Project Summary

EPRI Program 1: Power Quality

April 2015

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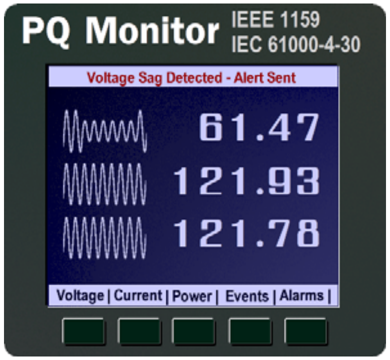
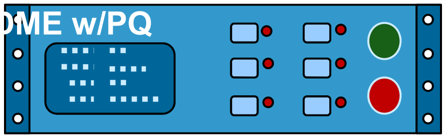
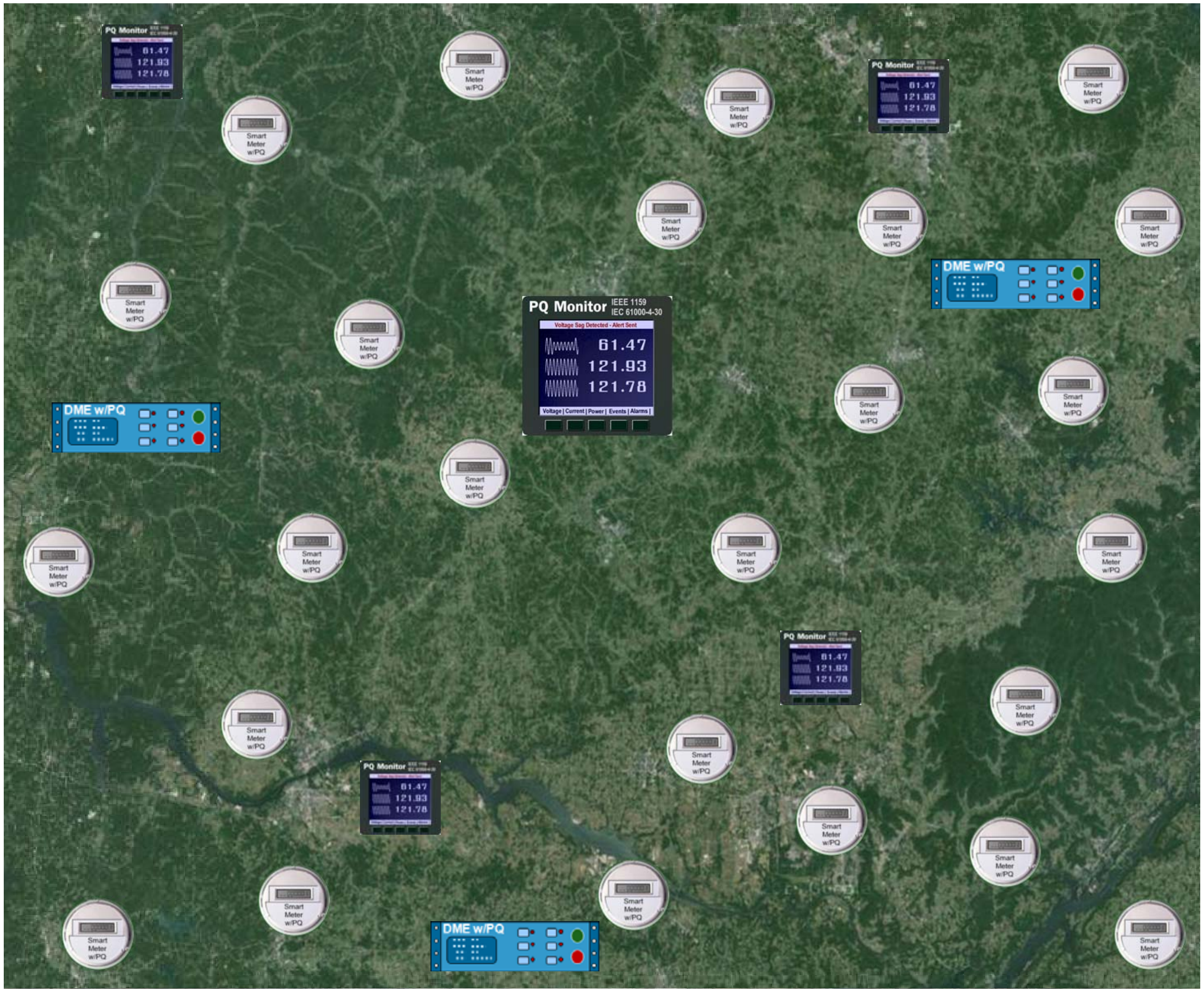
PQ Monitoring Evolving from Single-Site Investigations…
…. to Wide-Area PQ Monitoring Applications







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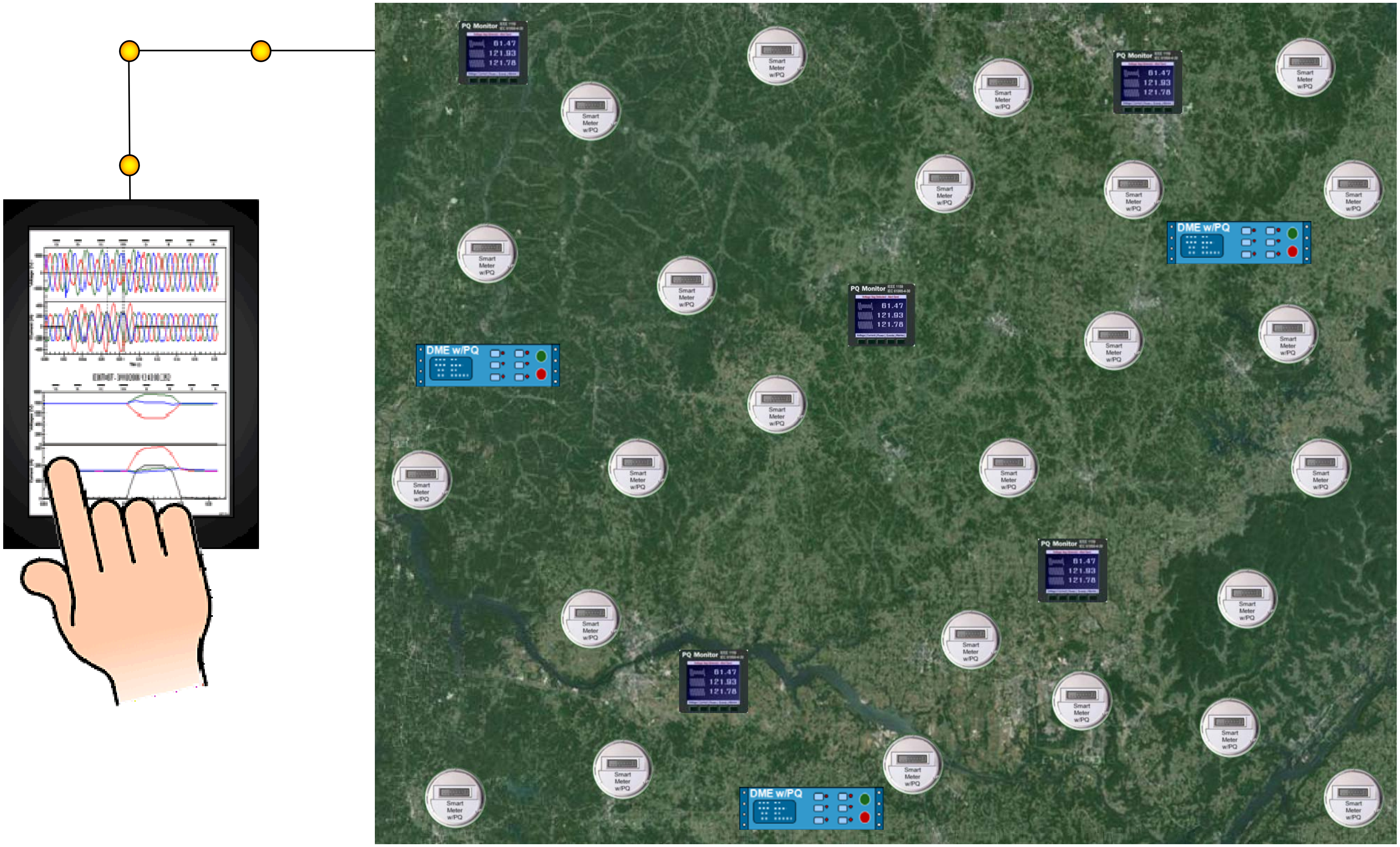
Equating to large amounts of PQ data to both communicate and interpret.



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EPRI PQ Program Project for Data Visualization

Problem

- No current method of quickly and efficiently identifying/reporting PQ data and events from a large amount of resources that reports PQ information.
- From PQ Strategic Plan
  - Need to integrate GIS and PQ data
  - Need tools for automatic data management
  - Need alarming on system problems
  - Need to extract and disseminate information from monitoring data

Objective

- A visual dashboard approach that has the flexibility to automatically integrate, correlate, and communicate meaningful PQ information to varying personnel, departments and customers.

• Benefits

- Proactive and increased response to PQ sensitive personnel and customers
- Preventive services to strengthen quality and reliability

