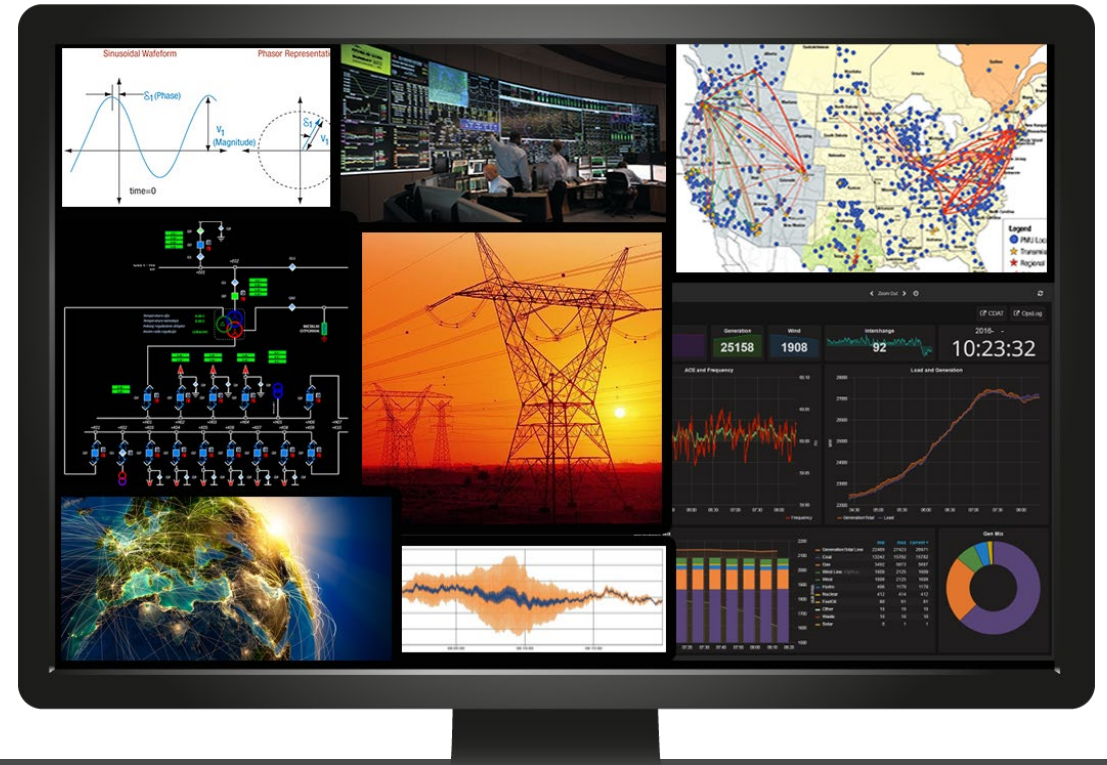




GRID  
PROTECTION  
ALLIANCE

April 17, 2024



# Use Cases for Big Synchronphasor Data

## Simple Options for Using Data in Asset Health Analysis

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# About GPA

# Grid Protection Alliance



**GPA is a not-for-profit corporation established in 2010.**

- Specializes in software and services for the electric utility industry
- All software is open-source, published under the permissive MIT license
- Focus is on a robust, reliable and resilient grid

<https://gridprotectionalliance.org>

*Tools Used for Analysis...*

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# GPA Synchrophasor Products


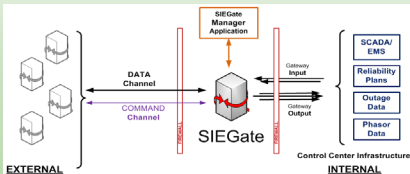
# GPA's Synchrophasor Open-Source Product Suite

<https://github.com/GridProtectionAlliance>

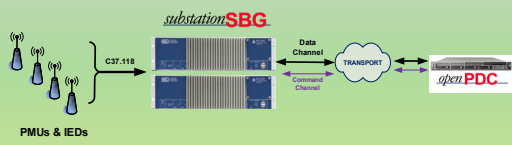
Daily updates available at <https://gridprotectionalliance.org/NightlyBuilds/>

