sense

Grid Edge Intelligence

Mike Phillips, CEO Sense

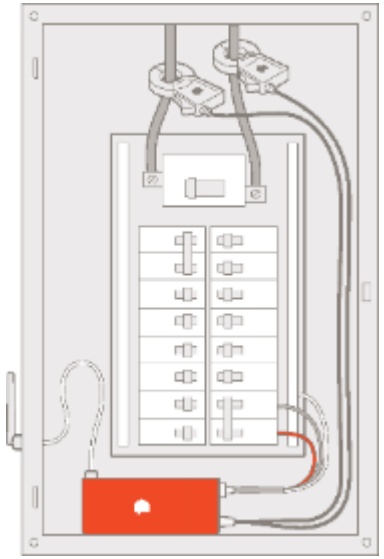
May 2023

Sense: Intelligence for the home

How does Sense work?

INSTALLATION

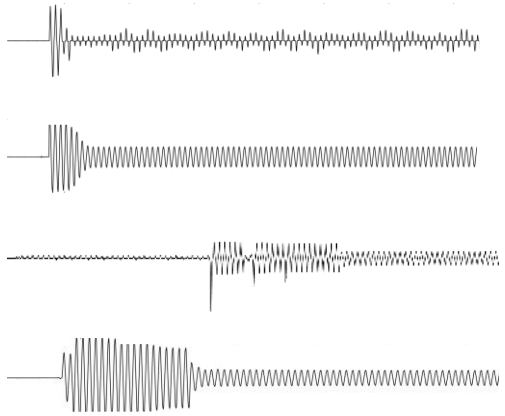
15 min installation in home's electric panel.
Sense recommends electrician install.
No need for sensors on each circuit breaker.
No need for smart plugs for each appliance.
No need for smart meter.



MACHINE LEARNING

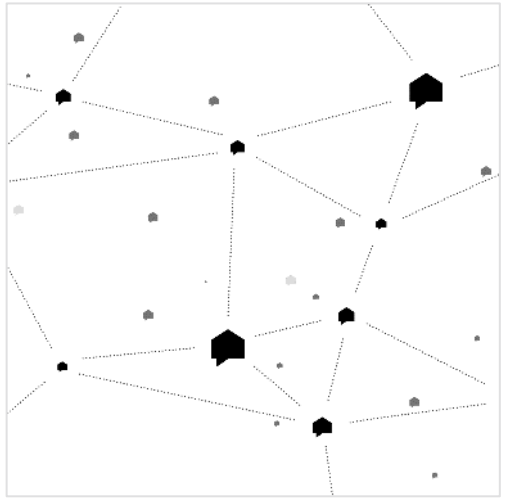
Sense samples each home's power one million times per second.

Sense conducts machine learning to identify the unique signature of each electronic device, determine its state and energy usage.



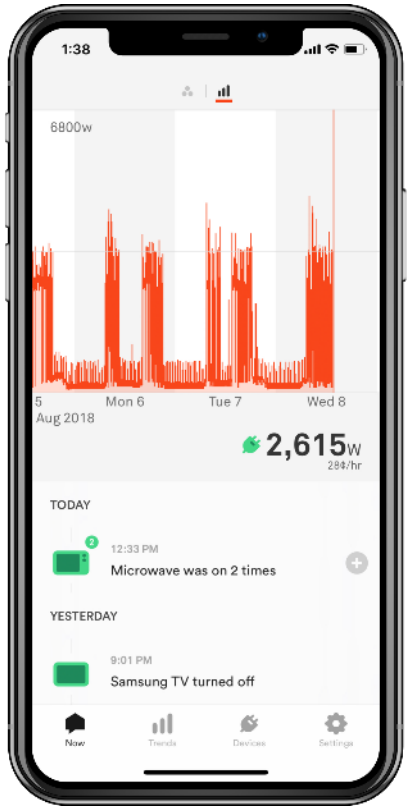
NETWORK EFFECT

Sense is building up a library of signatures. As Sense collects more data, is in more homes, and samples a diversity of appliances, the library is continually growing.



Consumer use cases

Sense: at the intersection of energy and the smart home



Google Home
Voice-activated speaker

ecobee

wemo

IFTTT

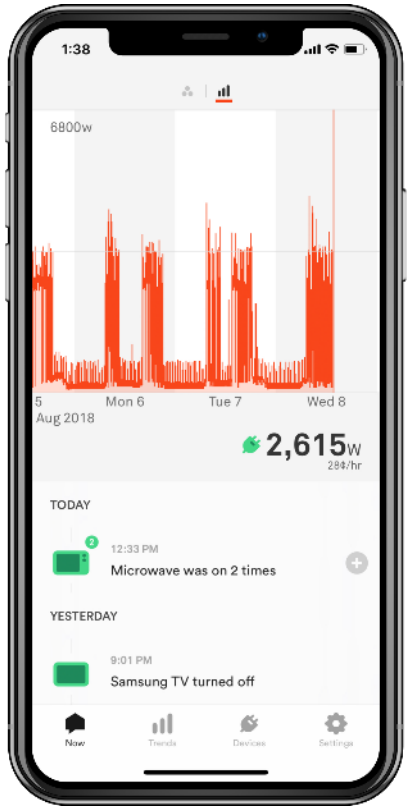
tp-link

hue personal wireless lighting

amazon echo

chargepoint

Sense: built into future homes with Schneider



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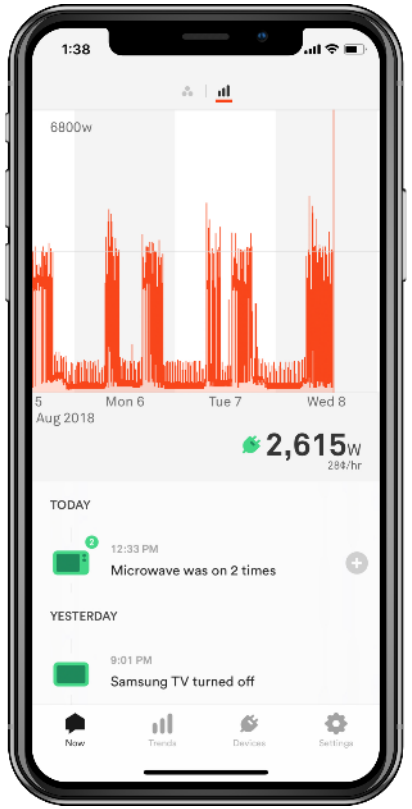
Sense: built into utility meters

Next Generation
Utility Meter



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Why high resolution is needed

Sense Data

Data sampling:

Current at 41kHz

Voltage at 1mHz

Local computation

Signal processing, feature extraction, event detection, load disaggregation runtime all running at edge

Model learning, analytics, and consumer app run in cloud

Data logging

Cloud side logging for events, features, and 60Hz power for 6 months for all homes

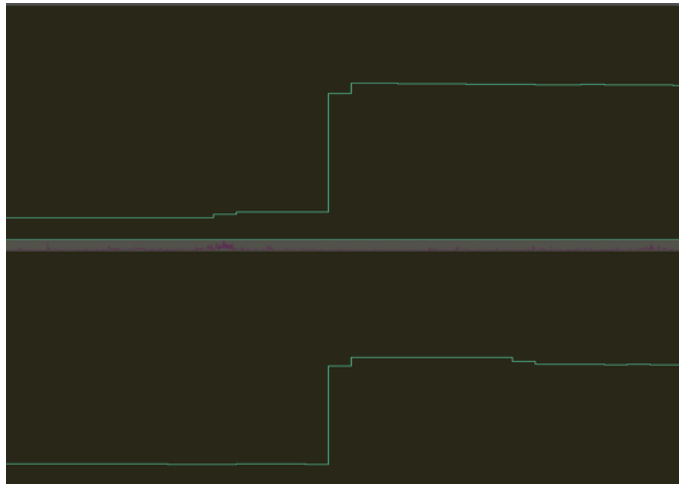
High resolution logging for anomalies or specific events

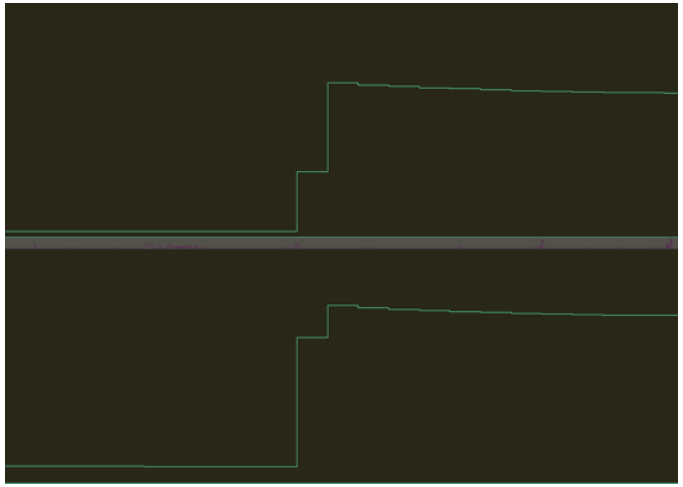
Full-time high resolution monitoring can be enabled on a monitor-by-monitor basis

