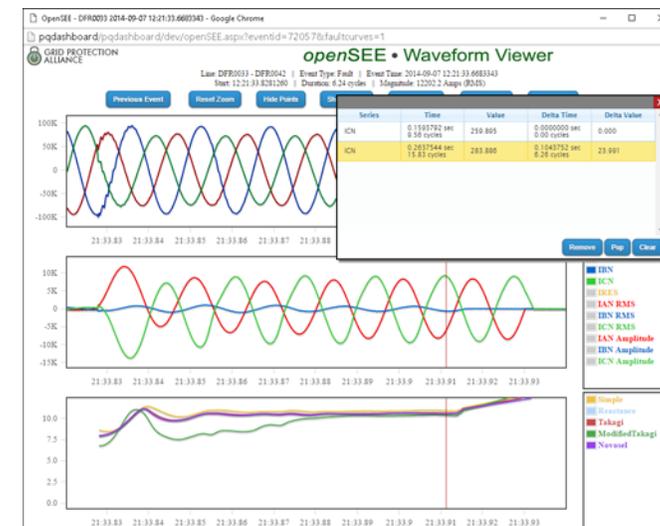
## Features

- The display layer for openXDA data
- Drill-down from wide-area data displays all the way to waveforms
- Complements traditional vendor-provided waveform analysis tools



## Recent Improvements

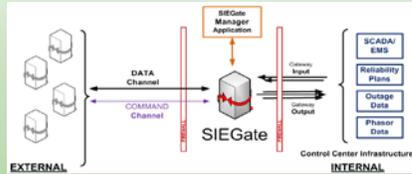
- Ability to manually override automated results and add notes



# GPA's Synchrophasor Product Suite

## Collect

*open* **PDC**



**SIEGate**

*substation* **SBG**



## Distribute

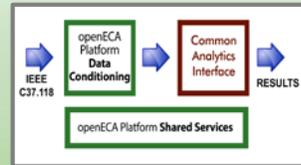
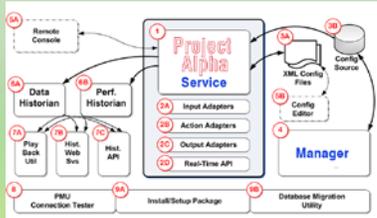
**Synchrophasor Stream Splitter**



**sttp**

## Analyze

**TSL Project Alpha**



**PDQ TRACKER**

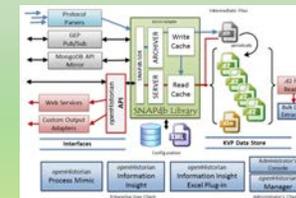
phasor data quality alarming & reporting



**open ECA** open and Extensible Control & Analytics platform for synchrophasor data

## Save

*open* **Historian 2**



## Display

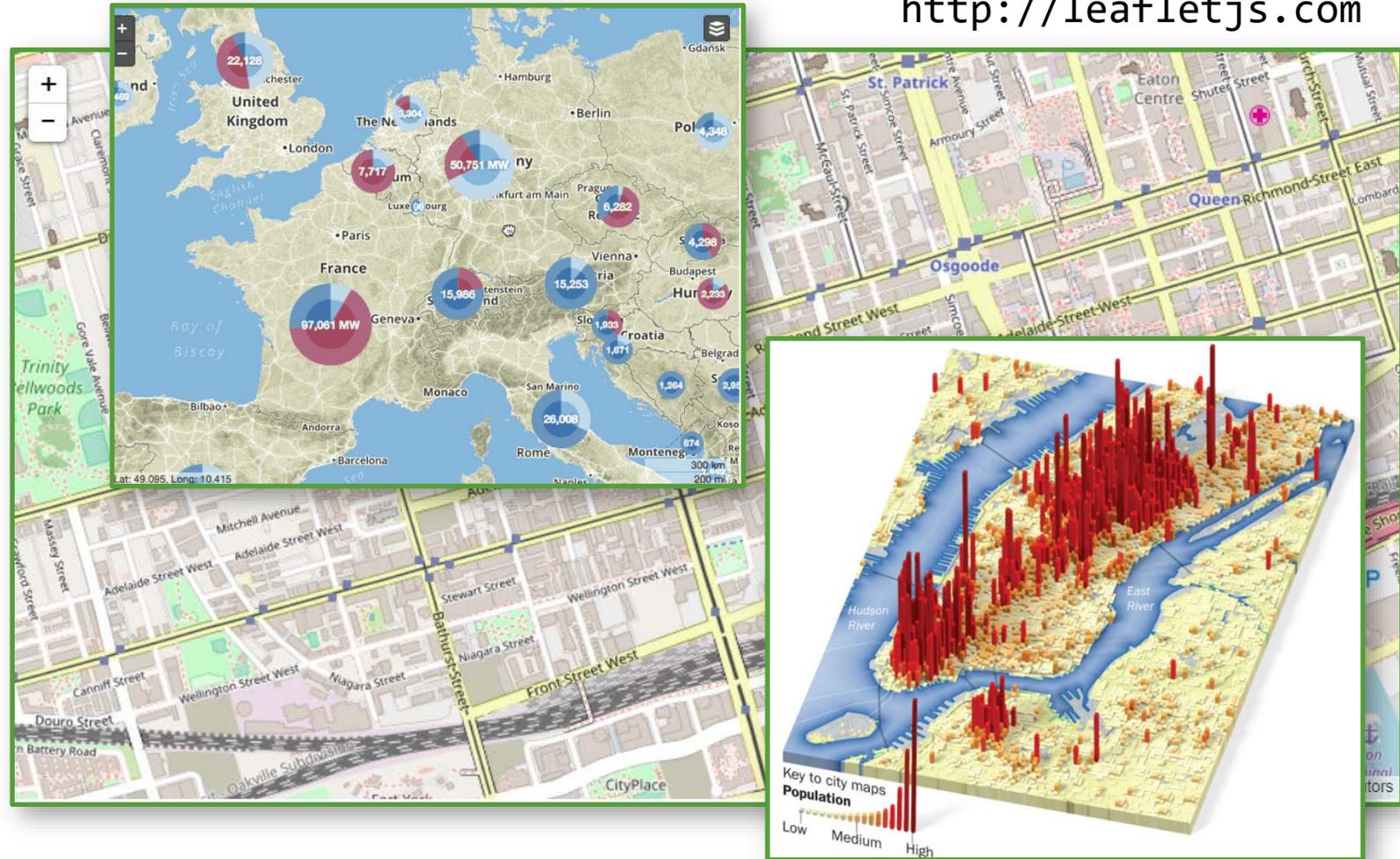


an open-source JavaScript library for mobile-friendly interactive maps

<http://leafletjs.com>

- Open source
- High performance
- Well-documented APIs
- Supports both map and non-map base layers
- Extensible
- ESRI provides a tile layer for Leaflet

<https://github.com/Esri/esri-leaflet>



## The open platform for beautiful analytics and monitoring

- Open source
- GPA published plug-ins for openHistorian and PI
- Rapidly expanding library of graphical widgets
- Displays easily shared
- Extensible