## Collect

### *open* PDC

### SIEGate



### substationSBG

## Distribute

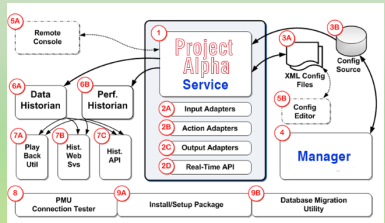

### Synchrophasor Stream Splitter





### sttp

## Analyze

### TSL Project Alpha





### DATA WALKER *open*Historian




### PDQ TRACKER

phasor data quality alarming & reporting



Category	Count	Percentage
2-Day Completeness Report	10/22	10/23
Good	21	24
L2 Gap	73	10
L1 Gap	5	5
L1 Off-Ph	0	0
L1 Failed	0	0
<b>Total</b>	<b>99</b>	<b>99</b>

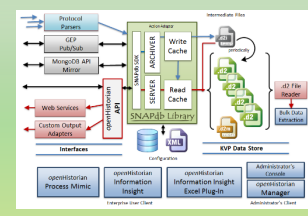


### openECA

open and Extensible Control & Analytics platform for synchrophasor data

## Save


### *open*Historian 2



## Display



### PLAYBACK UTILITY *open*Historian



### Grafana

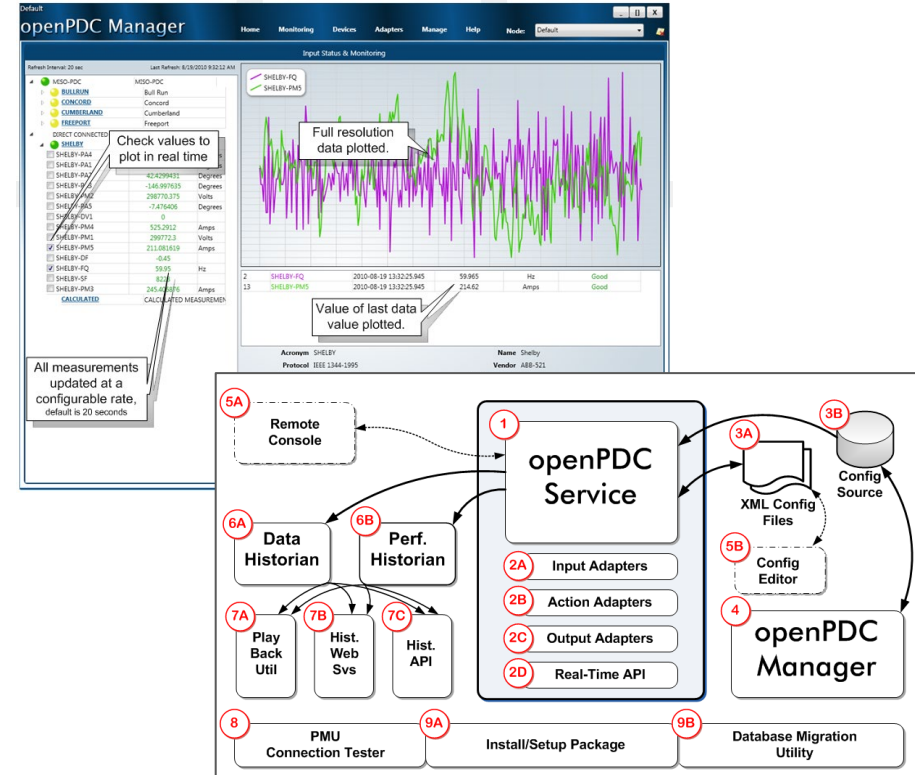
Beautiful metric & analytic dashboards



# openPDC

Version 2.8

- The electric industry's work-horse PDC supporting the largest synchrophasor data systems in North America
- Massively threaded, distributed multi-node architecture enables high availability and throughput  
Logs performance history every 10 seconds – includes latency, data completeness, and connection errors, among others
- Supports Windows (including Server versions) - Linux & Apple OSX deployments supported via Mono
- Easily extensible with the development of input, output or action adapters
- Remote manager simplifies administration





# openHistorian

Version 2.7

## High performance processing of time-series data

- For both data archival and retrieval
- High frame rate application refresh
- Fast extraction of large data blocks