OVEN

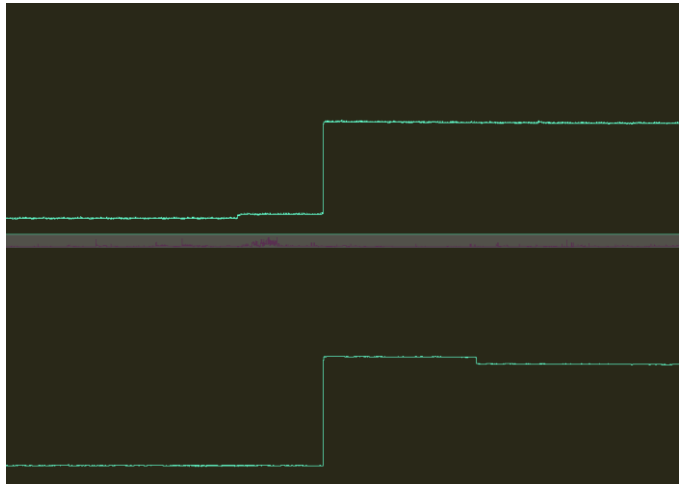
DRYER

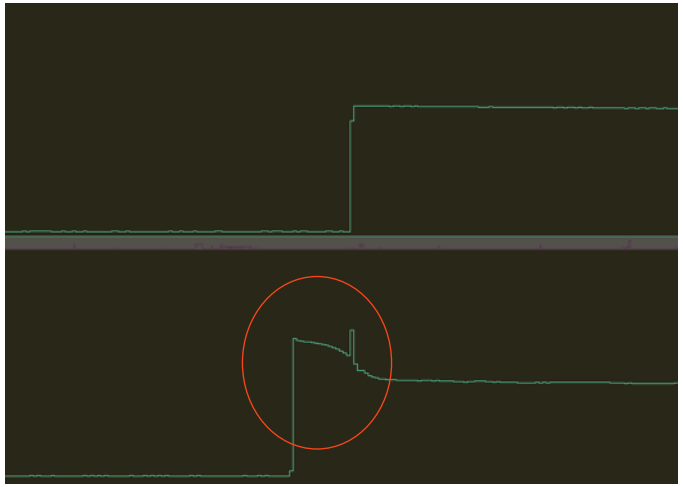
One sample per second



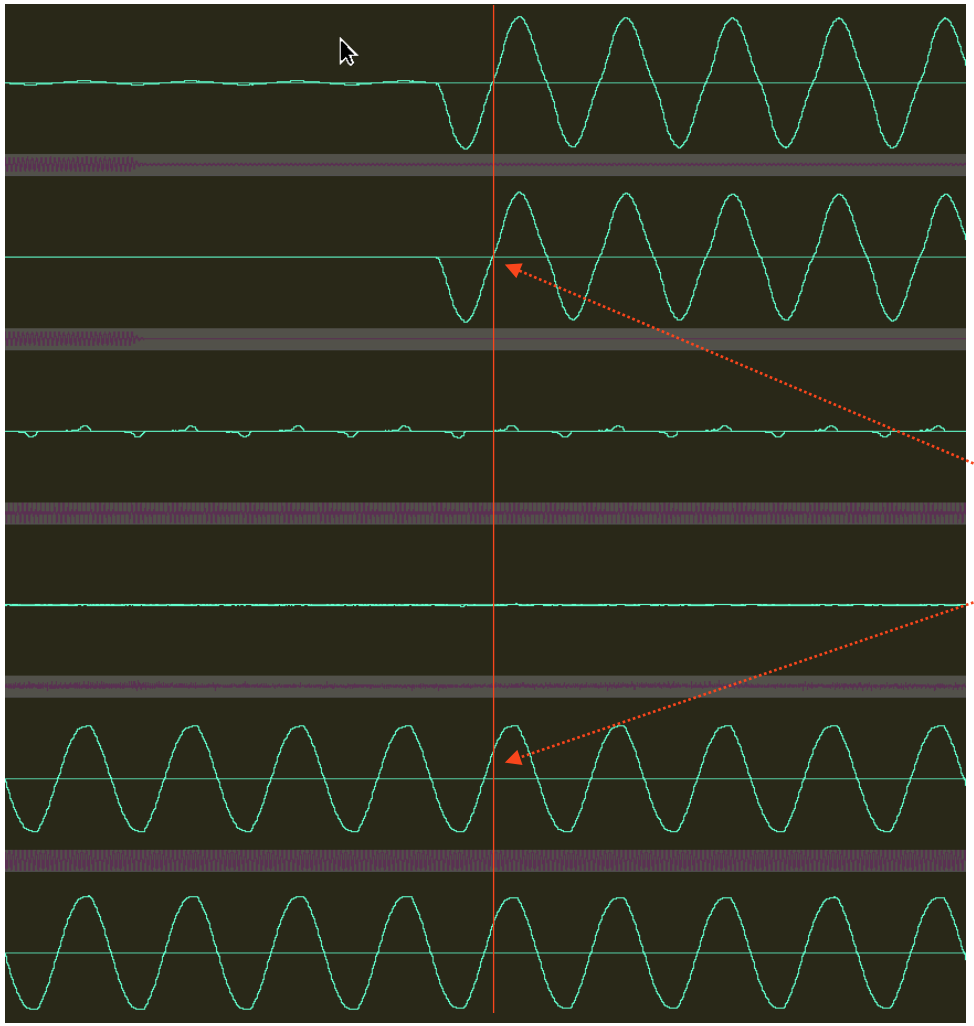


60 cycles per second





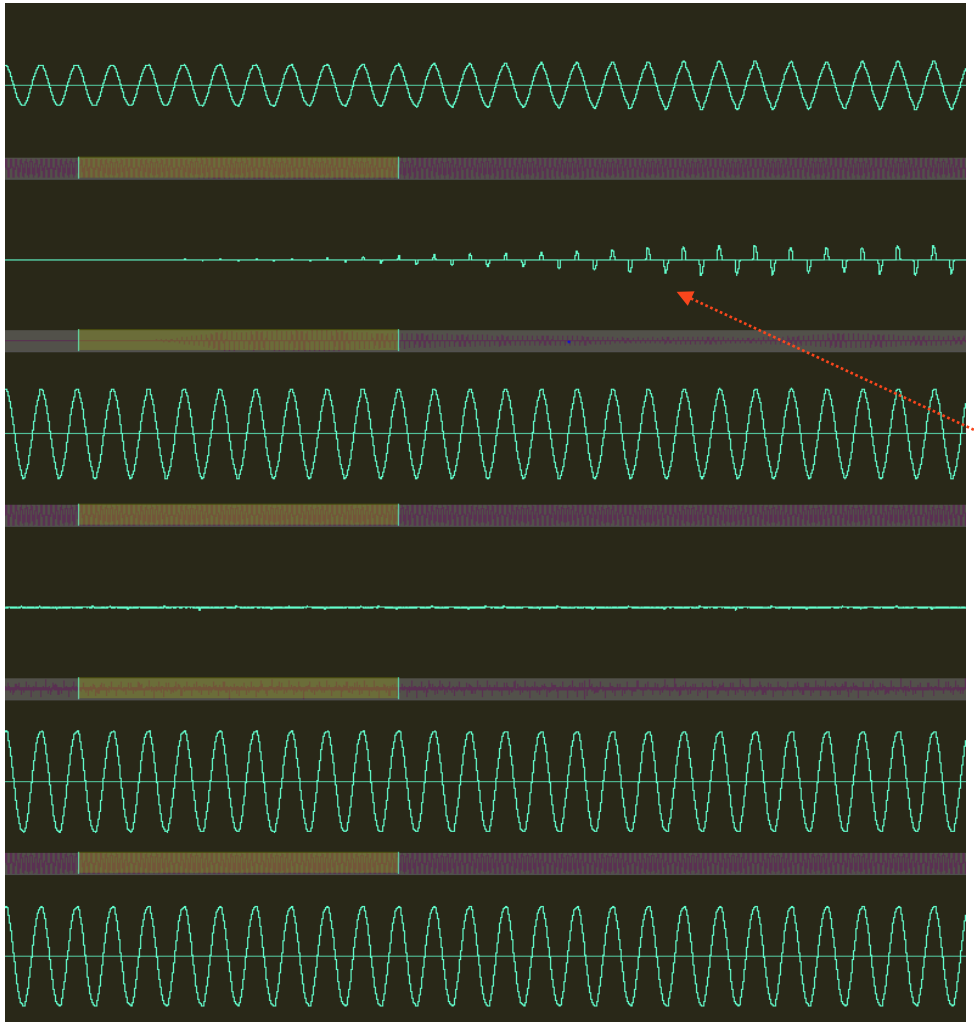
Waveform data



Induction Motor

Phase offset =
Inductive motor!