<https://grafana.com>

DATA SOURCE



### openHistorian

by Grid Protection Alliance

datasource plugin for openHistorian

DATA SOURCE

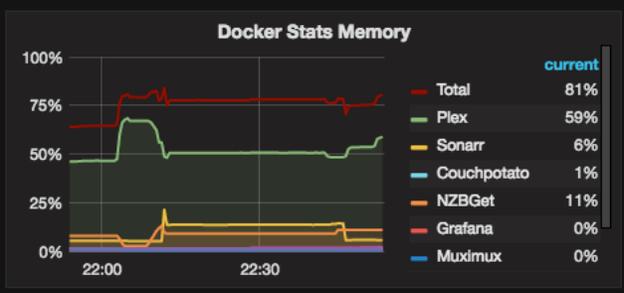
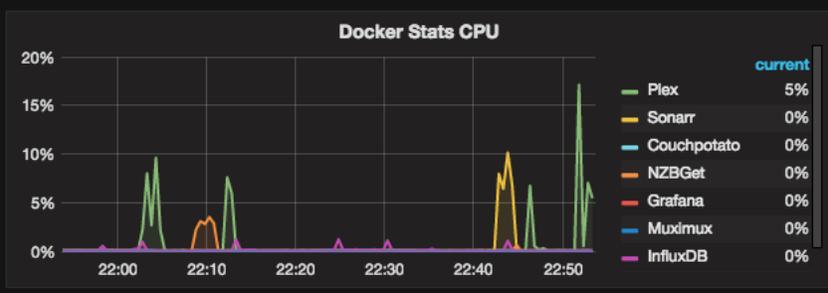
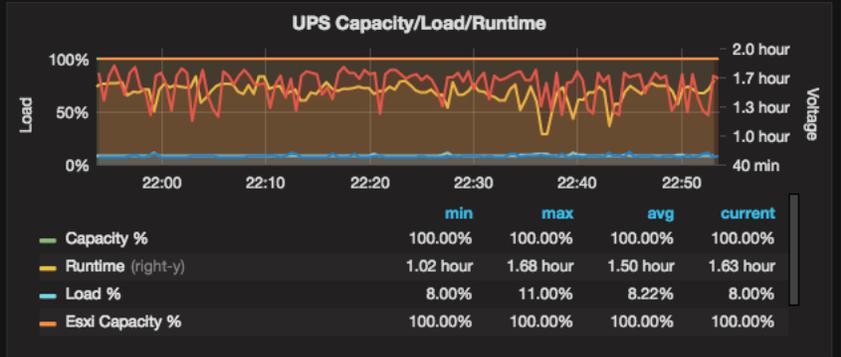
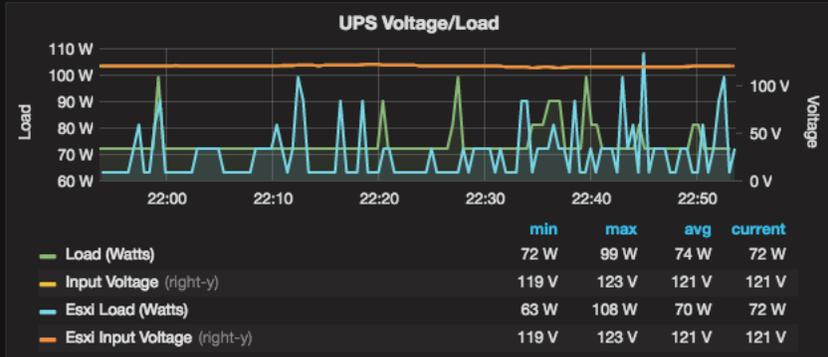
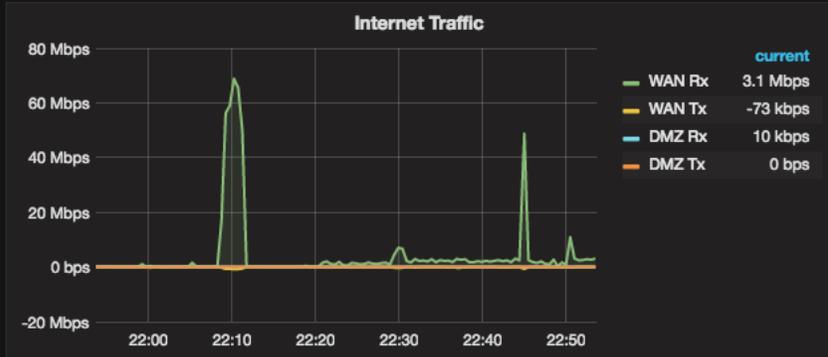
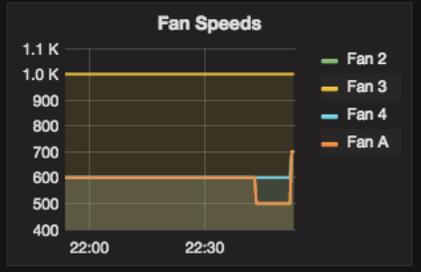
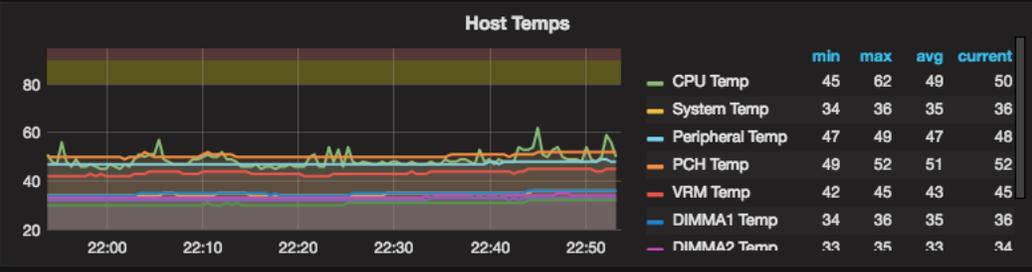
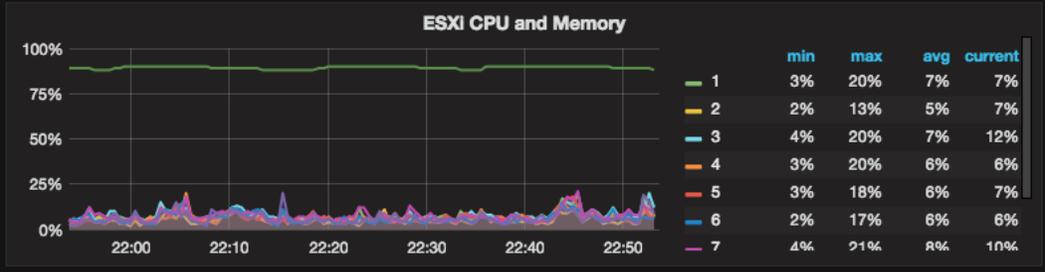


### OSIsoft-PI

by Grid Protection Alliance

Datasource plugin for OSIsoft PI Web API

<b>Uptime</b> <b>11.65 days</b>	<b>Lab Power</b> <b>144 watts</b>	<b>Lab Montly Cost Estimate</b> <b>\$ 10.65</b>	<b>Used Space</b> <b>10.30 TiB</b>	<b>Total Space</b> <b>14.30 TiB</b>	<b>Disk Health</b> <b>OK</b>	<b>Plex Transcodes</b> <b>0</b>
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### Synology DS1512+

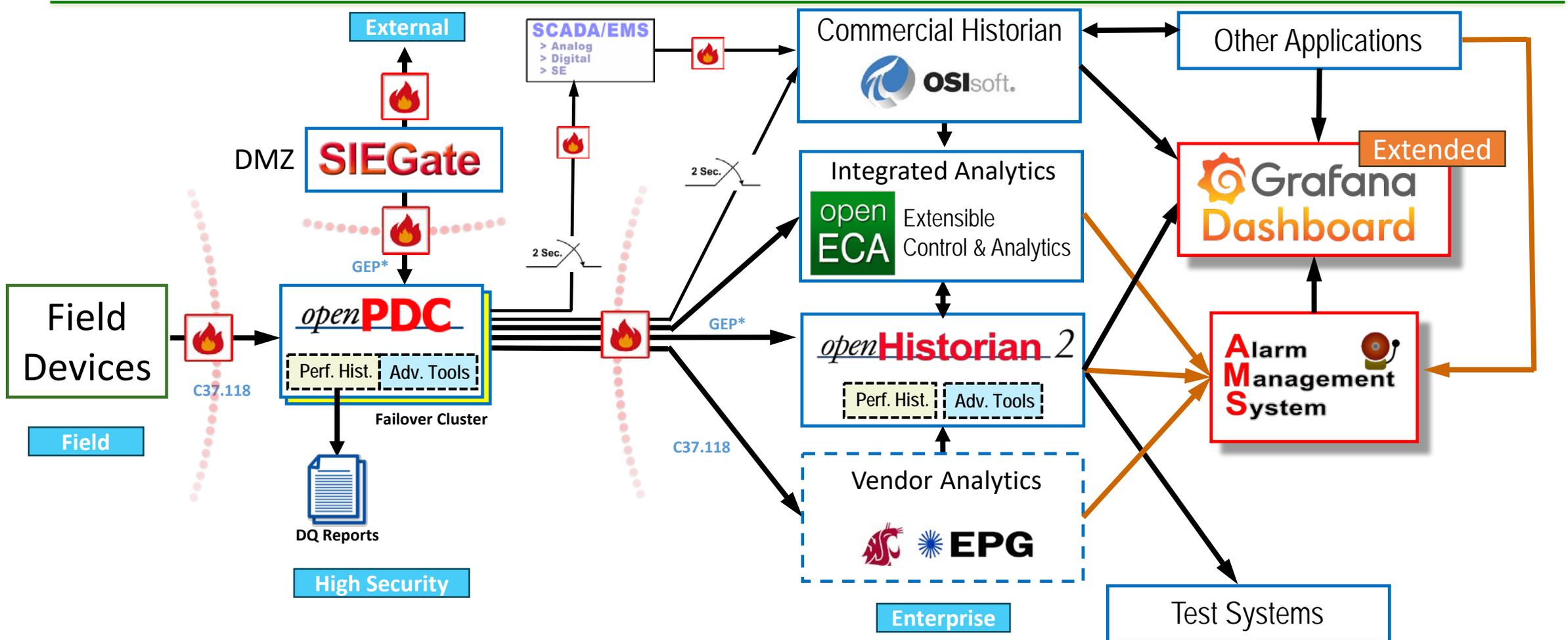
Metric	Min	Max	Avg	Current
Disk_1	31 °C	32 °C	32 °C	32 °C
Disk_2	31 °C	32 °C	31 °C	32 °C
Disk_3	31 °C	32 °C	31 °C	32 °C
Disk_4	31 °C	32 °C	31 °C	32 °C
Disk_5	30 °C	32 °C	31 °C	32 °C

### Synology DX513+

Metric	Min	Max	Avg	Current
Disk_1_(DX513-1)	33 °C	34 °C	33 °C	34 °C
Disk_2_(DX513-1)	33 °C	34 °C	33 °C	34 °C
Disk_3_(DX513-1)	33 °C	34 °C	33 °C	34 °C
Disk_4_(DX513-1)	32 °C	33 °C	32 °C	33 °C

# GPA Solution Typical Architecture

(GPA's version of RFP Attachment 4, Figure 4, page 12)



\* Connection established from the higher security zone

# The GPA Business Approach



1. Leverage existing open source software
2. Develop new open source software to close function and feature gaps
3. Test and document

## Approach Summary

The Grid Protection Alliance (GPA) is pleased to provide this response to the July 14, 2017, SDG&E Request for Proposal (RFP) that is a part of Phase 2 of WASA system development.

The proposal is focused on meeting SDG&E's current technical requirements while minimizing first and on-going costs. In doing so, GPA is also providing a highly-performant and flexible architectural foundation to allow SDG&E to easily incorporate new technology and components as well as to adapt the visualization system to meet changing business requirements without lock-in to GPA or any other vendor.

The central theme of this proposal is to meet the RFP's requirements largely through use of three existing open-source architectural components – (1) an analytics integration platform called openECA, (2) a web-based open-source visualization platform called Grafana, and (3) a display tool for event data called the open PQ Dashboard.

Following completion of the Functional Specification and Design Document, GPA proposes that the visualization system be delivered in a minimum of two phases. This phased delivery reduces technical and business risk and allows value to be returned to SDG&E earlier than with a grand "all at once" delivery approach.

The proposed team of GPA and T&D Consulting Engineers has extensive expertise in the development and integration of phasor data within production grid operating environments, and we are confident that we can deliver a system to fully meet SDG&E requirements.