## Support for multiple data types

## GPS precision timestamps

## Can insert data out of sequence

## Lossless data compression

**openHistorian System Components**

Interfaces: openHistorian, Home, Devices, Monitoring, Reports, Settings, Help

**New Device Commissioning Wizard** Editing TESTDEVICE Instance: PPA

Connection Settings

Device Acronym: TESTDEVICE [Build] [Save Device]

Device Name: Test Device [Export Config]

Latitude: 35.3671 Longitude: -89.803 [Import Config]

Tag Template: Three Phase Power Calculations

Config Frame: Device Count 1 - 2 Voltage Phasors, 3 Current Phasors, 0 Analogs, 0 Digitals  
 Connection String: Transp|Protocol=File; File=Sample1544.PmuCapture; user=HighResolution|InputTime=true; forwardOnly=false

Voltages				Currents			
Phasor Label	Phase	Nominal Voltage		Phasor Label	Phase	Associated Voltage	
<input checked="" type="checkbox"/> 500_KV_BUS_1	+	500 KV		<input checked="" type="checkbox"/> CORDOVA	+	500_KV_B_	
Tag name GPM_TESTDEVICE-500_KV_BUS_1_V1_300 (MAG/ANG)				Tag name GPM_TESTDEVICE-CORDOVA_V1_300 (MAG/ANG)			
<input checked="" type="checkbox"/> 500_KV_BUS_2	+	500 KV		<input checked="" type="checkbox"/> DELL	+	500_KV_B_	
Tag name GPM_TESTDEVICE-500_KV_BUS_2_V1_300 (MAG/ANG)				Tag name GPM_TESTDEVICE-DELL_V1_300 (MAG/ANG)			
				<input checked="" type="checkbox"/> LAGOON_CREEK	+	500_KV_B_	
				Tag name GPM_TESTDEVICE-LAGOON_CREEK_V1_300 (MAG/ANG)			

**23kV Sector**

AL-17: 0.3 MW, 0.4 MVAR  
 AL-16: 0.3 MW, 0.4 MVAR  
 AL-15: 0.2 MW, 0.2 MVAR  
 AL-14: 0.3 MW, 0.3 MVAR  
 AL-13: 0.5 MW, 0.3 MVAR  
 Transf.: 0.0 MW, 0.0 MVAR  
 AL-12: 0.5 MW, 0.2 MVAR  
 AL-11: 0.7 MW, 0.4 MVAR

*Tools Used to Move Data...*

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# Data Transfer Technologies



# New Protocol Streaming Data – IEEE 2664

## Advanced Synchrophasor Protocol Project

sttp



DOE FOA 1492  
DE-OE0000859

ASP

Streaming Telemetry Transport Protocol



- US DOE Project
- Intrinsically reduces losses and latency compared to frame-based protocols
- Allows the safe co-mingling of phasor data with other operational data network traffic
- Detailed metadata exchanged as part of protocol
- Includes lossless compression to reduce bandwidth utilization
- Security-first design with strong authentication and option for encryption

# Adapters Can Push Data to Cloud in Real-Time

- The openPDC and openHistorian include a new adapter that can send data to a cloud repository
- In production use for the Azure Event Hub
- Other cloud data repositories are being added
  - Amazon Kinesis
  - Google Pub/Sub

The screenshot shows the 'openHistorian Manager' web interface. The main content area is titled 'Manage Custom Output Adapters'. A form is displayed for configuring an adapter with the following details:

- Name:** AZURE-CLOUD-PUSH
- Load Order:** 0
- Adapter Type:** AzureEventHubAdapters.AzureEventHubOutputAdapter from AzureEventHubAdapters.dll
- Search Directory:** C:\Program Files\openHistorian\
- Type:** AzureEventHub: Sends measurements to an Azure Event Hub
- Connection String Parameters:**
  - EventHubMetadataClientConnectionString: Value: Default
  - EventHubMetadataClientName: Value: Default
  - InputMeasurementKeys: Selected in the dropdown
  - MetadataPartitionKey: Value: Default
- Connection String:** InputMeasurementKeys={FILTER ActiveMeasurements WHERE SignalType='FREQ'}; EventHubDataClientConnectionString=(Endpoint=sb://time-series-test.servicebus.windows.net;/SharedAccessKey=time-series-test;Name=publish); EventHubDataClientName=time-series
- Runtime ID:** Initialize
- Enabled:**

At the bottom, there is a table with columns: Name, Assembly Name, Type Name, and Enabled. The table is currently empty, and the page size is set to 7 of 0 items.

