



PQ Dashboard

2025 User Group



Project Manager:

Tom Cooke, EPRI

10 Sept 2025

AGENDA

- ▶ Welcome and Introductions
 - EPRI PQ Dashboard Service
 - Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
 - Q&A



tcooke@epri.com

Agenda

WEDNESDAY, SEPTEMBER 10, 2025 – PQ DASHBOARD USER'S GROUP- LIBERTY A&B

TIME (CST)	TOPIC	PRESENTER
1:00pm	Introductions	Tom Cooke, EPRI
1:15pm	EPRI Review of Upcoming Contributions	Tom Cooke, EPRI
1:45pm	GPA Updates	Christoph Lackner, GPA
2:05pm	openXDA Suite Refresher	Erika Wills, GPA
2:30pm	openMIC at TVA	Tony Murphy, TVA
3:00pm	Break- Houston Ballroom – Pre-function Space (level 2)	
3:30pm	GPA Application Demonstration	Erika Wills, GPA
4:00pm	Roundtable Discussion	
5:00pm	Meeting Adjourned	

AGENDA

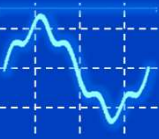
- ▶ Welcome and Introductions
 - EPRI PQ Dashboard Service
 - Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
 - Q&A



tcooke@epri.com

EPRI Review: Agenda

- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Considering a Compliance Reporting Initiative and Continuous Point on Wave research project.
- Q&A



EPRI

Power Quality

PS1B: PQ Data & Analytics

AGENDA

- Welcome and Introductions
- ▶ EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

EPRI PQ Dashboard Online



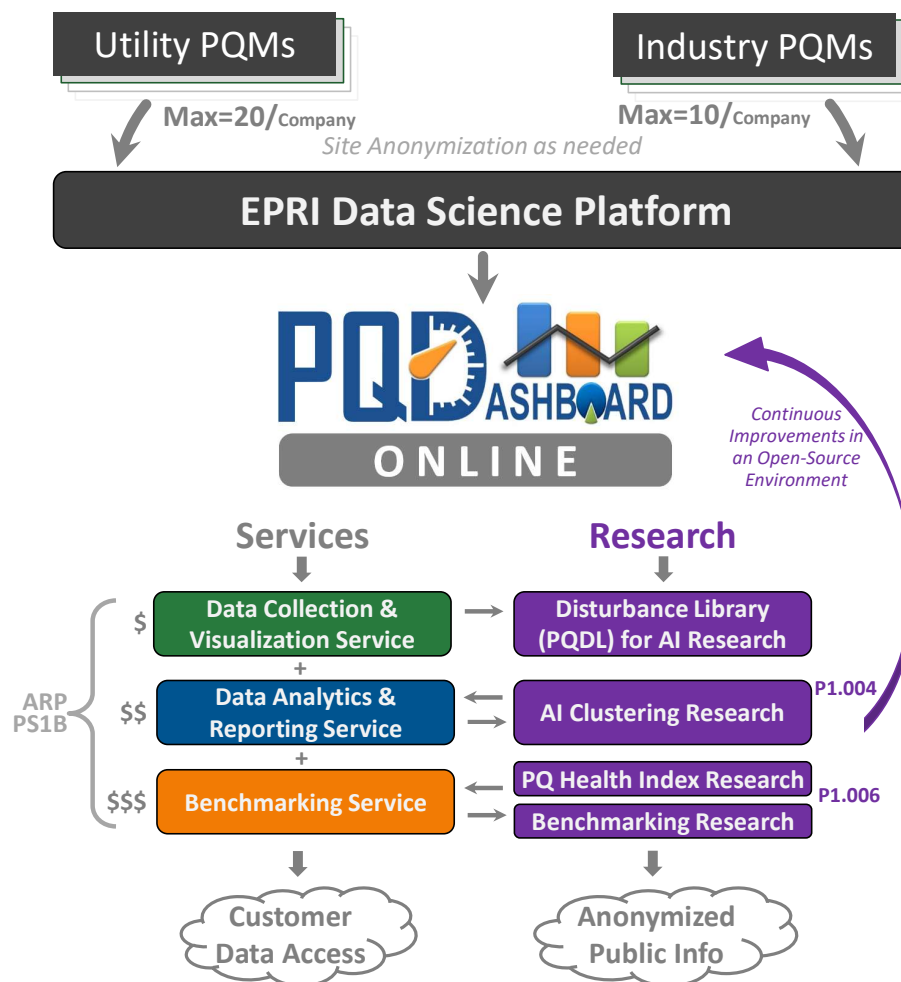
AGENDA

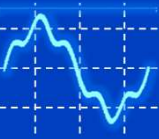
- Welcome and Introductions
- ▶ **EPRI PQ Dashboard Service**
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Scope





AGENDA

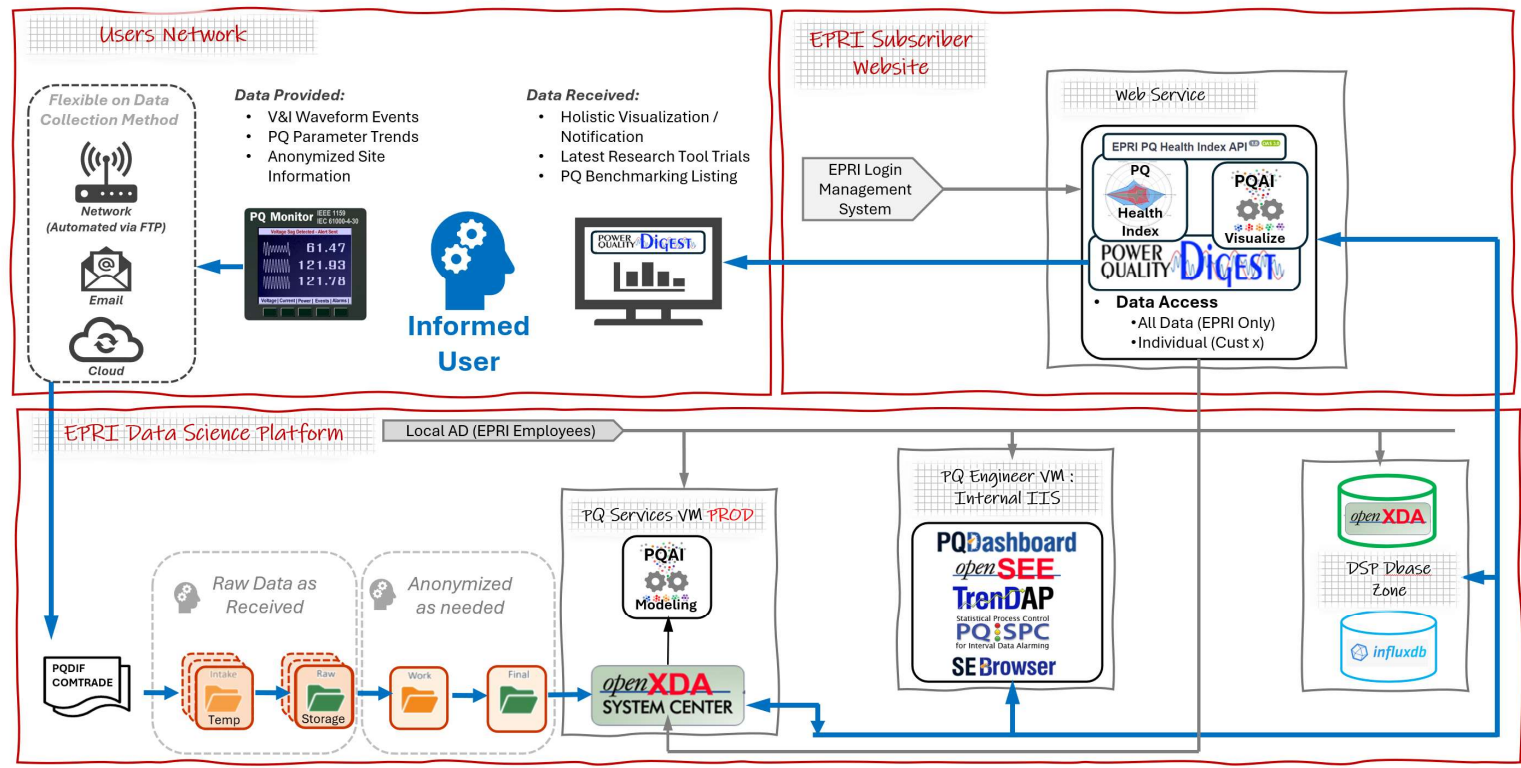
- Welcome and Introductions
- ▶ **EPRI PQ Dashboard Service**
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A

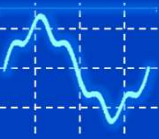


tcooke@epri.com

High-Level Network Flow Diagram

EPRI PQ Dashboard Service | A service for industry and utilities to pilot/demo the PQ dashboard and experience its value





EPRI

Power Quality

PS1B: PQ Data & Analytics

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

PQ Health Index



Automated PQ Benchmarking Service

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

PQ Health Index Development



Normalize our Categories of PQ Data

- Event Data: IEEE 1564-2014
- Parameter Trends: Universal Limit = 1

Temporal Aggregation

- Daily Statistical Values (Max, CP95, Avg, CP05, Min).
- Events per month multiplier for Temporal normalization.