- Minimizes first and on-going costs
- Performant and flexible architecture
- Adaptable to meet changing business requirements without vendor lock in
- Delivery is in phases to return value early
- The proposal team has the skills and experience to be successful

# Application Demonstrations

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- Trending Data Displays
- “Mapped Data” Displays
- Alarming
- Building New Displays
- Adding New Analytics
- Configuration
- Q&A

# GPA Solution Functionality – Trending Data Displays

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- Grafana Data Sources
- Grafana Dashboard
  - SPP Example
  - ODM Example
- Demo – TVA Phasor Data Monitor

# Grafana Data Sources

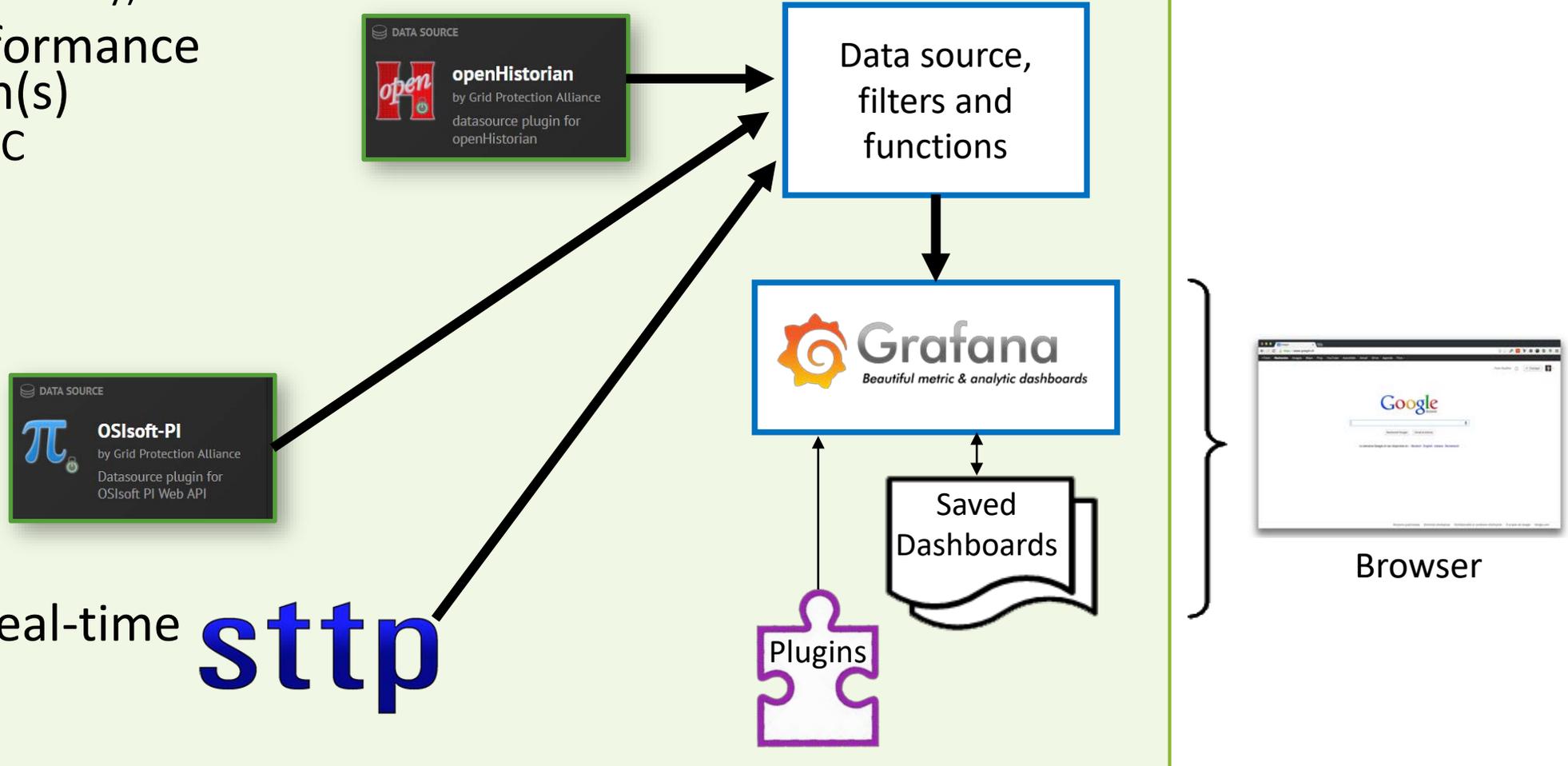
- openHistorian (~ 25 mSec Latency)
- GSF Performance Historian(s)
  - openPDC
  - SIEGate
  - ...

■ OSI-PI

■ STTP / Real-time (Futre)

**sttp**

## Server Side Systems



# openHistorian Data Source – Built-in Functions

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- Average
- Minimum
- Maximum
- Total
- Range
- Count
- Distinct
- Absolute Value
- Add
- Multiply
- Round
- Floor
- Ceiling
- Truncate
- Standard Deviation
- Median
- Mode
- Top
- Bottom
- Random
- First
- Last
- Percentile
- Difference
- Time Difference
- Derivative
- Time Integration
- Interval
- Include Range
- Exclude Range
- Filter NaN
- Unwrap Angle
- Wrap Angle
- Label
- Subtract
- Divide

*36 & Growing*

# Trending Data Displays – Grafana Dashboard, SPP

- Frequency
- ACE
- Load
- Generation (Wind Generation)
- Interchange
- Time



# Trending Data Displays – Grafana Dashboard, SPP

- 2-Axis
  - Control Limit
  - Load
  - Load % of ATC
- 2-Axis
  - Frequency
  - ACE
- Load and Generation



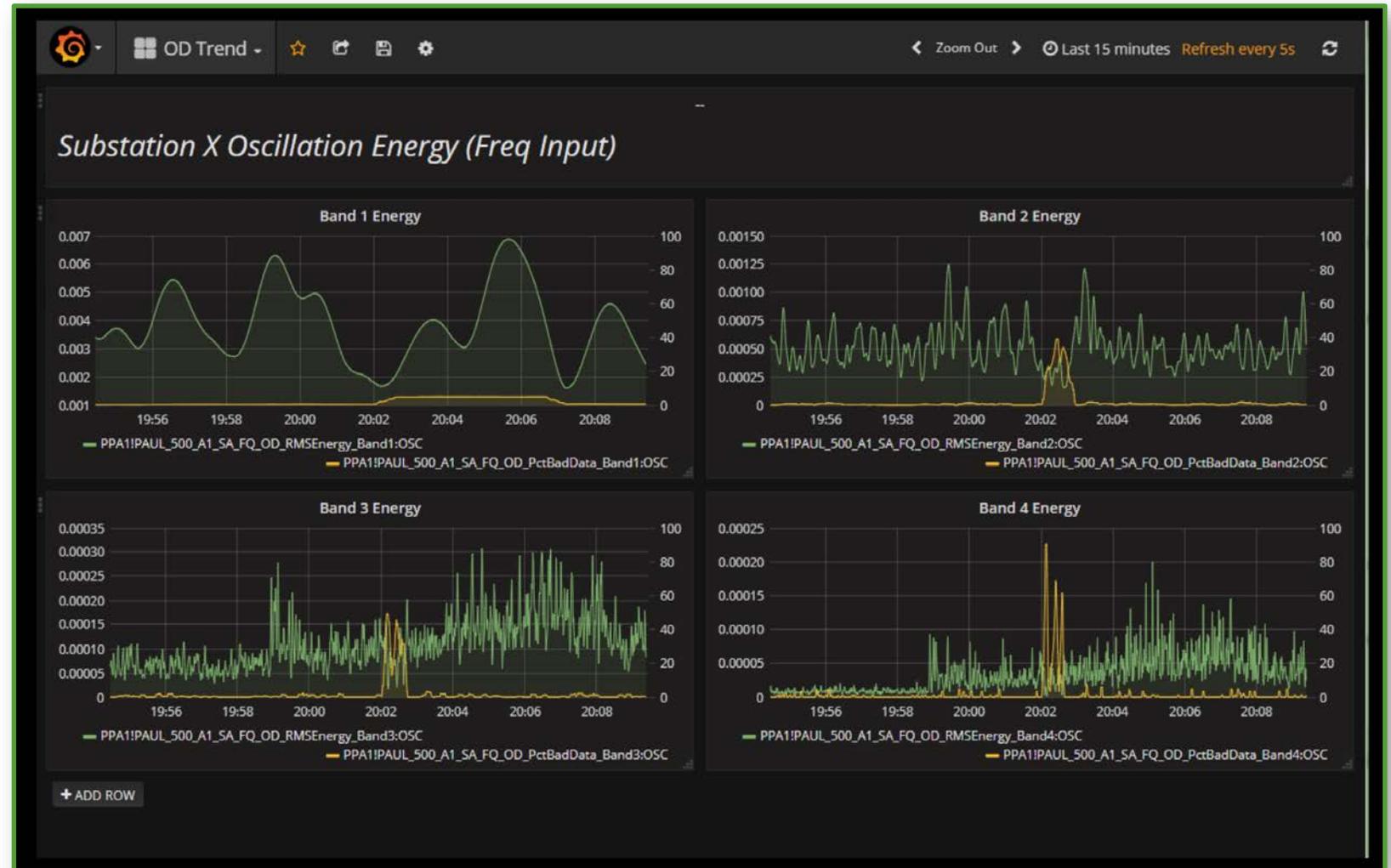
# Trending Data Displays – Grafana Dashboard, SPP

- Generation Mix
  - Mixed bar and line
  - Values and legend
  - Donut (current mix)