*Existing Reports for Analytic Use Cases...*

---

# Example Analytic Reports *operating on historical data*

# Signal to Noise Reports

- Cause of growing noise – failed fuse clip



## Unbalance and SNR Report

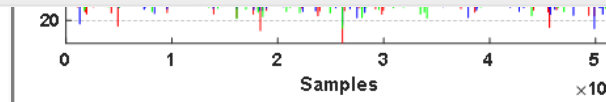
Instance: REP Records: 25

Report Period: Last 30 Days Start Time: 03/23/2020 18:21:41.63900 End Time: 04/22/2020 18:21:41.63900

Filter: Worst 25 Signal to Noise Ratio by Maximum Generate Report

## Worst 25 SNR Report

Tag Name	# of Alarms	Time in Alarm	Percent in Alarm	Mean	Standard Dev.	Maximum	Minimum	Clear Sort
XFR99999:F	2200	0d 0h 1m 13s	50.00	53.29	2.545	60.26	40.47	
XFR88888:F	2155	0d 0h 1m 12s	50.00	49.73	1.534	55.24	40.75	
XFR77777:F	2152	0d 0h 1m 12s	50.00	49.72	1.532	55.24	40.76	
XFR66666:F	2152	0d 0h 1m 12s	50.00	49.72	1.532	55.24	40.76	
Line-A.IH	2134	0d 0h 1m 11s	43.85	41.61	7.247	48.87	-26.54	
Line-B	2132	0d 0h 1m 11s	42.75	42.29	7.282	48.06	-17.63	



Source: Tennessee Valley Authority

# Unbalance Reports

- Unbalanced Operation leads to
  - Higher losses
  - Stress on transformers and generators
- Unbalance Reports
  - Identify unbalanced lines
  - Alert and notify

Unbalance and SNR Report

Instance: REP Records: 25

Report Period: Last 30 Days Start Time: 03/23/2020 18:21:41.63900 End Time: 04/22/2020 18:21:41.63900

Filter: Worst 25 Voltage Unbalance by Maximum Generate Report

### Worst 100 Unbalance Report

Tag Name	# of Alarms	Time in Alarm	Percent in Alarm	Mean	Standard Dev.	Maximum	Minimum	Clear Sort
XFR99999	2200	0d 0h 1m 13s	50.00	3.50	0.054	4.28	0.00	
XFR88888	2155	0d 0h 1m 12s	50.00	3.48	0.206	4.01	0.00	
XFR77777	2152	0d 0h 1m 12s	50.00	3.27	0.032	3.39	0.00	
XFR66666	2152	0d 0h 1m 12s	50.00	3.22	0.049	3.30	0.00	
Line-A	2134	0d 0h 1m 11s	43.85	2.98	0.042	3.29	0.00	

