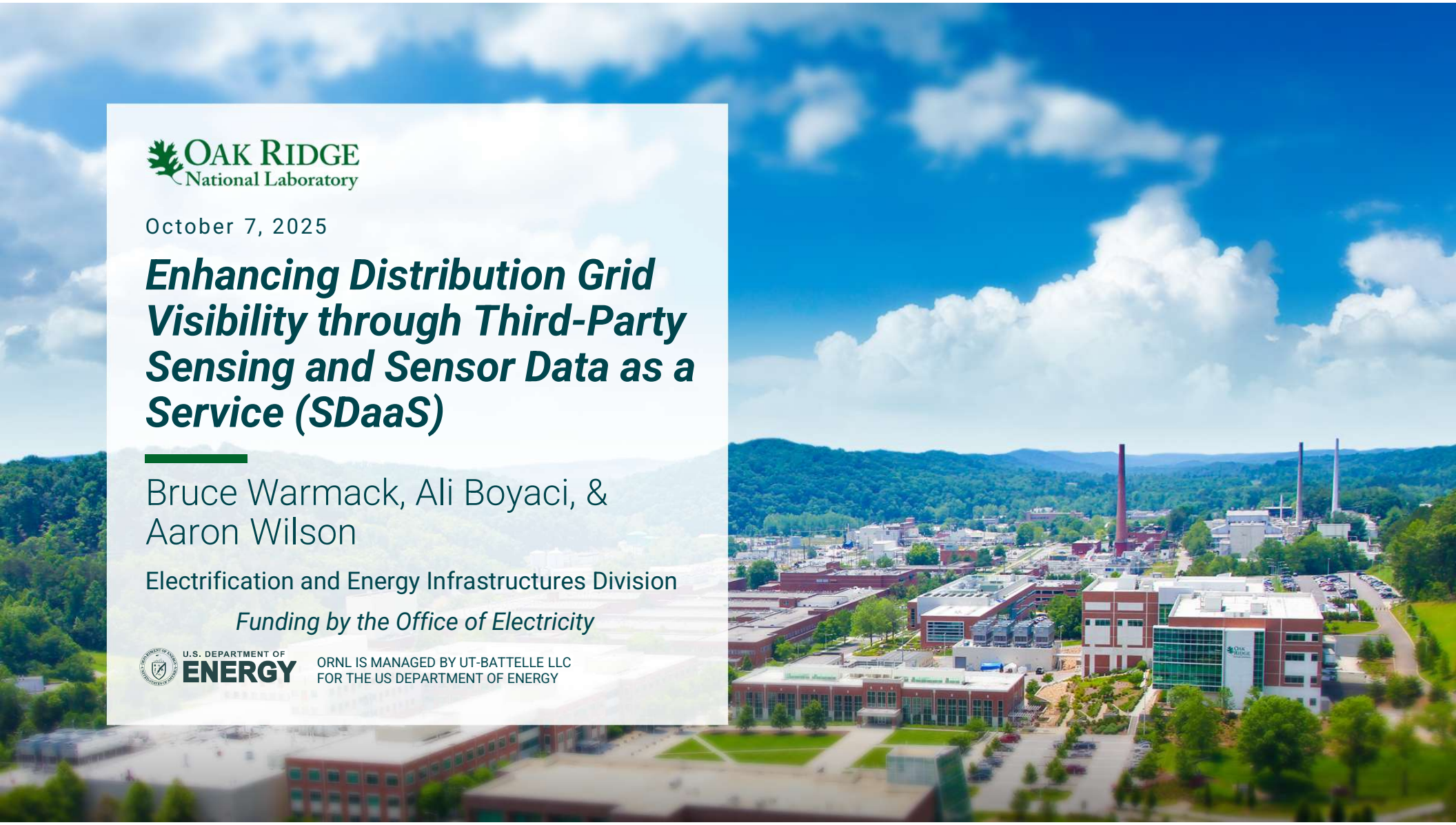

OAK RIDGE National Laboratory

October 7, 2025

Enhancing Distribution Grid Visibility through Third-Party Sensing and Sensor Data as a Service (SDaaS)

Bruce Warmack, Ali Boyaci, & Aaron Wilson

Electrification and Energy Infrastructures Division

Funding by the Office of Electricity

U.S. DEPARTMENT OF ENERGY

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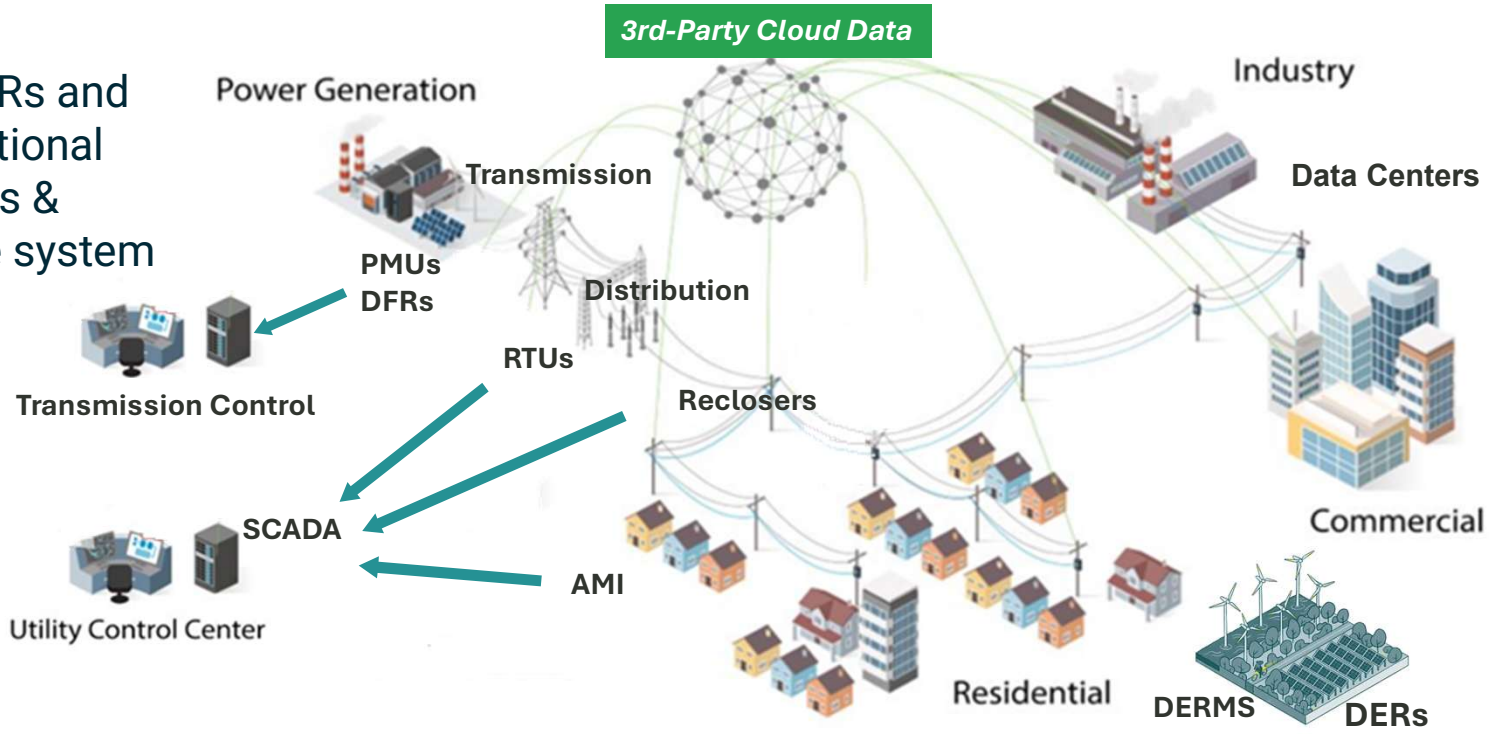
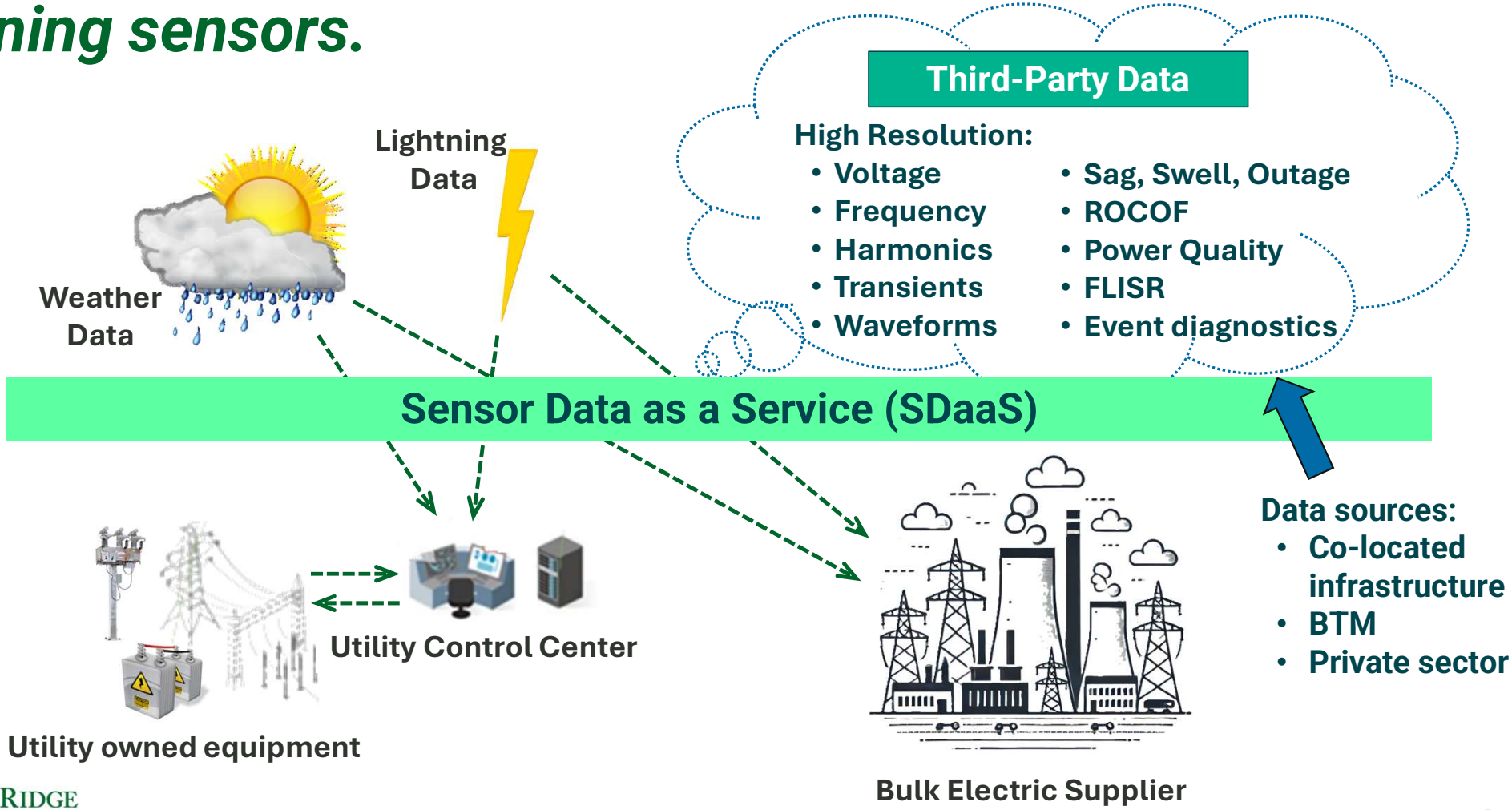
Grid operations need more observability than ever.