# Trending Data Displays – T&D Oscillation Detection

- 2-Axis
  - Energy
  - Bad Data
- 15 minute window
- 5 second refresh
- Oscillation Bands
  - Band 1 – 0.0 to 0.1 Hz
  - Band 2 – 0.1 to 1 Hz
  - Band 3 – 1 to 5 Hz
  - Band 4 – 5 Hz and Up



# Trending Data Displays – Grafana Data Monitor

- Display developed to monitor phasor data flow availability for TVA
- Connected to SDG&E test data for demonstration
- Demo will show:
  - Connecting to data sources
  - Using openHistorian time-series data functions
  - Speed of data load
  - Ease of adjustment of time scales
  - Ability to set local alarms



*A display to monitor data availability.*



# GPA Solution Functionality – “Mapped Data” Displays

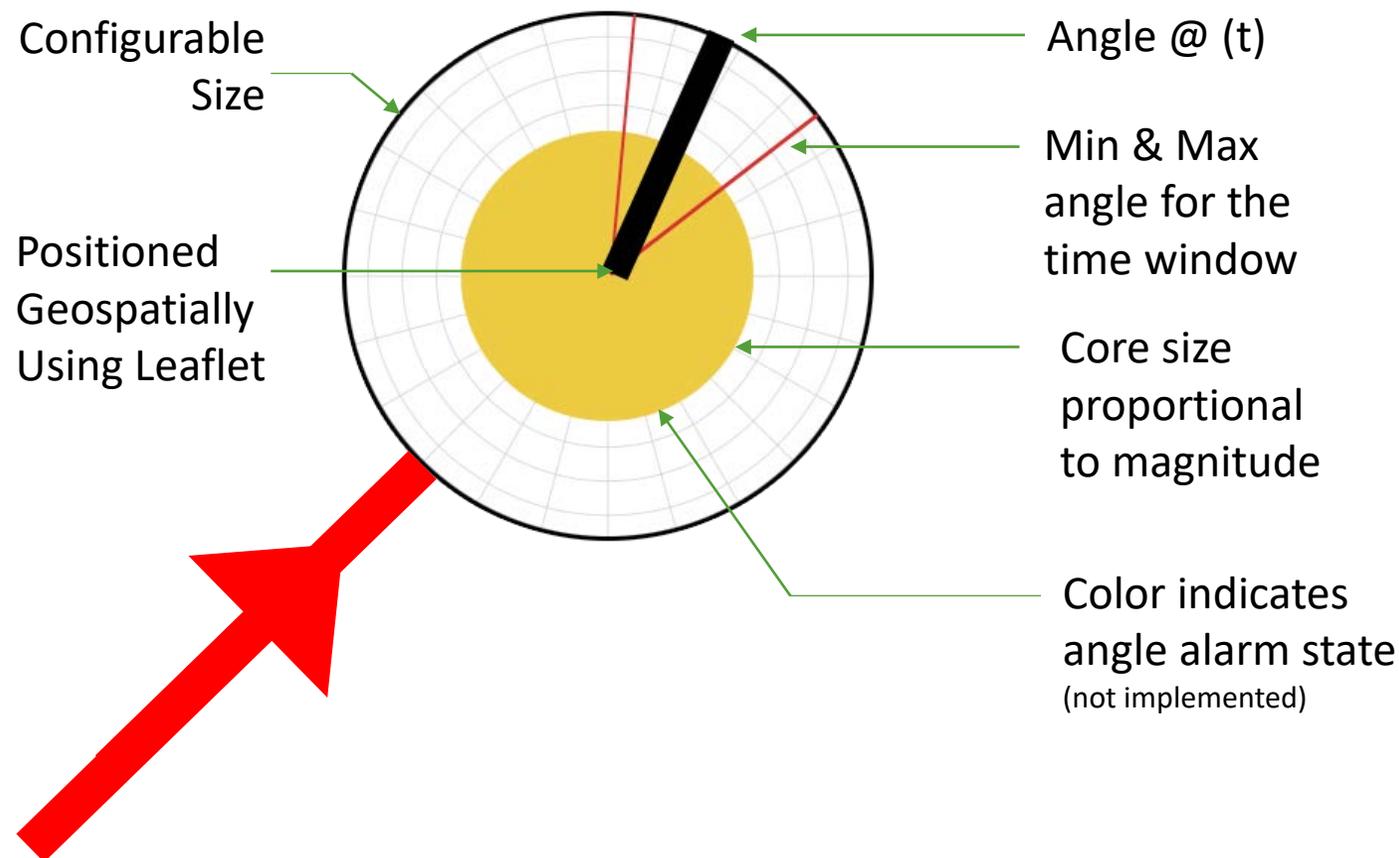
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- Demo – Phase Angle Difference Monitoring
- Demo – Over an Image
- Demo – Gradient Display / Map Overlay

# Developing a New Grafana Plugin – Leveraging Leaflet

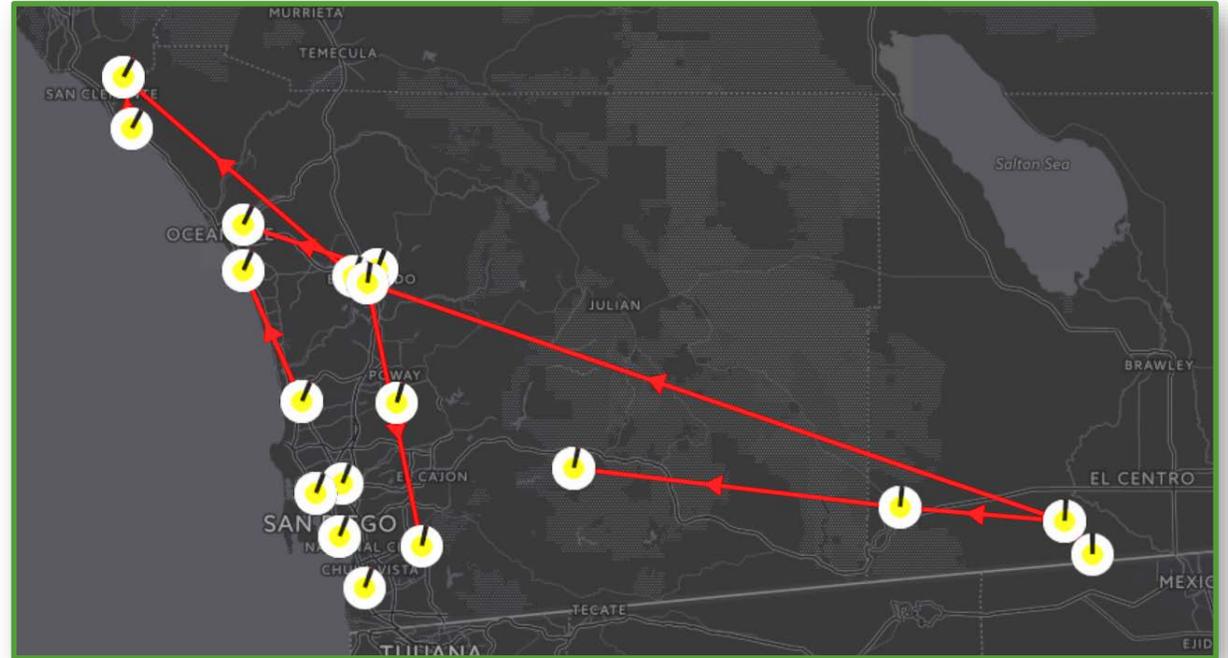
- Experiment to explore techniques and level of difficulty
- Widget consists of:
  - Value phase angle
  - Value magnitude
  - Min and max angle for the displayed time window
- Leverages native Leaflet “lines”
- Effort
  - 300 lines of TypeScript (compiled down to JavaScript)
  - About 2 days to develop and test

## The “Polar Widget” Design



# “Mapped Data” Displays – Phase Angle Difference Monitoring

- Used Leaflet and new “polar widget”
- Demo will show:
  - Ability to build custom Grafana panel with configurable options.
  - Geospatial display with zooming
  - Options for multiple map base layers
  - Drill down to more detail

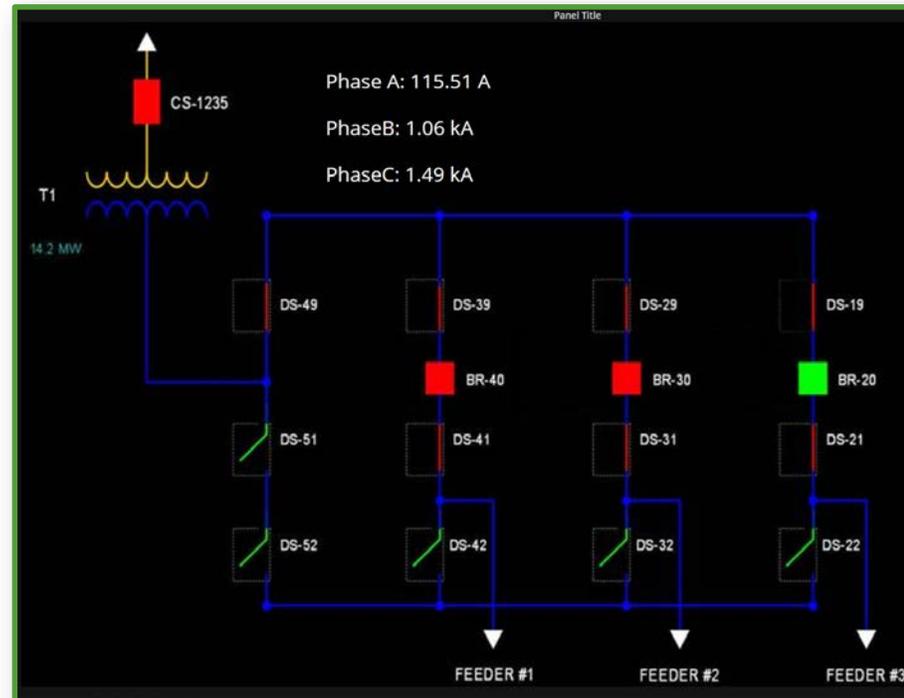


*A display to monitor angle differences.*



# “Mapped Data” Displays – Overlay Data on Image

- Data can be displayed over images – in this case a single line diagram
- Demo will show:
  - Superimposed data over an image with fast refresh