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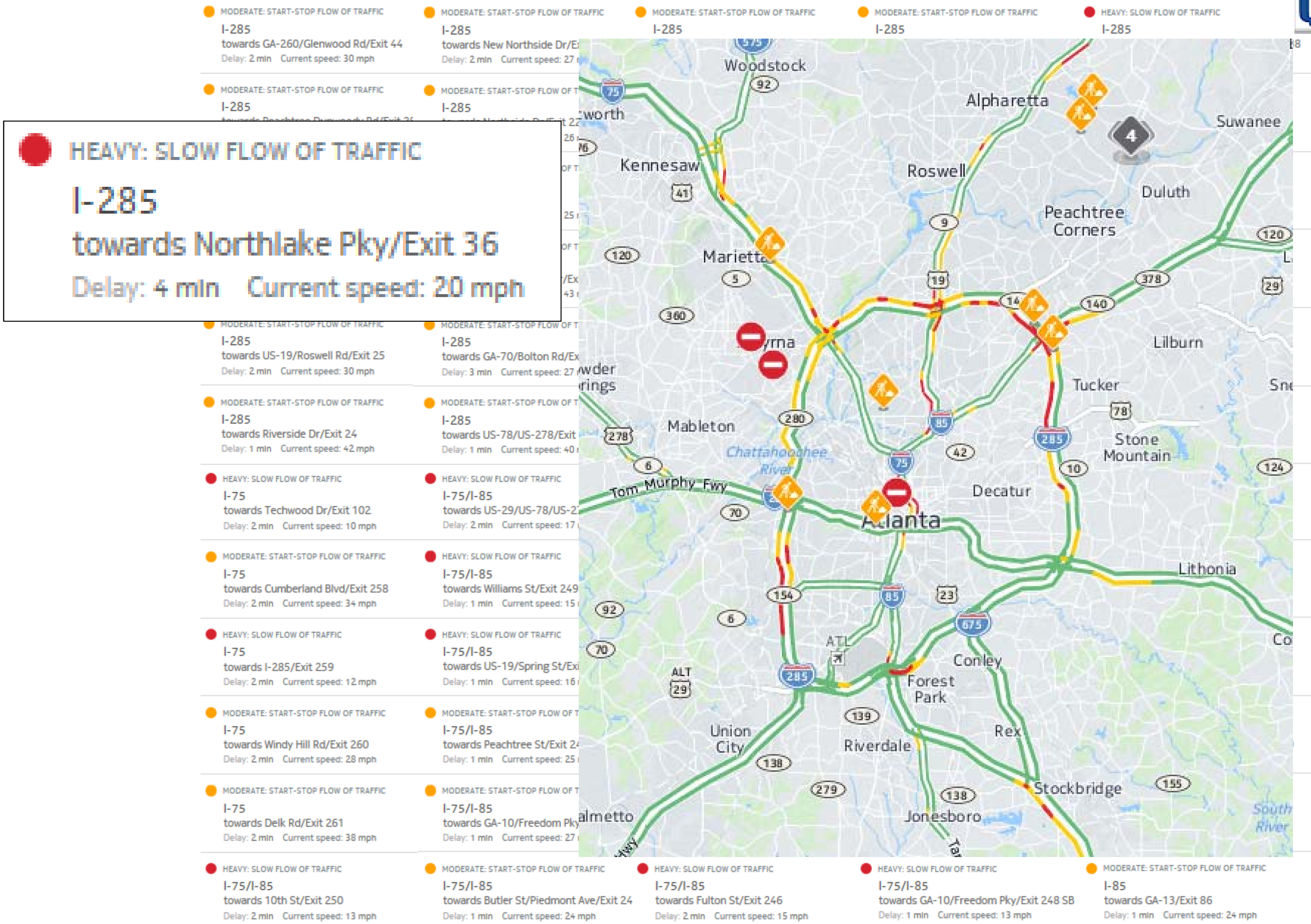
Example: Visualizing Atlanta Traffic Data



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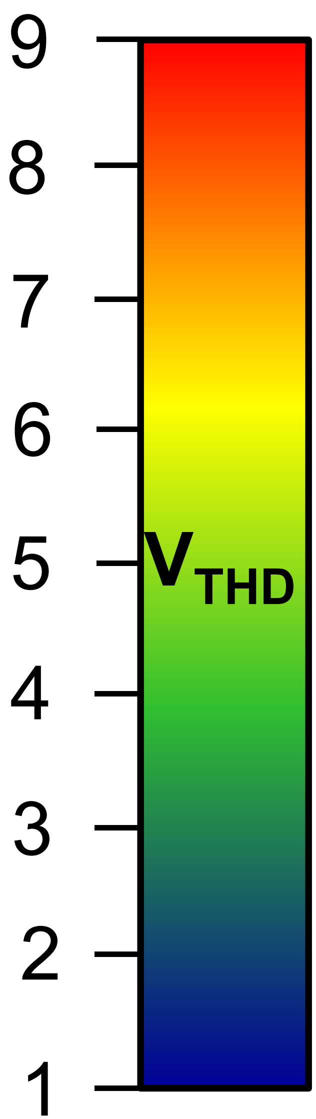
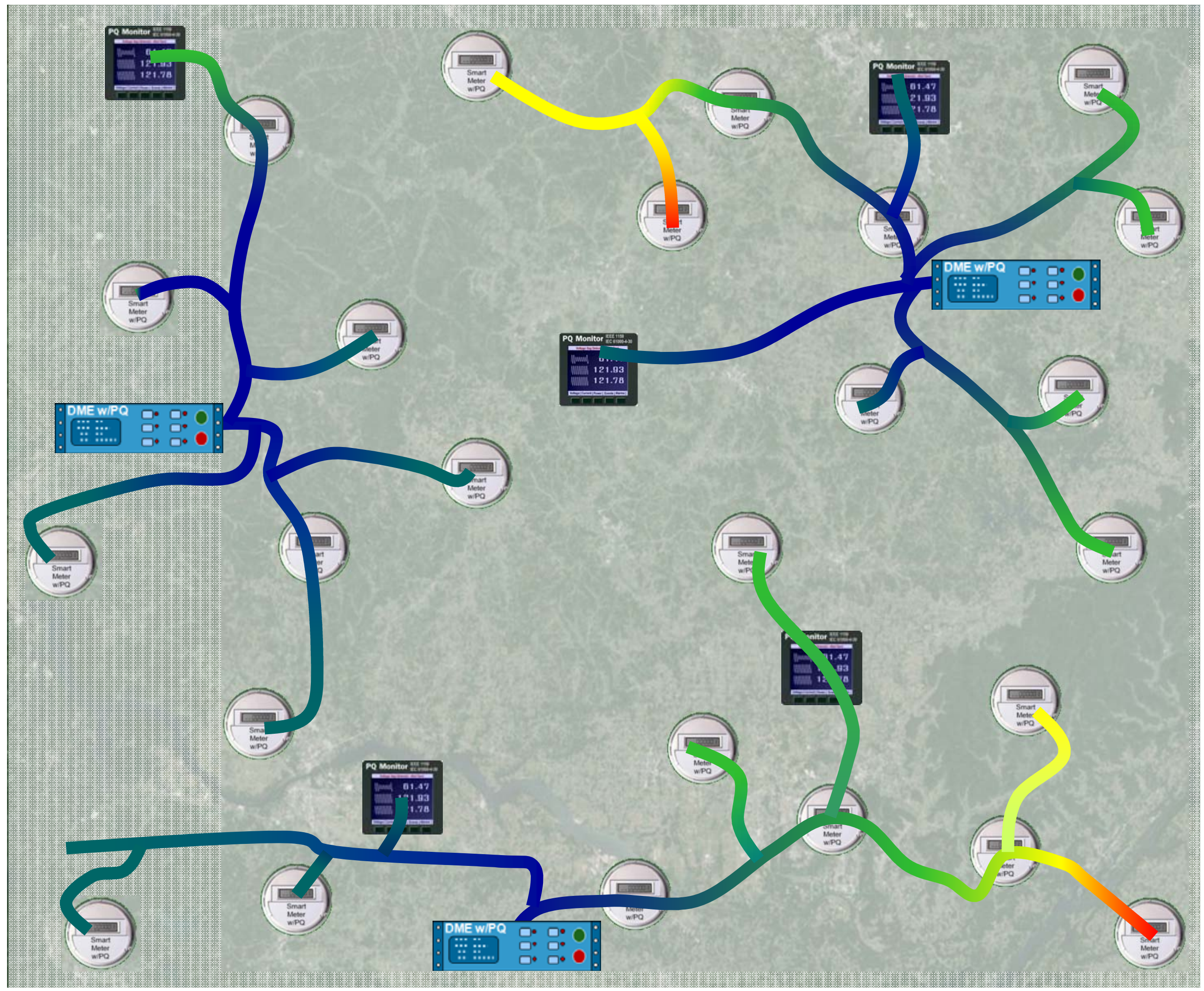
Opportunities using Data Visualization for Reporting Quick and Interpretable PQ Information





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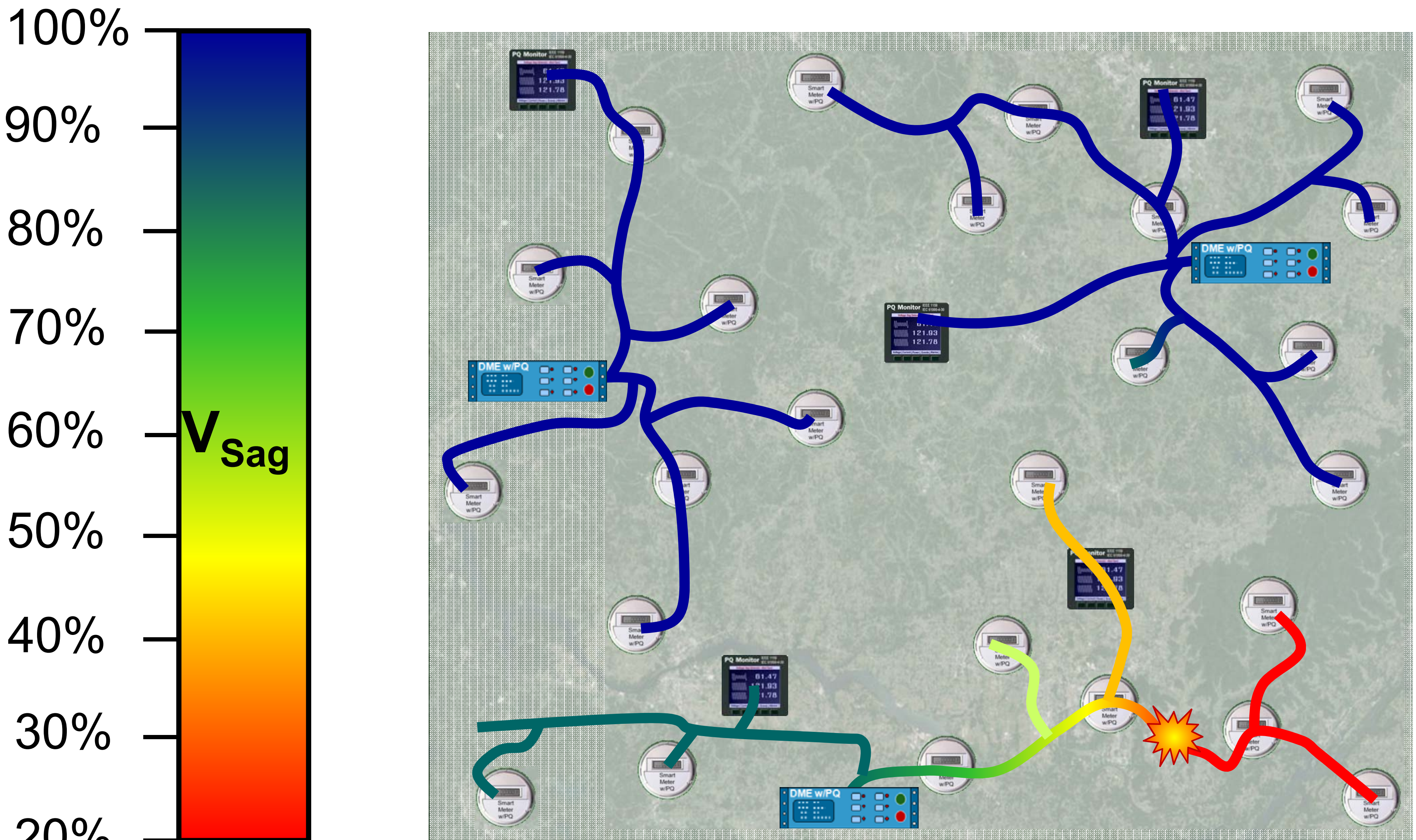
Voltage Sag Severity from a Fault