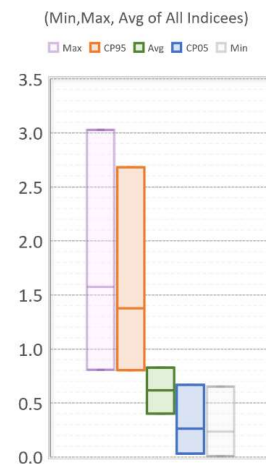
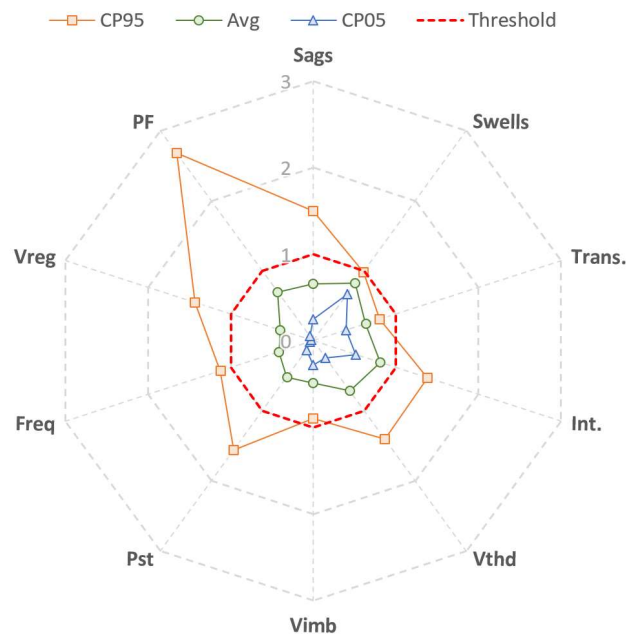
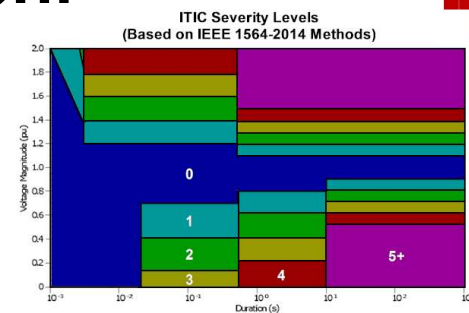
Phenomena Aggregation

Min, Max, Avg of All PQ Indices represents Single PQ Health spread.

4

Geospatial Aggregation

Average of Spider Diagram, Box and Whiskers, or the Index Average



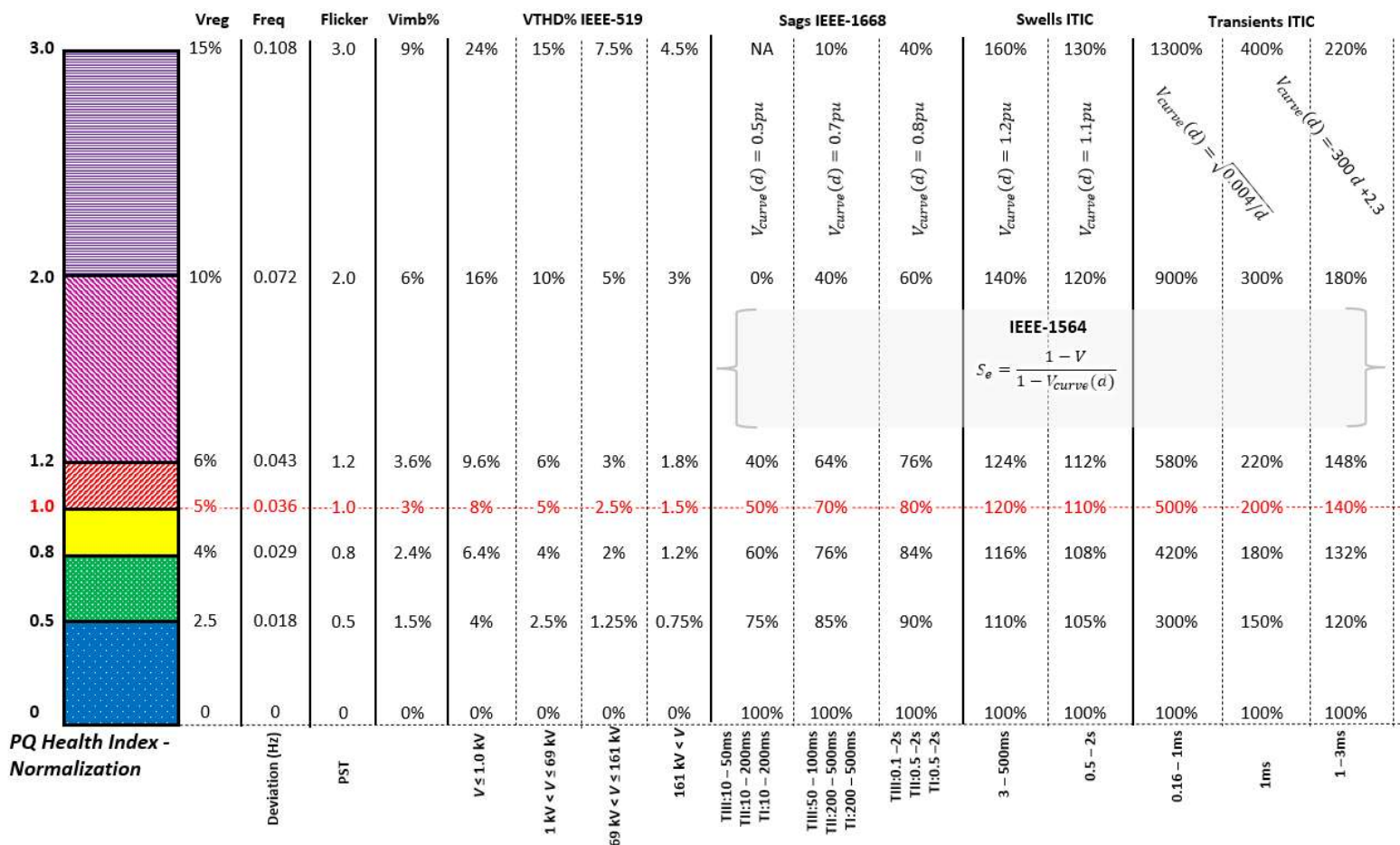
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Normalize All PQ Phenomena Levels



AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

PQ Health Index Tool PoC Excel Worksheet



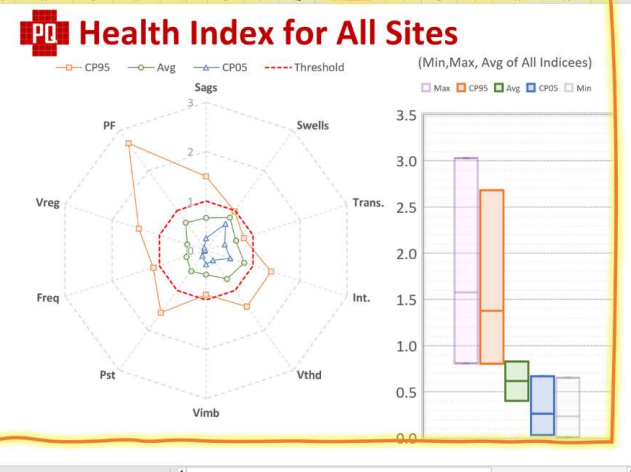
INPUTS

Site Selection

Date Range Selection

Select a Site		Set Dates		Range of Event Data		# of Sites 5		# of Days 365	
All Sites		1/1/2018		1/1/2018					
Start Date (mm/dd/yyyy)		End Date (mm/dd/yyyy)		12/31/2018					
	Max	CP95	Avg	CP05	Min	# of Events	Events/30d/Size Multiplier		
Sags	2.420	1.501	0.659	0.250	0.227	276	22.685	1.134	
Swells	1.000	0.983	0.825	0.668	0.650	2	0.164	1.000	
Trans.	0.809	0.802	0.636	0.396	0.357	3	0.247	1.000	
Int.	1.409	1.384	0.814	0.513	0.507	6	0.493	0.282	
Vthd	1.534	1.402	0.715	0.240	0.212				
Vimb	1.028	0.895	0.485	0.281	0.243				
Pst	1.674	1.556	0.517	0.130	0.090				
Freq	1.292	1.125	0.419	0.042	0.021				
Vreg	1.563	1.438	0.400	0.030	0.007				
PF	3.029	2.682	0.697	0.071	0.015				
Max	3.029	2.682	0.825	0.668	0.650				
Avg	1.576	1.377	0.617	0.262	0.233				
Min	0.809	0.802	0.400	0.030	0.007				

OUTPUTS



Sheet Selection

About	PQ Health Index_Main	Sites	Event_MagDur_Data	VTHD	VIMB	Pst	Freq	VREG	PF
-------	----------------------	-------	-------------------	------	------	-----	------	------	----

Copyright and
Disclaimer Information

Sheet for
Viewing Results

Sheet for Populating Sites
and Configuring Variables

Sheet for Populating
Event Mag/Dur Data

Sheets for Populating Statistical Trend Data

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Data Formatting for the PQ Health Index Tool

Event Data Formatting

Characterization Per IEEE Std 1668

Per IEEE Std 1159TM-2009 [B14], duration of the voltage sag is defined as the time from when the rms voltage decreased below 90% of the nominal steady-state voltage to when it returned above 90% of the nominal steady-state voltage, measured in milliseconds, seconds, or cycles. An example of a voltage sag as an rms plot to 46% of nominal for 5.4 cycles (60 Hz) is shown in Figure 1.