The dynamics of DERs and IBRs challenge traditional utility-owned sensors & comms for accurate system state estimation.

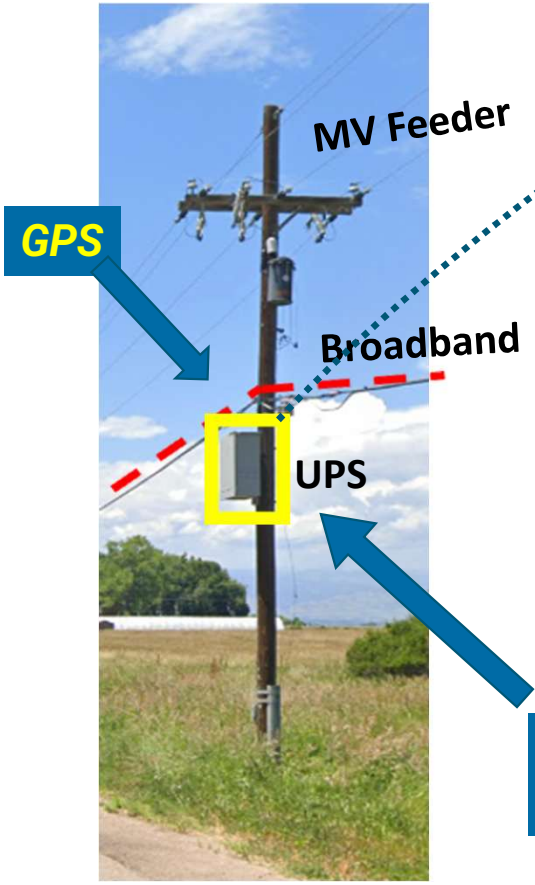


Opportunity: Emerging BTM and other third-party sensors offer high time and spatial resolution, providing real-time grid visibility and disturbance detection.

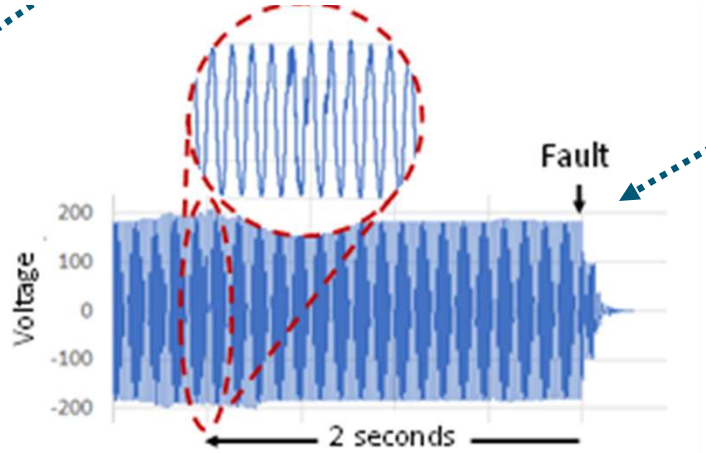
SDaaS allows utilities to access critical grid data without owning sensors.



Broadband parallels dis*tribution feeders and can be tapped for high-resolution data.*



Presently 650,000 broadband UPS boxes connect to >90% of population.



Actual recording capturing small arcing activity 2 seconds prior to outage.

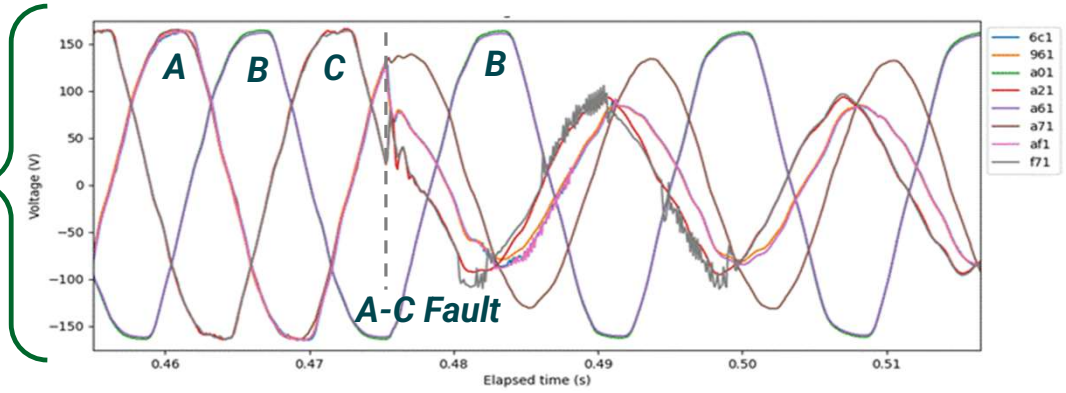
DAQ box added to the UPS can stream 10kHz data – with power ride-through

High Fidelity GridVisibility, inc.

Cloud Aggregation Server

Waveforms contain details of transient and steady state behaviors.