Details of device only available in waveforms



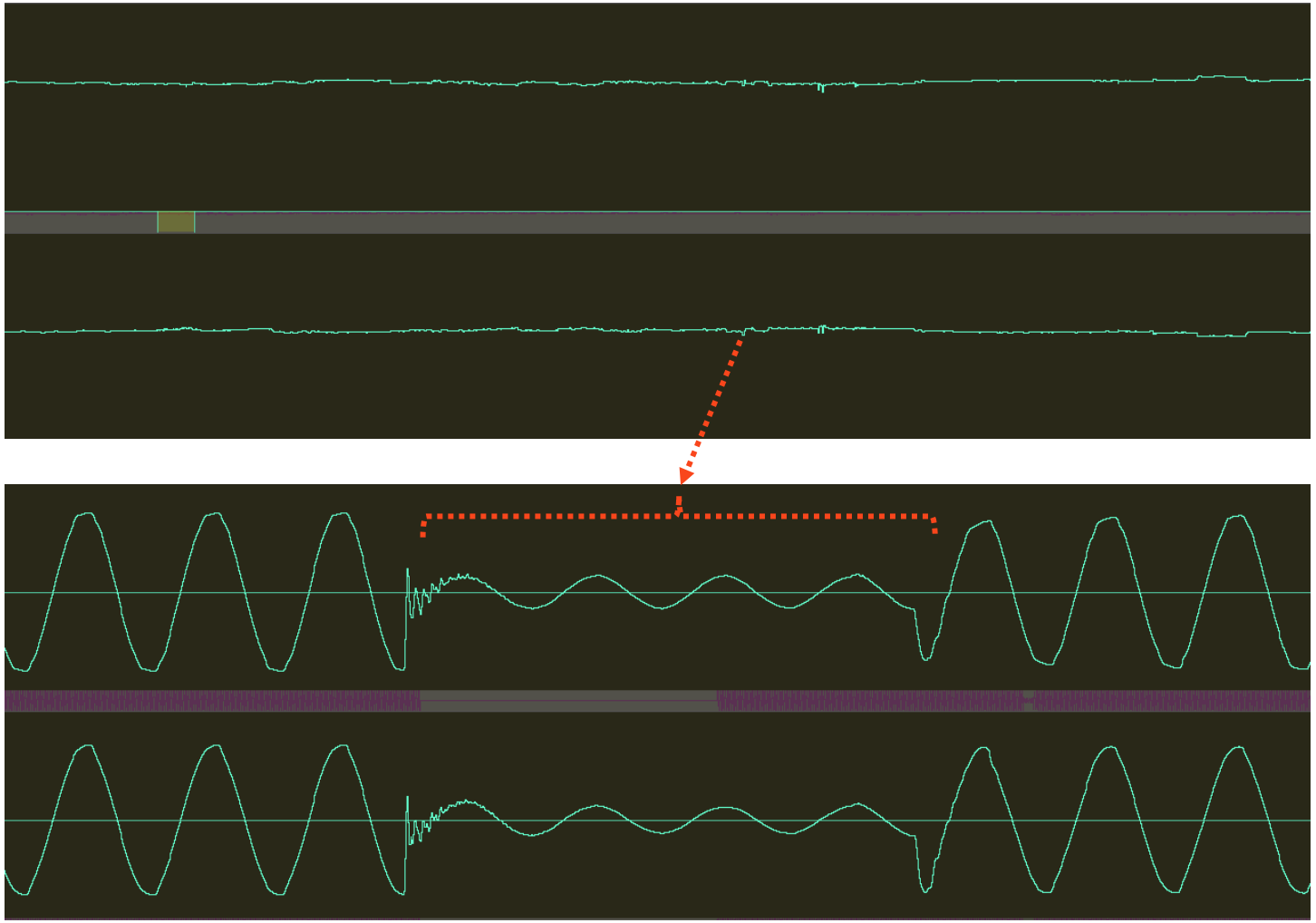
Front Load Washer

Distinct waveform
=
Front-loader
washer.

Many grid anomalies only detectable in waveforms

One Second Interval

Voltage waveforms



Voltage Anomalies

Sense data

Waveform capture trigger

Continuous processing of voltage waveforms

Capture to cloud ~ 1 second of 41kHz waveform if cycle voltage is out of range

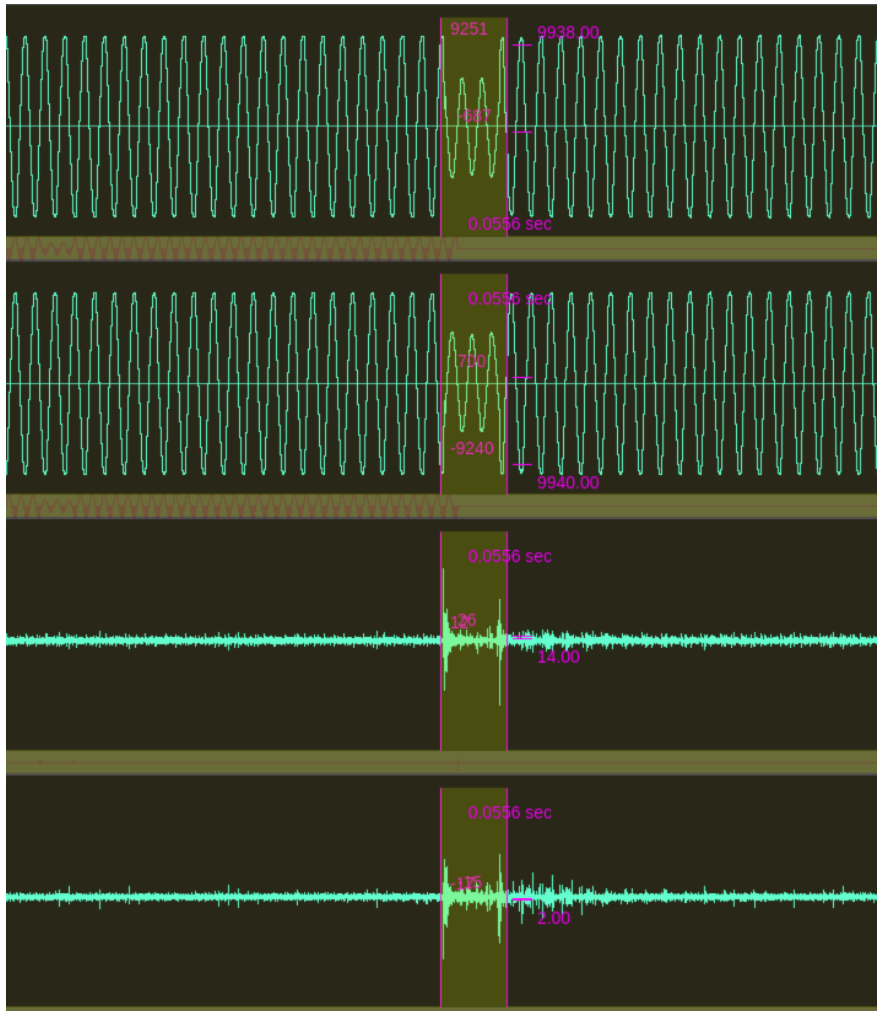
Trigger can be changed with software update

Sense has captured over 5 million anomalies from approx. 60,000 homes throughout US