*Existing Reports for Analytic Use Cases (expanded set)...*

---

# Other Example Reports *using “more” than synchrophasors*

## **Synchophasor++**

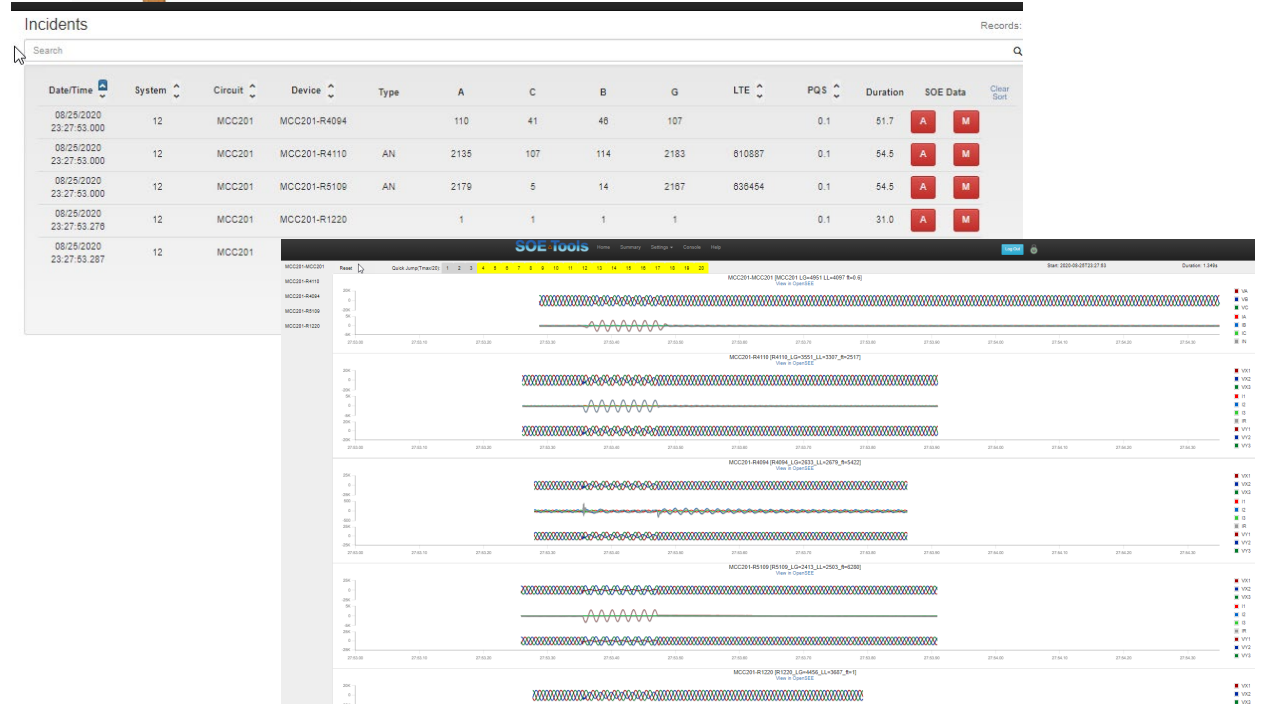
# Sequence-of-Event Analytics

## Features

- EPB Chattanooga has 1100+ “self-healing” S&C IntelliRupters connected to their fiber network
- Has made major improvements to EPB SAIDI and SAIFI
- GPA has developed SOE Tools to help EPB investigate disturbances and validate IntelliRupter operation
- Next step are displays for distribution operators to augment data from distribution SCADA