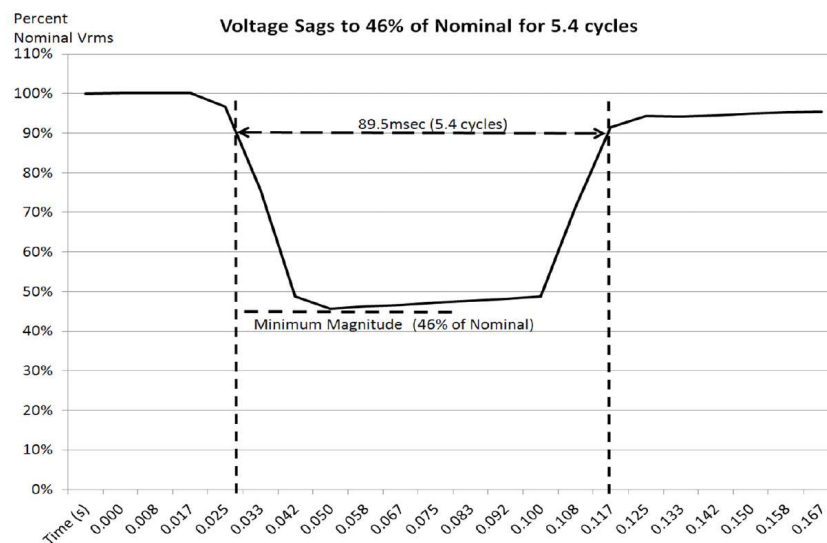


Figure 1—Single-phase voltage sag (instantaneous voltage rms plot)

	A	B	C	D	E
			Magnitude (%)	Duration (sec)	IEEE 1668 Type
1	Date	Site			
2	1/1/18 1:51	Site 1	87	0.025	Type 2
3	1/10/18 13:27	Site 1	81	0.046	Type 2

Table 8—Recommended Type I, II, and III voltage-sag classifications [B1]

Voltage-sag type	Description ^a	Vector diagram	Waveform
Type I	<p>This is a voltage sag in which a drop in voltage takes place mainly in one of the phase-to-ground voltages.</p> $\begin{aligned}\bar{U}_a &= \bar{V} \\ \bar{U}_b &= -\frac{1}{2}\bar{V} - \frac{1}{2}j\bar{E}\sqrt{3} \\ \bar{U}_c &= -\frac{1}{2}\bar{V} + \frac{1}{2}j\bar{E}\sqrt{3}\end{aligned}$		
Type II	<p>This is a voltage sag in which a drop in voltage magnitude takes place mainly in one of the phase-to-phase voltages.</p> $\begin{aligned}\bar{U}_a &= \bar{E} \\ \bar{U}_b &= -\frac{1}{2}\bar{E} - \frac{1}{2}j\bar{V}\sqrt{3} \\ \bar{U}_c &= -\frac{1}{2}\bar{E} + \frac{1}{2}j\bar{V}\sqrt{3}\end{aligned}$		
Type III	<p>This is a voltage sag in which there is a drop in voltage magnitude that is equal for the three voltages.</p> $\begin{aligned}\bar{U}_a &= \bar{V} \\ \bar{U}_b &= -\frac{1}{2}\bar{V} - \frac{1}{2}j\bar{V}\sqrt{3} \\ \bar{U}_c &= -\frac{1}{2}\bar{V} + \frac{1}{2}j\bar{V}\sqrt{3}\end{aligned}$		

^aWhere: \bar{V} – characteristic voltage, \bar{E} – pre-sag voltage, and $\bar{U}_a, \bar{U}_b, \bar{U}_c$ – phase-to-neutral voltages.
© CIGRE 2010

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Data Formatting for the PQ Health Index Tool

Trend Data Formatting

	A	B	C	D	E	F	G
1	Site	Date	Max	CP95	Avg	CP05	Min
2	Site 1	1/1/2018	1.82	1.64	1.43	1.25	1.09
3	Site 1	1/2/2018	1.79	1.68	1.47	1.22	1.12
4	Site 1	1/3/2018	1.81	1.69	1.41	1.26	1.11
5	Site 1	1/4/2018	1.77	1.72	1.47	1.19	1.13
6	Site 1	1/5/2018	1.84	1.71	1.45	1.22	1.11

THD-V(%) Daily Trend



F2 =PERCENTILE.INC(B2:B289,0.95)

	A	B	C	D	E	F	G	H	I
1	Start Date and Time	THD-V Avg(%)		Max	CP95	Avg	CP05	Min	
2	6/12/2023 0:00	1.47	6/12/2023	1.800	1.720	1.466	1.280	1.220	
3	6/12/2023 0:05	1.45	6/13/2023	1.860	1.757	1.480	1.280	1.260	
4	6/12/2023 0:10	1.5	6/14/2023	1.790	1.770	1.496	1.300	1.260	
5	6/12/2023 0:15	1.48	6/15/2023	1.860	1.810	1.517	1.300	1.230	
6	6/12/2023 0:20	1.48	6/16/2023	1.800	1.757	1.506	1.290	1.250	
7	6/12/2023 0:25	1.44	6/17/2023	1.770	1.700	1.487	1.280	1.250	
8	6/12/2023 0:30	1.43	6/18/2023	1.780	1.717	1.490	1.290	1.250	

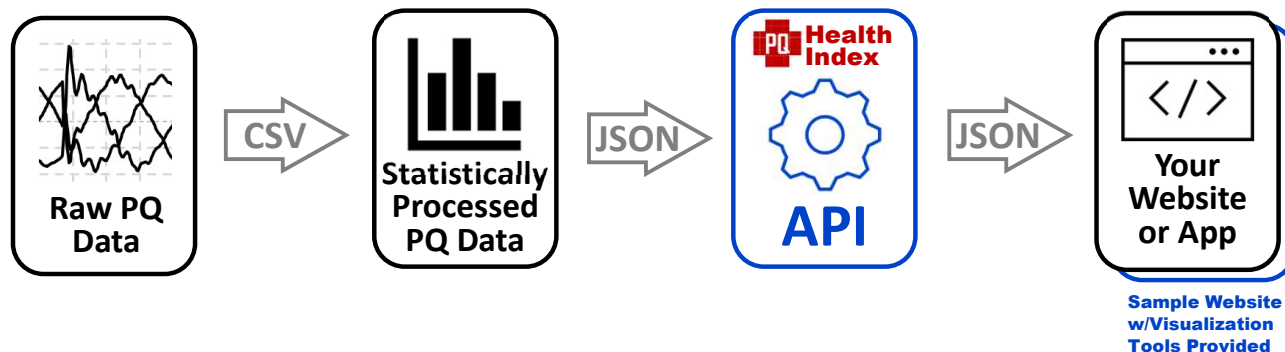
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

PQ Health Index API



Theo Laughner
Director of Engineering,
Lifescale Analytics

3. Installation

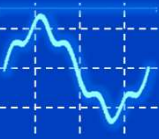
3.1 System Requirements

- This system is designed to run on windows based servers using Python 3.11.9.
- The backed uses MS SQL server or SQL Express.
- The API layer has a FLASK Server built in which is sufficient for testing, but for production a WSGI should be installed. (This will be covered more in the API Section)
- The web front end uses Streamlit v 1.38.0

3.2 Database

The database folder has two SQL files in it.

File	Description
epriwhit_final.sql	This file has the schema only and can be used to set up a fresh installation of the database.
epriwhit_final_w_sampledata.sql	This file has the schema and sample data and can be used to evaluate the system.