- *Phase ID*
- *Fault analysis*
- *Arcing*



Simple impedance loading

$Length_{Line} := 6mi \quad Power := 10MW \quad Voltage := 14kV$

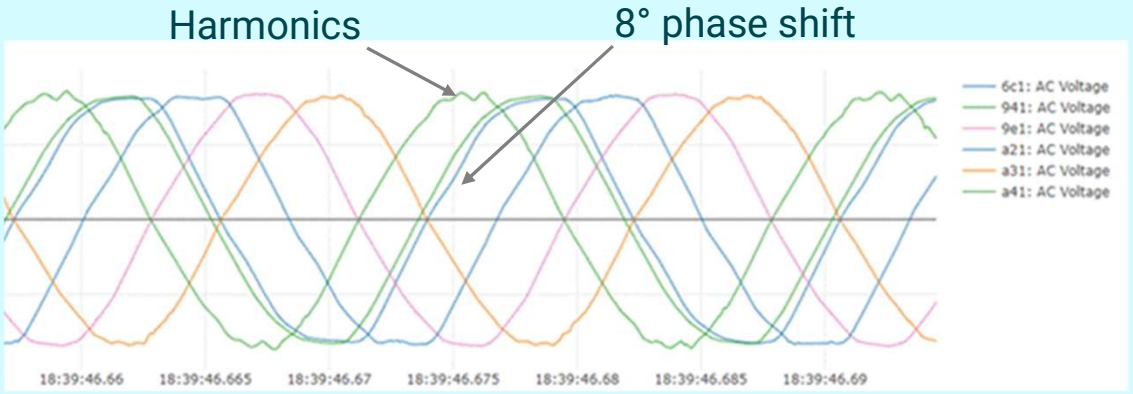
$R_{Line} := 0.0335 \frac{\Omega}{1000ft} \cdot Length_{Line} = 1.06\,\Omega$ 636MCM AAC

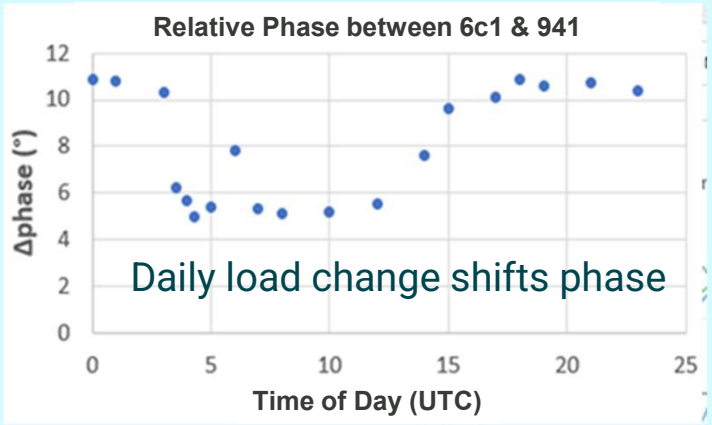
$X_{Line} := 2\pi \cdot 60Hz \cdot 1.3 \frac{mH}{mi} \cdot Length_{Line} = 2.94\,\Omega$

$R\_load := \frac{(14kV)^2}{Power} = 19.6\,\Omega$

$\operatorname{atan}\left(\frac{X_{Line}}{R\_load + R_{Line}}\right) = 8.1\,deg$

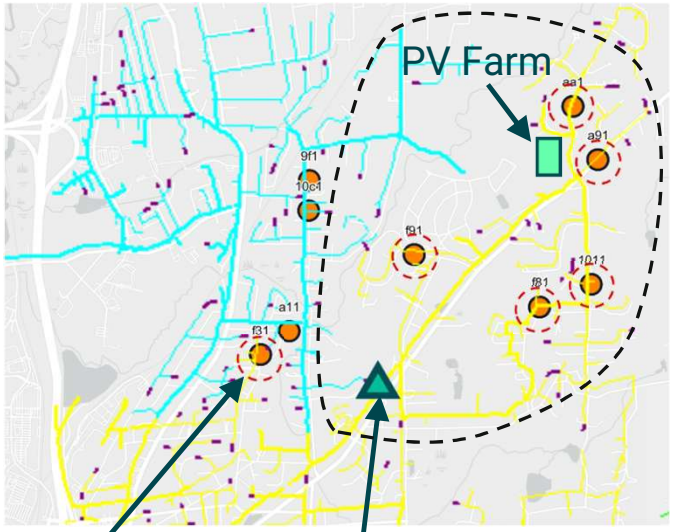
Phase shift shows power load and direction by line impedance.





Power outage reveals aberrant PV farm disconnect behavior.

PV farm appears to sustain outage with over-voltage and oscillating 5-6 cycles at 84Hz before disconnect.



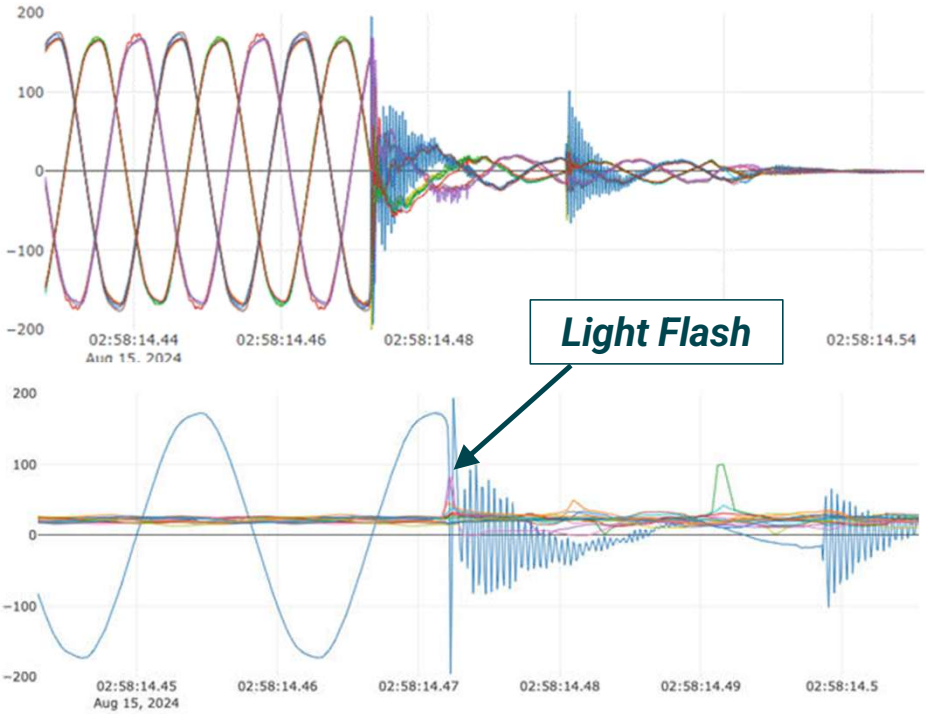
Upstream of Recloser

Recloser disconnected downstream sensors on all phases.

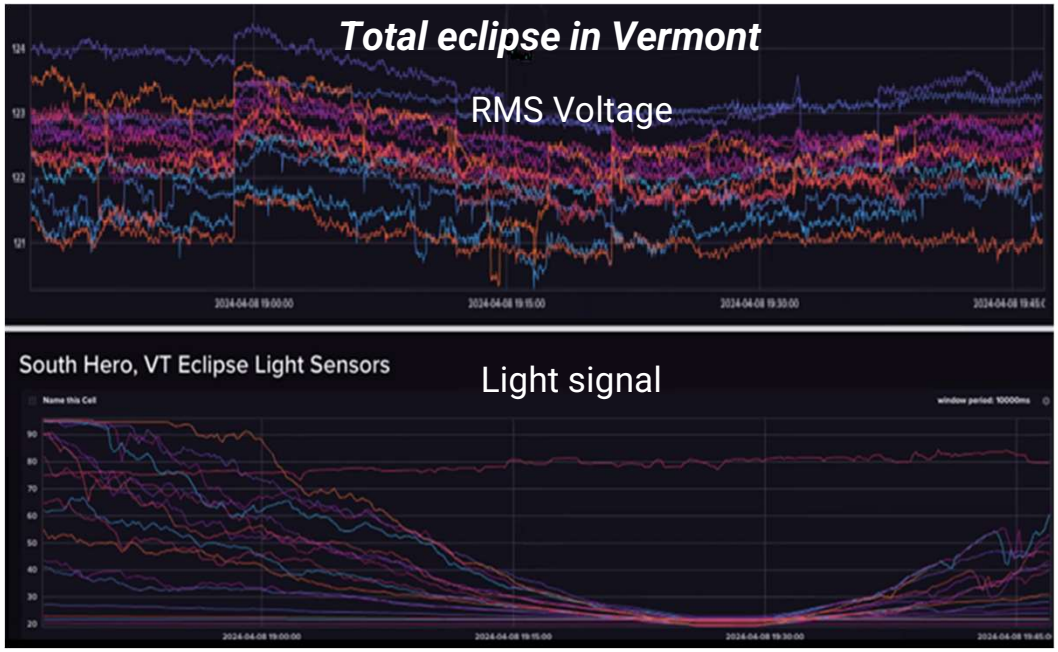
Multiple GPS-timestamped broadband sensors in New Haven, CT

Light sensors in GridVisibility DAQs detect ambient light, including lightning flashes in the area.

Lightning precipitated outage



Voltage depression caused by eclipse on DERs countered by tap changes.