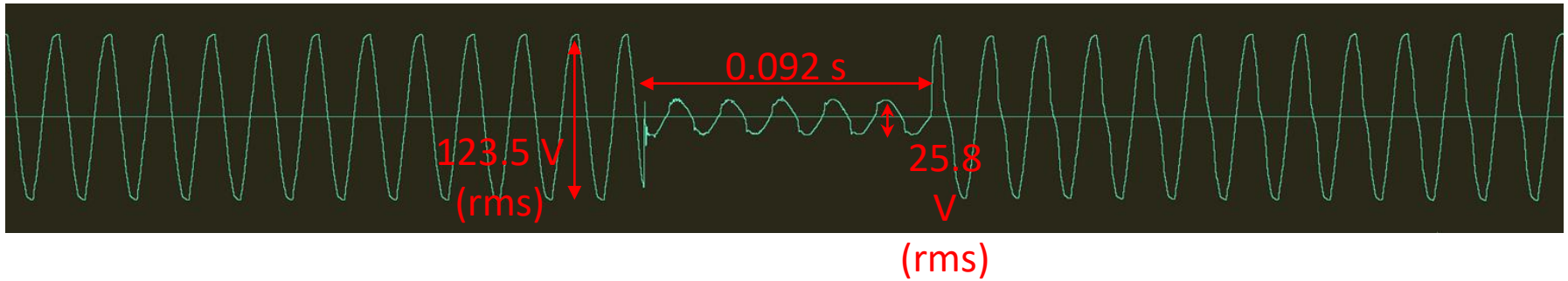
Most are voltage sags – problem in the grid followed by protective device

Can see operation of grid (tap changers, reclosers, etc)

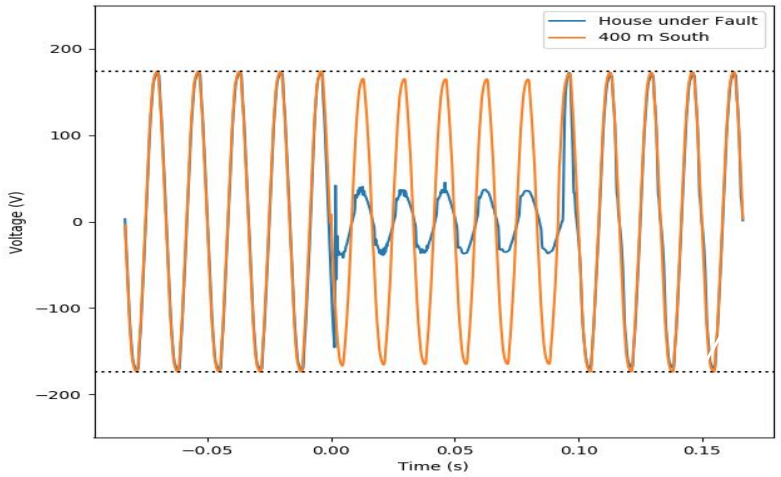
Have not had ground truth to map waveforms to cause

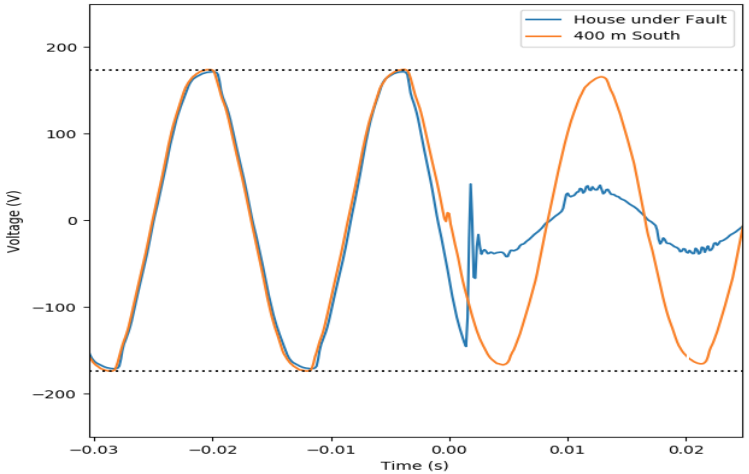


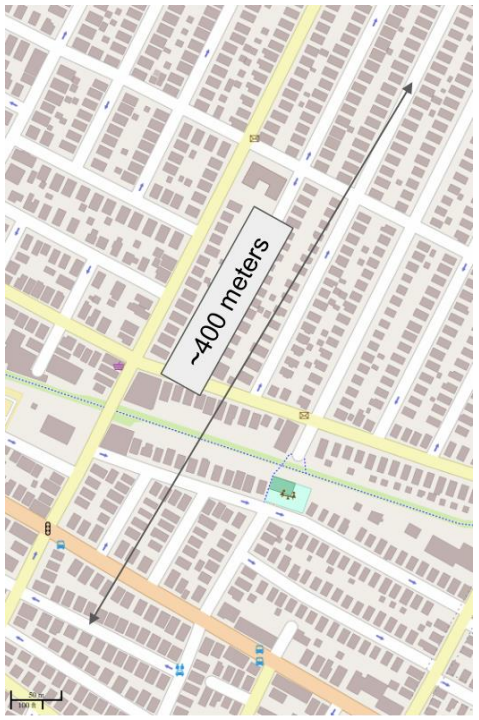
With enough monitors, can geo locate problem