AGENDA

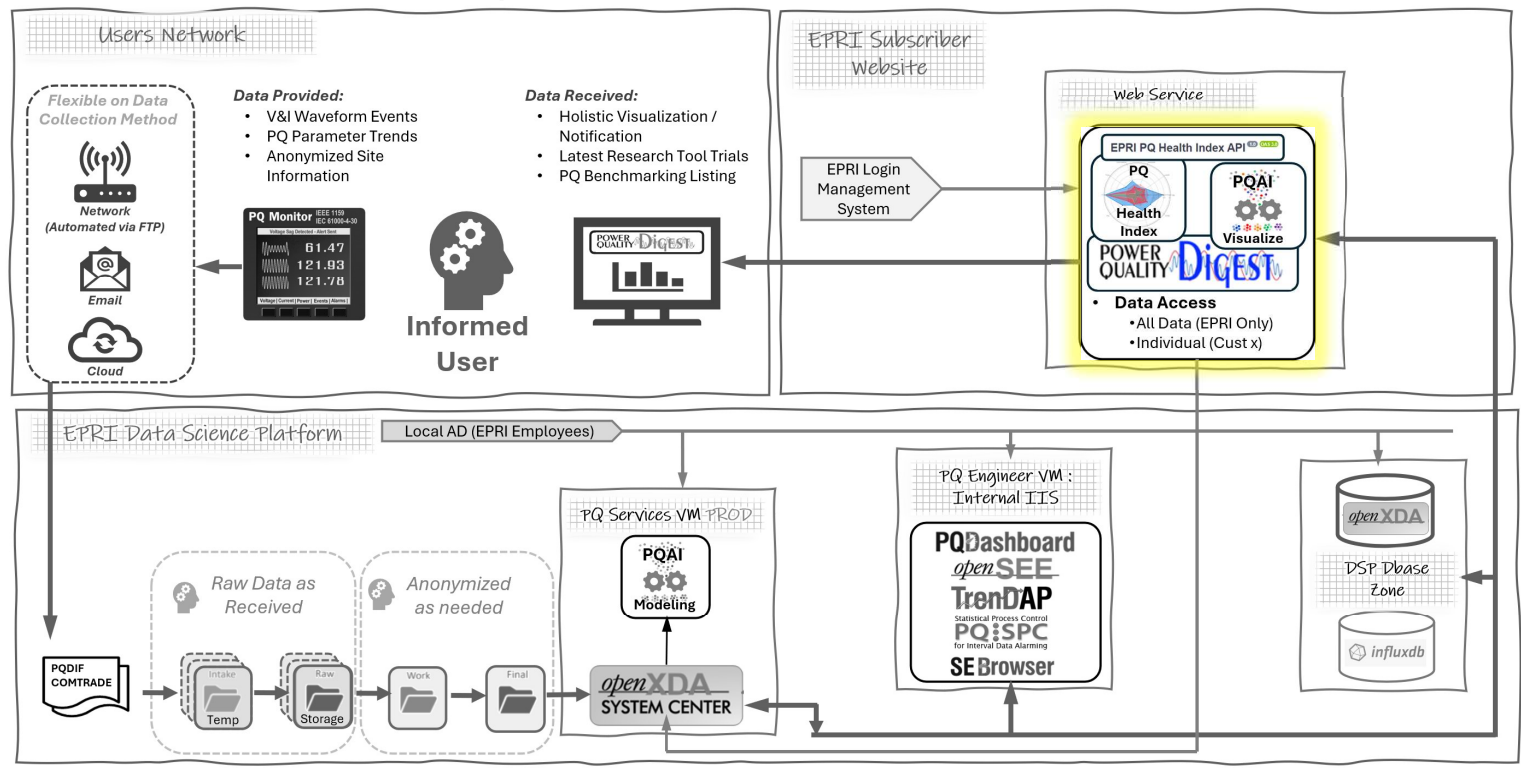
- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - ▶ **PQ Health Index**
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A

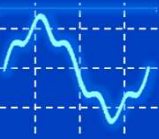


tcooke@epri.com

PQ Dashboard Integration

EPRI PQ Dashboard Service | A service for industry and utilities to pilot/demo the PQ dashboard and experience its value





EPRI

Power Quality

PS1B: PQ Data & Analytics

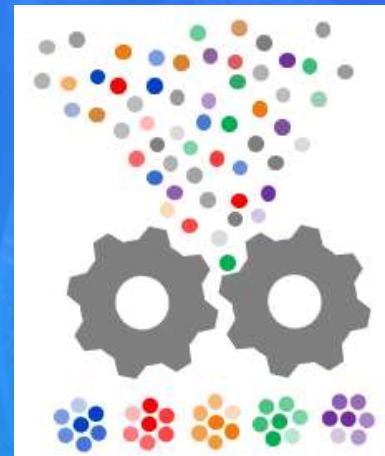
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

AI/ML Clustering Tool



Waveform Clustering

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A

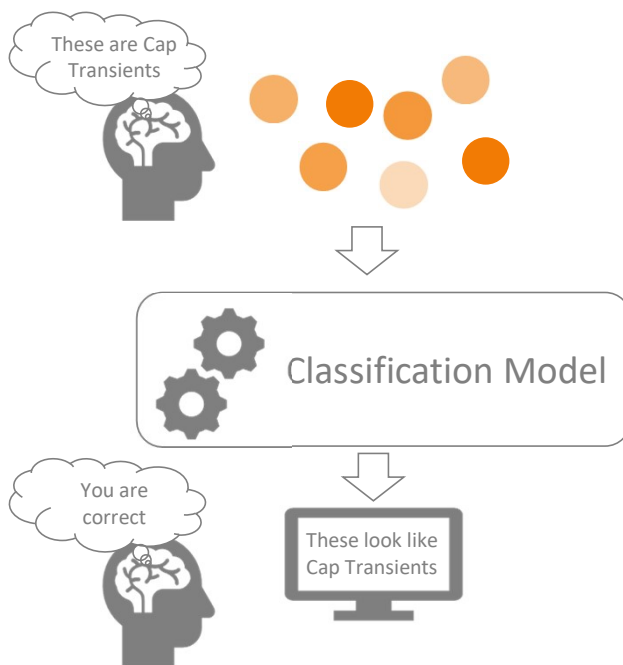


tcooke@epri.com

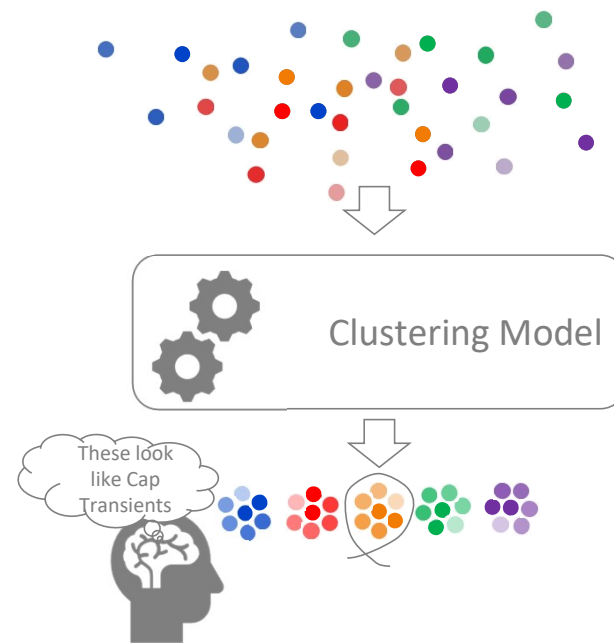
Two Approaches or Combination



- With Metadata
 - Classification
 - Human transfer of knowledge
 - Supervised Learning



- Without Metadata
 - Clustering
 - Looks for similarities
 - Unsupervised learning



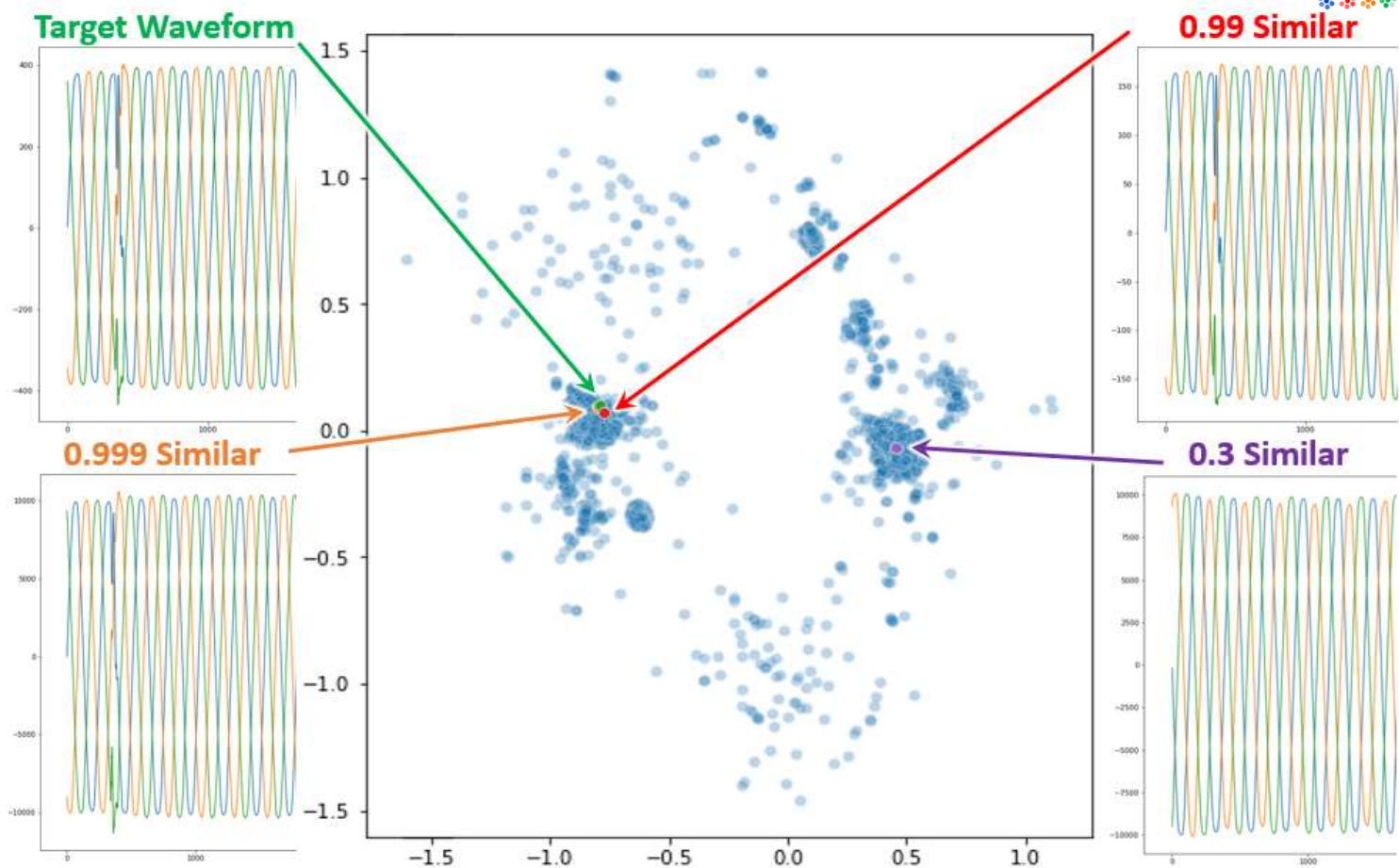
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Clustering Similarity