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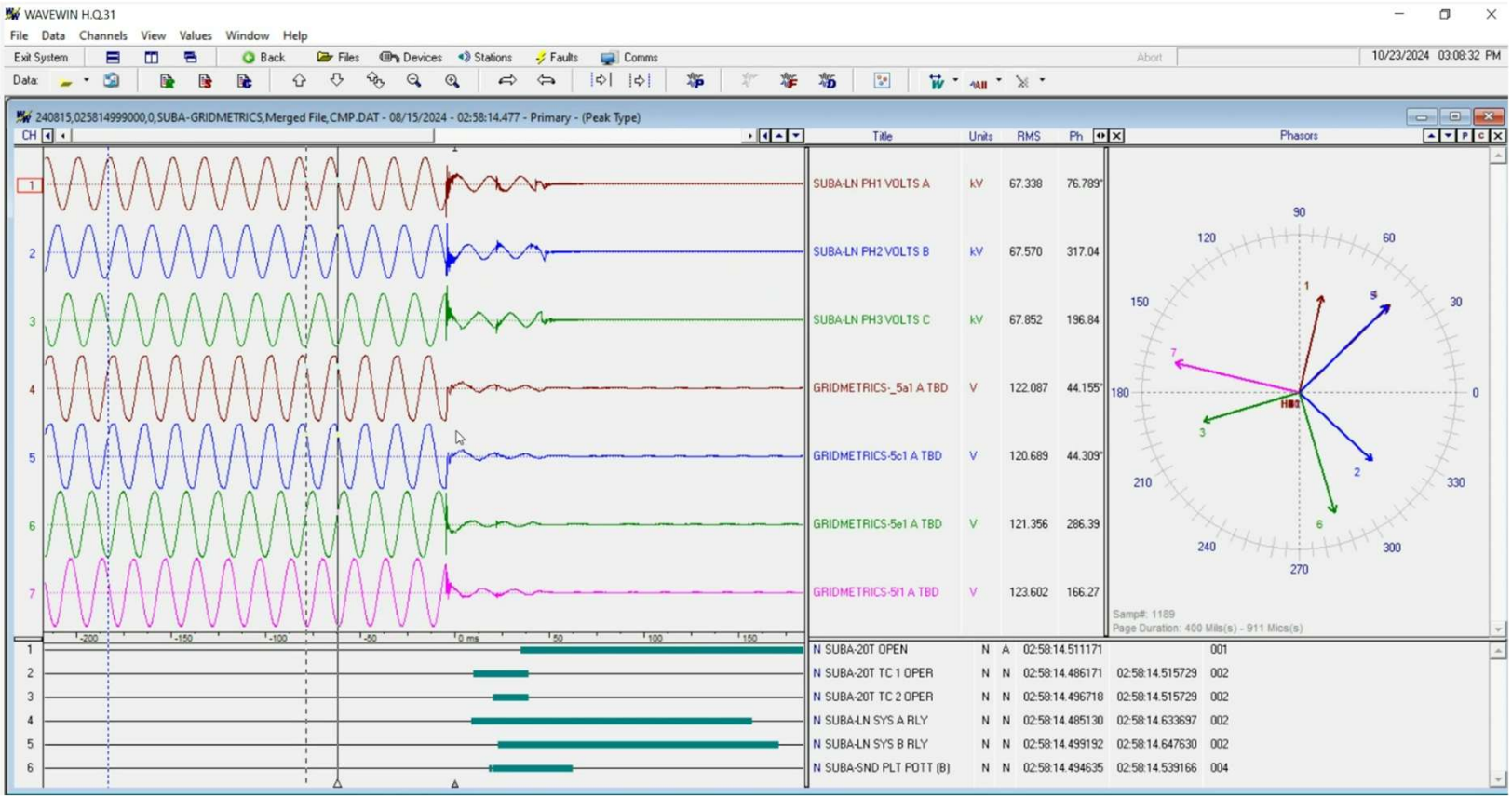
Compatibility of SDaaS with utility software eases adoption by utilities.

Utility PTs

GridVisibility sensors

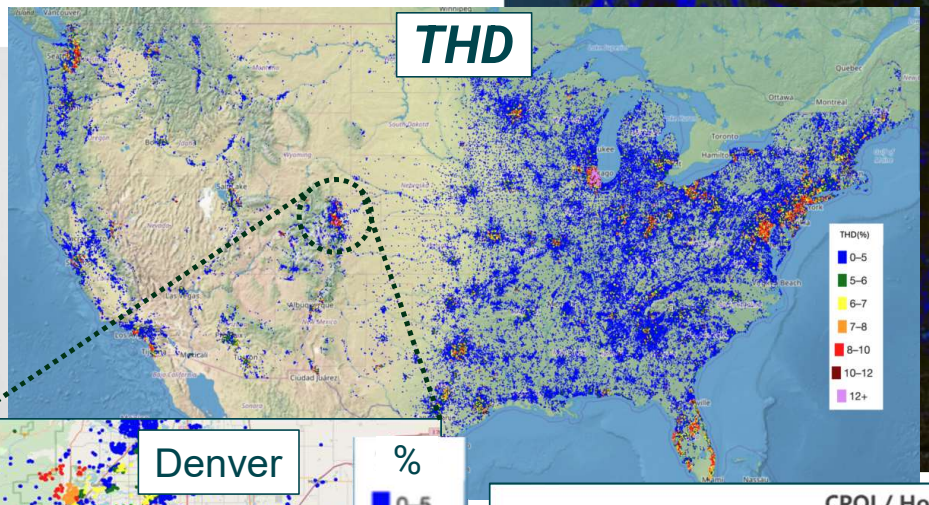
Utility digital data



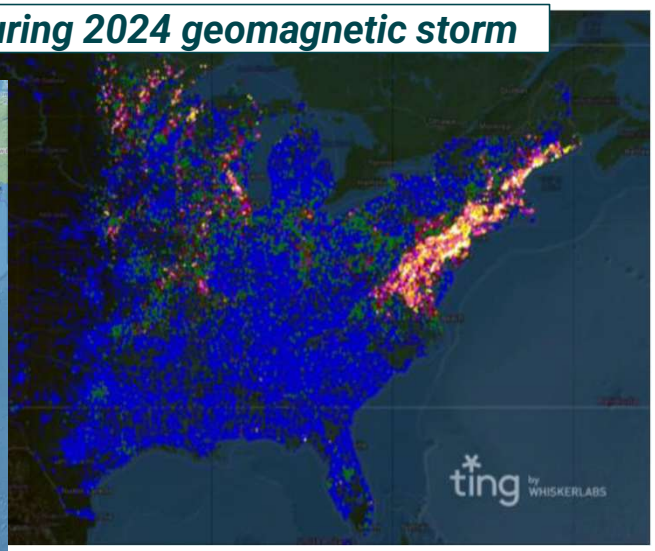
Whisker Labs Ting sensor monitors voltage and arcing in the home.

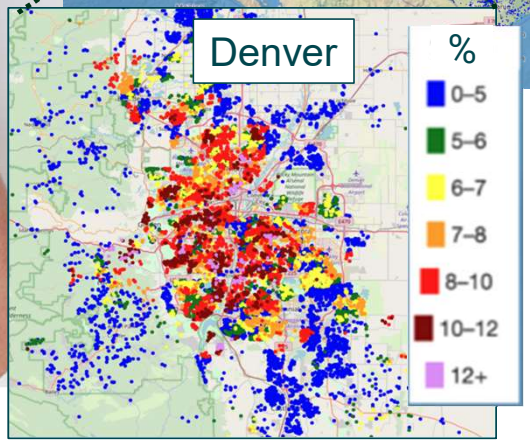
Installed by the homeowner, it connects with Wi-Fi.