# SOE Tools



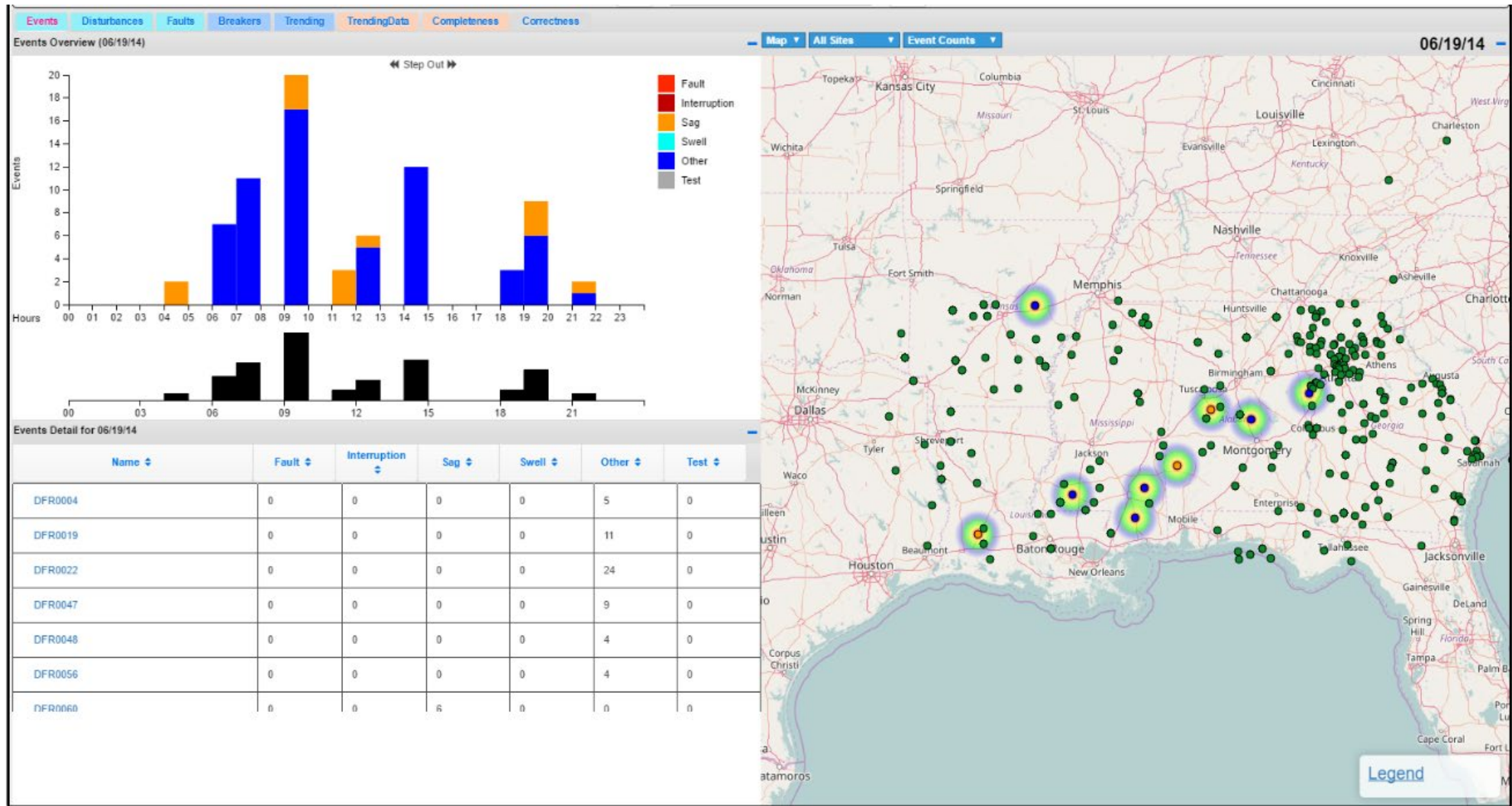
# Breaker dashboard from Relay Data

*Near Real-time*  
data from  
relays via  
DNP3

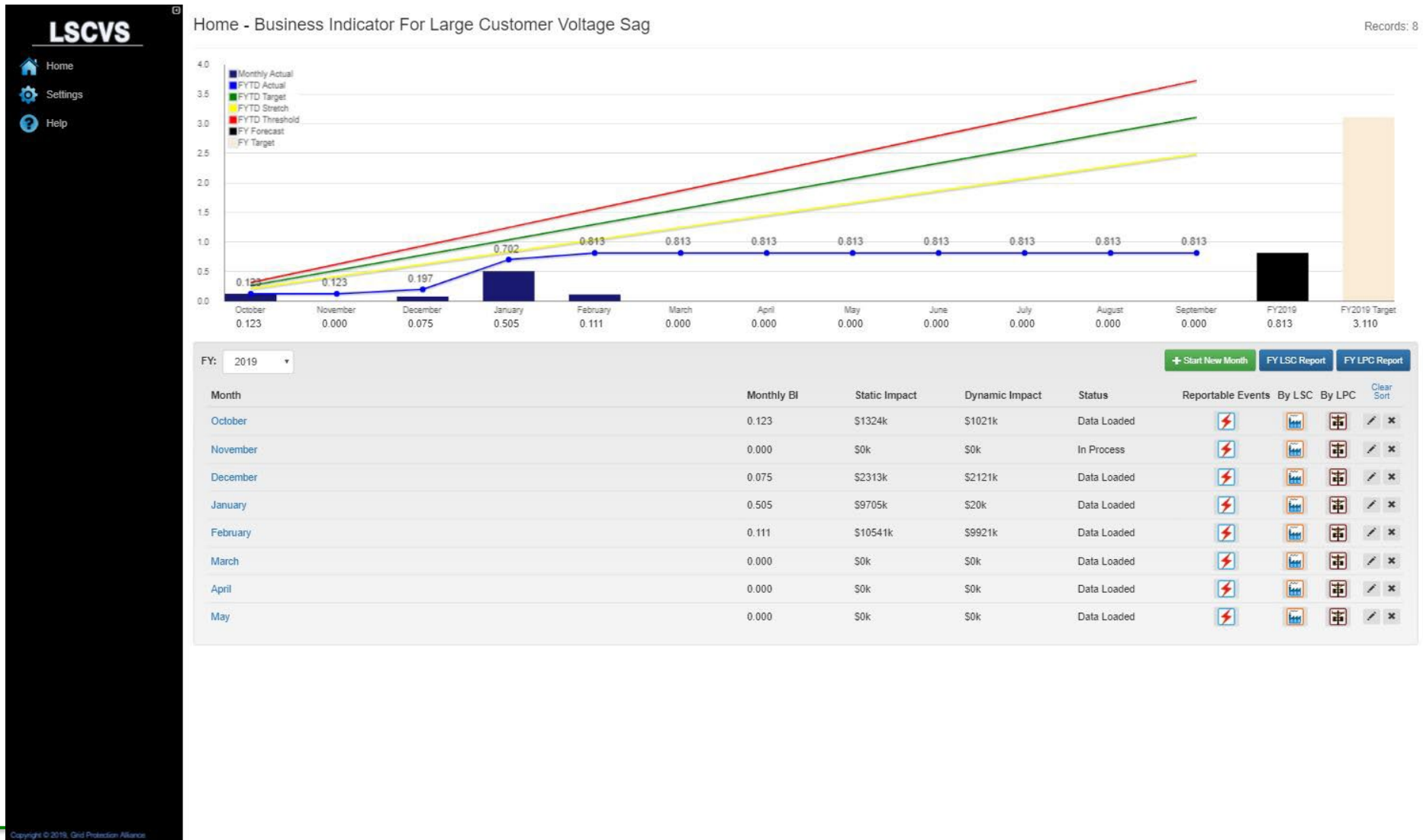




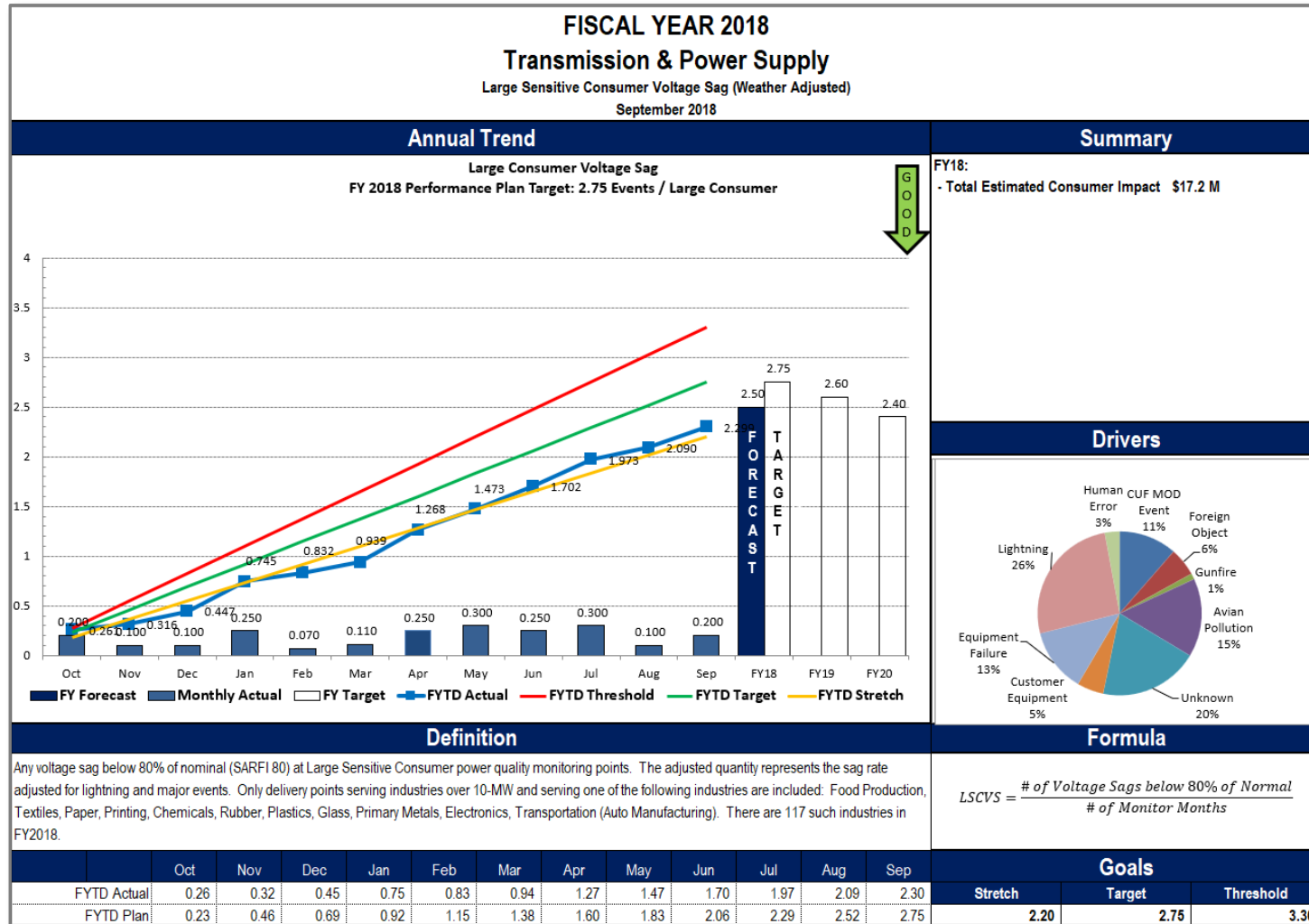
# Event Dashboard



# Large Sensitive Customer Voltage Sag Report



# Large Sensitive Consumer Corporate Business Metric



*Not actual TVA metric data.*

*Alarms for Analytic Use Cases...*

---

# Example Analytic Alarming *operating on real-time data*

# Real-time Current Unbalance

---

- Simple equation:

$$\mathbf{I2} / \mathbf{I1}$$

- Where **I2** is the negative sequence current magnitude
- And **I1** is the positive sequence current magnitude

# Current Unbalance Benefits

---

- **Fault Detection and Analysis:** Quickly identifies imbalances that may indicate phase-to-phase faults, or ground faults, which are often signaled by an increase in the negative sequence current component relative to the positive sequence.