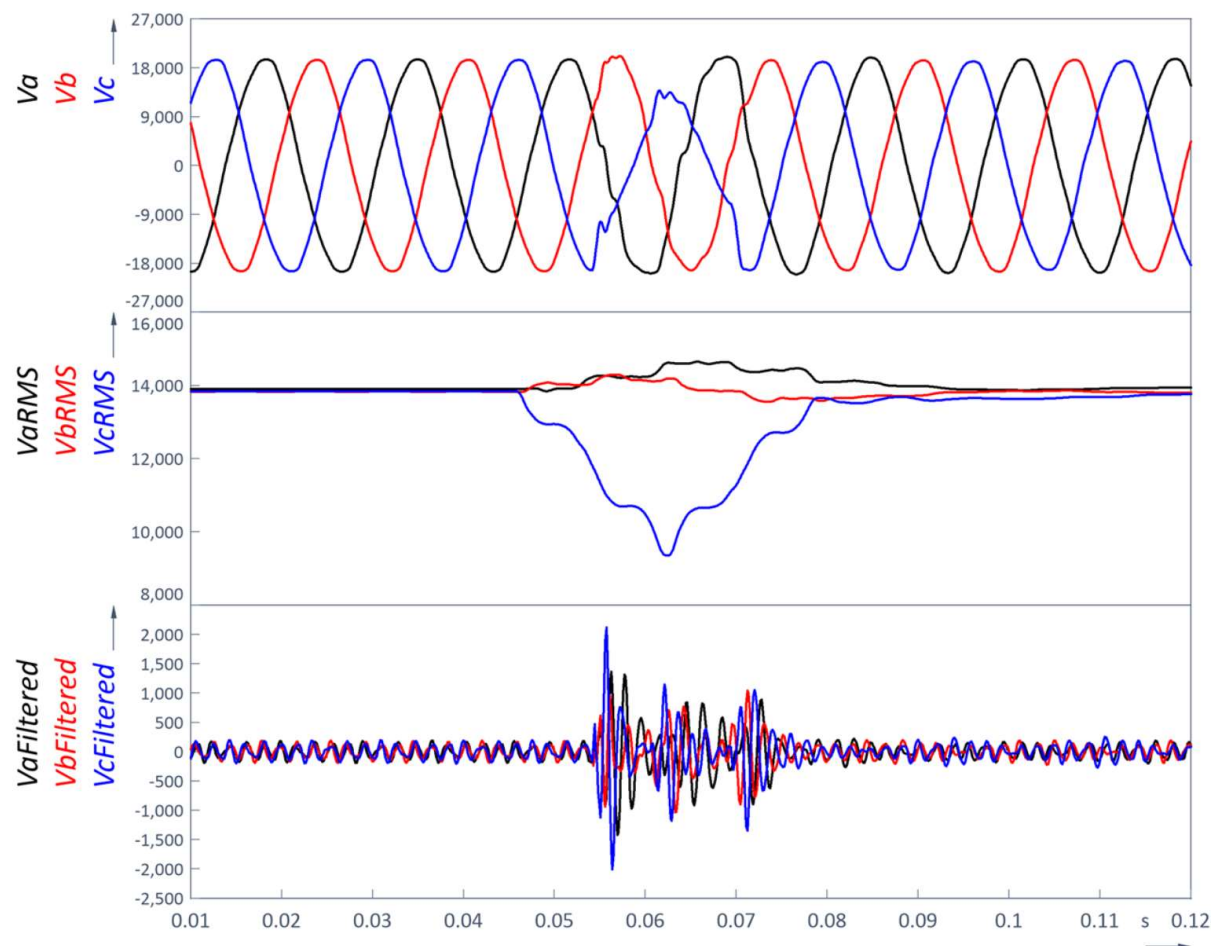
AGENDA

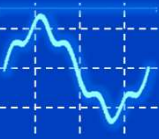
- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Event Characterization





AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
- ▶ Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

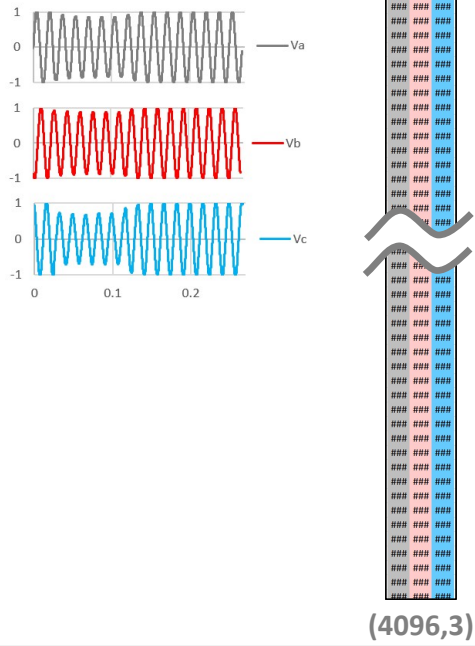
How Phases are Processed



Md Maidul Islam
EPRI
Engineer/Scientist

Data Prep

- 5,000 3-ph voltage recordings
- 256 SPC
- 3-ph Series Data length 4096
- Removed data < 2048 samples
- Padded Nominal to data < 4096 samples
- Scaled data to (-1 to 1) range



(4096,3)

Feature Encoding

- Convolutional encoding
- Reducing the bottleneck size
- 60 seems to work best
- 50 or less than 50, data got distorted.

Convolution & Pooling Layers

C (4096,16)
P (2048,16)
C (2048,32)
P (1024,32)
C (1024,64)
P (512,64)
C (512,128)
P (256,128)
C (256,512)
P (128,512)

Flattening

(65536,1)

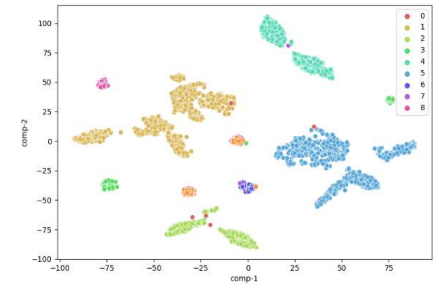
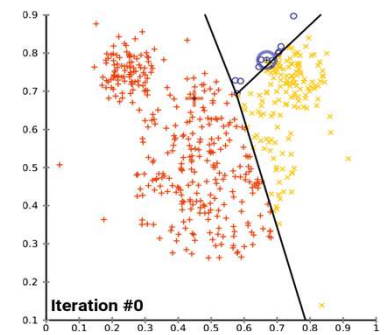
Dense Layer

Output Layer

(60,1)

Clustering

- K-means Clustering
- Principal Component Analysis (PCA) Feature Extraction / Reduction
- t-SNE visualization



AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com


Web-based AI Clustering

<https://apps.epri.com/pqai/>

Important: All lowercase



Md Maidul Islam
EPRI
Engineer/Scientist

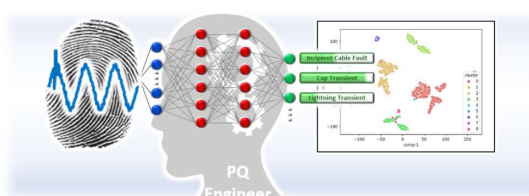

×

Home

- Waveform Clustering Tool
- Instructions
- Future tool link

PQAI

Artificial Intelligence Tools for Power Quality



PQ Engineer

Power waveforms are captured periodically by power analyzers placed throughout the electric power grid. These captured data contain valuable information of power quality and careful analysis can help resolve power quality issue through preventive actions. This tool can be instrumental in analyzing huge amounts of waveform captures quickly. The interactive visualization window allows user to investigate samples further with different signal processing tools and compare two samples to identify potential power quality violations.

This AI based clustering tool is designed to analyze waveform captures using convolutional autoencoders, visualize clusters to identify different power quality events, and investigate event captures with different signal processing tools for root cause analysis.

Benefits and Value:

- Provides an enhanced capability to analyze large amounts of disturbance waveforms to characterize common power quality events.
- Clustering visualizations that help distinguish between normal and abnormal system events to prioritize power quality investigations.
- Clustering of groups that may lead to new characterizations and signatures not recognized by traditional signature analysis methods.

For more information on how to use this application, please review the manual using the navigation menu (sidebar).

This web application is managed by Program 1 – Power Quality, Project Set B – PQ Monitoring and Data. Contact [Tom Cooke](mailto:tcooke@epri.com) (tcooke@epri.com) for more information.