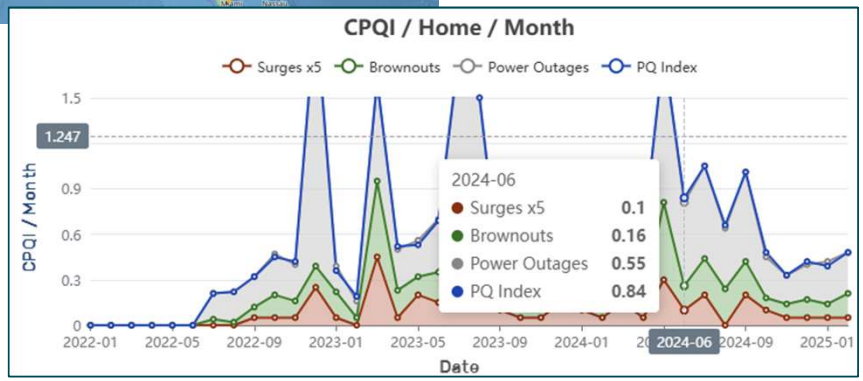
THD



Excess THD during 2024 geomagnetic storm







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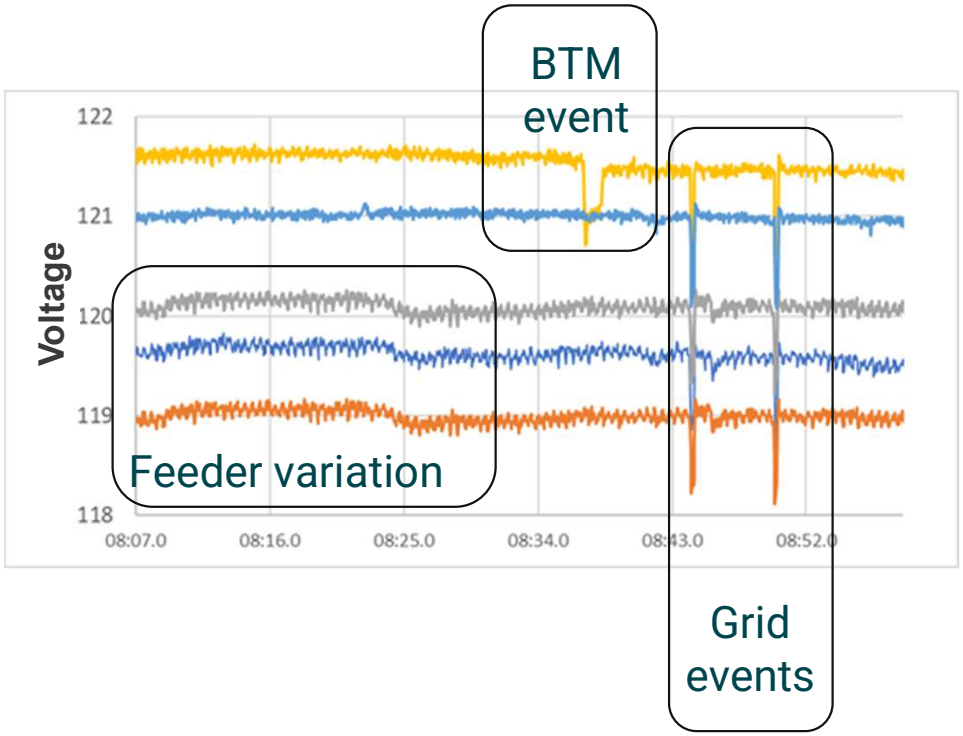
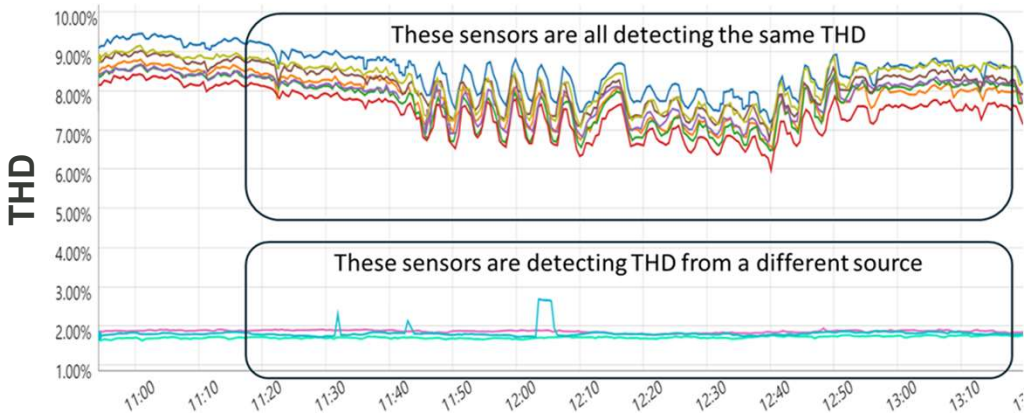
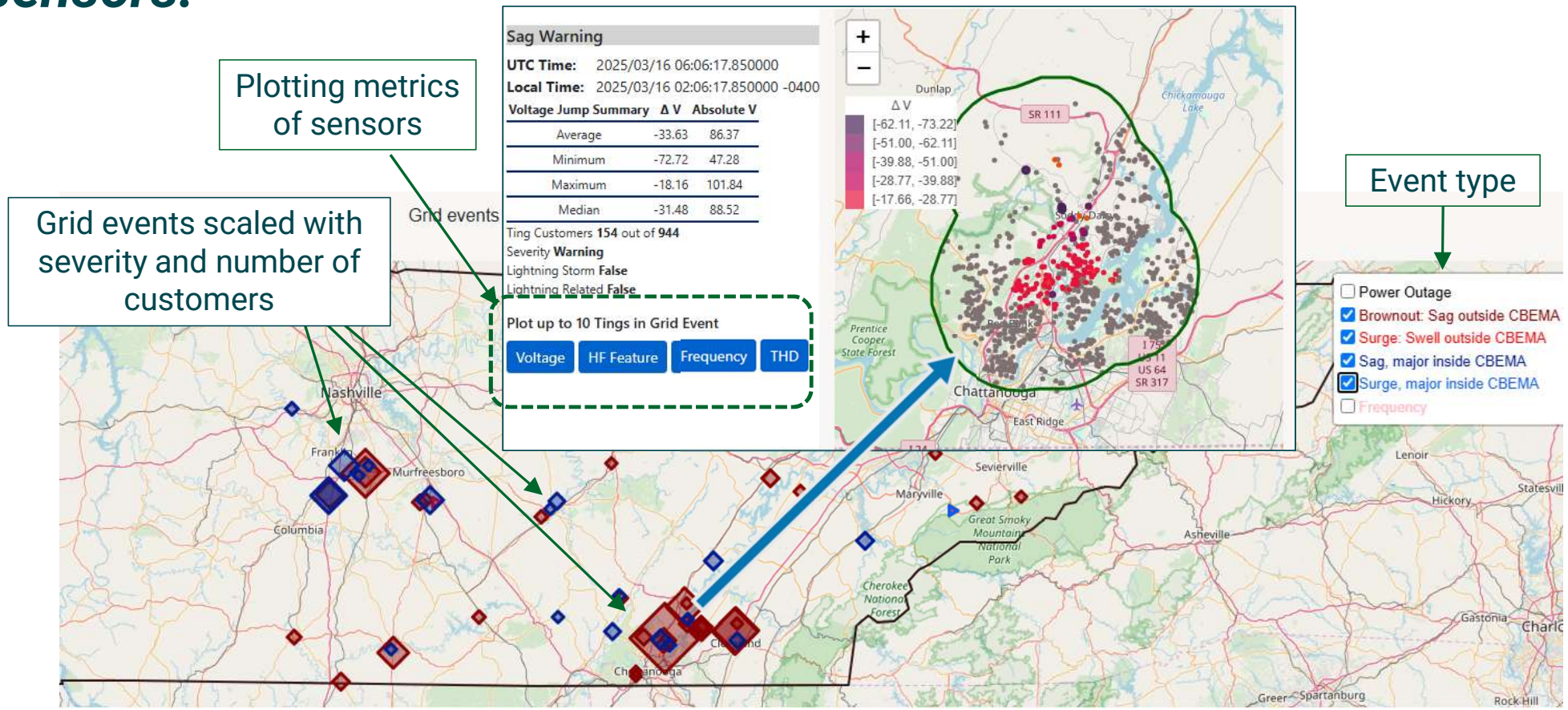
Data correlation can readily distinguish BTM noise and grid variances and events.

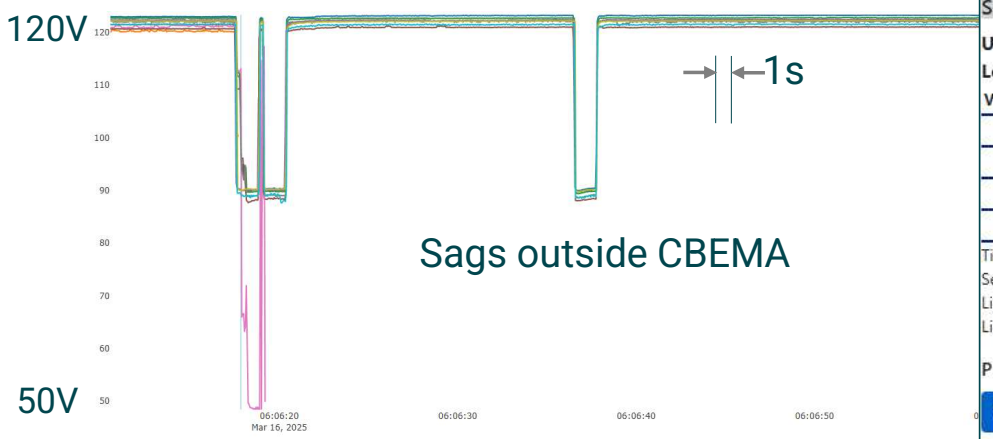


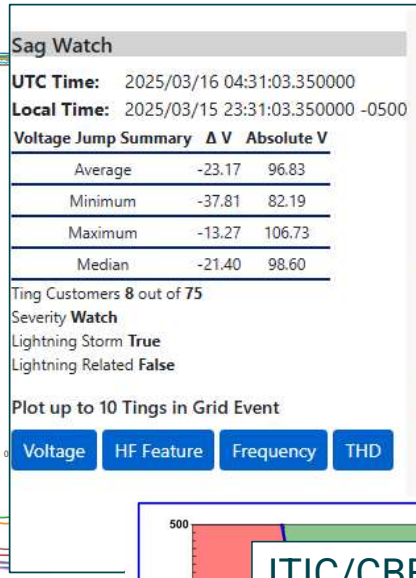


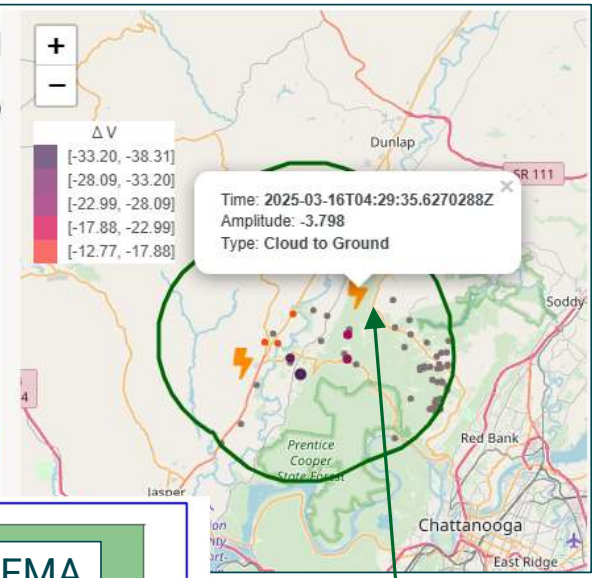
Selectable grid events show locations and number of affected sensors.