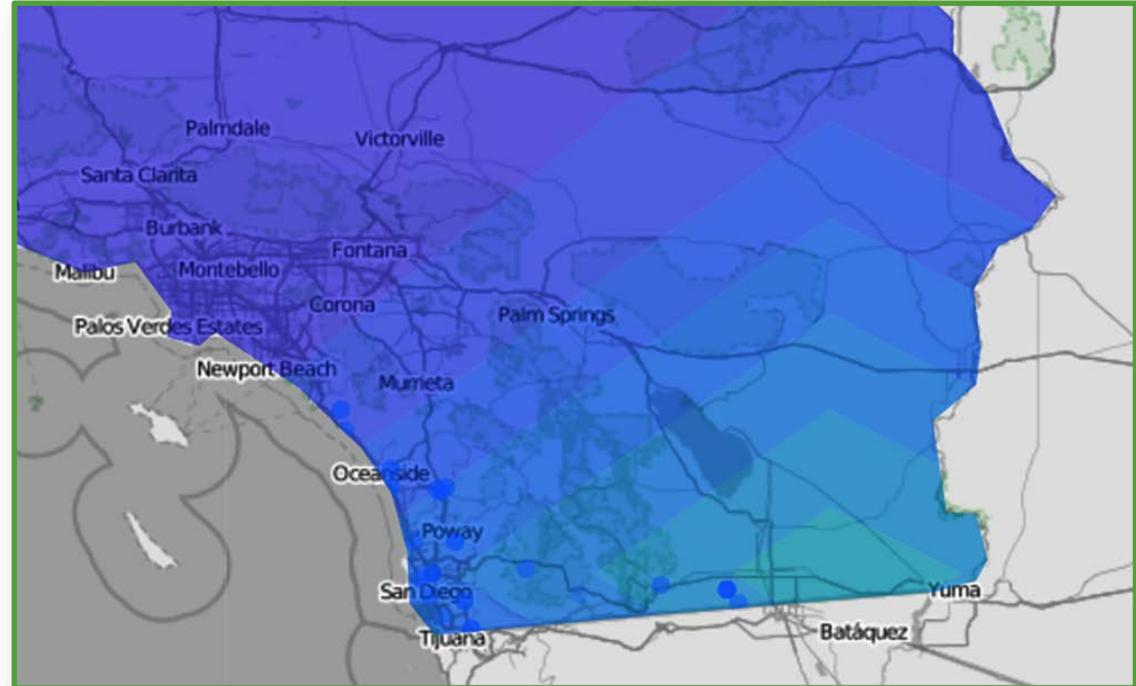


Note: GPA has researched building SCADA like HMIs (substation schematics) as a Grafana panel. We believe that highly functional displays can be built that meet SDG&E's requirements.



# “Mapped Data” Displays – Map Overlays

- Map overlays via Leaflet
- ESRI provides a tile layer for Leaflet
- Demo will show:
  - $df/dt$  on a gradient display
  - Ability to zoom and pan the map display
  - Addition of a weather layer



*A display to highlight frequency change.*



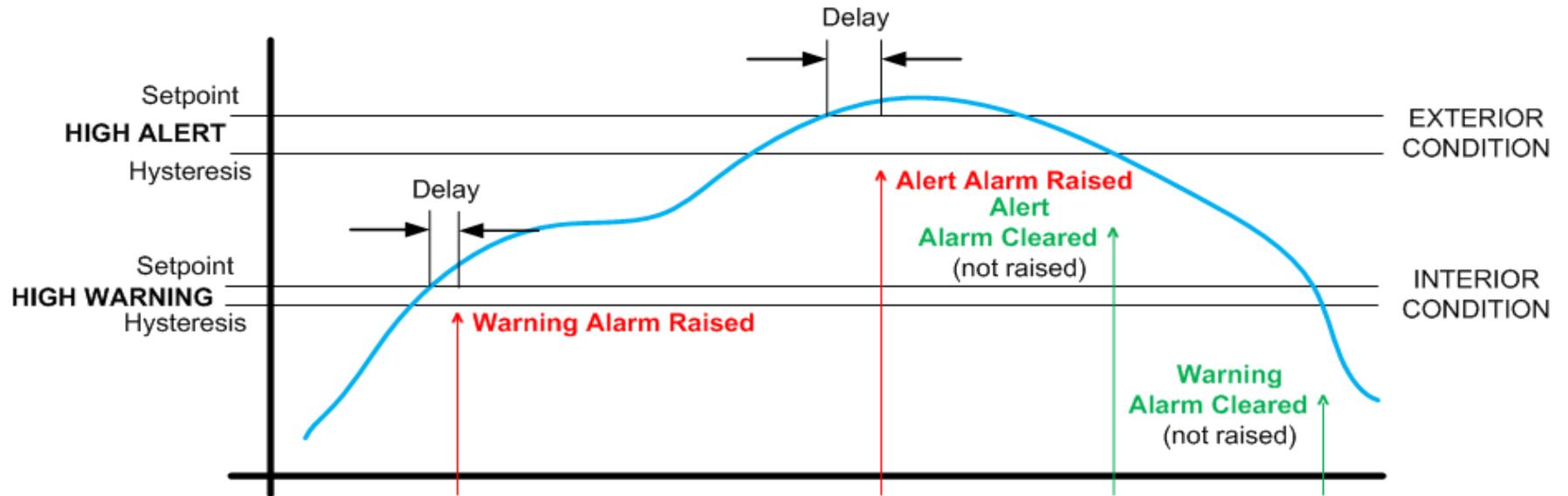
# GPA Solution Functionality - Alarming

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- Standard Alarming
- New “Advanced Tools” Alarming
- Alarm Management
- RFP Requirements vs. GPA Proposal

# GPA Standard Alarming

- Full featured alarming service in use since 2011
- Includes
  - Delay
  - Hysteresis



# Enhanced Data Quality and Range Flags Carried with Data

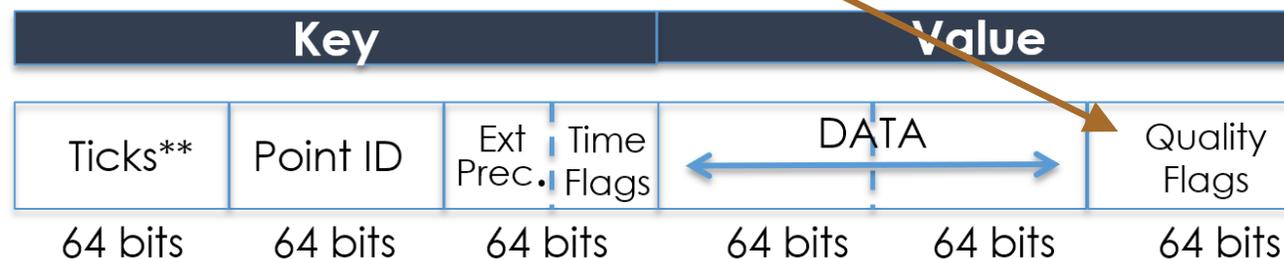
## ■ Bad Data Flags

- Time
  - Data
- } *As identified by the PMU*
- Unreasonable  
*Outside engineering possibility*
  - Latched
  - ... and more

High Bits	Bad Data Flagging	Low Bits	Good Data Flagging
16	Bad Time	0	RESERVED
17	ReceivedAsBad	1	Implausibly Low
18	MissingValue or NAN	2	Low Alarm
19	UnreasonableLow	3	Low Warning
20	UnreasonableHigh	4	Low Atypical
21	Flatline	5	High Atypical
22	Noisy	6	High Warning
23	RESERVED	7	High Alarm
24	RESERVED	8	Implausibly High
25	RESERVED	9	Non-congruent
26	RESERVED	10	RESERVED
27	RESERVED	11	RESERVED
28	RESERVED	12	RESERVED
29	RESERVED	13	RESERVED
30	RESERVED	14	RESERVED
31	RESERVED	15	RESERVED