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Web-based AI Clustering - Demo



EPRI

×

[Home](#)
[Waveform Clustering Tool](#)
[Instructions](#)
[About](#)
[Future tool link](#)

Select Dataset
 PQ event Data 1

Select classifier
 K-means clustering

No. of Clusters
 1 9 15

Select Plotting Style
☒ 2D
☐ 3D
☐ UMAP Approximation
☐ Assign cluster name
☒ Signal Analysis
☐ Cyclic histogram plot

Waveform Identifier
 5103

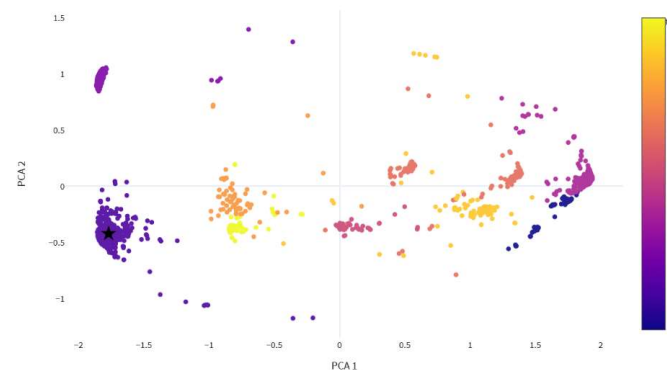
Investigate Selected Waveform
☒ Signal Plot
☐ FFT Plot
☒ FFT Plot without fundamental
☐ RMS per cycle
☐ Compare two signals

PQ event Data 1 Dataset

Selected parameter: {'K': 9}

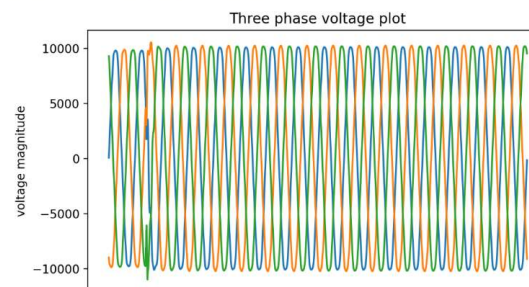
Shape of dataset: (5112, 4096, 3)

number of classes: 9



Your selected signal (5103) belongs to cluster 1

Cluster 1 has 1592 samples, 31.14% of total data



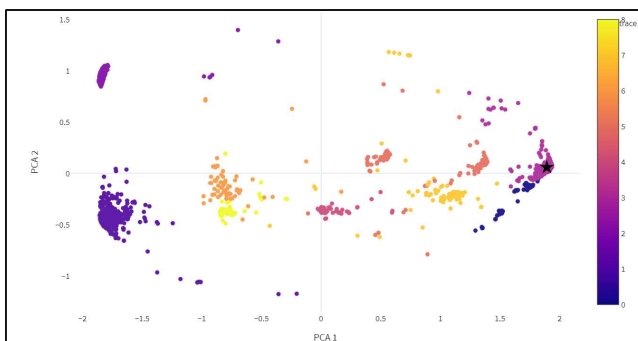
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



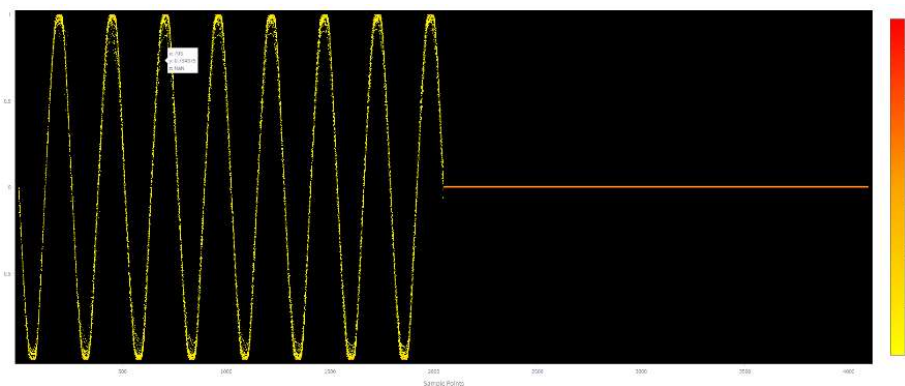
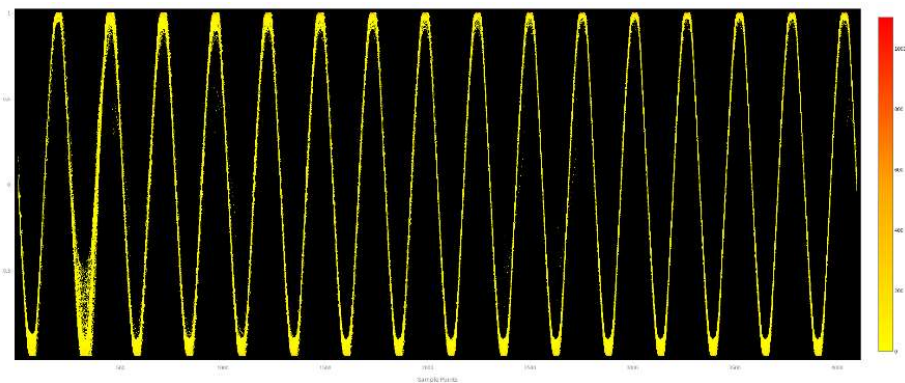
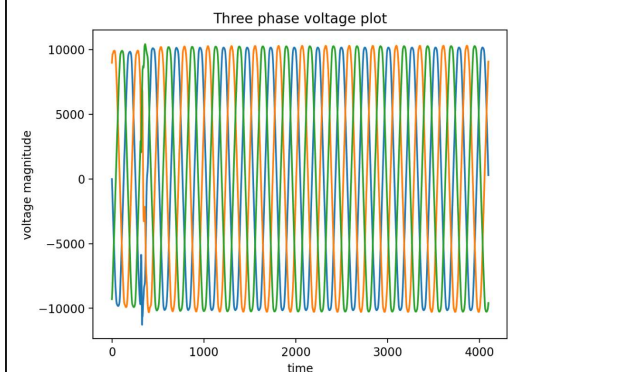
tcooke@epri.com

Web-based AI Clustering - Demo



Your selected signal belongs to cluster 3

Cluster 3 has 1594 samples, 31.18% of total data



AGENDA

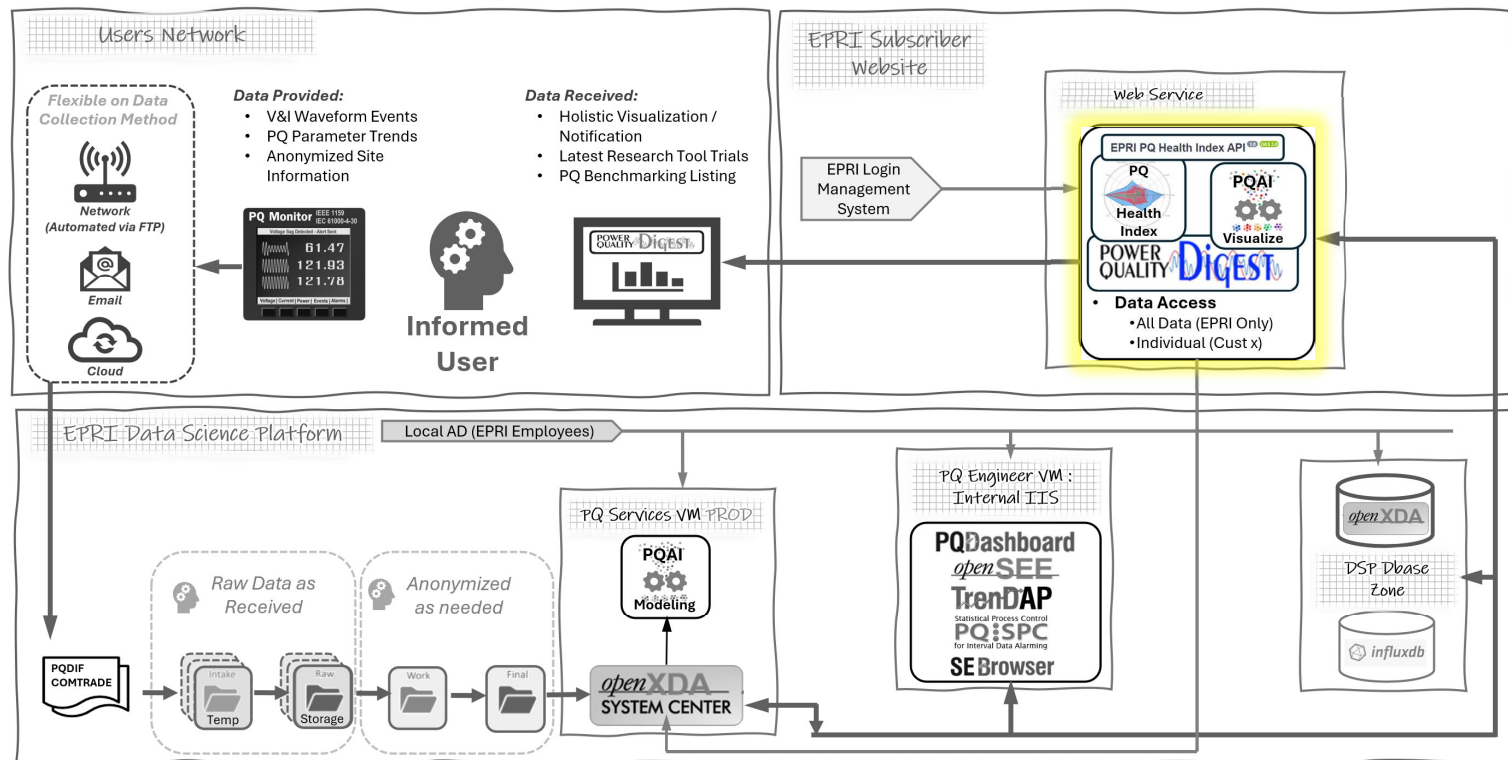
- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ **Waveform Clustering Tool**
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