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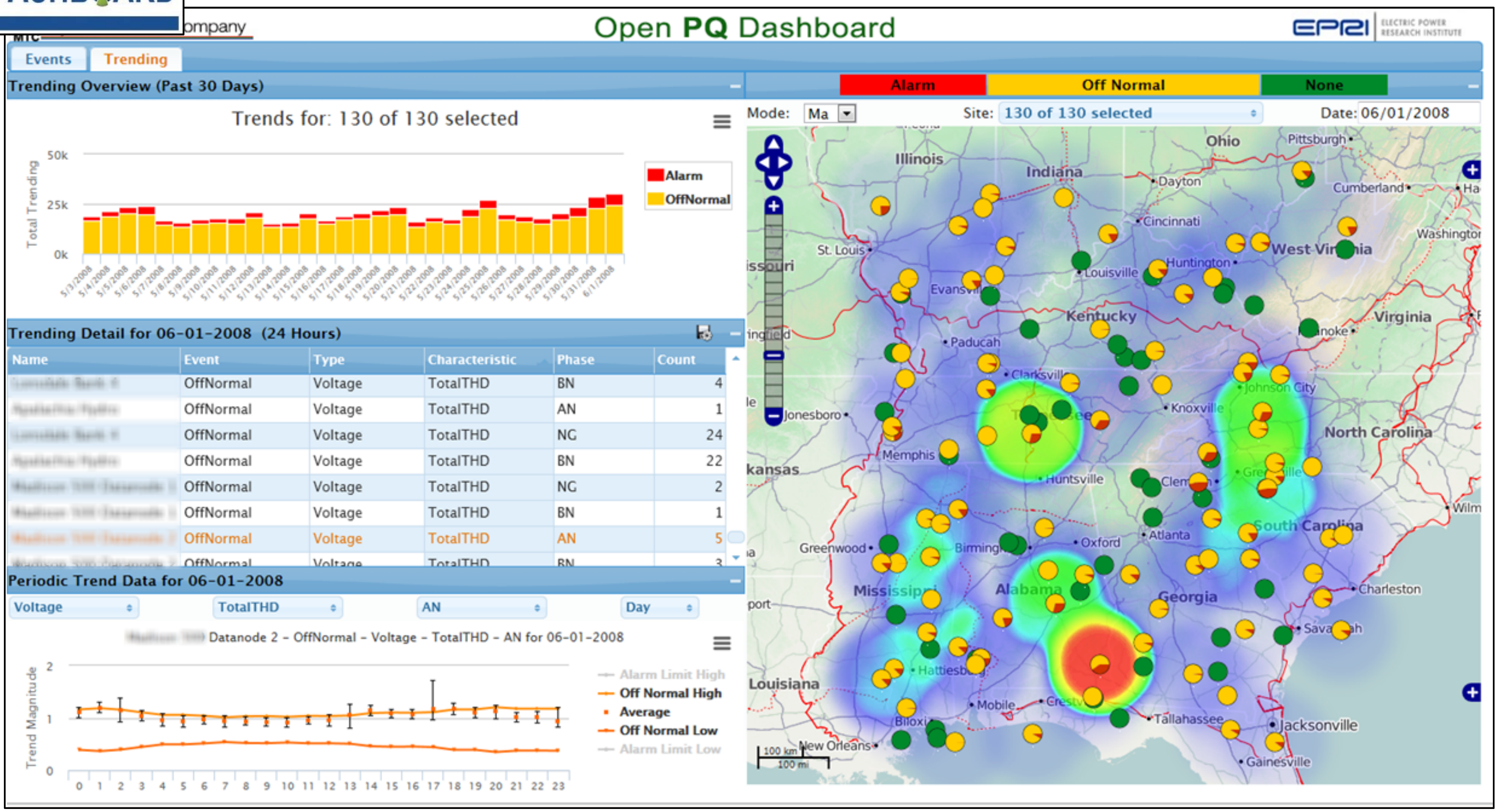
2014: OpenPQDashboard Beta Ver. 0.7 POC

- Geographic Spatial Analysis
- Historical and Statistical Process Control Visualizations for Automated Alerts of Trend Deviations



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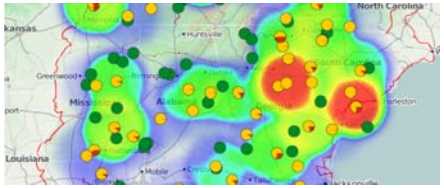
2015 Work

- Production-Grade Deployment & Configuration Enhancements
  1. Configuration and installer improvements to automate setup and deployment; addition of security features
  2. PQView Data Integration
  3. One-line GIS layer import capability. Shape-file (Esri) and/or KML (Google)?
- Apply New Visualizations Research
  1. Parameter and Event Magnitude GIS heat-map for geospatial relationship
     - Animating Steps for Visual Sequence Analysis



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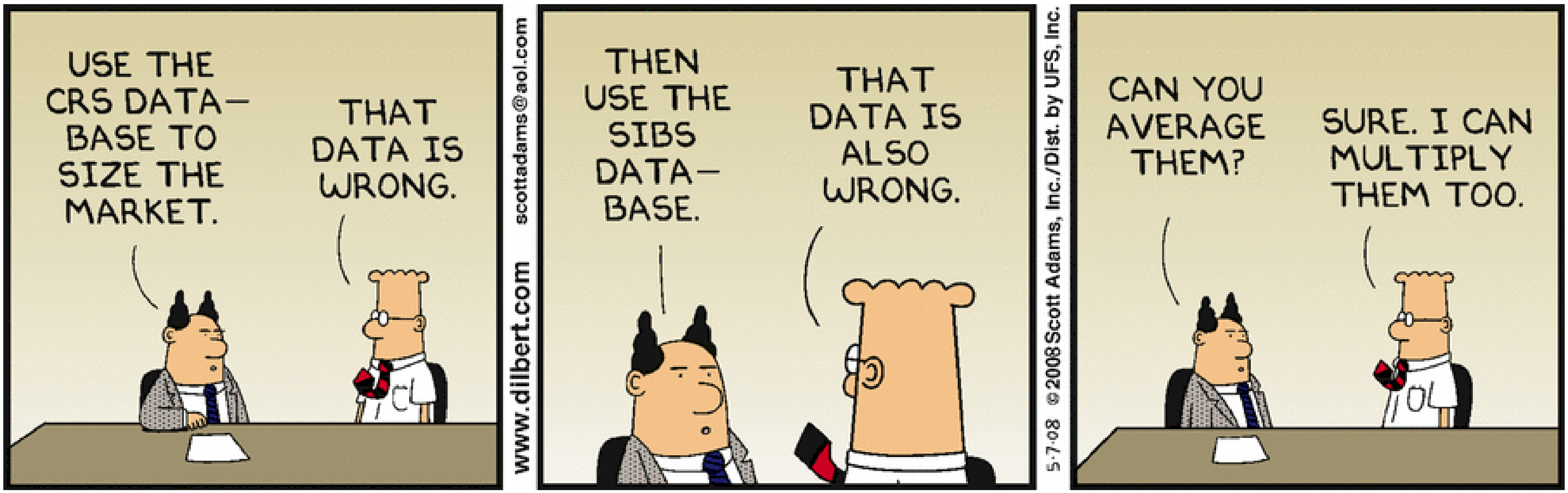