- **Health Monitoring of Equipment:** Regular monitoring of sequence components helps in assessing the health of electrical equipment. An increase in the negative sequence component can indicate issues like uneven load distribution or potential equipment failures.
- **Grid Stability Insights:** Helps in understanding the stability and balance of the grid by analyzing the distribution of currents. An ideal balanced system should have minimal negative sequence currents, so deviations from this can signal potential issues.
- **Preventive Maintenance Triggers:** Can be used to automate alerts for maintenance teams when certain thresholds are breached, potentially preventing more significant problems by addressing issues early.
- **Enhanced Operational Decision Making:** Provides operators with real-time data to make informed decisions regarding load balancing, phase adjustment, and other operational strategies to maintain system reliability and efficiency.

## Real-time Alarming Trigger (configurable)

---

- 1) **I2/I1 ratio is greater than 10, and**
- 2) **I1 value is greater than 10 amps for 5 seconds.**

*When alarm is triggered, can send an e-mail  
or trigger an alarm monitoring system*

# Don't Fear the Code...

---

*Simple calculation executed every 1/30 of a second  
Implemented as an **openPDC Action Adapter***

```
// Get values
```

```
double i1 = measurementI1.AdjustedValue;
```

```
double i2 = measurementI2.AdjustedValue;
```

```
// Calculate value
```

```
double result = i1 == 0.0D ? double.NaN : i2 / i1;
```

```
// Publish result
```

```
OnNewMeasurements(new [] { Measurement.Clone(pair.Value, result, frame.Timestamp) });
```