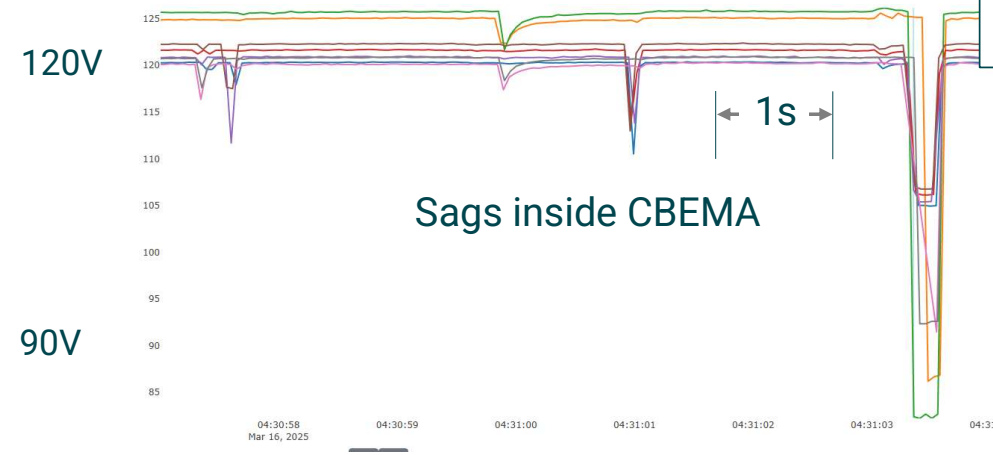


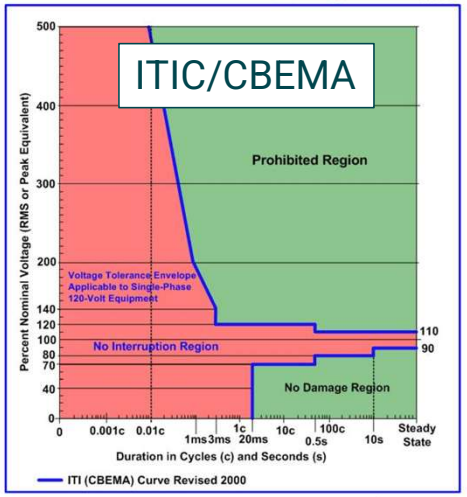
Events not seen by utilities are selectable.







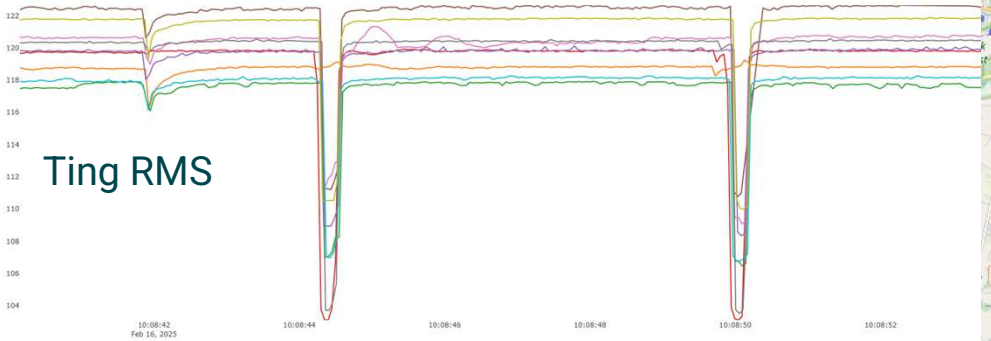


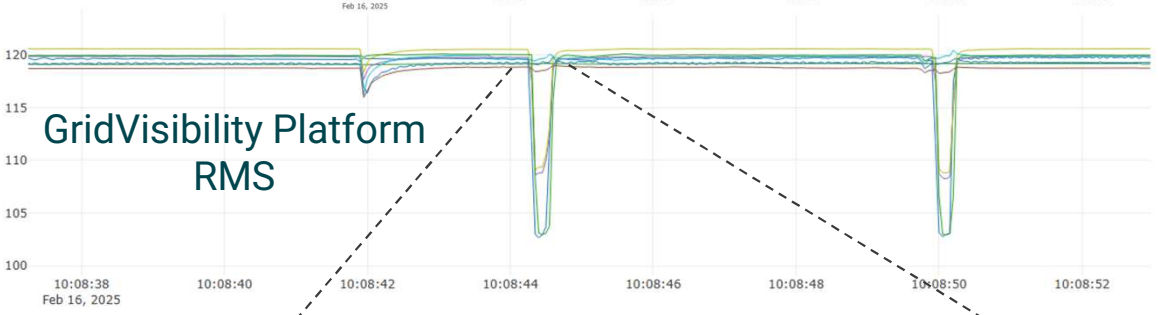


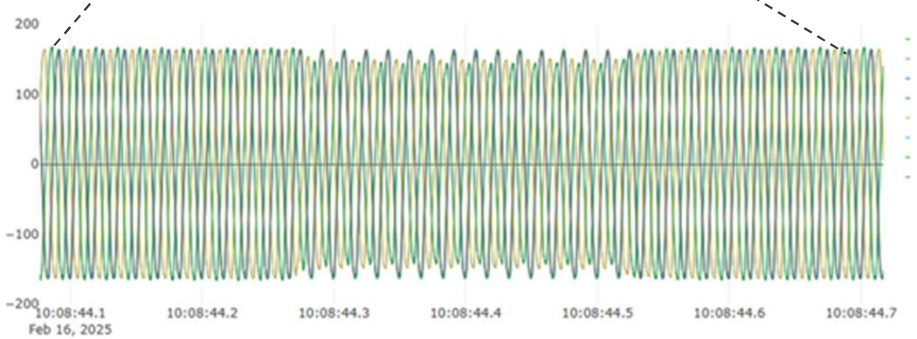
Lightning awareness

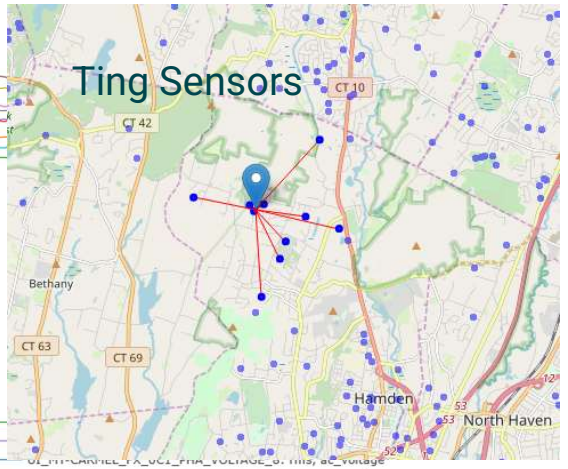
Comparing the same event with two independent SDaaS platforms