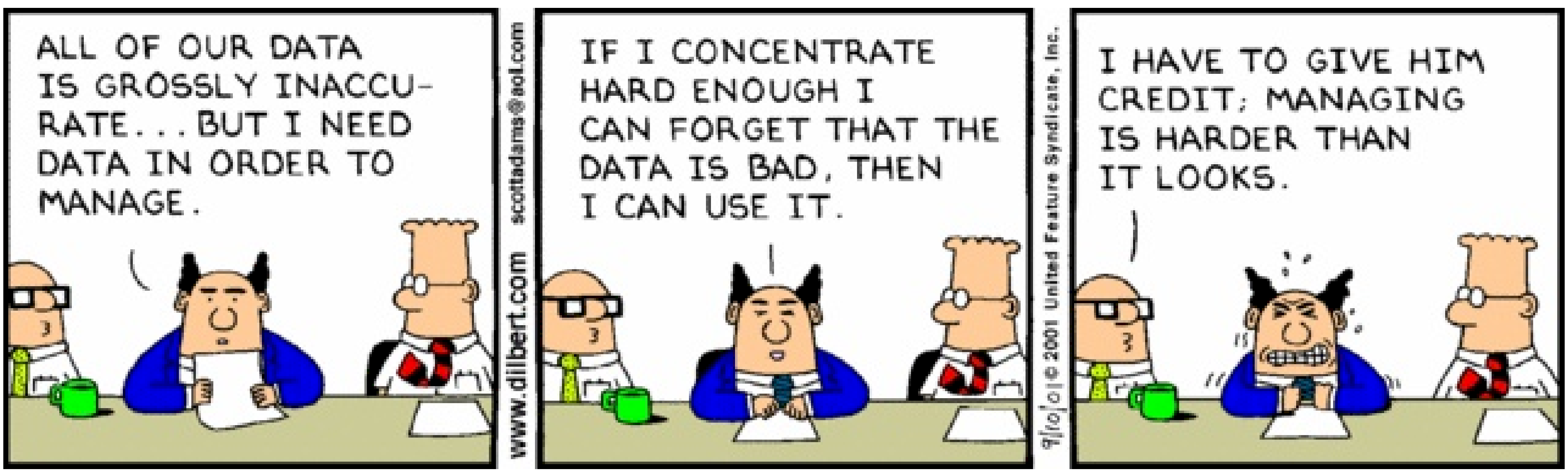

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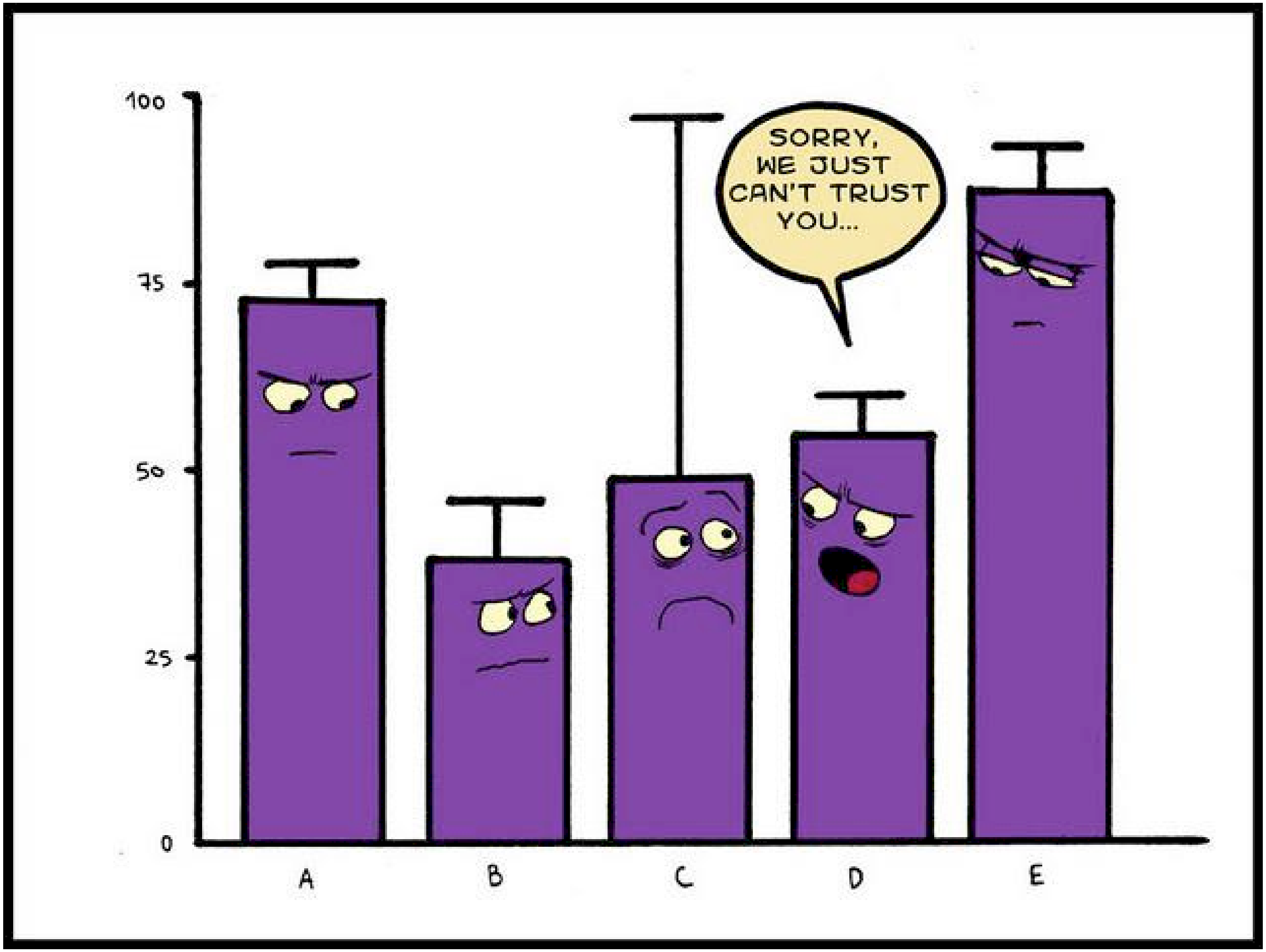
Bad Data



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EPRI PQ Program Project for Data Validation

- **Problem**
  - No current method of detecting defective PQ data caused from faulty monitors, sensors, or other sources to which can cause misrepresentation of actual PQ conditions. (Bad Data)
  - From PQ Strategic Plan
    - Need tools for automatic data management
    - We need alarming on data unavailability
- **Objective**
  - Integrate data validation techniques into the openPQDashboard to which includes automatic characterization and statistical visualizations for alarming and management of defective PQ data.

- **Benefits**
  - Defective data is not passed to and unnecessarily alarming PQ sensitive personnel and customers
  - Efficiency in monitoring operations, with less man-hours used in detecting and explaining data that is false-positive PQ.

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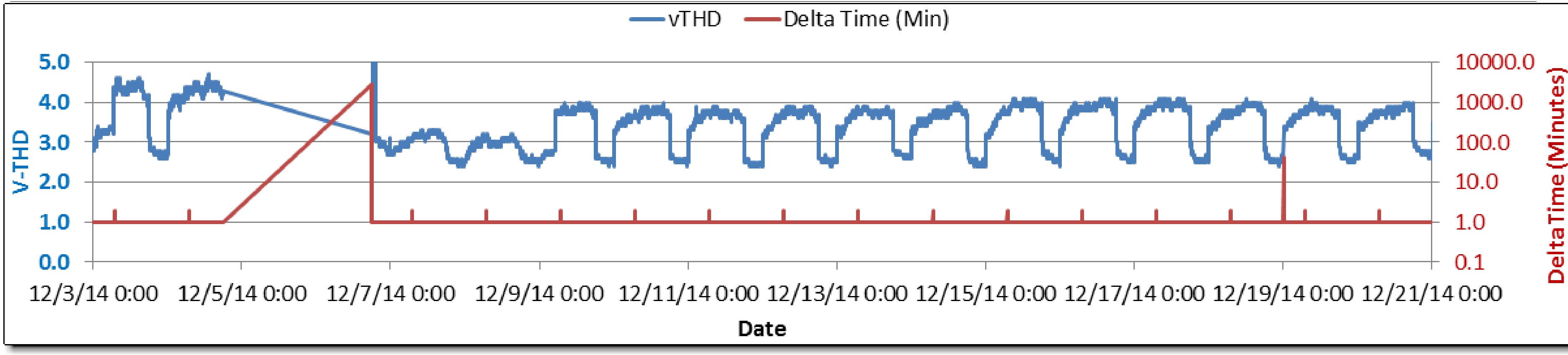
Data Validation (Example #1 of Bad Data)



1/26/15 6:56	3.8
1/26/15 6:57	3.8
1/26/15 6:58	3.8
1/26/15 6:59	3.9
1/26/15 7:01	3.9
1/26/15 7:02	3.9
1/26/15 7:03	3.8
1/26/15 7:04	3.8

7:00 → ← 3.9

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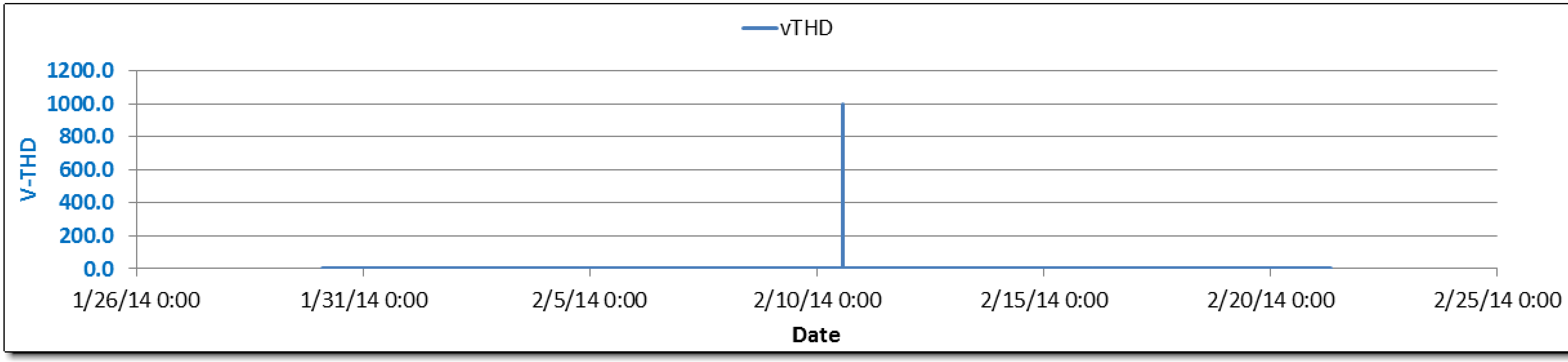
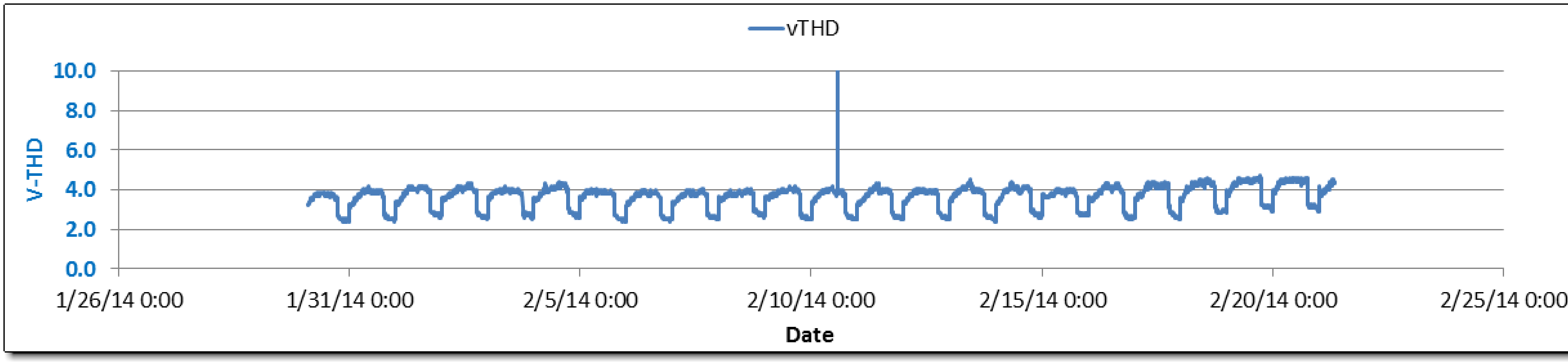
Data Validation (Example #2 of Bad Data)





Suppose averaging one “glitch” with 1-min-res steady 3 % V_{THD} :