High resolution data from two homes



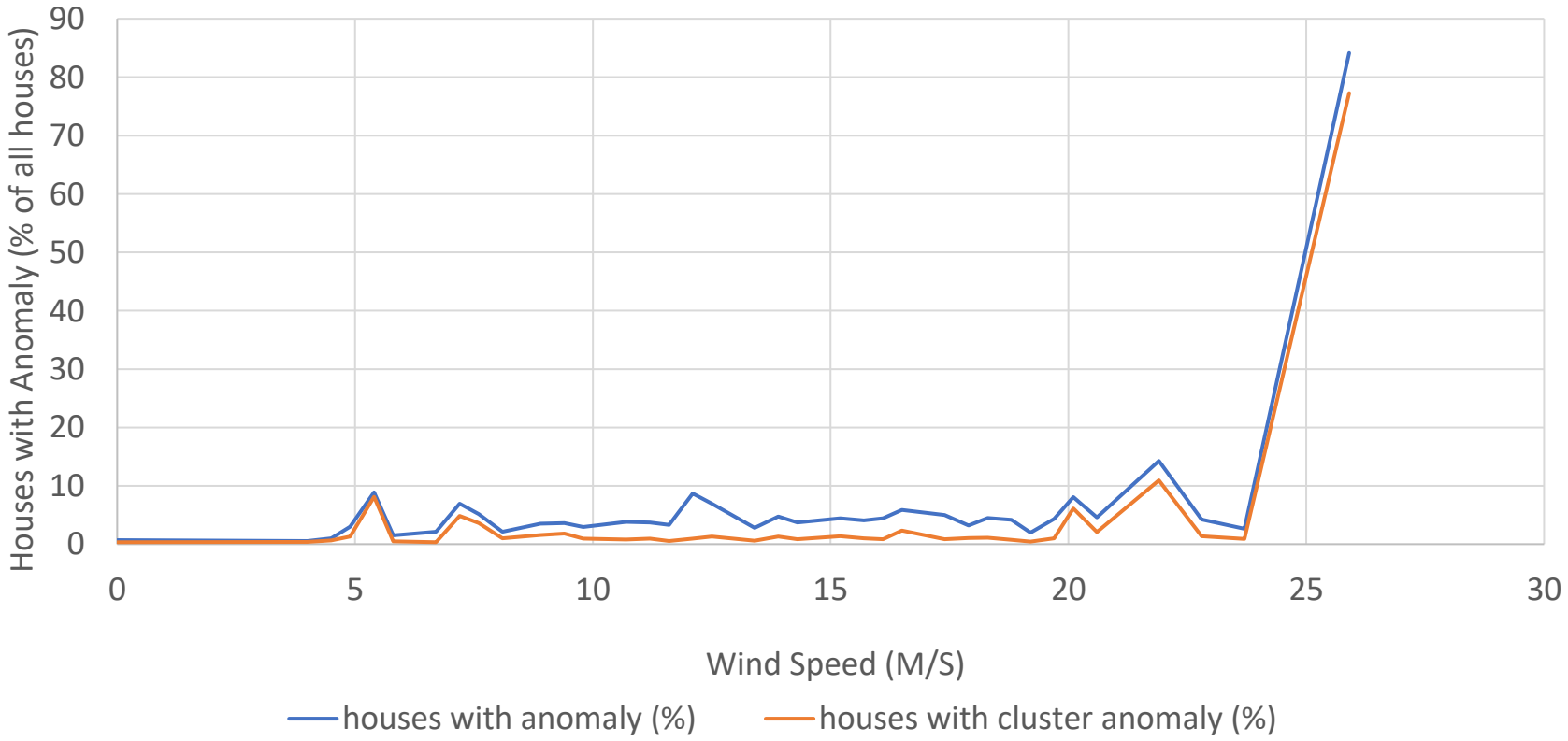




Voltage anomalies related to weather

Given correlation with windspeed, likely due to vegetation hitting power lines

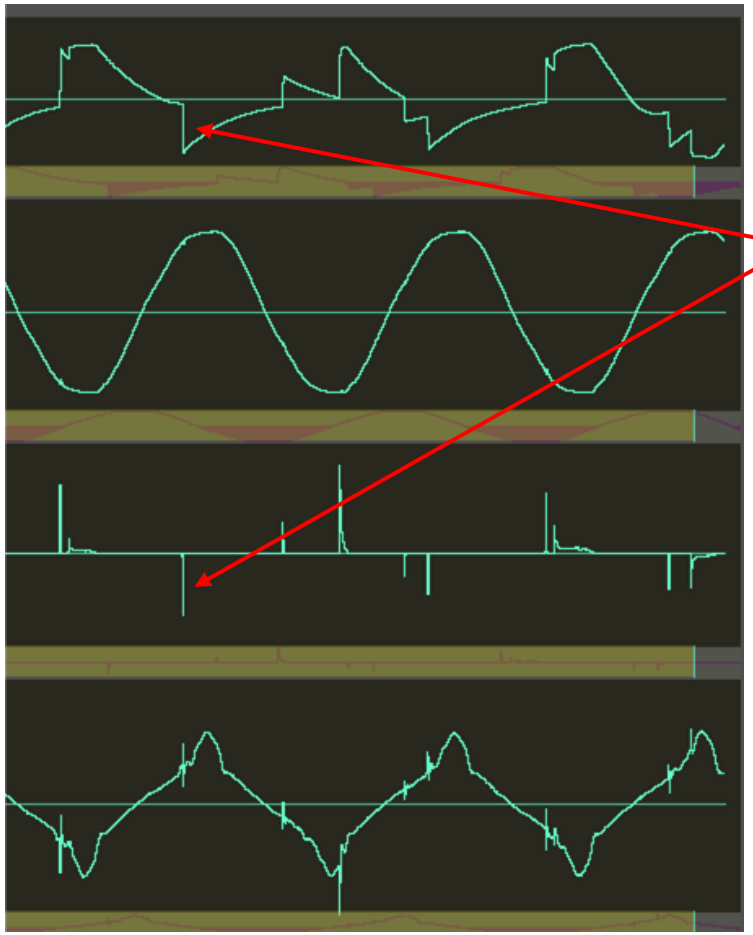
Varies by region (Colorado shown in this example)



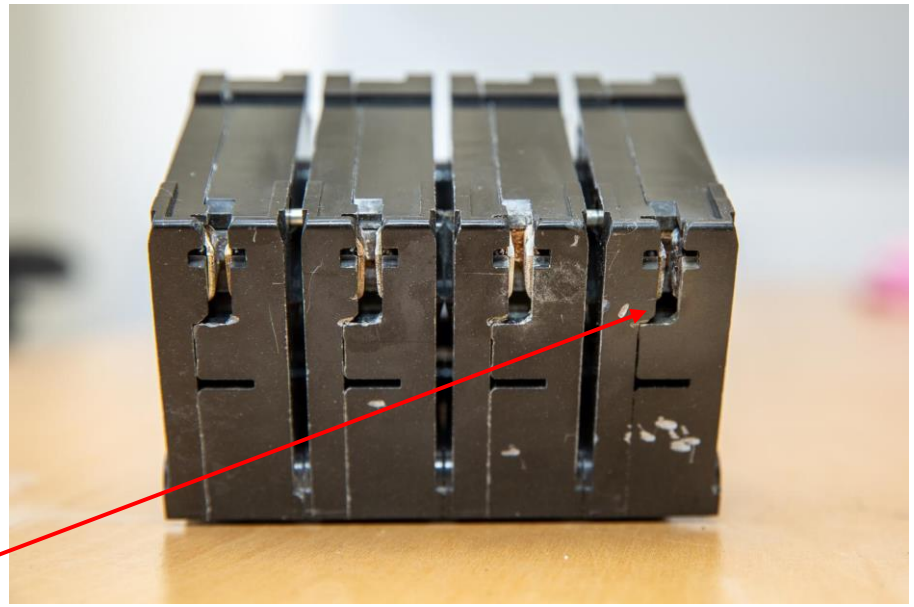
Example Data

Arc Faults: Previously Confirmed Example

- Confirmed arc fault data from summer 2022 (voltage, voltage, current, current):



Intermittent arcing from corroded contact causes current spikes, voltage changes

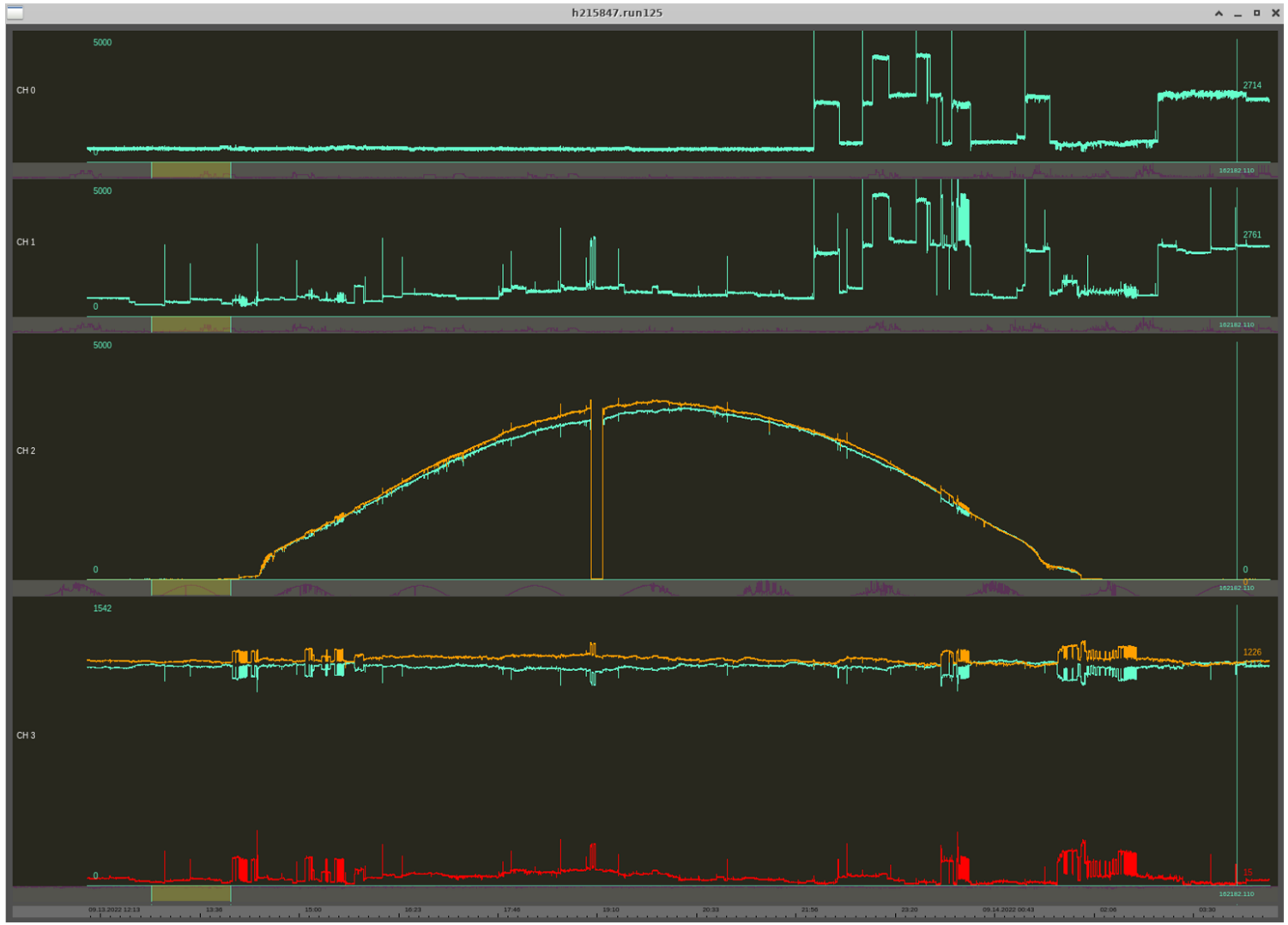


Corroded contact where arcing occurred

Nov 2022 Example: Rio Vista, CA Issue

- Contacted customer on N 6th Street in Rio Vista, CA
  - Energized neutral
  - Solar cutouts when microwave ran
  - Another home's consumption distorting power signal
- Customer contacted PG&E in early November, 2022
- Transformer replaced on Nov 16th, 2022