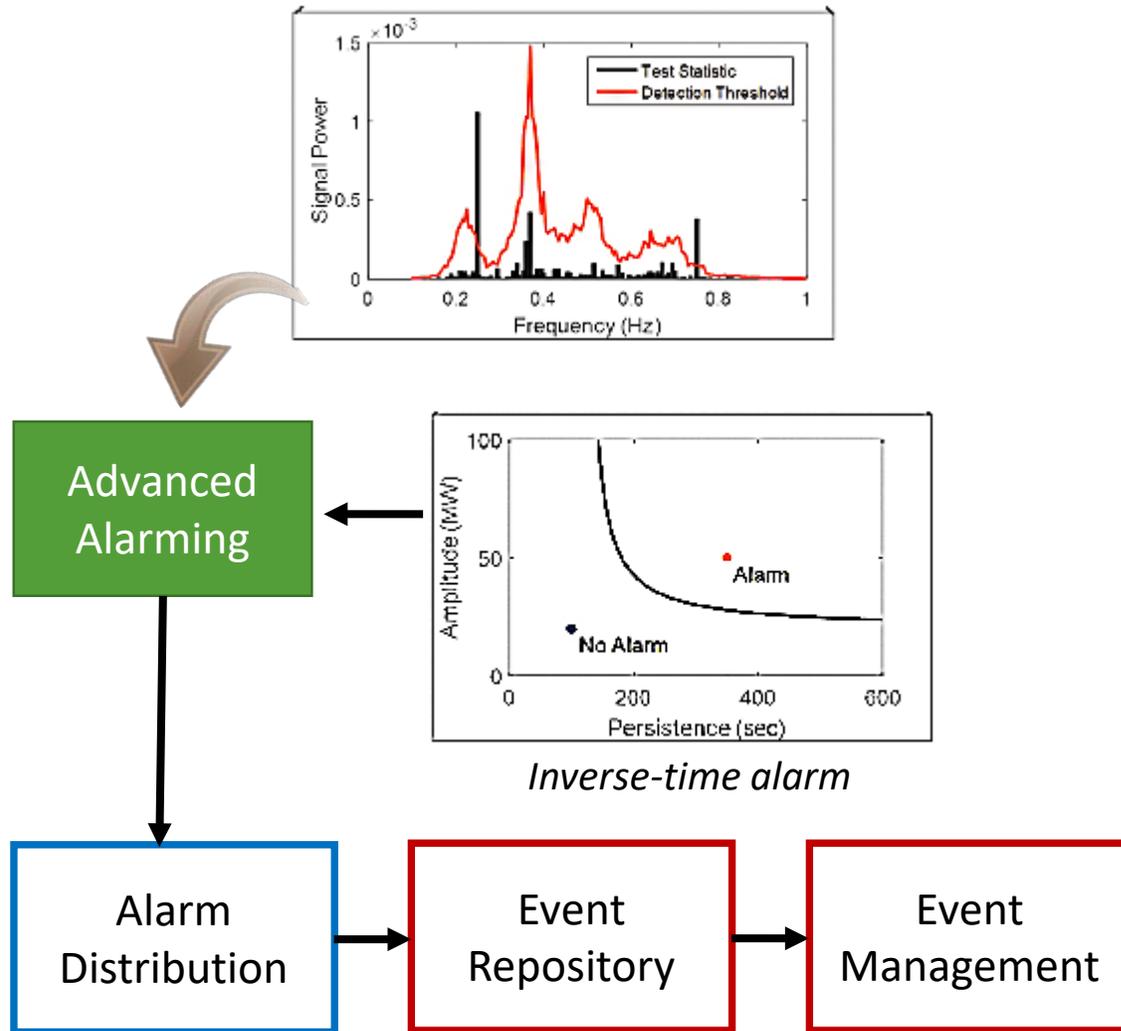
## ■ Data Range Flags

- Standard Control Chart
  - Warning
  - Alarm
- Implausible



*open* **Historian 2** & **sttp**

# Advanced Alarm Generation – For Example, Oscillation



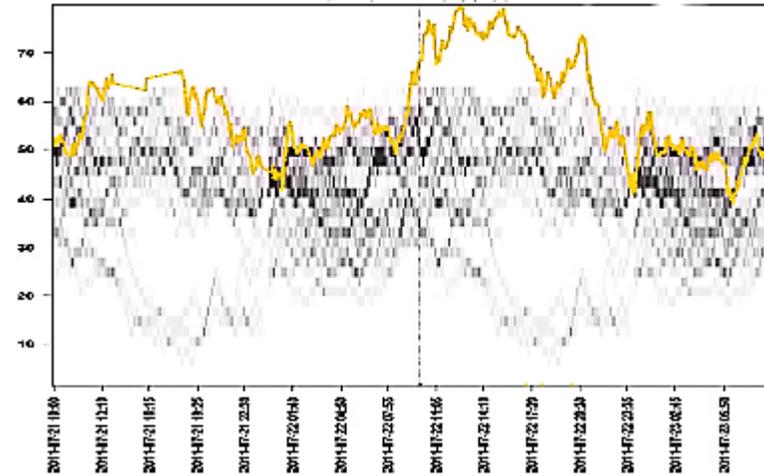
- Advanced alarms can be derived from multiple other values and/or alarms
- Advanced alarms can be based on more complex alarming criteria.
- Advanced alarms can include suppression logic.

**Alarm Management System**

# Atypical (off-normal) Alarming

- Simple learning required
  - Histogram of minute-of-week data
- Data science techniques could yield higher value

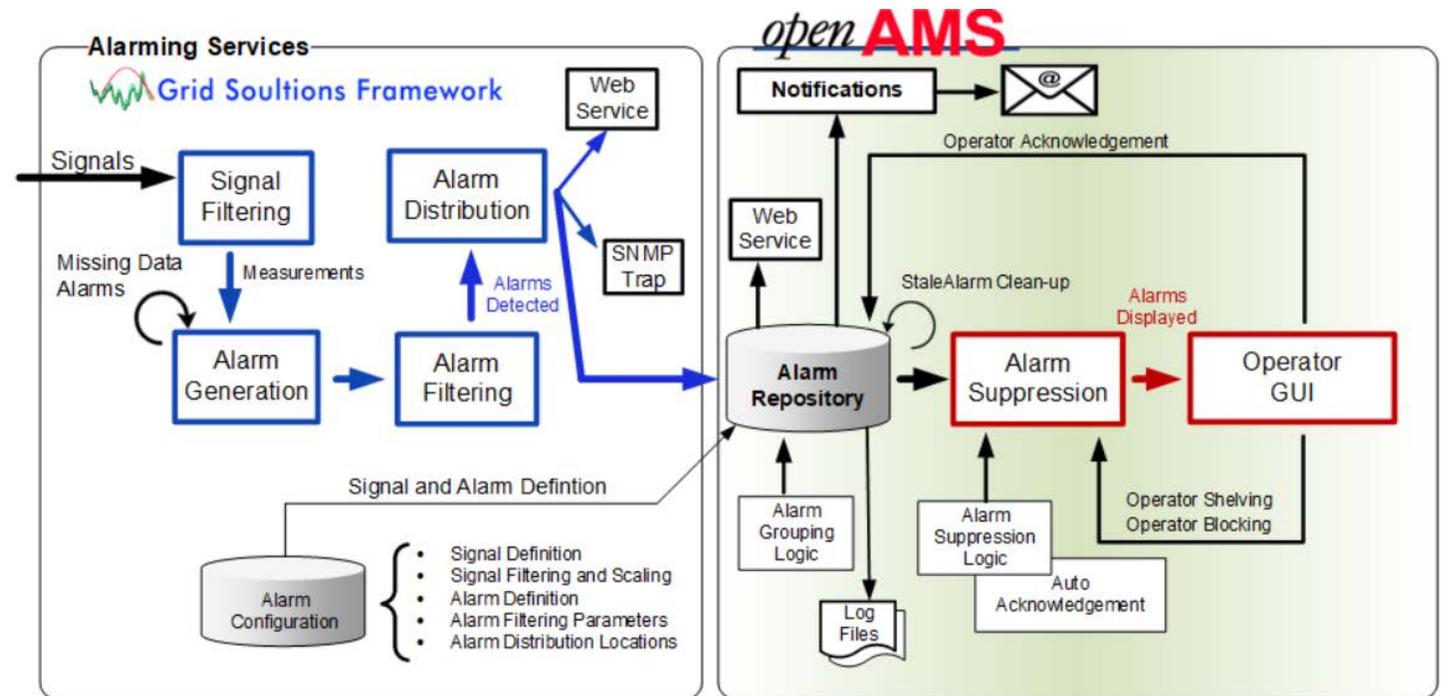
### Historical Angle-Pair Data



■ Atypical pattern

# Alarming Vision

- Alarms – Something that requires operator attention and action
- Alarms can be raised from events from multiple tools and systems
- A single system manages the operator interface