PQ Dashboard Integration

EPRI PQ Dashboard Service | A service for industry and utilities to pilot/demo the PQ dashboard and experience its value



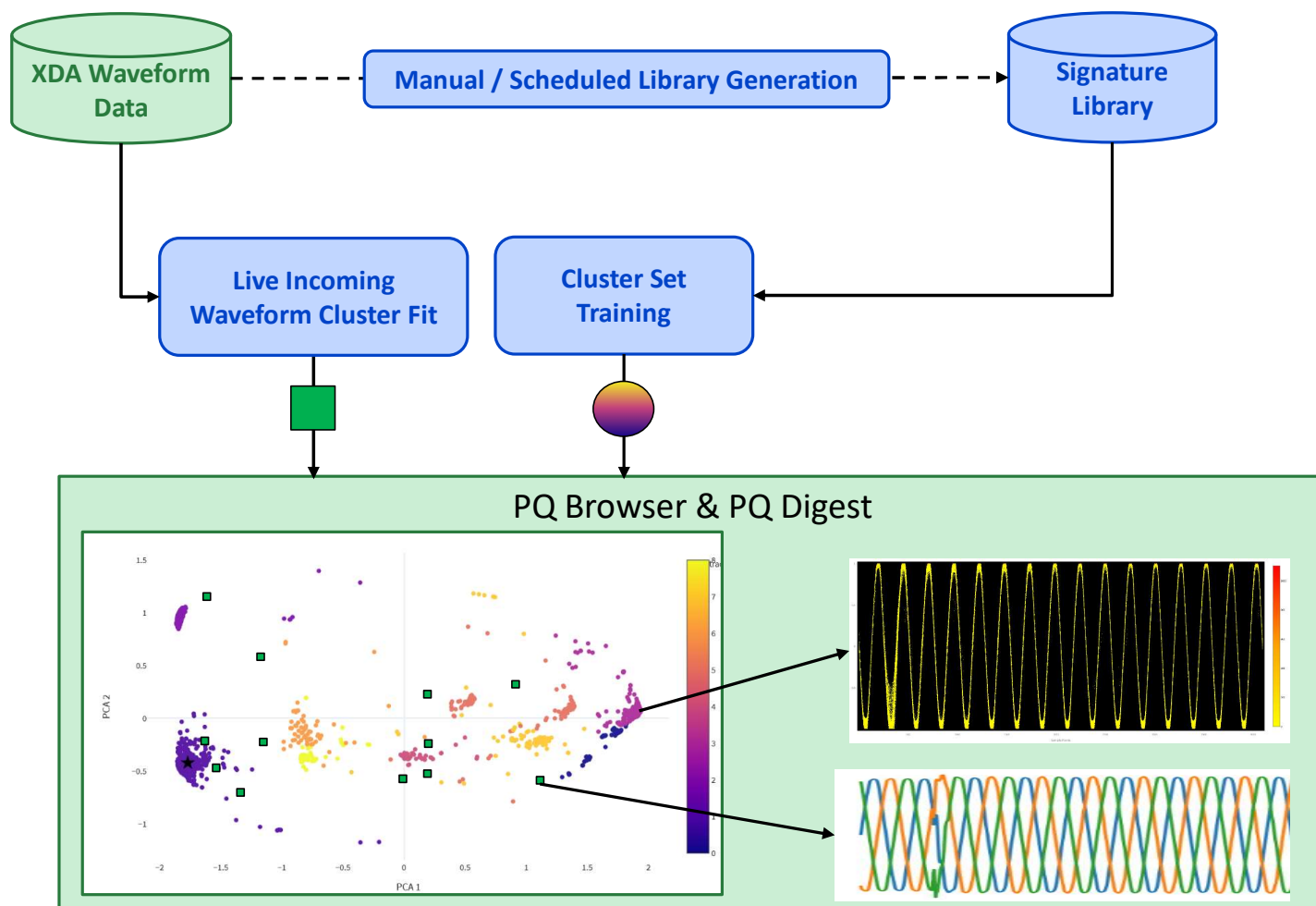
AGENDA

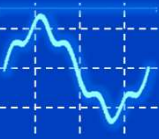
- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - ▶ Waveform Clustering Tool
 - Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

PQ Dashboard Integration Design





EPRI

Power Quality

PS1B: PQ Data & Analytics

AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - ▶ **Compliance Reporting Initiative**
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

IEEE 519 and Other Future Compliance Reporting



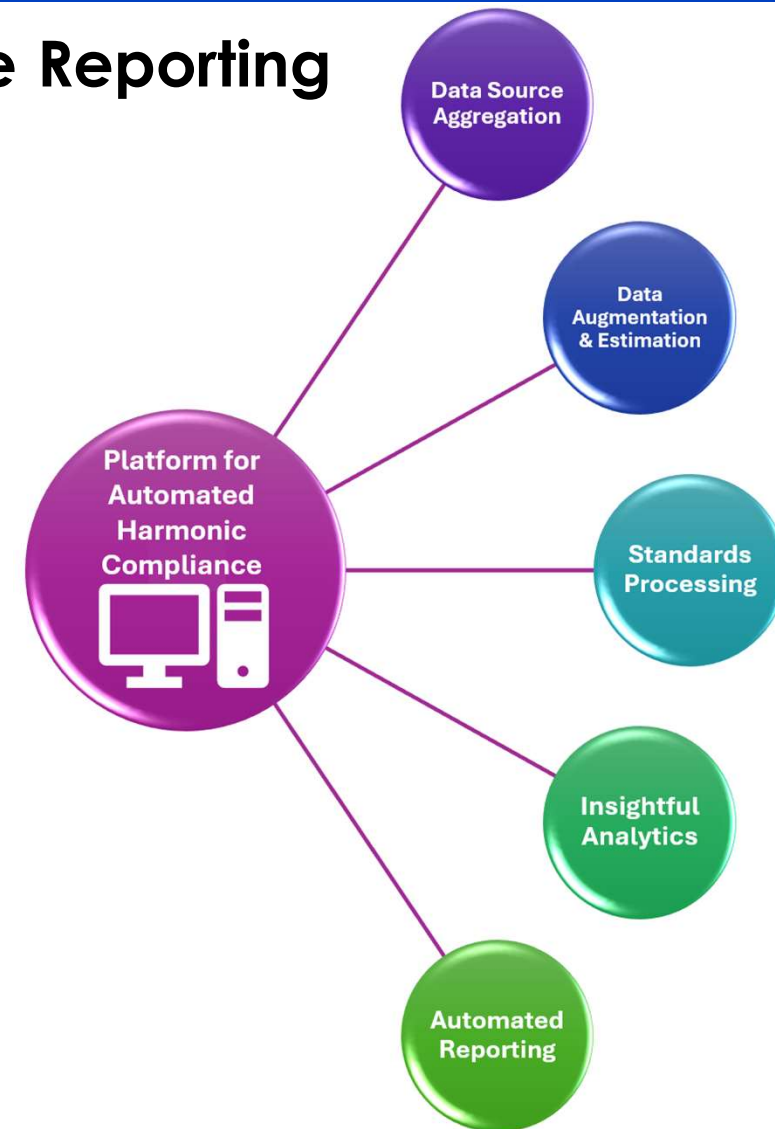
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - ▶ **Compliance Reporting Initiative**
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Platform for Compliance Reporting



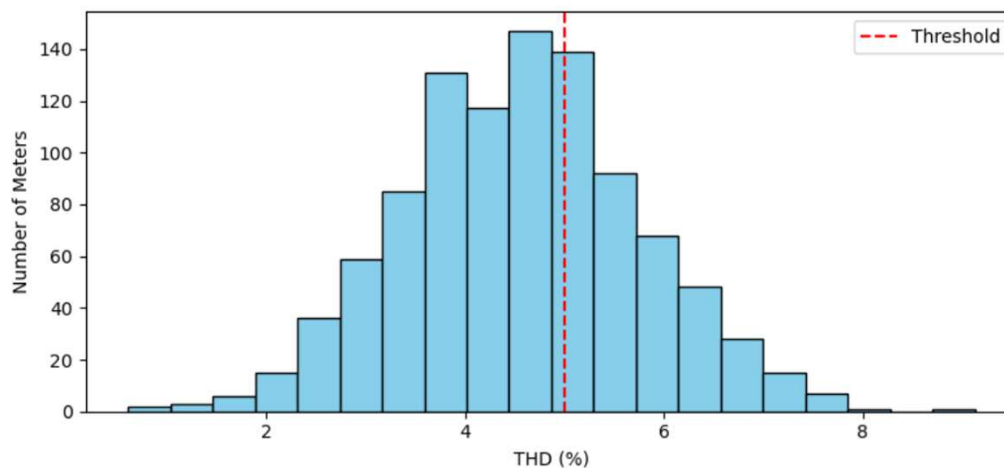
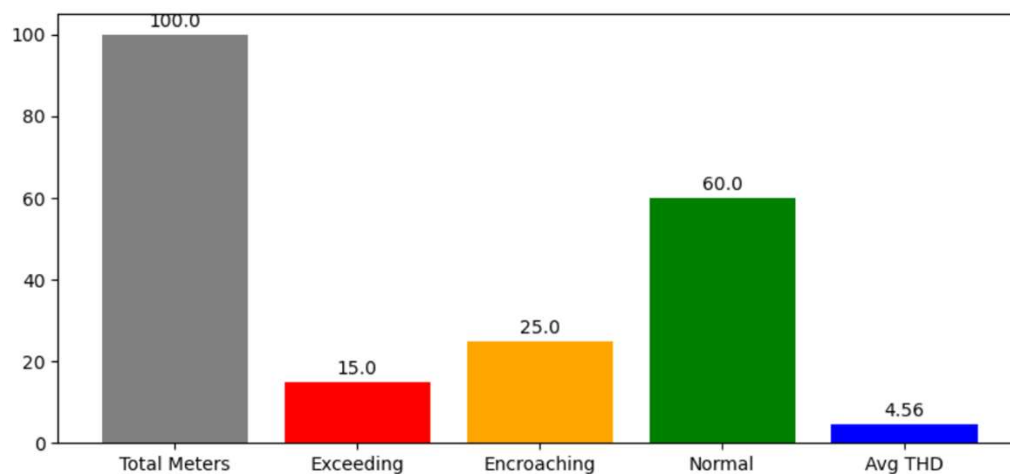
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
- ▶ Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Insightful Analytics: Sites Quantitative Statistics