Nov 2022 Example: Power Quality Issues



Mains Power Leg One

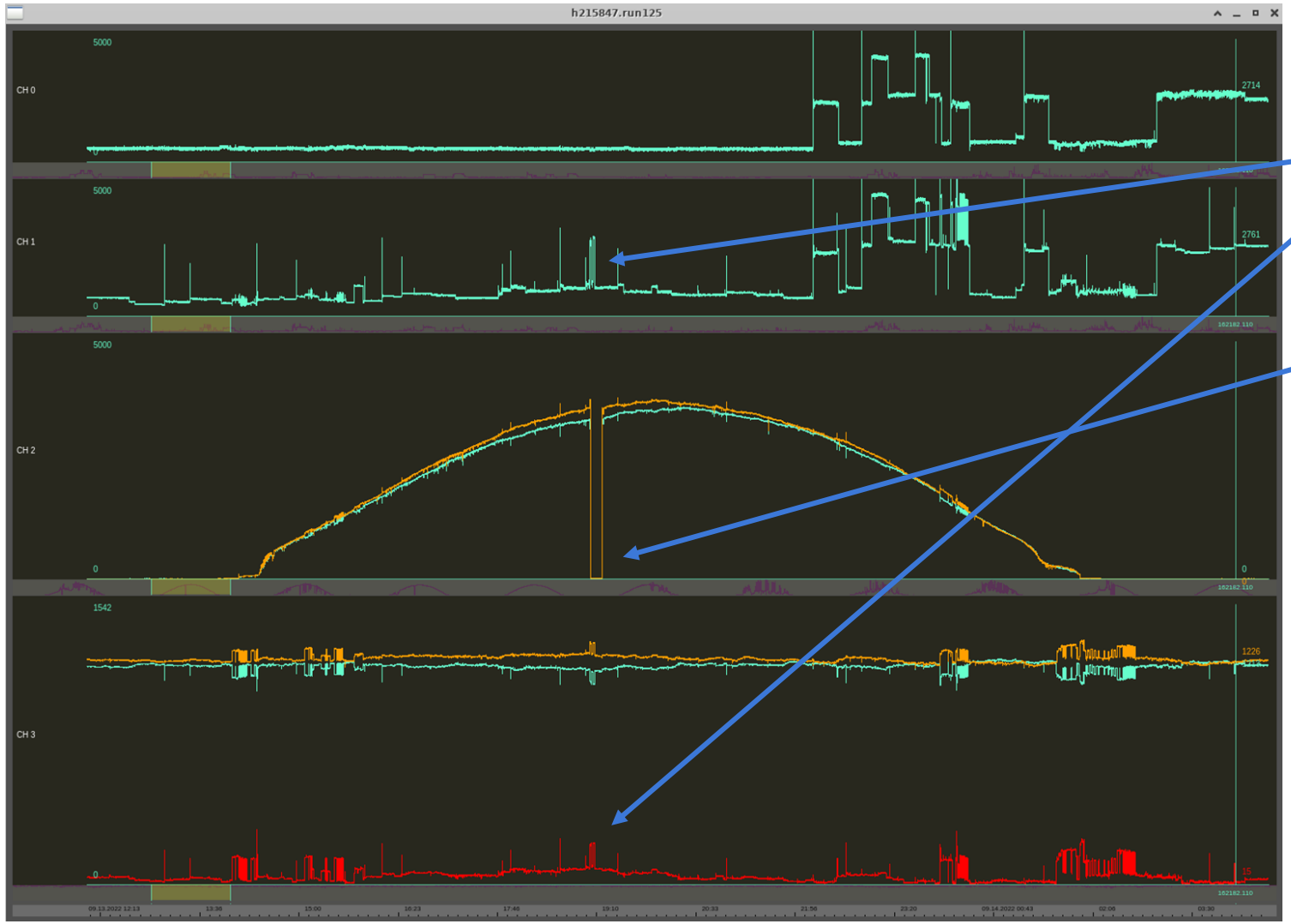
Mains Power Leg Two

Solar Generation

Voltage Leg One (blue)
Voltage Leg Two (orange)
Voltage Difference (red)

4 am - 9 pm

Nov 2022 Example: Power Quality Issues



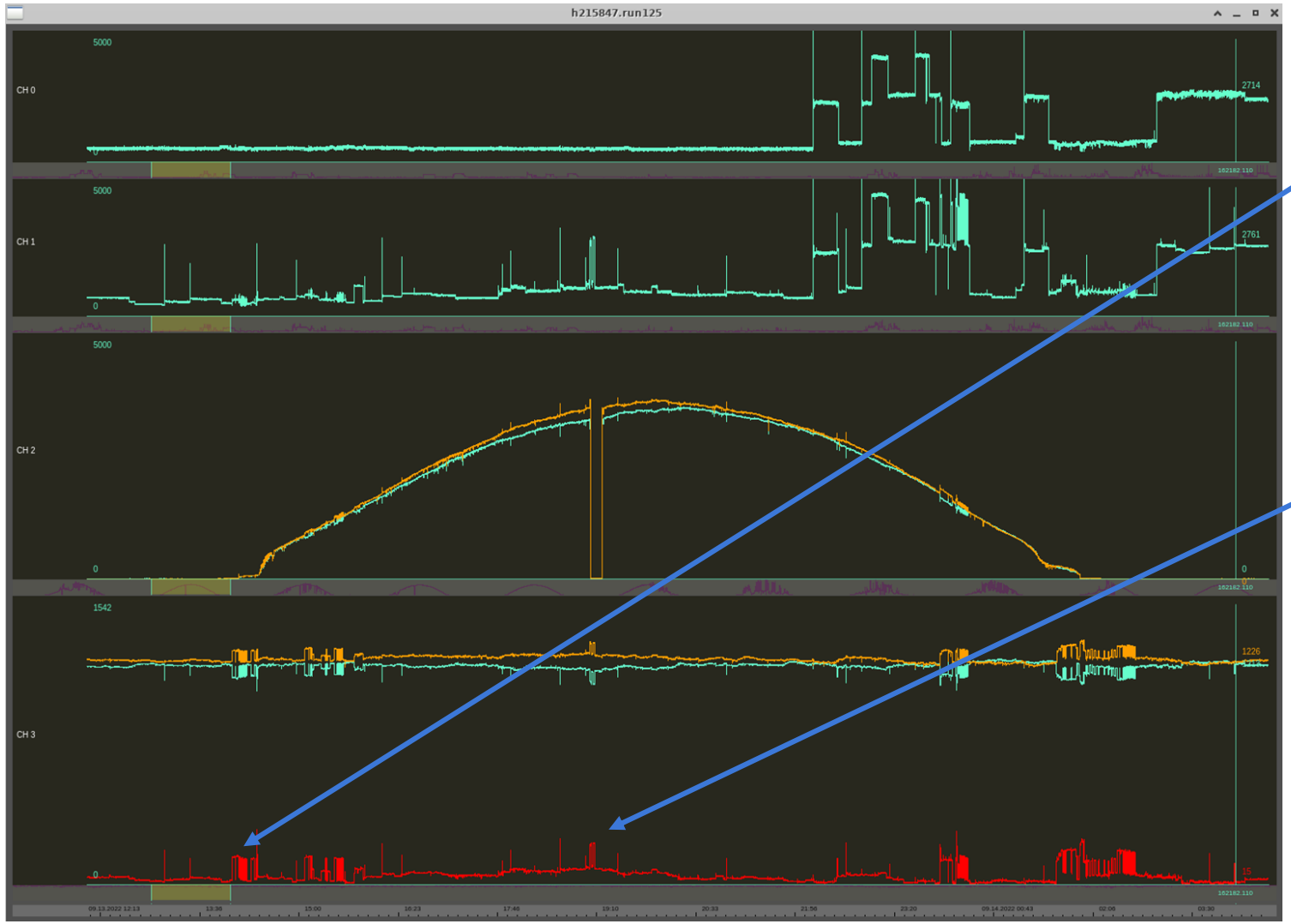
Order of suspected events

1. Microwave runs
2. Microwave causes voltage distortion due to poor power quality
3. Solar stops production for 5 minutes as a safety mechanism

This pattern shows up once or twice per day, though sometimes a different appliance (e.g. laser printer) appears at the solar production stoppage.