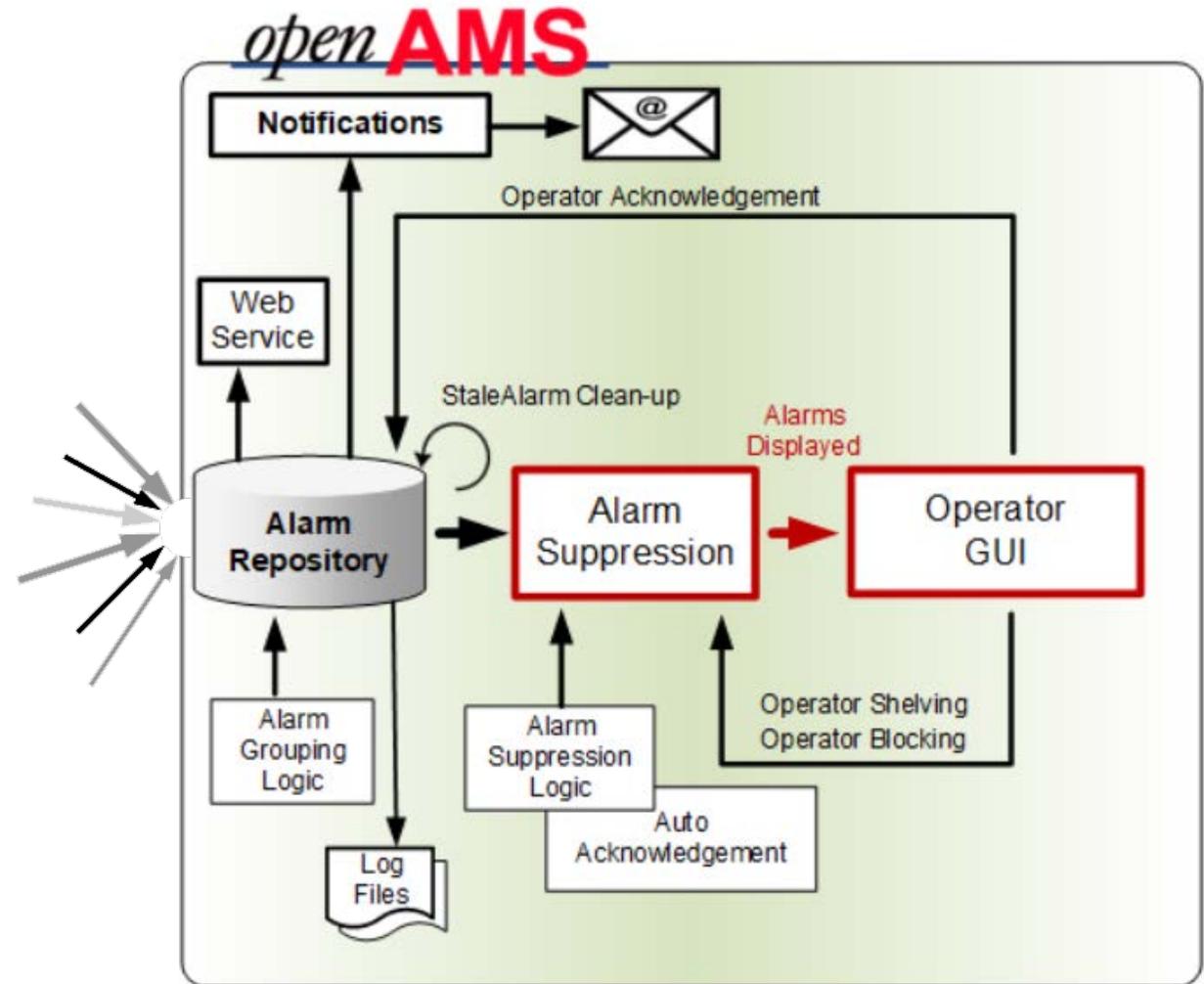


ISA 18.2



# RFP Requirements vs. GPA Proposal

- Multiple Outputs
- GUI(s) Configurable
- System Flexibility
- Drill to substation schematic
- Display in tables
- Operator Acknowledgement
- Suppress nuisance alarms



# GPA Solution Functionality - Building New Displays

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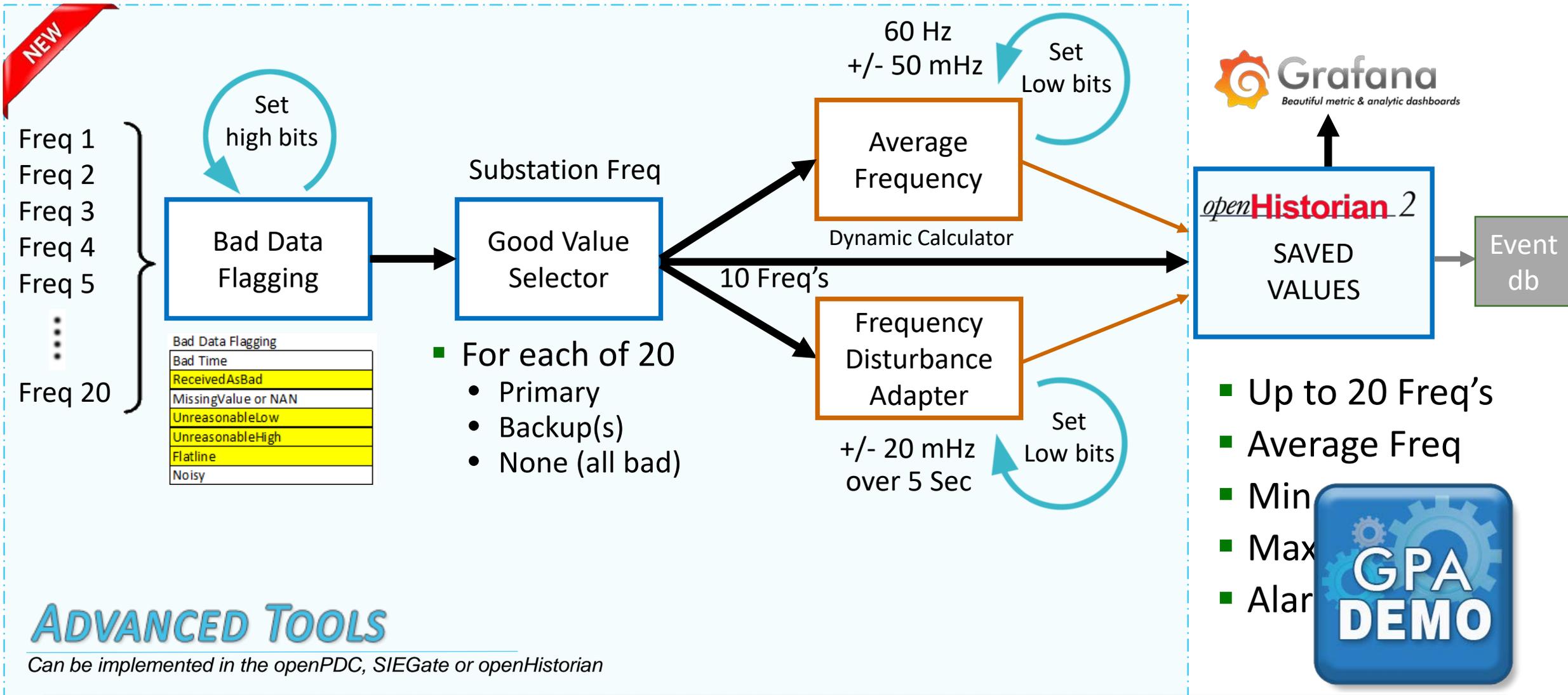
- Demo – Building a frequency disturbance monitor

# Frequency Disturbance Monitor Requirements (for Demo)

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- Based on frequencies from each substation – each with a primary and one or more back-up measurement sources. Alert if primary is not available.
- Alarm if average frequency is outside 50 mHz control band from nominal
- Alarm if any frequency deviates by more than 20 mHz vs. a 5 second rolling average.
- Show alarm clearly on the display

# Frequency Disturbance Panel – Data Flow



# Solution Functionality – Adding New Analytics

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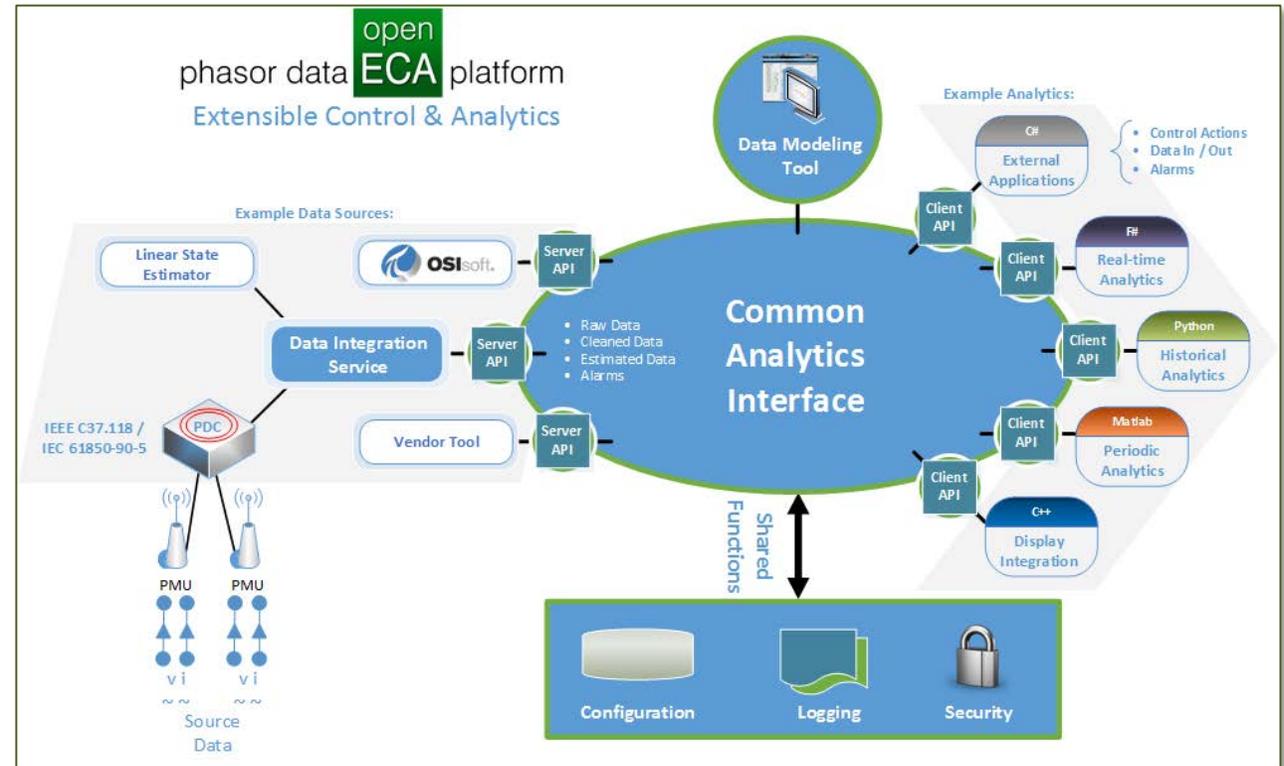
- Introduction to openECA
- Demo – building a new analytic from scratch

# Analytic Functionality – Introduction to openECA



DOE FOA 970  
DE-OE-778

- Lowers cost of addition of new production analytic tools
- Simplified end-to-end configuration and change management
- Improved availability of phasor data with greater visibility of phasor data quality
- Robust scalable solution to support phasor data infrastructure of any size
- Complements existing phasor data architectures and supports integration with other data sources such as SCADA