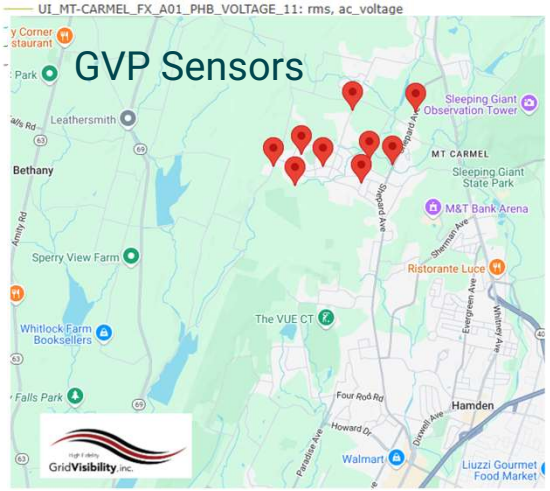
Sag events in New Haven, CT, 2/16/2025











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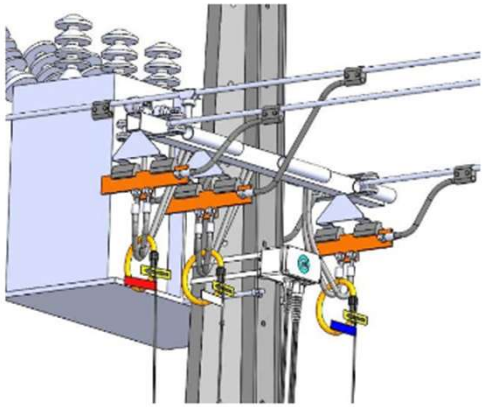
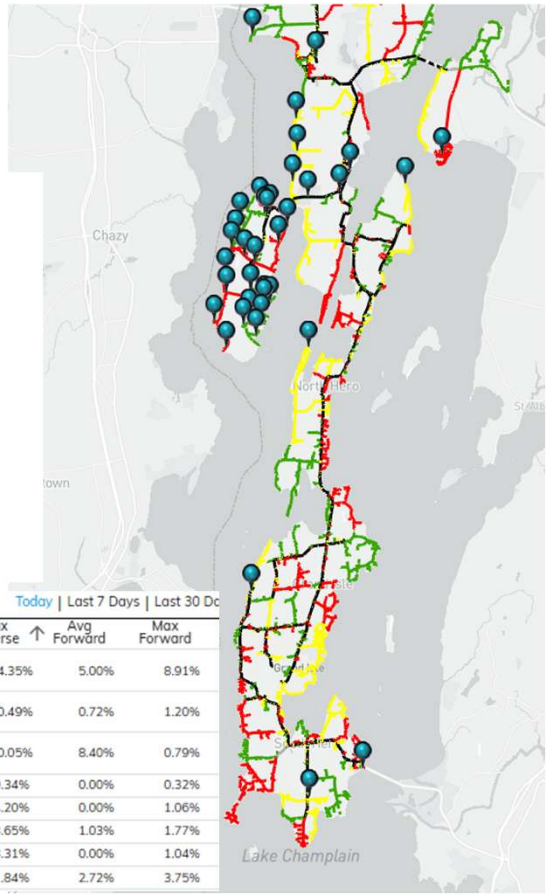
EdgeZero LV data includes transformer loading and history.

- Voltage and current sensors connected to LV side of distribution transformers
- Reports at 1-minute intervals using 4G
- Voltage, Current, Power, Power Flow, Energy, THD, individual harmonics

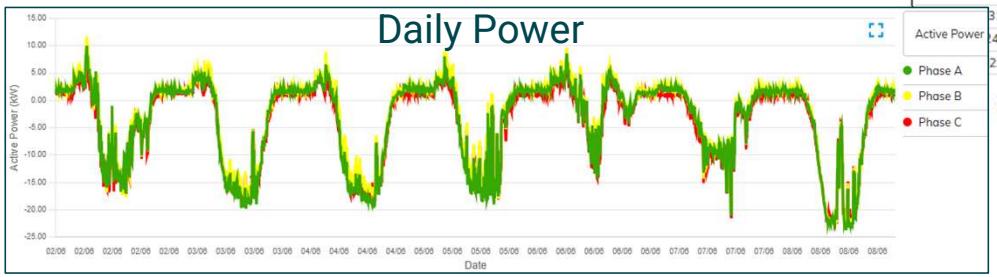




kVA Loading

Today | Last 7 Days | Last 30 Da

Transformer	Circuit	Area	Rating	Avg Reverse	Max Reverse	Avg Forward	Max Forward
27499 30350 30344	3A	42	75	15.17%	24.35%	5.00%	8.91%
33198	79B 67E V1	29	50	5.05%	10.49%	0.72%	1.20%
15804	100A 32N1	28	167	8.74%	10.05%	8.40%	0.79%
25076	4A	28	10	8.64%	9.34%	0.00%	0.32%
29560	SA43 8	28	38	2.82%	4.20%	0.00%	1.06%
31	1A	28	15	2.24%	3.65%	1.03%	1.77%
48	103D 60	28	10	2.38%	3.31%	0.00%	1.04%
224	4A	28	10	1.58%	1.84%	2.72%	3.75%



Power Flow Direction

Positive
100%
135 unit/s

0.48MW Power Flow
0.38MW (AVG over past month)

Negative
0%
0 unit/s

0.00MW Power Flow
0.15MW (AVG over past month)