4 am – 9 pm

Nov 2022 Example: Power Quality Issues



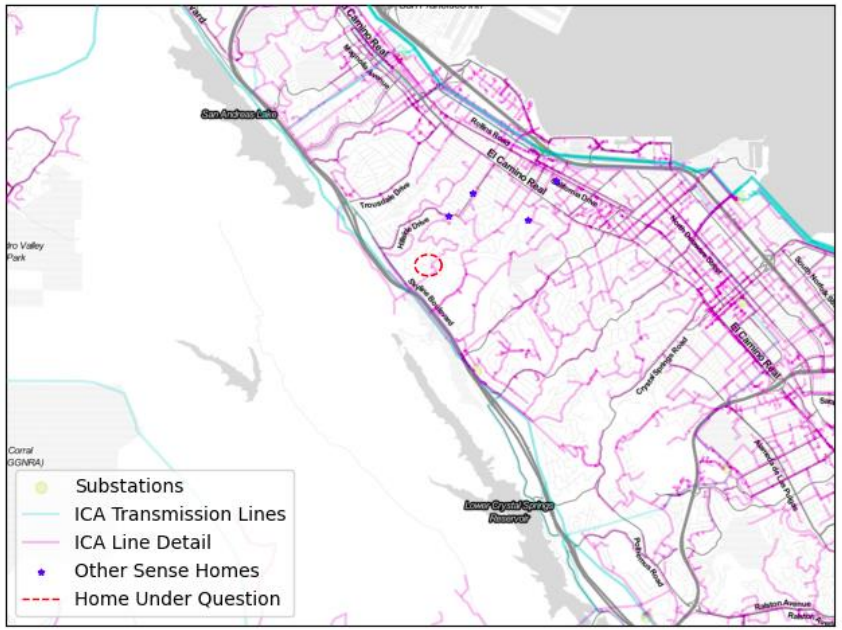
Power signal distortions unrelated to activity in home imply issue is grid-side. In other words, another home's power consumption causes some voltage distortions

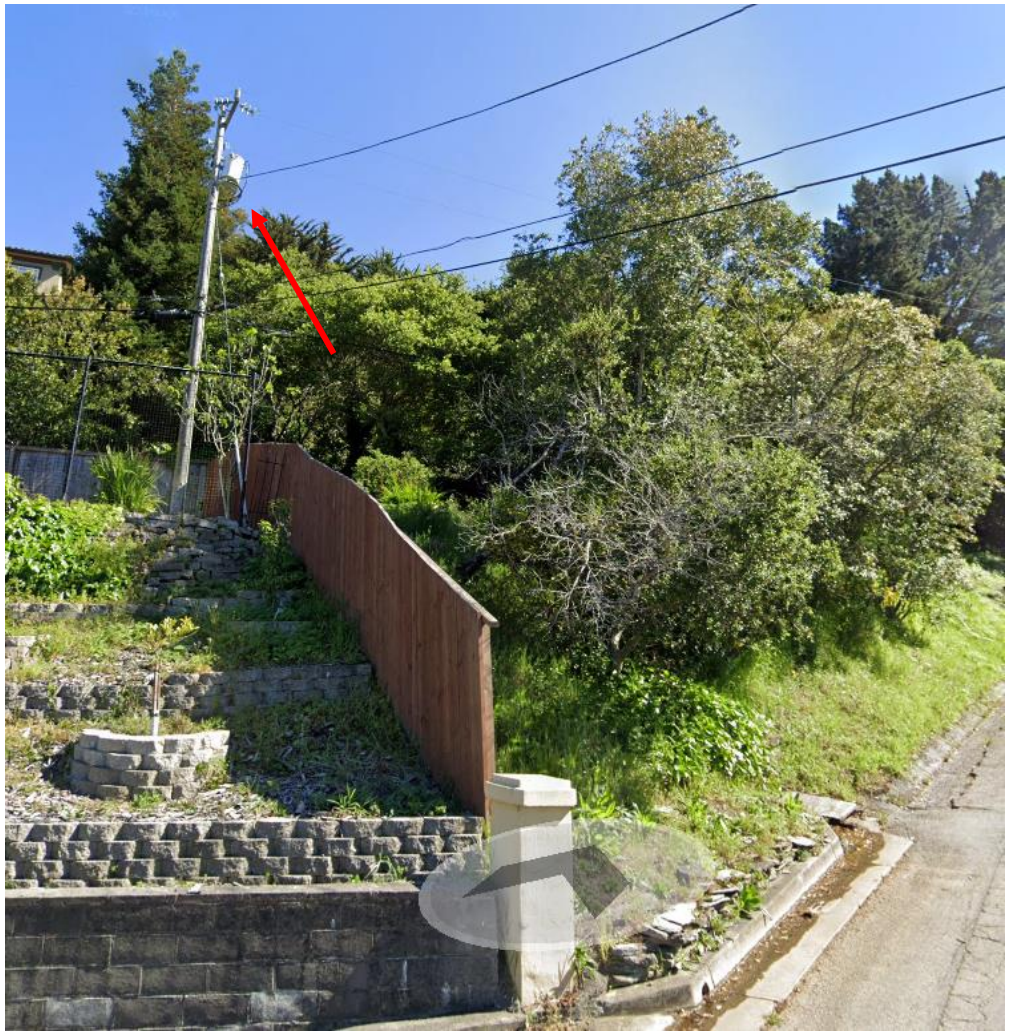
Sustained differences in leg voltage exceed 20V, likely an energized neutral with 10V rms.

4 am – 9 pm

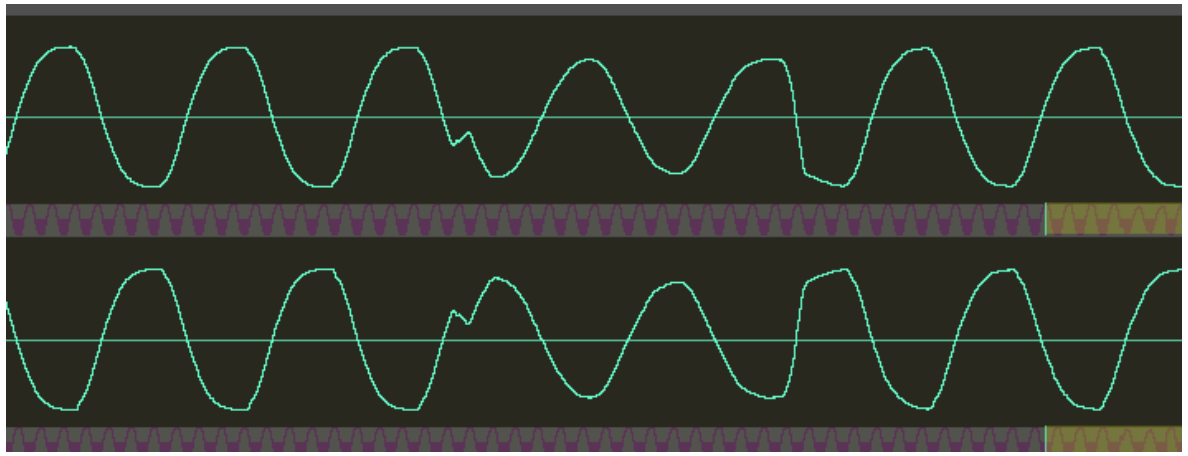
Persistent, Grid-side Issues: Example

- Issues started in mid February, multiple power anomalies per day
- Guessed transformer location, serves multiple homes in Burlingame
  - 37.57114778572996, -122.38788959535854