Hourly Average = 19.6 % V_{THD}

Daily Average = 3.7 % V_{THD}

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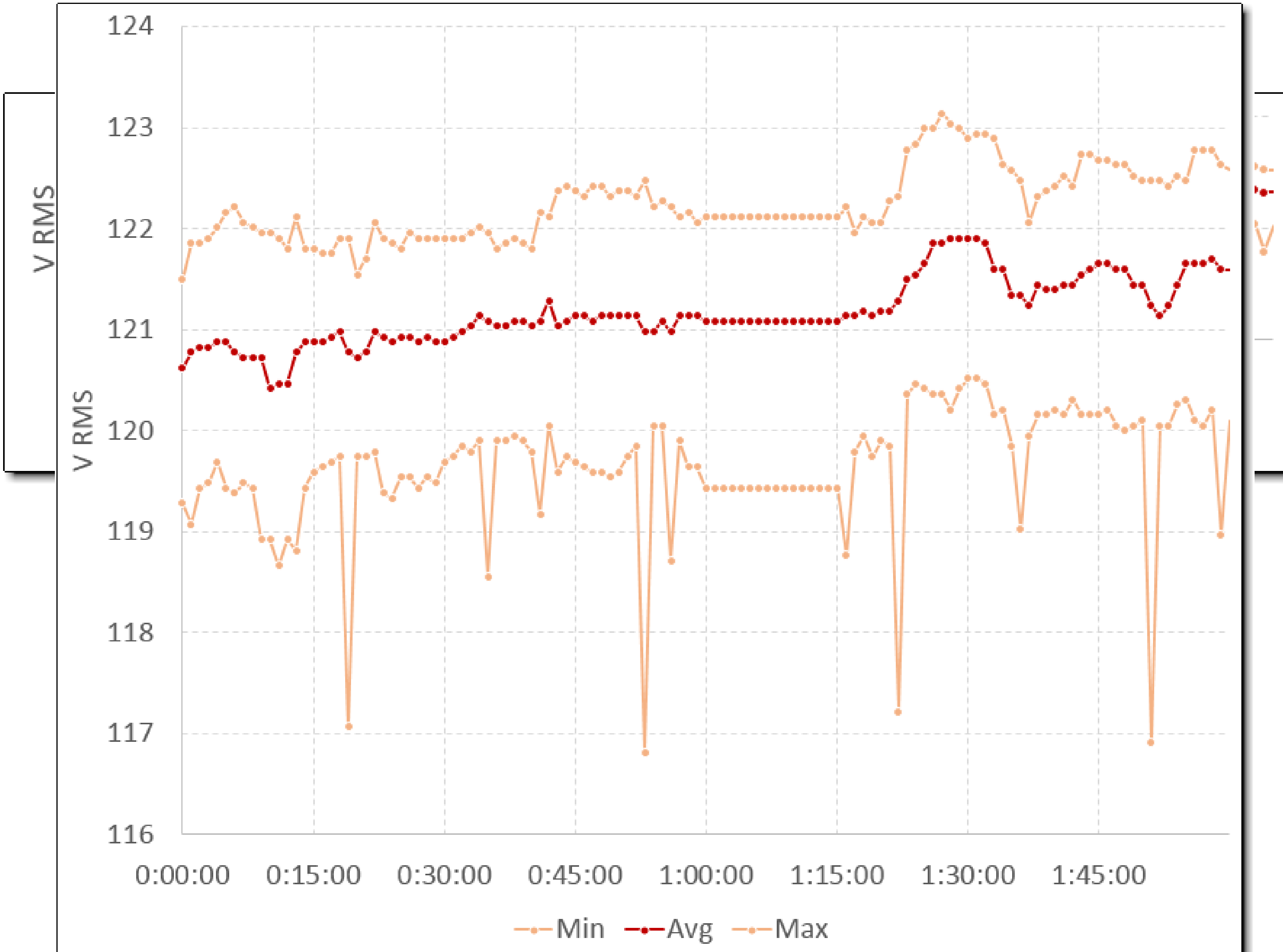
Data Validation (Example #3 of Bad Data)



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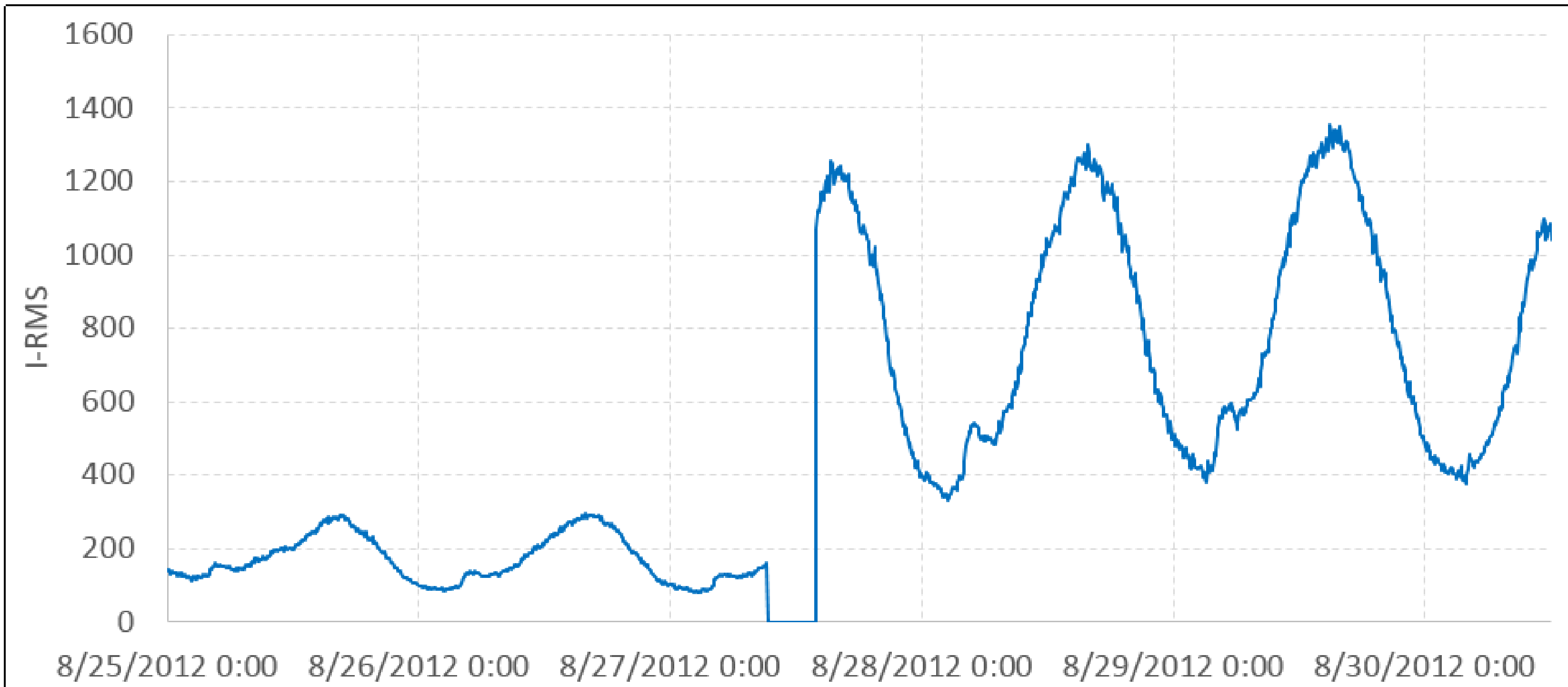
Data Validation (Example #4 of Bad Data)



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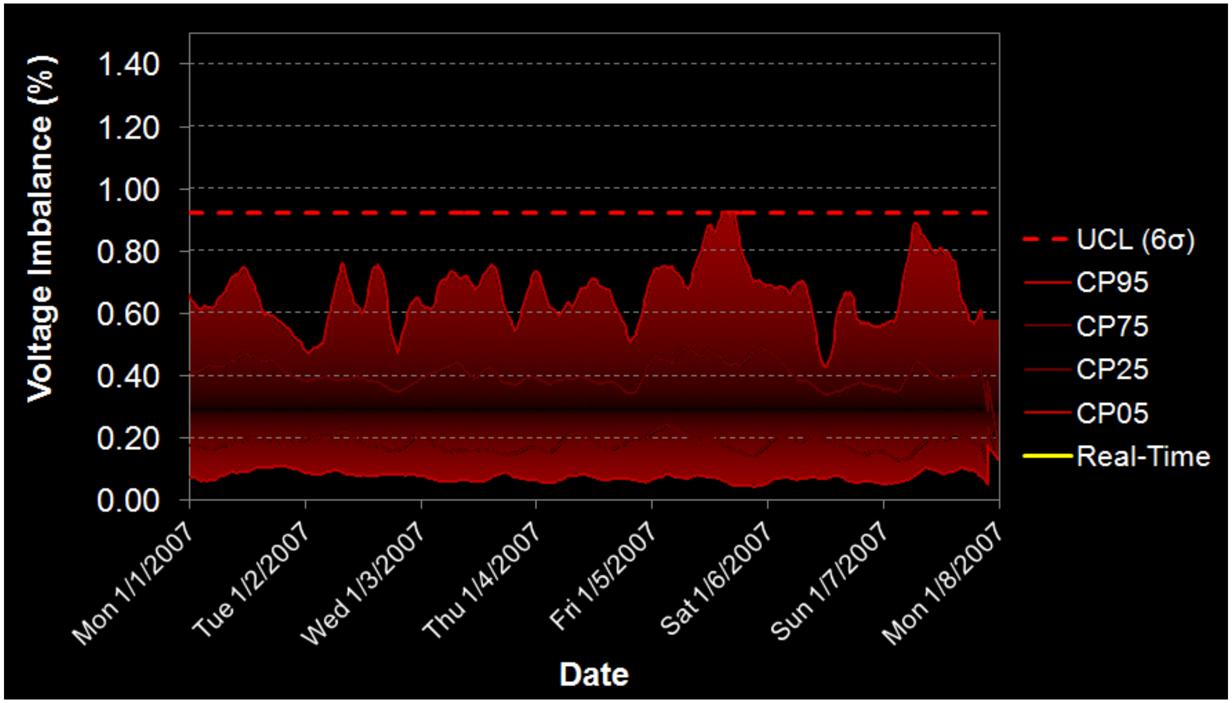
More on Trending with Statistical Process Control Techniques for Increased Situational Awareness



- Comparing real-time to historical trends for a given site
- Presents the capability for soft alarms (below regulatory limit) that are triggered when real-time exceeds historical norms.
- This abnormality of 1.2% voltage imbalance is due to a capacitor bank fuse opening on one phase. Conventional triggers are set to 5% and would have missed this event.

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Example Data Validation Process

- Automated Data Screening
  - Input: Screen all data for potential erroneous values.
    - Trend Availability (configuration periodicity)
    - Time correctness
    - Bad data, Events (saturated?, flat top / latched, reversed CT) and Trend
  - Output: Data validation report (Dashboard Screen)
    - List includes suspect parameter, date & time of occurrence, failed criteria.
- Data Verification
  - Qualified personnel are alerted and checks each incident, logs assignable cause, and either retains, rejects, or replaces suspect value(s).

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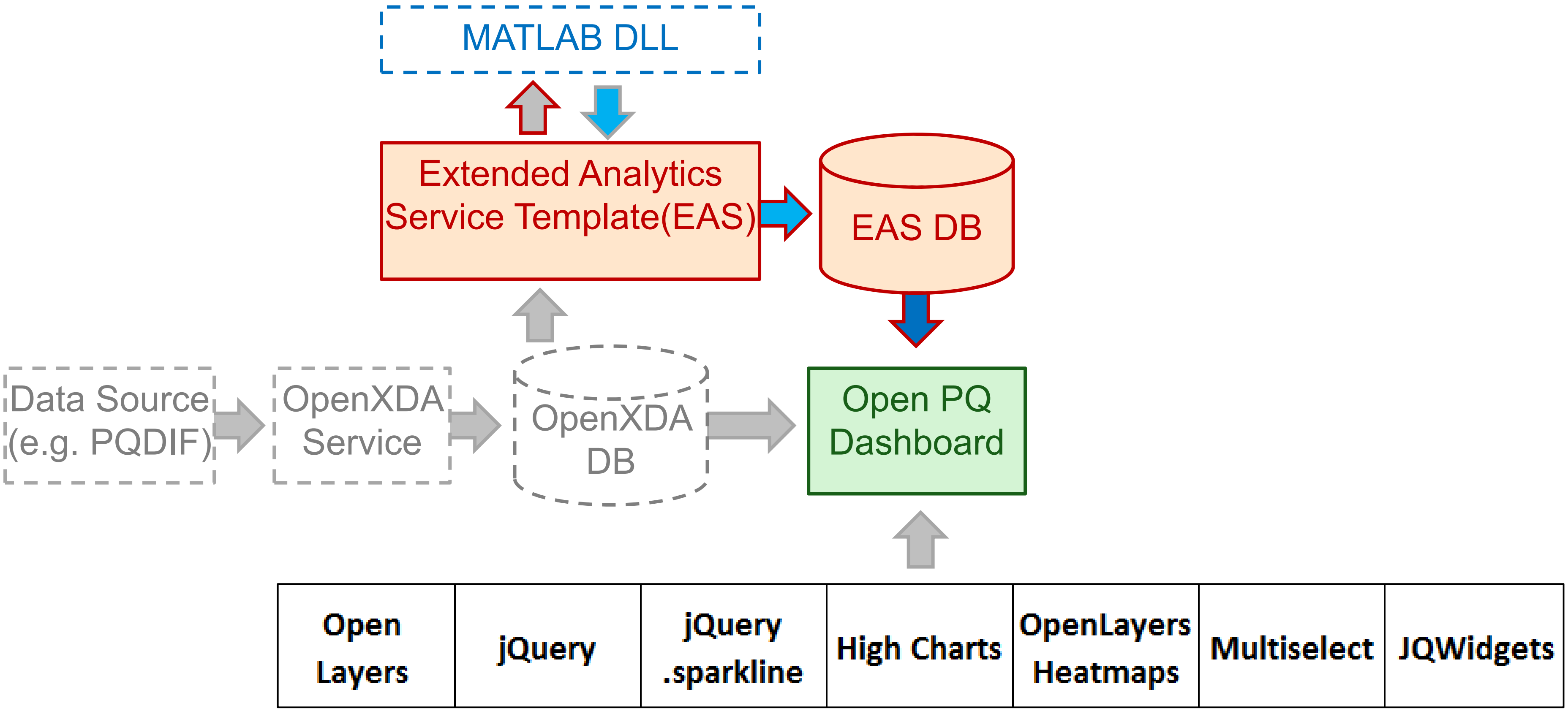
Supporting EPRI Research: Waveform Analysis



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Supplemental Project: PQ Investigator – Open PQ Dashboard Integration

- If you have PQI, a web service will provide information on equipment/customers effected by voltage sag events to the dashboard.
- Release with openPQDashboard Ver. 1.0

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Future EPRI Research Contributions to the Dashboard

- Continuous Power Quality Benchmarking - Automated management of EPRI hosted PQ data from multiple utilities.
- Waveform characterization (statistical probability of cause)
- External Data Layers for PQ Correlation (e.g. Sunburst, Weather)
- Visualizing continuous waveform data

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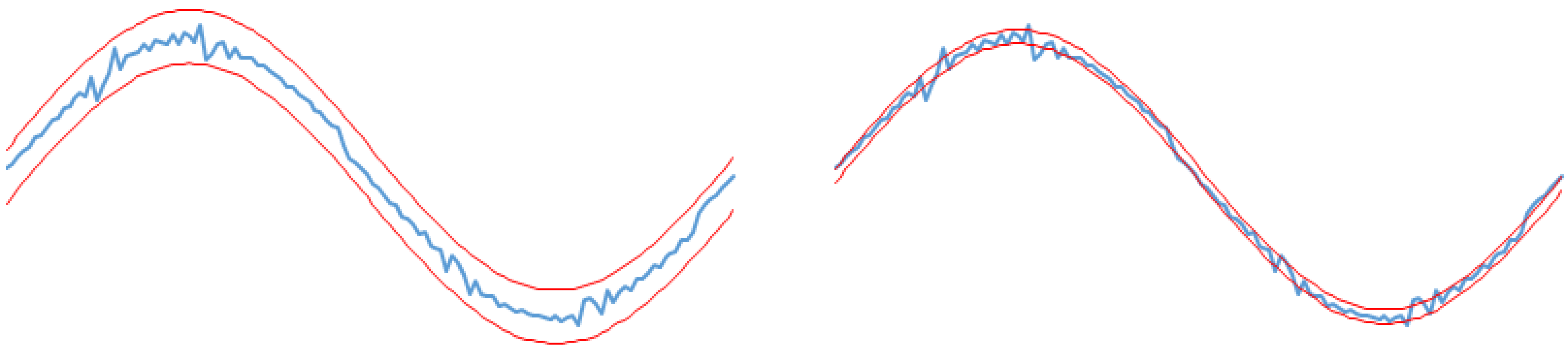
What are we missing with present triggering methods?



- If the thresholds are not sensitive enough, anomalies can be missed. (High Impedance Fault Deviations)
- If the sensitivities of thresholds are set too low, the user is inundated with a large amount of data sets to parse and zoom through

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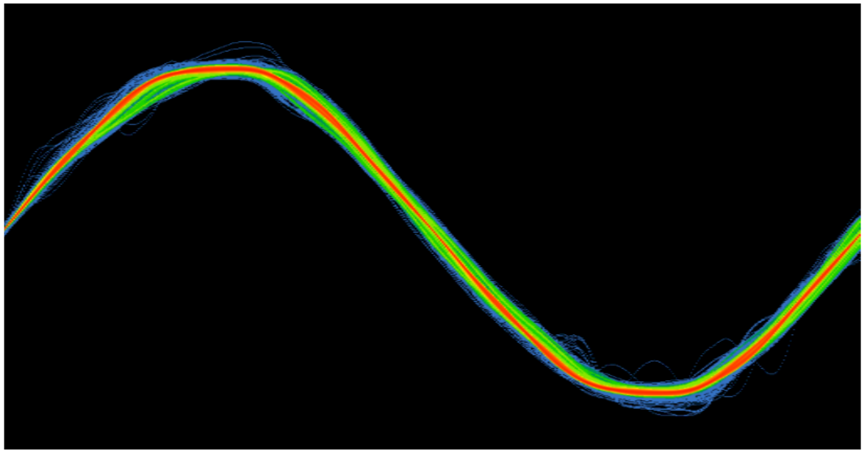

EPRI Cyclic Histogram

Open Conceptual Design Guide

Tom Cooke

April 2015

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Background

In the electric power industry, the voltage and current waveforms are the rawest forms of data that are analyzed for power system anomalies. To capture these anomalies, digital signal processors sample amplitude values from 128 to 1024 times per waveform cycle in order to deliver an interpretable anomalous event cause. Historically, it is not efficient to collect and store this type of data continuously because such data storage is impractical, nor is it preferable to sort through this amount of data to find the anomalies that have occurred in one 60-hertz cycle out of millions of cycles recorded in a given day.

Today, power quality monitors are configured to record data only when the waveform exceeds preset boundaries as predetermined by input variables. If the waveform is not changing significantly, the data-acquisition system does not record that data, therefore reducing the size of stored data. The problem with this method is often anomalies are not captured because the threshold triggers are not preset correctly. If the thresholds are not sensitive enough, anomalies can be missed. Conversely, if the sensitivity of thresholds are set too low, the user is inundated with a large amount of data sets to parse and zoom through, requiring a significant amount of time for analysis.

The new Cyclic Histogram method reduces the impact of large amounts of waveform data and resolves the issues associated with the current methods mentioned above. <u>Note that this method is meant to enhance current methods, rather than replace it.</u>

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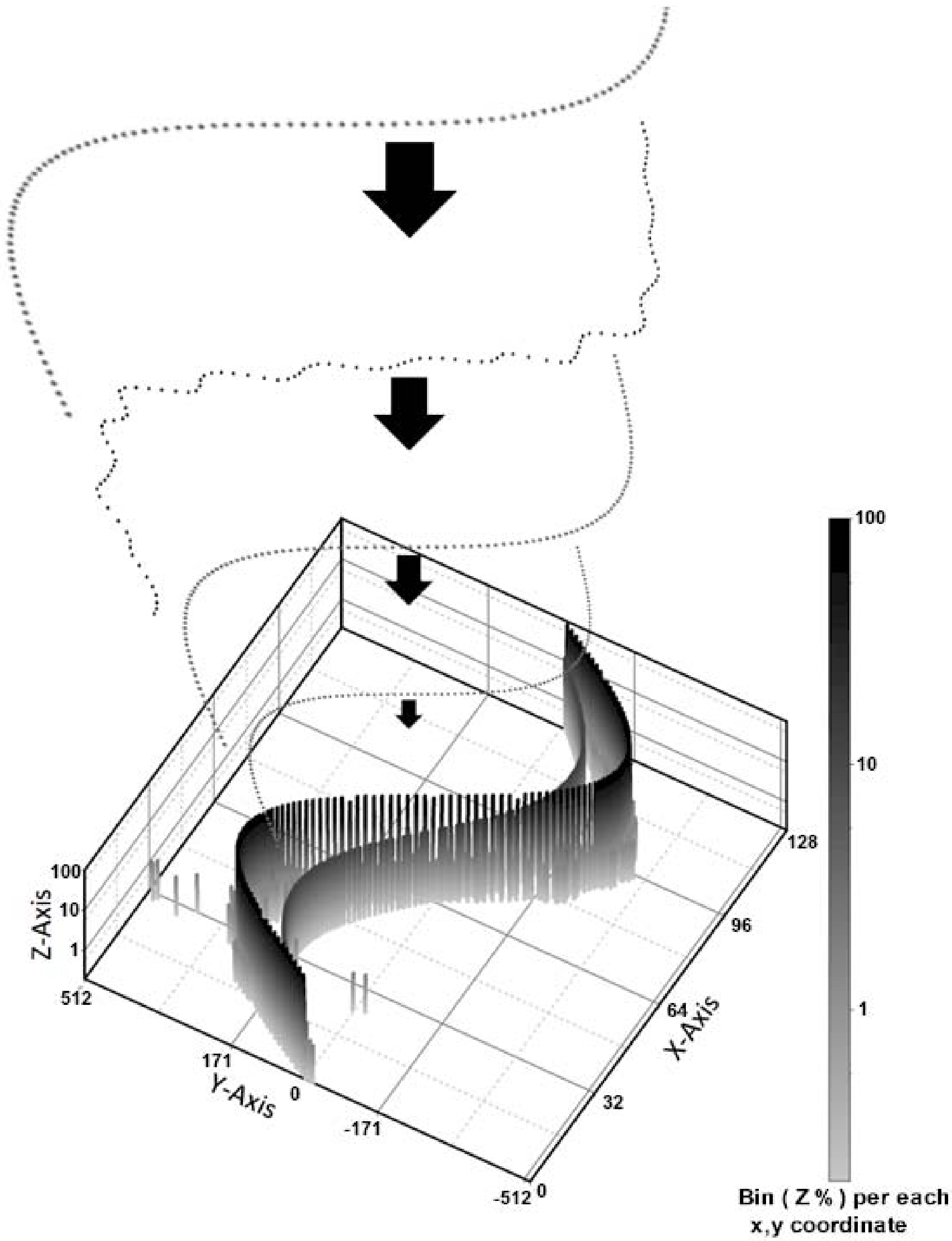
Basic Cyclic Histogram Structure

This Cyclic Histogram method is a three-dimensional representation of many continuous cycles of historical current or voltage waveforms in a one-cycle view.

The X and Y axes make up a given matrix of bins for a stack of Z values to be established. As a given X sample is selected, the Y value is measured and placed in the corresponding bin. The number of bins is determined by horizontal and vertical resolution.



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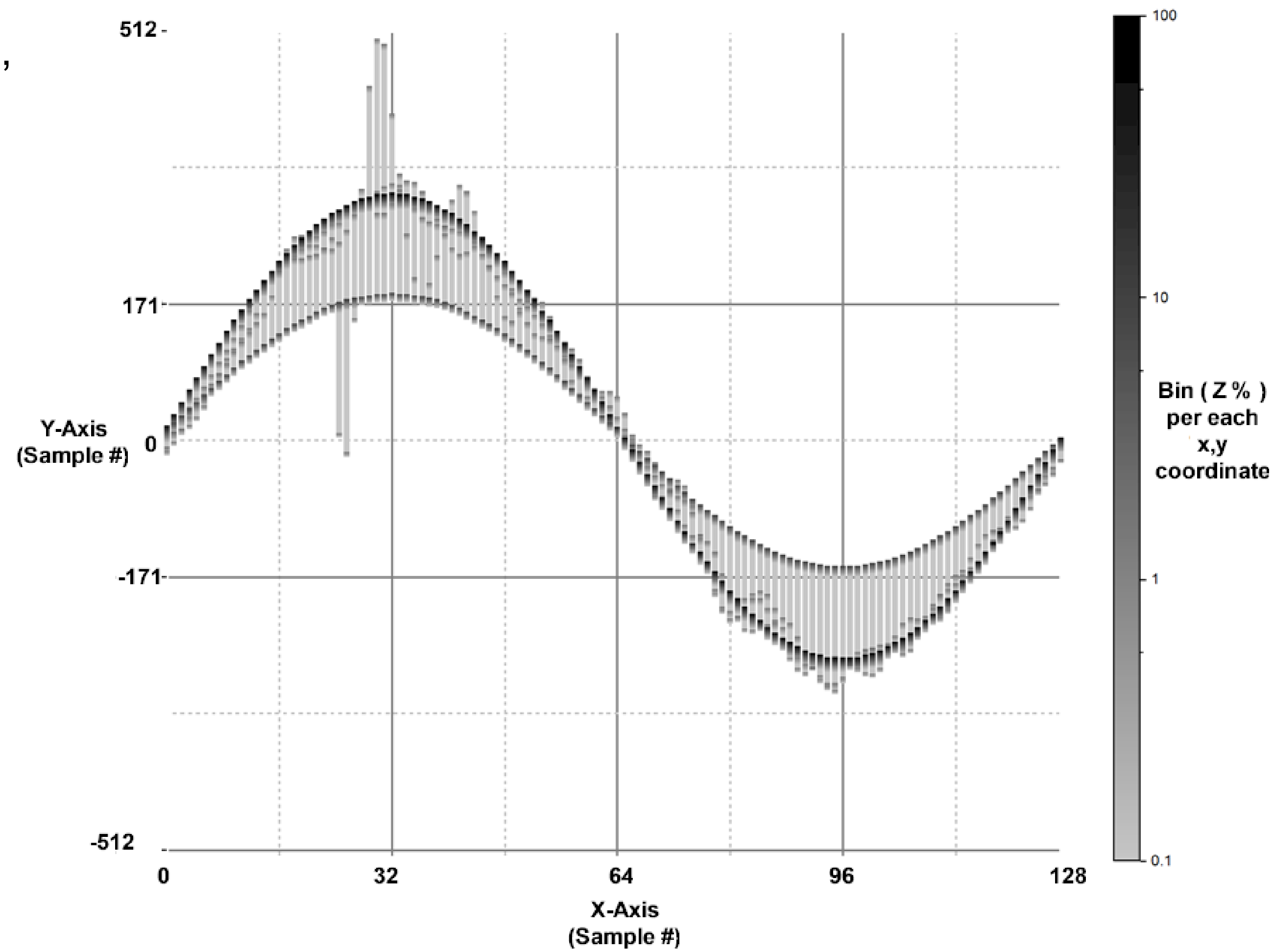
Cyclic Histogram (X and Y Axis)

The X axes should represent the number of points per cycle, with each sample having a delta-t that is the inverse-frequency divided by the number of points.
For visual needs, the Y axis will not need the same vertical resolution as the source data. Most meters record 16 bit (65536) resolution. 10 bit (1024) may suffice which in this case would aggregate 64 vertical value levels into 1 bin.



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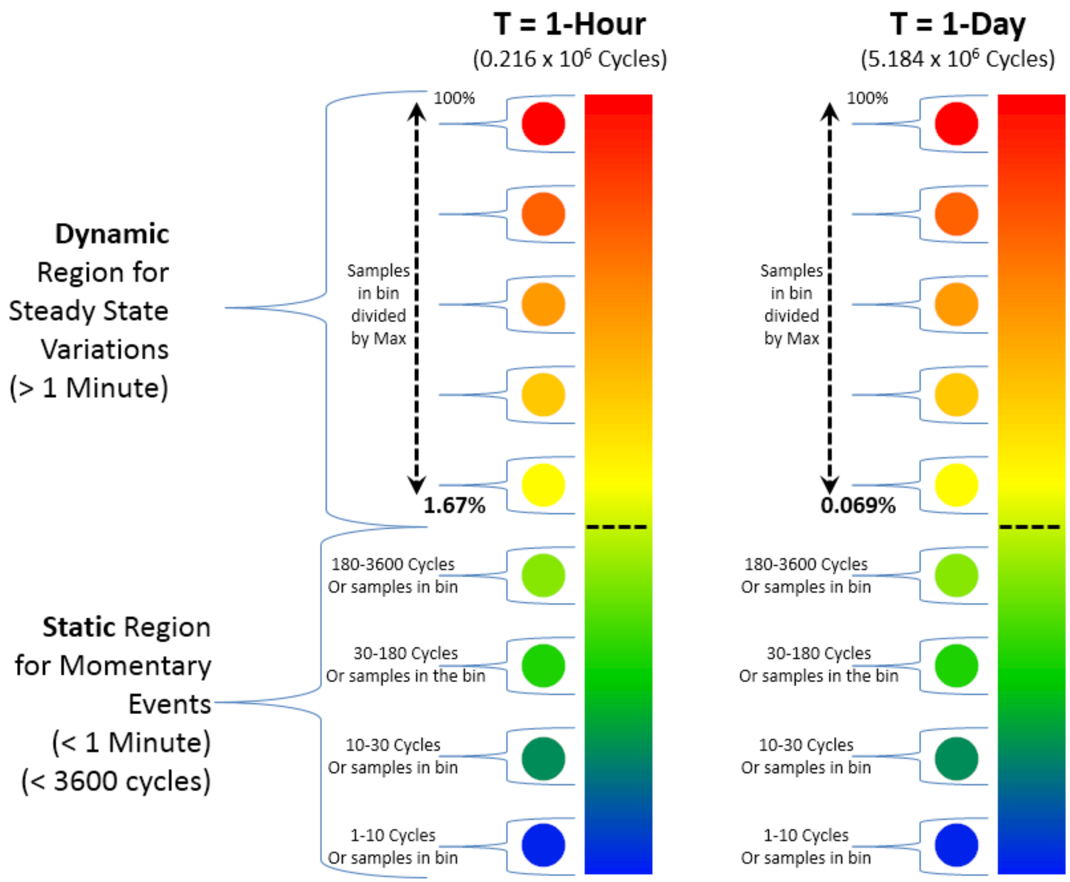
Z axis Coloring

For power quality phenomena we have two distinct variations in waveforms…. steady state variations, and event variations. And each have their typical range as defined in PQ standard IEEE 1159. For events, we typically see variations from 1 to ~180 cycles. A series of events are typically less than one minute (3600 cycles). Steady state variations are greater than one minute. As shown in the graphic, events have a color region that presents static duration (1 to 3600 cycles) regardless of the cyclic histograms total period (T). For the static algorithm one pass by a bin equals 1 cycle. Counting the number of samples in a bin establishes what color of blue to green is presented.

For steady state, values in this color region (yellow to red) will be percentage values and the representative color will be dynamic depending on the total period (T) of the cyclic histogram. For this algorithm, the value will be stored as a percent, which is derived from one sample divided by total samples in the T measurement period. If one or more values already exists in this bin, the percent value is mathematically added to the previous value(s). The minimum percentage will depend on the total period selected, but it will always be based on 1 minute.
(1 minute / 1 hour = 1.67%) or (1 minute / 1 day = 0.069%)

This method gives us some visual distinction between events and steady state variations.