T&D CONSULTING ENGINEERS



OG/E



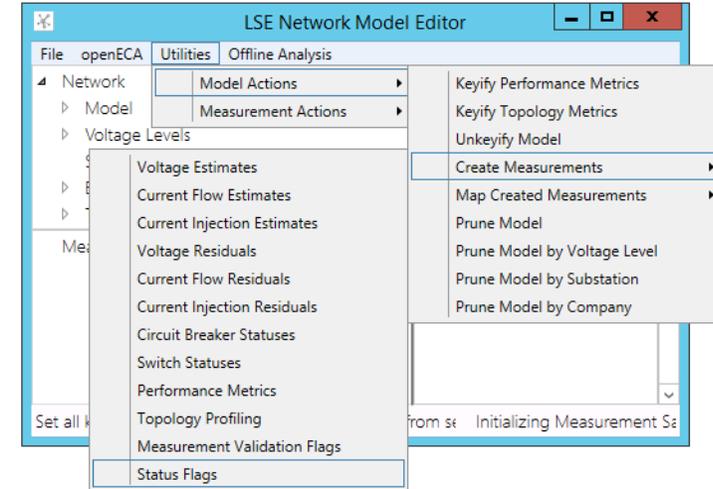
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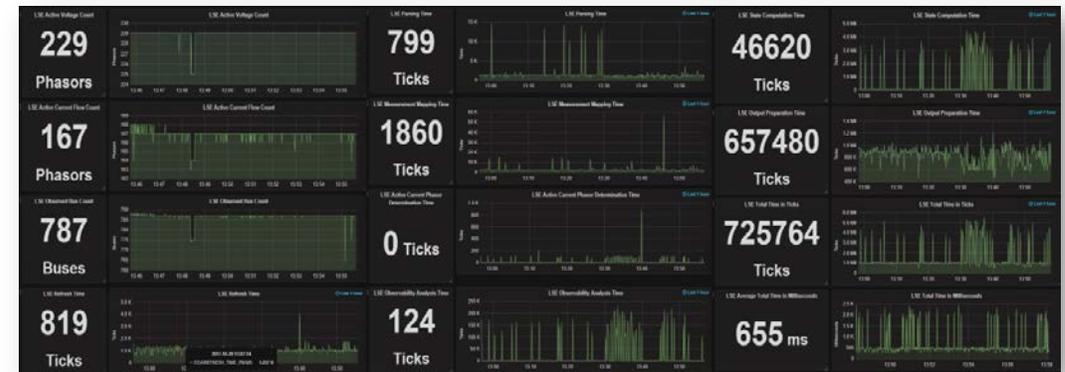
## Features

Service, Installers: <https://github.com/kdjones/openLSE>  
 Core Libraries: <https://github.com/kdjones/lse>

- **Architecture:**
  - Easy to use installation package
  - Deployable as a real-time service.
  - Directly integrated with openECA.
- **Tools: Modeling and Offline Analysis Tool**
  - Automated model build & measurement mapping
    - Model Schemas: GE-Alstom, PSSEv33, and expanding
  - Integration with openECA for automated meta-data creation
  - Integrated measurement sampler for offline testing
  - Single and batch offline analysis, reports
- **Visualization: Out-of-the-box Grafana dashboards for trending of Input, Output, Performance Metrics**
- **Docs: Wiki contains walkthrough for all procedures**



Integrated Modeling and Offline Analysis Tool



LSE Performance Metrics shown in Grafana

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## Advantages over other LSEs

- Performs estimation with or without breaker status telemetry
- Completely open source software
- Interoperability through openECA
- Positive Sequence and Three Phase Estimator
- Native Intel MKL Linear Algebra Providers
- Automatically disables input measurement chatter
- Multiple output data types:
  - flows, residuals, breaker statuses, validation flags, metrics, etc.
- Supported with domain expertise and active development



## ■ Real-Time Analytics

- Oscillation Detection Monitor (ODM) T&D
- Oscillation Mode Meter (OMM) T&D
- Topology Estimation

## ■ Control

- Regional Volt-Ampere-Reactive (VAR) Control
- Local VAR Control
- PMU Synchroscope

## ■ Off-Line Analytics

- Dynamic PMU Transducer Calibration (Automated, Periodic Use Case)
- Line Parameter Estimation (Ad-Hoc Use Case)
- Synchronous Machine Parameter Estimation (Research Use Case) T&D
- Acceleration Trend Relay (ATR) Improvement (Research Use Case) T&D

Plus: Linear State Estimation

- Proprietary
- Open source

# T&D Domain Expertise Will Be Applied To Analytics

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- Development of analytics related to 24 use cases from Appendix C of RFP
- Specification and QC for visualization widgets related to “custom” analytics (i.e. those analytics that are more sophisticated than built-in functions)
- Testing, training and refinement of analytics and visualization widgets

# Demonstration – Building and deploying a new analytic

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- Standard Deviation of Power

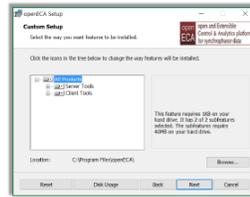


- Oscillation detection “on the cheap”

# openECA – Process for Building an Analytic

## 1. Install

<https://github.com/GridProtectionAlliance/openECA/releases>

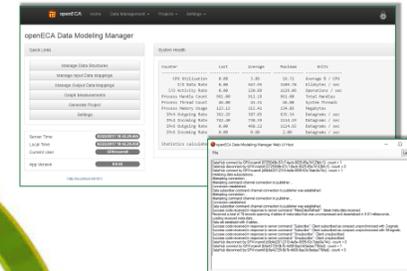


During configuration setup, pick the data to provide the new analytic

or select "Sample Dataset"

## 2. Model the Data

openECA client starts a browser-based tool



open  
ECA open and Extensible  
Control & Analytics platform  
for synchrophasor data

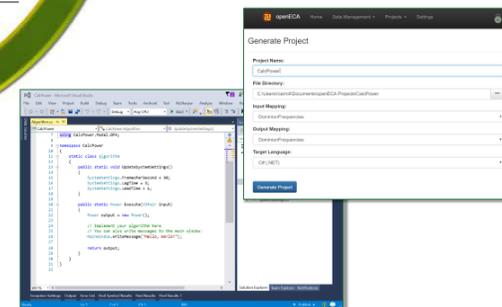
## Workflow

## Implementing An Analytic

## 4. Run & View Results



## 3. Create Project & Add Analytic



# Managing Configuration

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- Metadata Management
- Configuration Management Tools

# Meta Data Management

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- Metadata dynamically exchanged via GEP
- Modeled after C37.118  
signal → phasor → device → location
- Extensible
- Patterns for metadata management currently being debated within the STTP project

# Configuration Management Tools

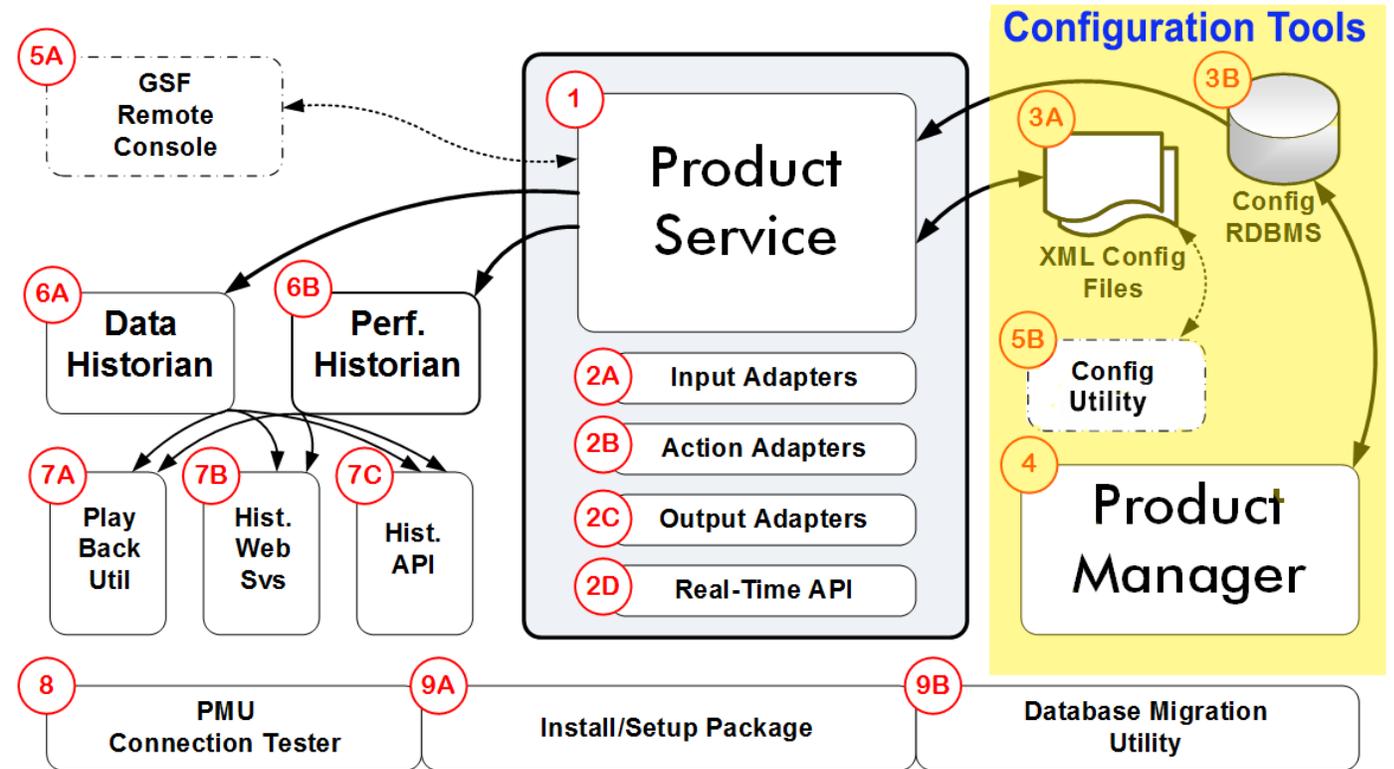
- openPDC/SIEGate/openHistorian Manager

- Add a PMU / Add a signal
- Apply security settings
- Monitor application status

- Console provide low-level system diagnostics

- Configuration Utility

- Installation
- Switch configurations (e.g., promote test to production)



# Application Demonstration – Additional Questions ?

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