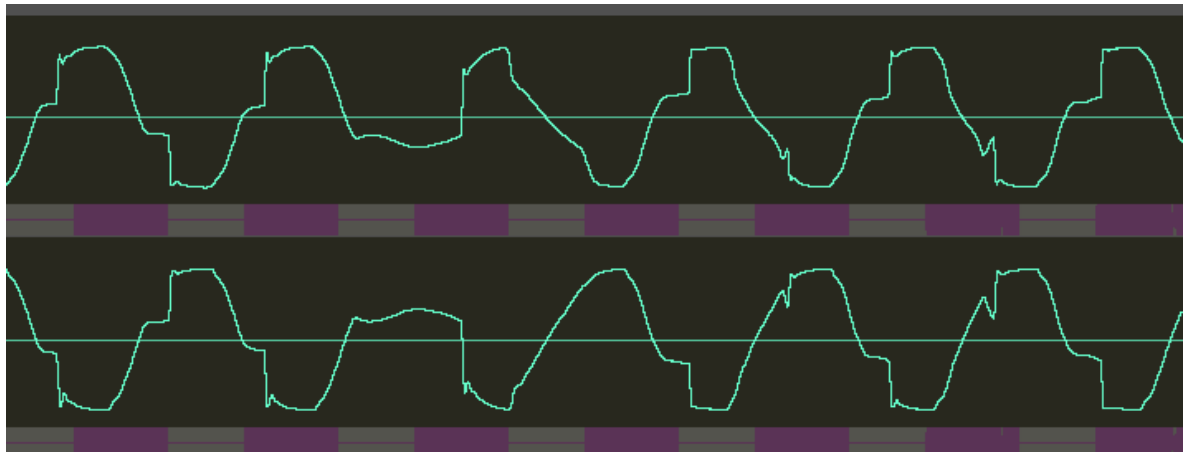




Persistent, Grid-side Issues: Example Waveforms

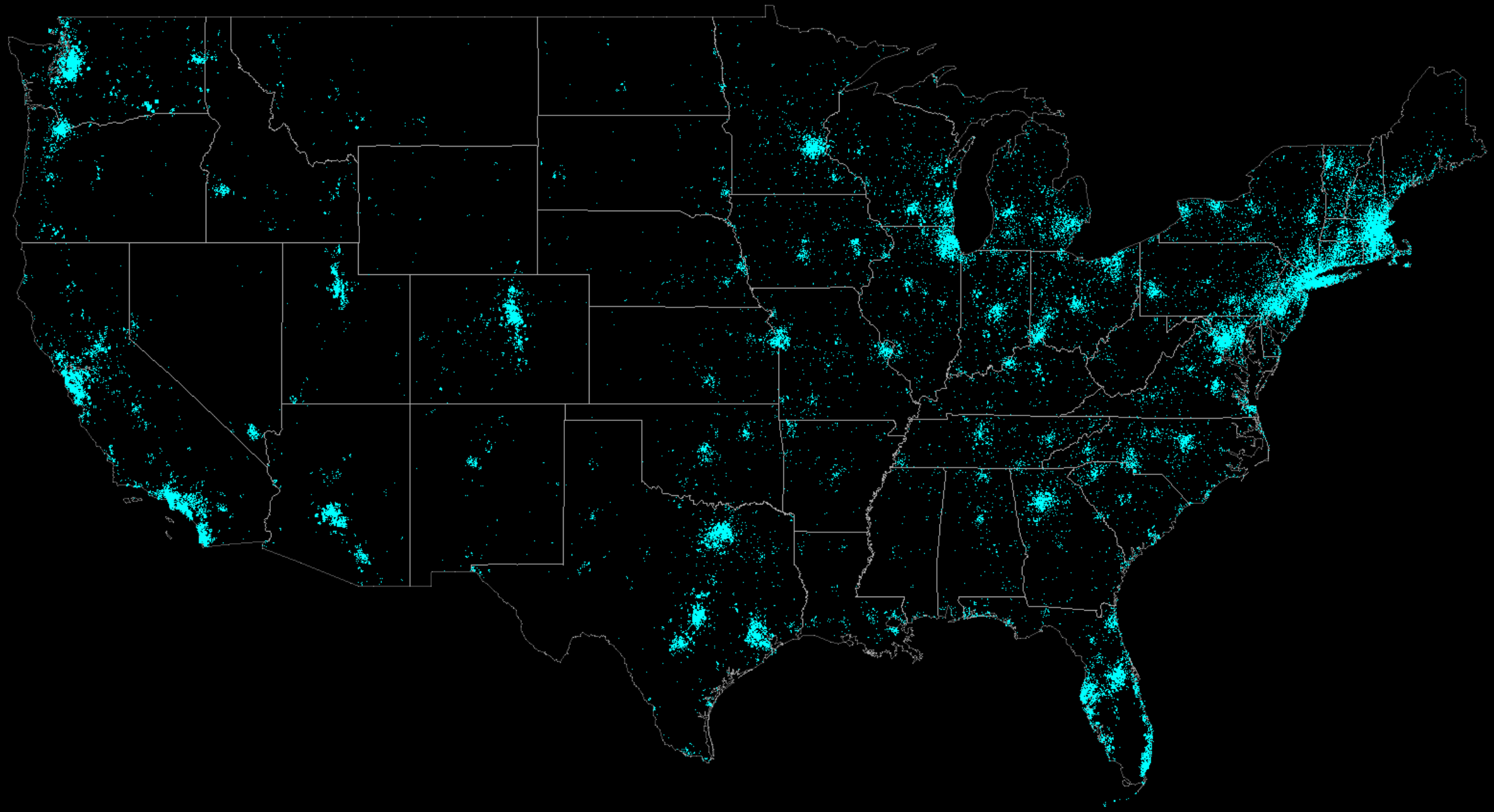


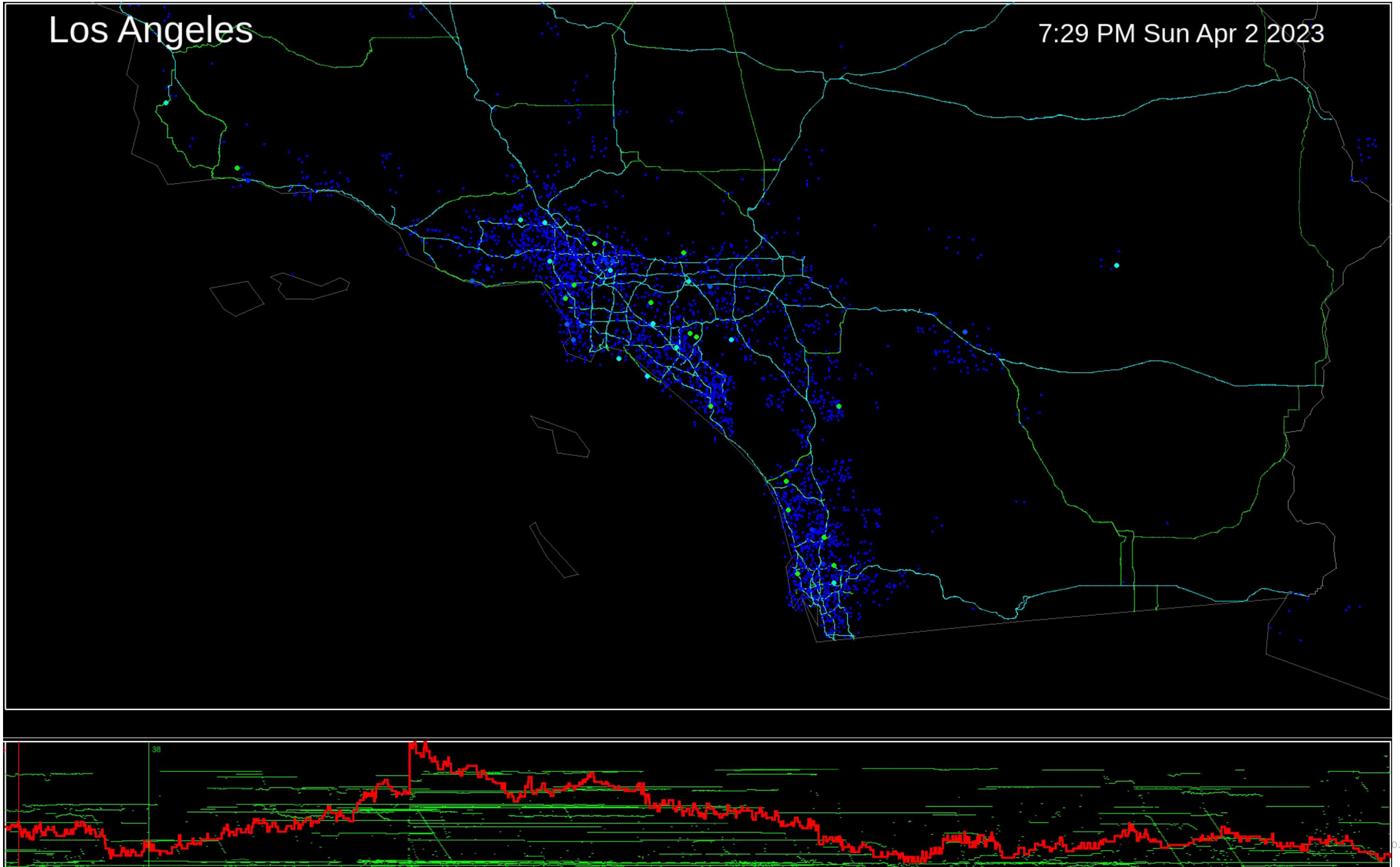
Feb 13th



Feb 22nd

Sense at Scale




Los Angeles
7:29 PM Sun Apr 2 2023
38

Meter Requirements

Technical Requirements

High Resolution waveform data for current and voltage

Minimum of 128 points per cycle (7680 samples per second)

Oversampling (30-50kHz) allow line-locking in software plus provides greater anomaly resolution

1mHz voltage data helps with arcing and localization

Edge computing

1 GHz 64bit ARMv8 or better

Min 128 MB RAM, 512MB flash

Networking

Need low latency, medium bandwidth (20-50MB per day per home)

Wifi, LTE, etc.

Meter Status

Announced

Landis+Gyr Revelo meters

Itron Riva meters (4.2 and above)

In progress

Various stages with all meter makers, including International

Thank you

sense.com