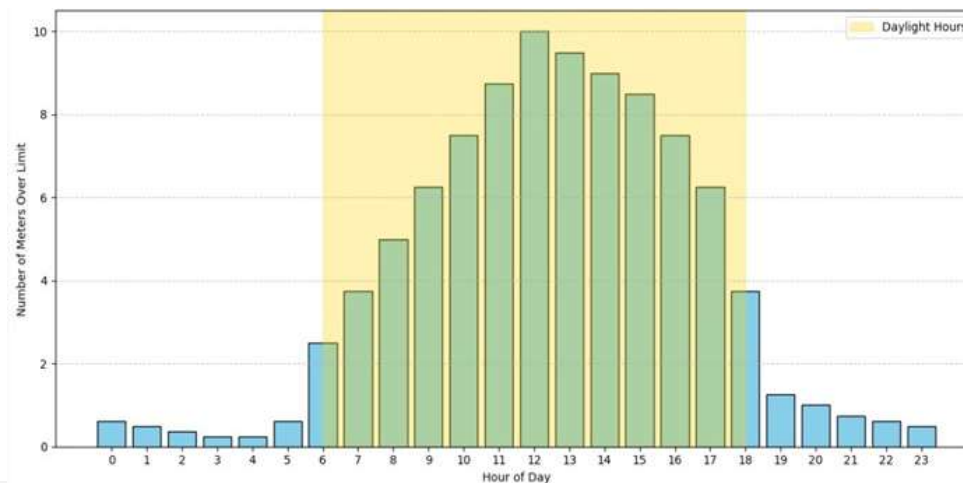
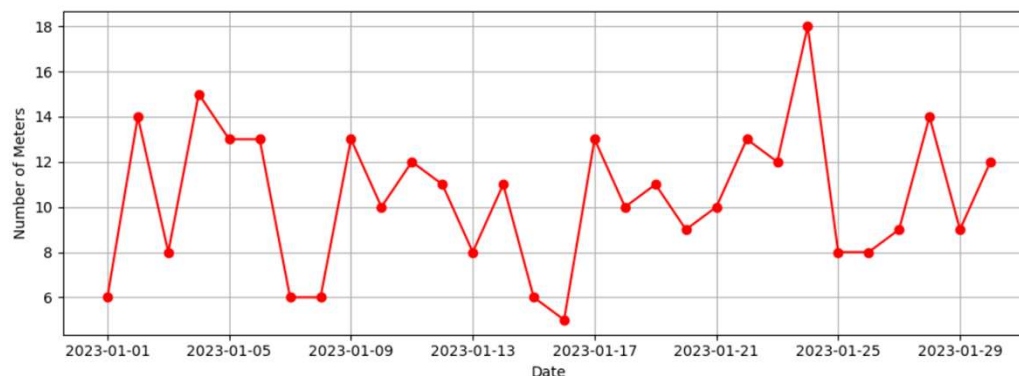
AGENDA

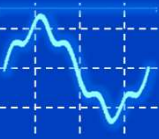
- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - ▶ Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Insightful Analytics: Sites Temporal Statistics





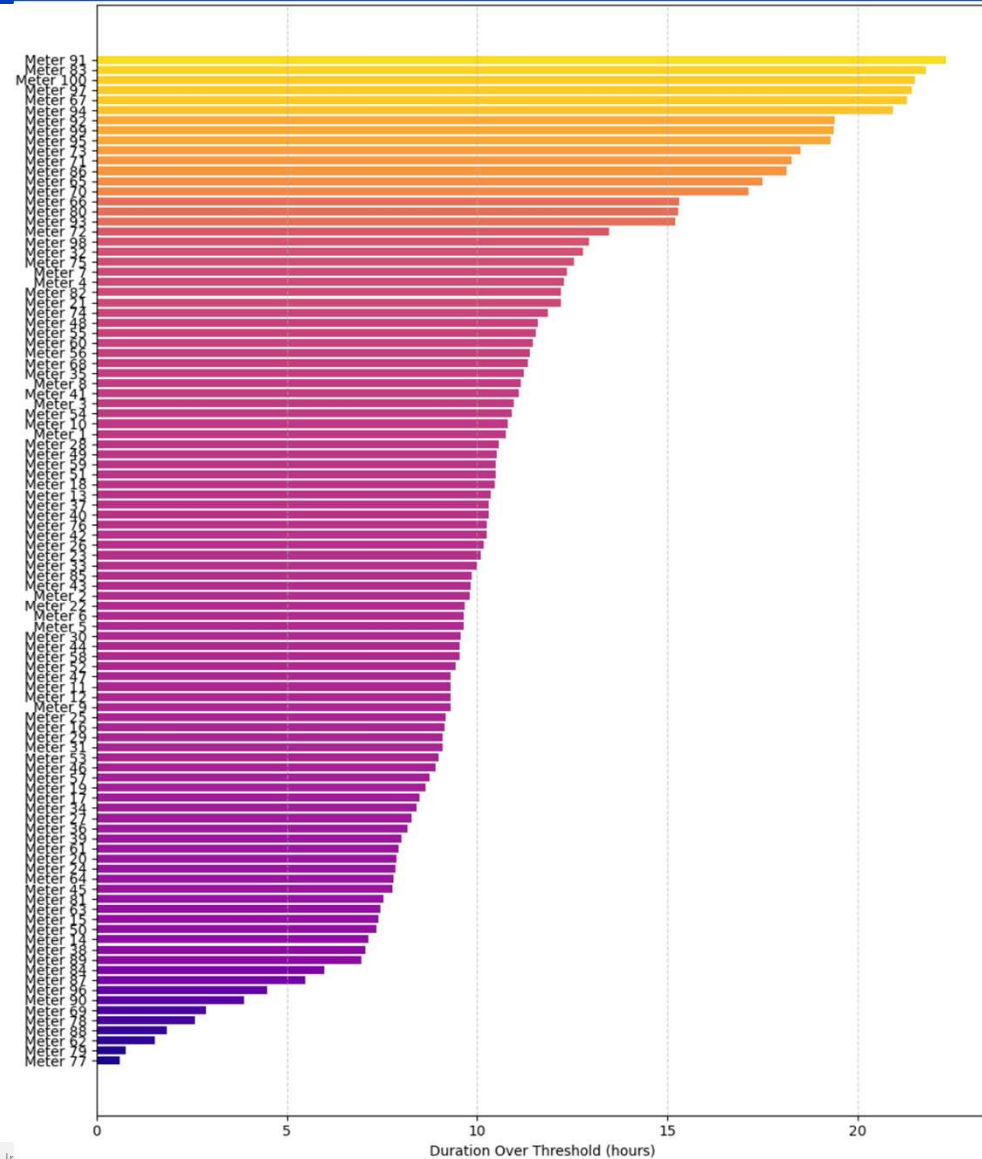
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - ▶ Compliance Reporting Initiative
 - Continuous Point on Wave
- Q&A



tcooke@epri.com

Insightful Analytics: Site Duration over Threshold



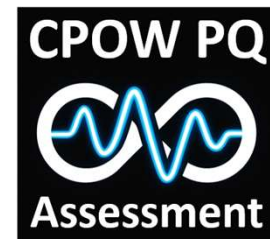
AGENDA

- Welcome and Introductions
- EPRI PQ Dashboard Service
- Developments
 - PQ Health Index
 - Waveform Clustering Tool
 - Compliance Reporting Initiative
- ▶ Continuous Point on Wave
- Q&A



tcooke@epri.com

Proposing for 2026 CPOW for Incipient Fault Analysis and Asset Health.



- Data Requirements
 - How to manage CPOW data flow and reporting.
- Developments
 - Work with prototypes and interested manufactures (SELs, APP, OZM)
- Support P37 T&S Asset Health Testing
- Demonstrations



TOGETHER...SHAPING THE FUTURE OF ENERGY®

in X f
www.epri.com

© 2025 Electric Power Research Institute, Inc. All rights reserved.