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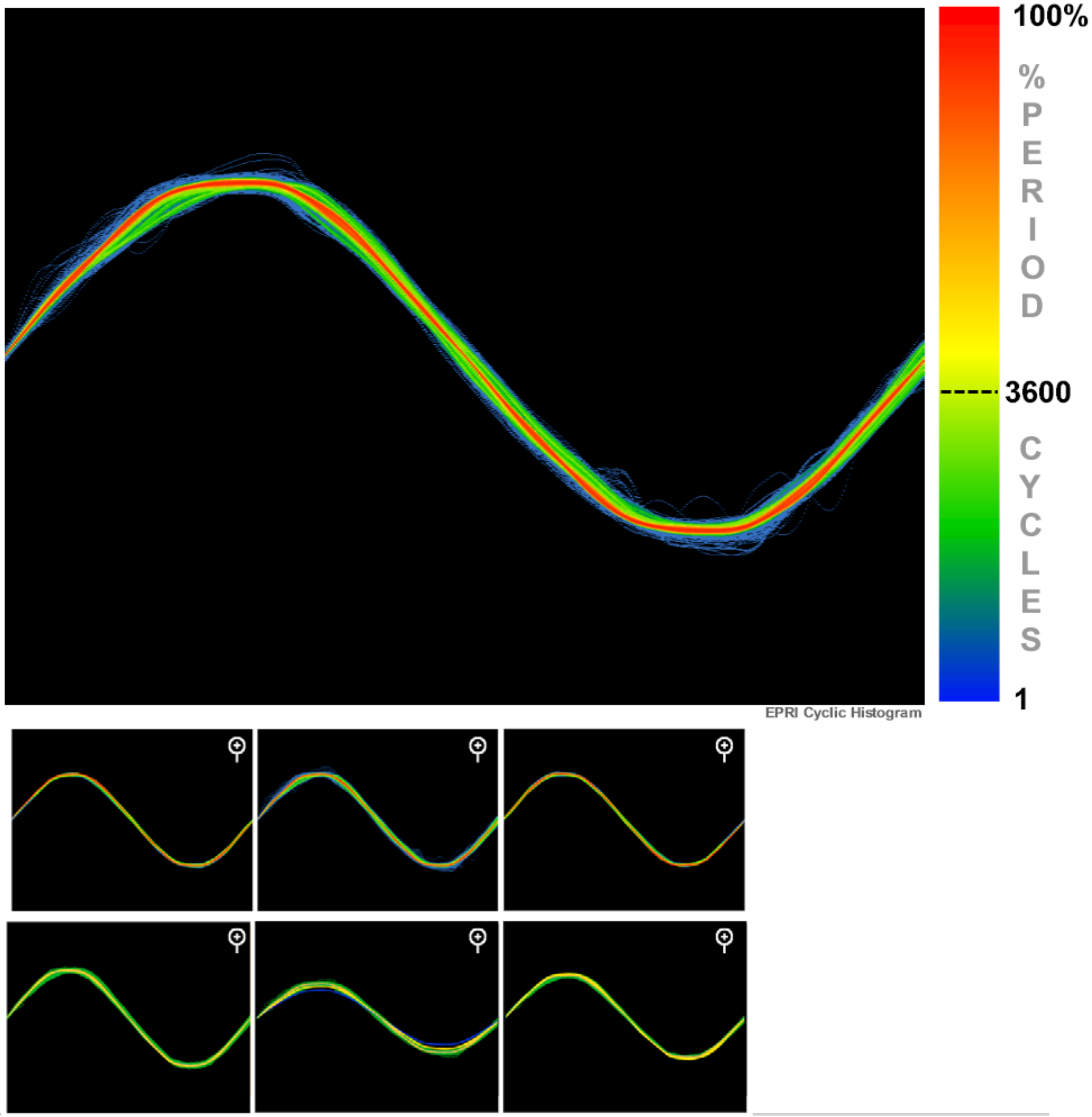
Format and Display

To ease storage, transfer, and display of the cyclic histogram, it can be distributed as a static image (gif, png, etc).
There can be multiple images for each phase, voltage and current.
Furthermore, there may be multiple pages of images representing different time periods (i.e. 1 hour, 1 day, or maybe 1 week)



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For more information on the Cyclic Histogram, contact…..

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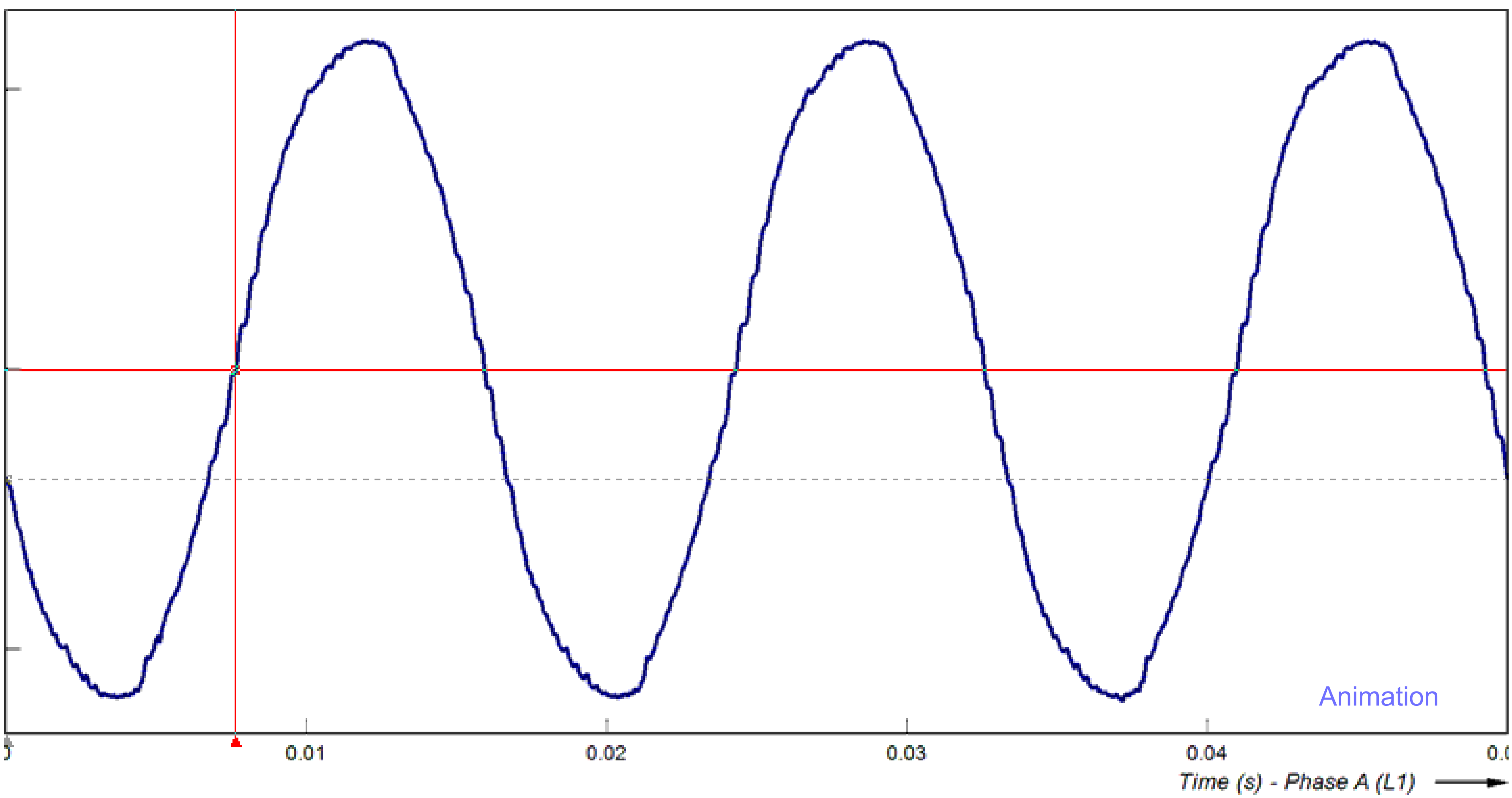
Subtle Waveform Deviation from Arcing



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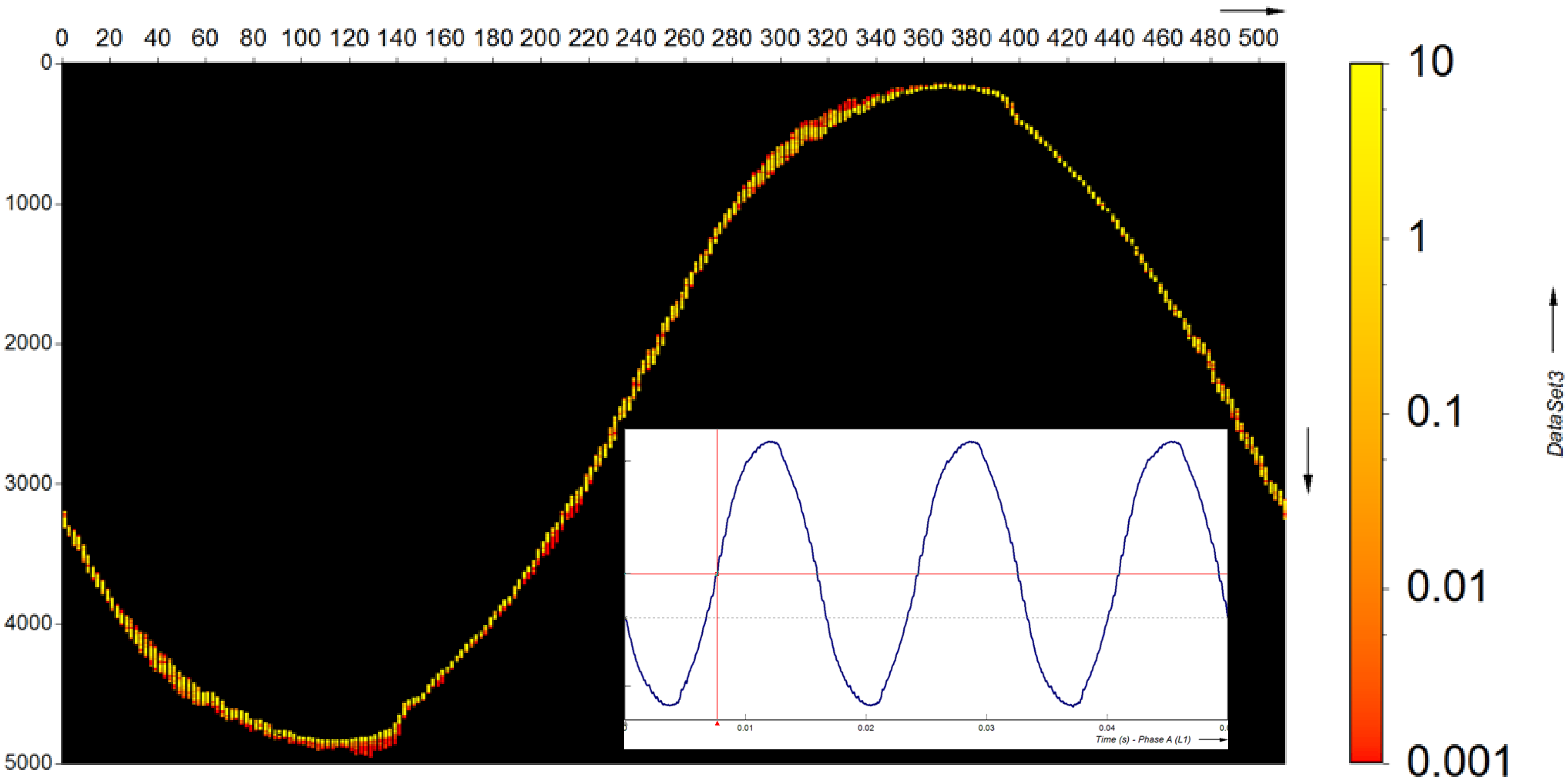
Cyclic Histogram Highlights Deviations



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