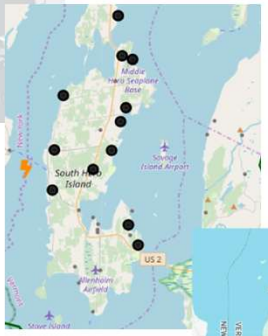
Today
67.0 °F

Tomorrow
67.9 °F

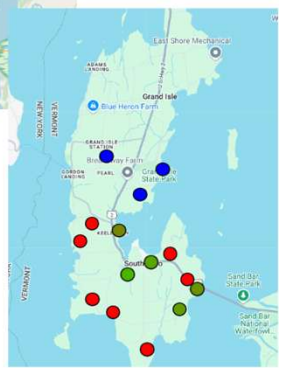
Wed
74.9 °F

Assessing Time Resolution and Ride-Through for Three Sensor Types

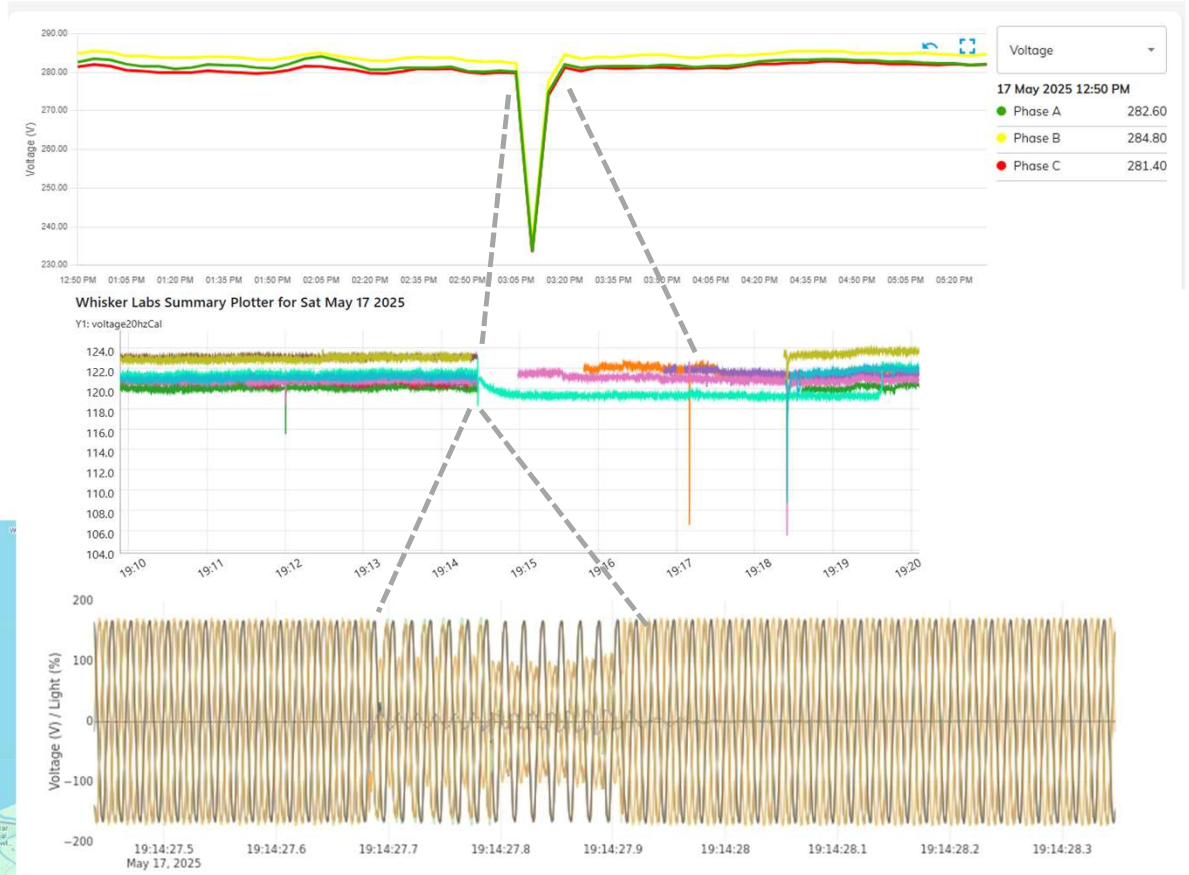
EdgeZero



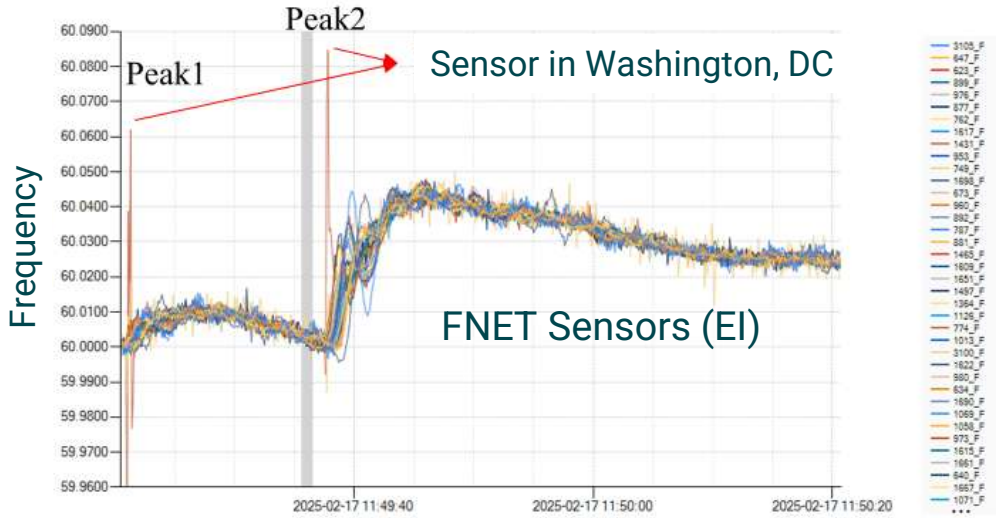
Ting

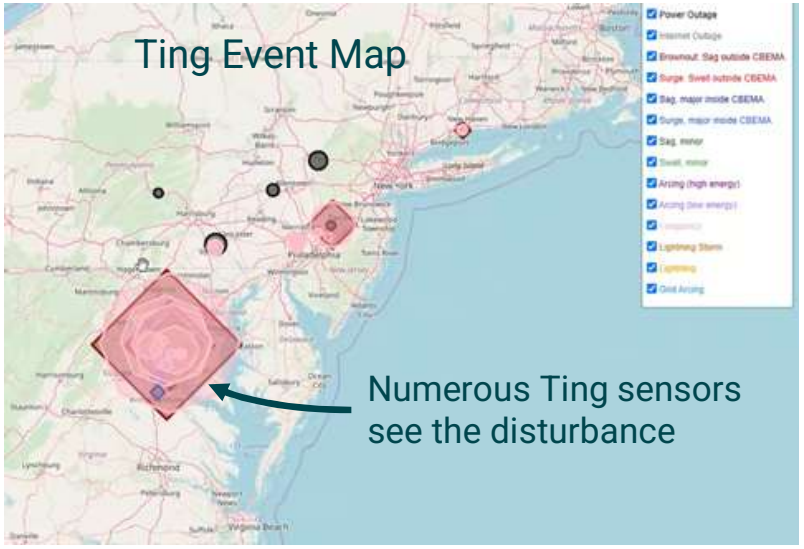


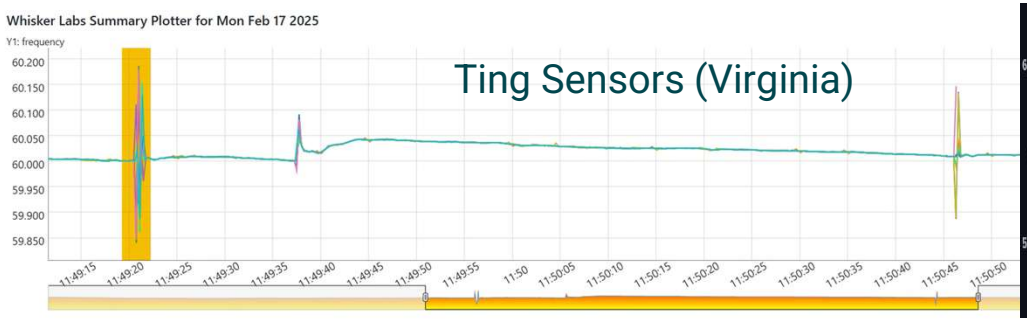
GridVisibility

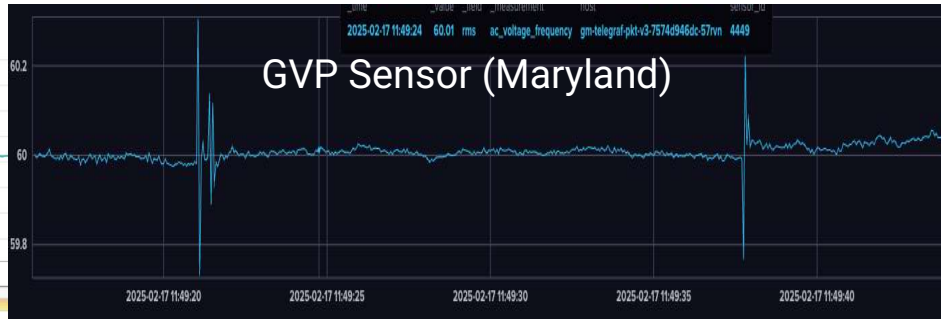


Sudden loss of load caused an Eastern Interconnect incident that was observed by three third parties: FNET, Ting & GridVisibility.



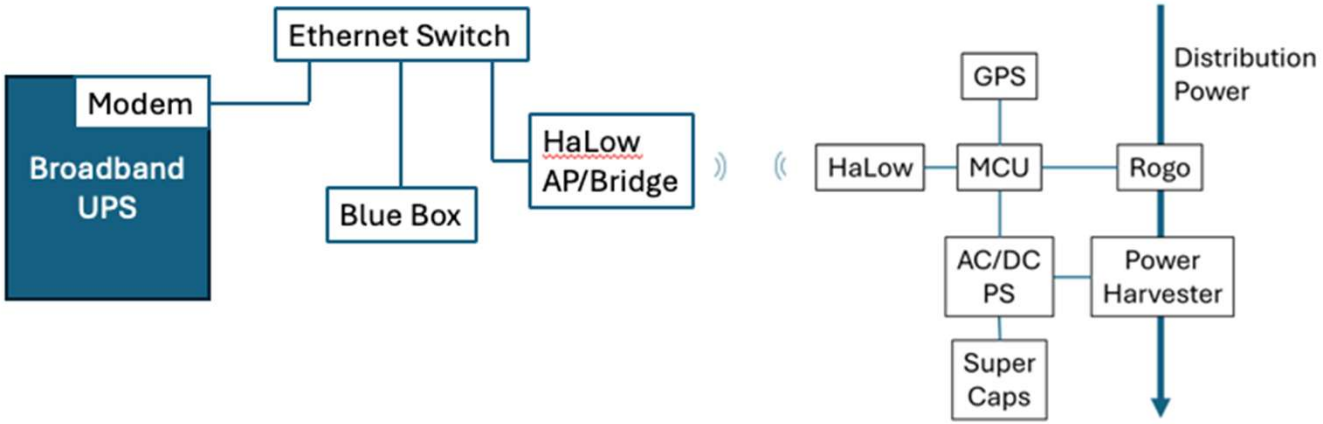




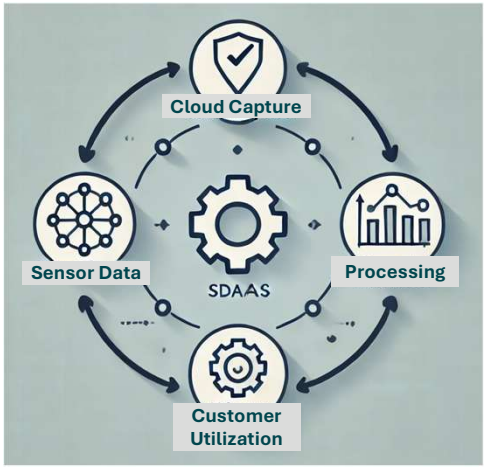


A power-harvesting current sensor prototype is being developed.

- Applications: fault location, power factor, power flow, DER current harmonics
- Collaborate with industry for commercialization



Offering SDaaS must ensure data reliability, accuracy, security, and customer value.



Data Value

- Comprehensive, detailed coverage
- Customizable, actionable data streams
- Intelligent filtering for event detection
- Historical event time sequencing and playback

Data Integrity and Curation

- Reliable, continuous, time-stamped data capture
- Automated validation, redundancy and retention

Security

- Encryption, access controls, regulatory compliance
- Clear data ownership and usage rights

Standardization & Compliance

- Seamless utility integration with utility apps
- Exchange with industry-standard protocols (e.g., IEC 61850, DNP3, OPC UA, CIM, IEEE C37.118 for synchrophasors, P2030.5 for DER.

Business Model

- Defined data ownership and IP rights
- Tiered licensing and flexible pricing
- Continuous updates, support 24/7
- Scalability for future technology needs

Thank you!

DOE – Office of Electricity

and Collaborators: