TESCO METERING

Advanced AMI Analytics at the Utility-Case Study on Power Quality Measurements

TESCO's Meter School

TESCOOL

July 19-22, 2026

July 20, 2026

1:00 PM – 2:30 PM

Nathaniel Nichols P.E., PECO

Introduction & Overview

- Introduction / overview
- What is Power Quality and the importance of Power Quality?
- Why consider AMI in Power Quality?
- Current practice and needs of Power Quality
- Comparison of Power Quality standards vs. Metering / AMI standards
- Considerations for Power Quality data impact on an AMI network
- Leveraging existing AMI data for Power Quality analytics
- Understanding the evolving grid, power quality and the role of AMI
- Potential opportunities for large scale data analytics and AI
- Q&A

Nathaniel Nichols, P.E.

Nathaniel Nichols is Manager of Advanced Metering Infrastructure at PECO and a licensed Professional Engineer in the Commonwealth of Pennsylvania. He has over 14 years of utility experience across distribution planning, substation cyber security, grid modernization, and DER integration. Throughout his career, he has led strategic initiatives, developed engineering talent, and worked at the intersection of technology, reliability, and customer value. Nathaniel is passionate about advancing the electric utility industry through innovation, engineering excellence, and professional development.

Nate lives in the greater Philadelphia area with his wife and 4 kids. Together they enjoy growing vegetables, playing and watching sports, and are engaged in their community.

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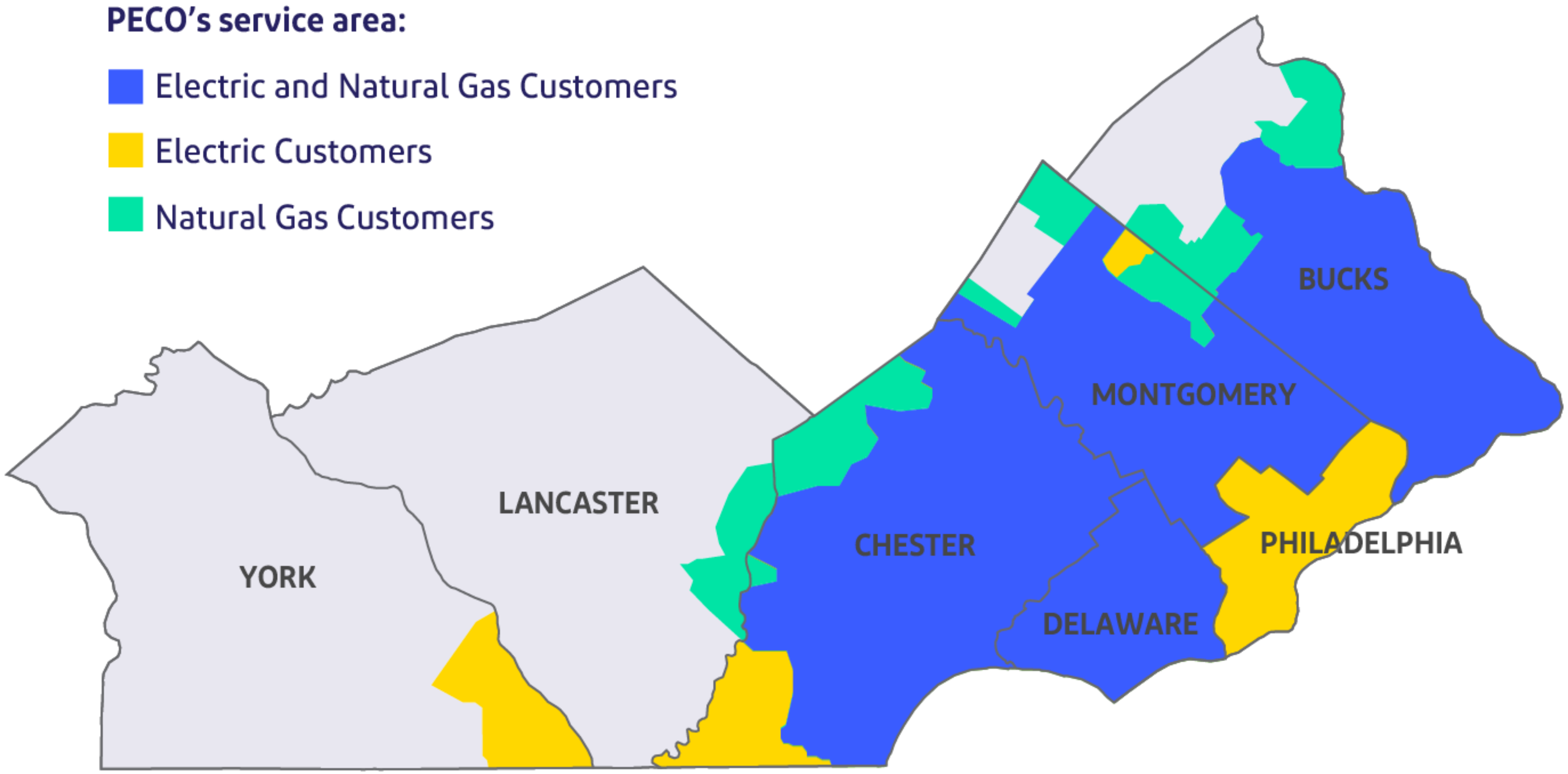
About PECO

Headquartered in Philadelphia, PECO is Pennsylvania's largest electric and natural gas energy delivery company, serving 1.7 million electric customers and more than 553,000 natural gas customers in southeastern Pennsylvania. PECO employs approximately 3,000 people and is a subsidiary of Exelon Corporation (NASDAQ: EXC), the largest fully regulated utility company in the nation with more than 10 million customers.

About PECO

PECO's service area:



22,659 distribution miles

1.7 million electric customers

553,000 natural gas customers

10% commercial/industrial

90% residential

Key Learning Outcomes

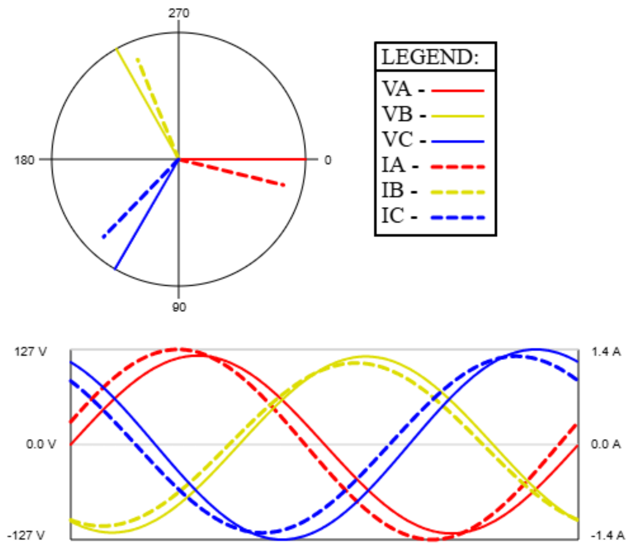
1. AMI data can be leveraged to help in broad power quality analysis
2. Localized or focused power quality analysis still requires more specialized tools
3. Evolving data analytics coupled with “temporary” meter configurations with higher power quality data resolutions on the AMI network may help augment the need for #2 above.

WHAT IS POWER QUALITY AND ITS IMPORTANCE?

- Power quality is how well the electrical power characteristics conform to established specifications.
- Ideal: voltage and current follow a mathematical sinusoidal function
- Reality: nothing is ideal!
- Industry standards and guidelines provide specifications for normal operating parameters.

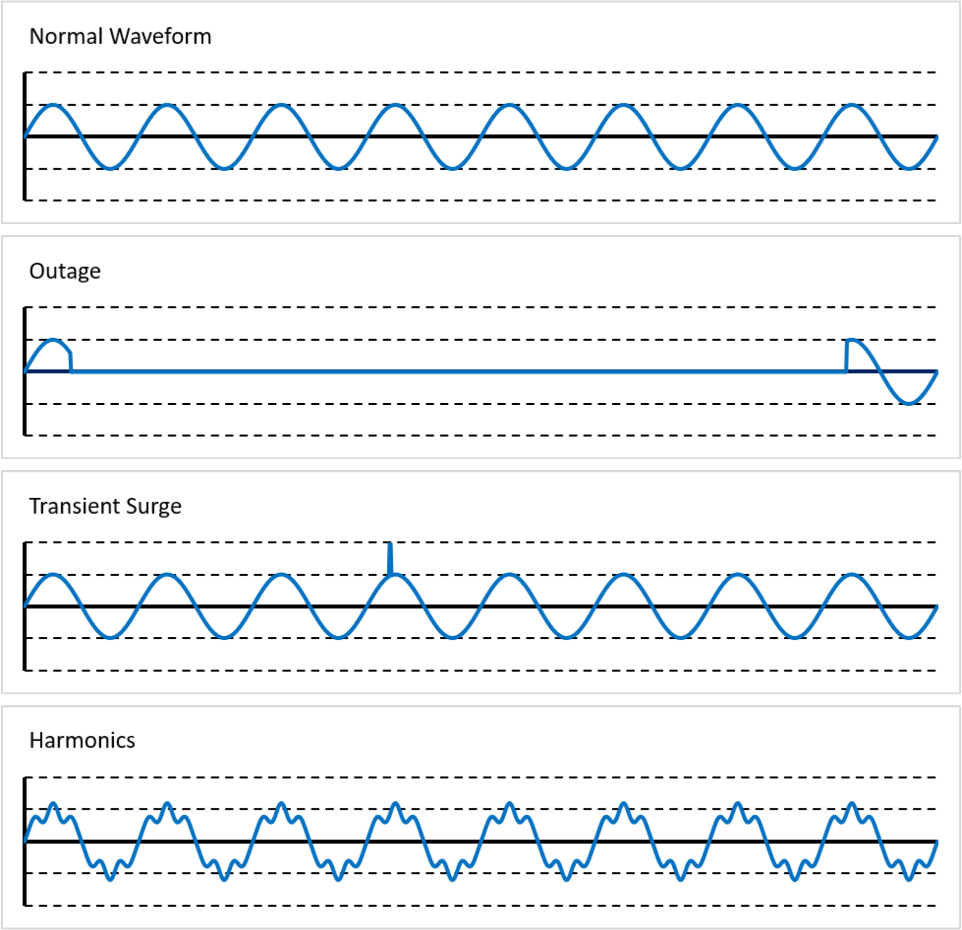
- Key electrical characteristics for 3-phase Alternating Current (AC)
  - Frequency (Hz)
  - Voltage (V)
  - Current (I)
  - Phase Angles
  - Power Factor
  - Harmonics

Phasor and Waveform Diagrams



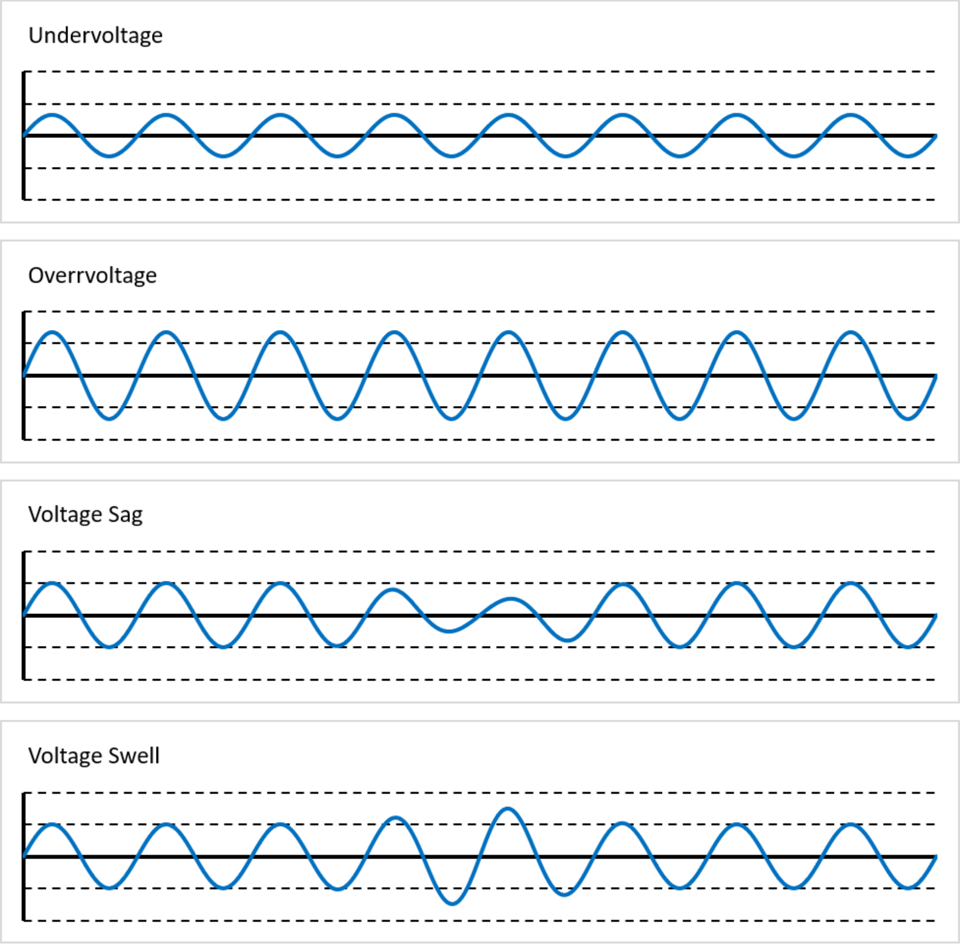
WHAT IS POWER QUALITY AND ITS IMPORTANCE?

- Consumer equipment and devices purchased by customers are designed by manufacturers to operate based on industry standards.
- Deviations from normal operating parameters can cause issues for customer devices.
- Power quality is typically a concern of the end user having equipment not operating as expected.



What is power quality and its importance?

- Power quality analysis is understanding the causes of electrical power deviations from normal operating parameters.
- Then as necessary mitigating and remediating those causes to prevent or reduce the impact of future deviations to customers.



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Current Practice and Needs of Power Quality

- What does your state (or country) regulations for utilities require?
  - Some may provide specific requirements
  - Some may refer to industry standards
- What do your company policies state?
  - Is there anything above and beyond the government guidelines?
- How is your company structured to respond to power quality questions from customers?
  - Dedicated teams focused on power quality, or
  - Embedded in day-to-day activities of some employees?
- What are your customer expectations?
  - Simple explanation of outages
  - Detailed explanation of deviations in power quality

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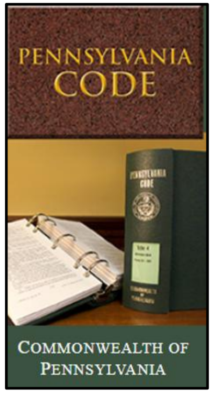
CURRENT PRACTICE AND NEEDS OF POWER QUALITY

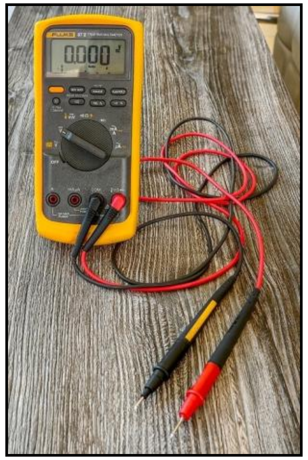
- Pennsylvania
  - PA Code Title 52 sections 57.14 Service Voltage and 57.15 System Frequency
  - “allowable variation”
- PECO
  - Tariff defines service for both standard single-phase secondary and standard polyphase secondary
  - Tariff includes section on Customer’s Use of Service, Section 13.2 Fluctuations
  - Department with Power Quality Technicians



- Summary of PA Code and PECO Electric Tariff:
  - +/- 5% at the service point for 120V/240V service
  - Minimum Threshold = 228 V, Nominal Voltage = 240V, Maximum Threshold = 252 V
- Customer Expectations Vary:
  - Residential: Flickering lights, stray voltage/shocks
  - Commercial & Industrial: Power Factor, motor start-up, impacts to battery systems for power conditioning (particularly data centers)

CURRENT PRACTICE AND NEEDS OF POWER QUALITY

- Addressing power quality concerns:
  - Stray Voltage / Shocks:
    - require localized monitoring and testing
  - Voltage swells and sags, brown-outs, momentary interruptions, flickering lights:
    - recommend analysis to correlate to known outage or non-outage events on the utility system before localized monitoring and testing
- Tools of the trade:
  - Data loggers
    - Standalone
    - Meter Socket Adapter
  - Handheld multimeters
  - Analysis software
  - Company data and historical records

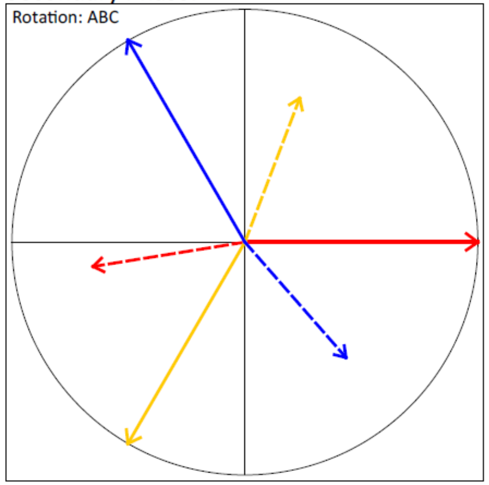


CURRENT PRACTICE AND NEEDS OF POWER QUALITY

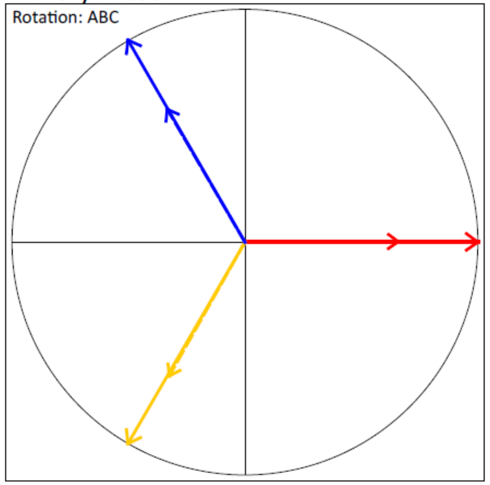
Site Measurements

Phase	Voltage	Voltage Phase	Current	Current Phase	Probe I	Probe I Phase
A	120.003	0.000°	0.000	170.724°	5.046	359.910°
B	120.008	120.000°	0.000	290.940°	5.027	119.411°
C	120.015	239.999°	0.000	48.809°	5.044	239.751°

Secondary Phasor



Primary Phasor



Power

Phase	Watts	VA	VAR	Voltage THD	Current THD	Power Factor	CT Ratio
A	-0.023	0.028	0.004	0.39%	57.86%	-0.853	110026.44:5
B	-0.024	0.028	0.004	0.02%	60.93%	-0.843	108205.48:5
C	-0.018	0.023	0.004	0.00%	70.61%	-0.801	131748.09:5

- Occasionally you may need to check and verify wiring of a meter (this should have been done correctly at install!)

Example:

- Tesco Meter Site Analyzer (6330)
- PDF report includes vector diagrams and highlights Total Harmonic Distortion (THD)

Current practice and needs of power quality

- What is done when the root of a problem is identified?
  - Customer repairs to customer-owned equipment
  - Utility repairs to utility-owned equipment
  - Installation of equipment to isolate issues

- Examples of Remediation
  - new neutral wires
  - repairs of cables / taps
  - Installation of neutral isolators

Standards comparison power quality vs. metering

Power Quality

- ANSI NEMA C84.1: American National Standard for Electric Power Systems and Equipment—Voltage Ratings (60 Hz)
- IEEE 1159: Recommended Practice for Monitoring Electric Power Quality
- IEEE 519: Harmonic Control in Electric Power Systems
- IEEE 1453: Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems
- IEEE 1250: Guide for Identifying and Improving Voltage Quality in Power Systems
- IEEE 1564: Guide for Voltage Sag Indices

Electric Metering

- ANSI NEMA C12 series: American National Standard for Electric Meters
  - C12.19: Utility Industry End Device Data Tables
  - C12.20: Electricity Meters 0.1, 0.2 and 0.5 Accuracy Classes
  - C12.24 TR Definitions for Calculations of VA, VAh, VAR, and VARh for Electricity Meters
- IEEE C57.13 series: Standard Requirements for Instrument Transformers
- Meter manufacturer and AMI provider proprietary data and analytics

LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

If…

AMI meter data ≠ Power Quality measurement data

Then…

Why and how do you use AMI in support of Power Quality?

WHY CONSIDER AMI IN POWER QUALITY?

- AMI meters are located between the customer and utility.
- AMI meters provide more than just billing data.
- May prevent more extensive power quality investigations, including prevention of intentional interruptions of power to leverage other power quality measurement tools.
- Access of AMI information to more utility employees than just Power Quality specialists (double edged sword!)
- Widespread data points vs. targeted/isolated measurement points

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PECO'S ELECTRIC METER LANDSCAPE

- Total electric meter count: ≈1.7 million
  - Residential customers ≈90%
  - Commercial/Industrial customers ≈10%
- Original AMI meters were the L&G Focus
  - Mass deployment 2012-2016
- Form 2S meter: Most common for residential customers
  - 200A, 120V/240V Service
  - ≈88% of total electric meters
- Currently have a mix of meter vendors
- All meters use PECOs AMI network

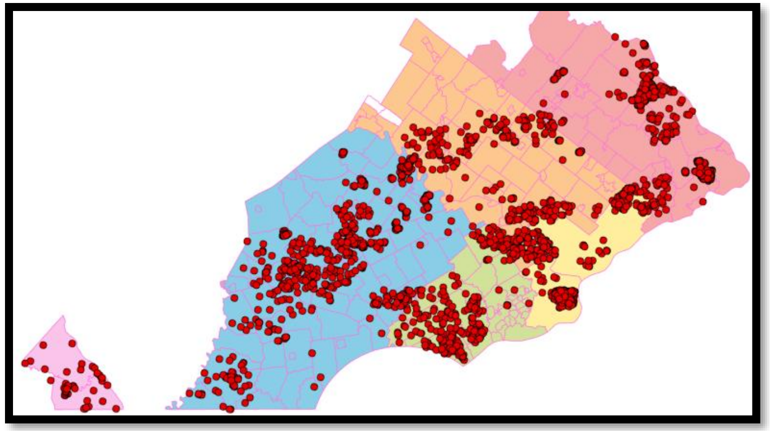
LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

- AMI meters provide more than just energy usage readings needed for billing a customer
  - AMI meters can be configured to provide various data points or to alarm on various data points at differing periods of time
    - Will vary based on meter models, AMI network integration, etc.
  - Examples of alerts becoming common on AMI meters:
    - Power Outage and Power Restore alarms
    - Brownout (low voltage / voltage sag)
    - Voltage (instantaneous or RMS)
    - Temperature
    - Tilt alarm (theft)
    - Loss of Neutral
    - Arcing detection

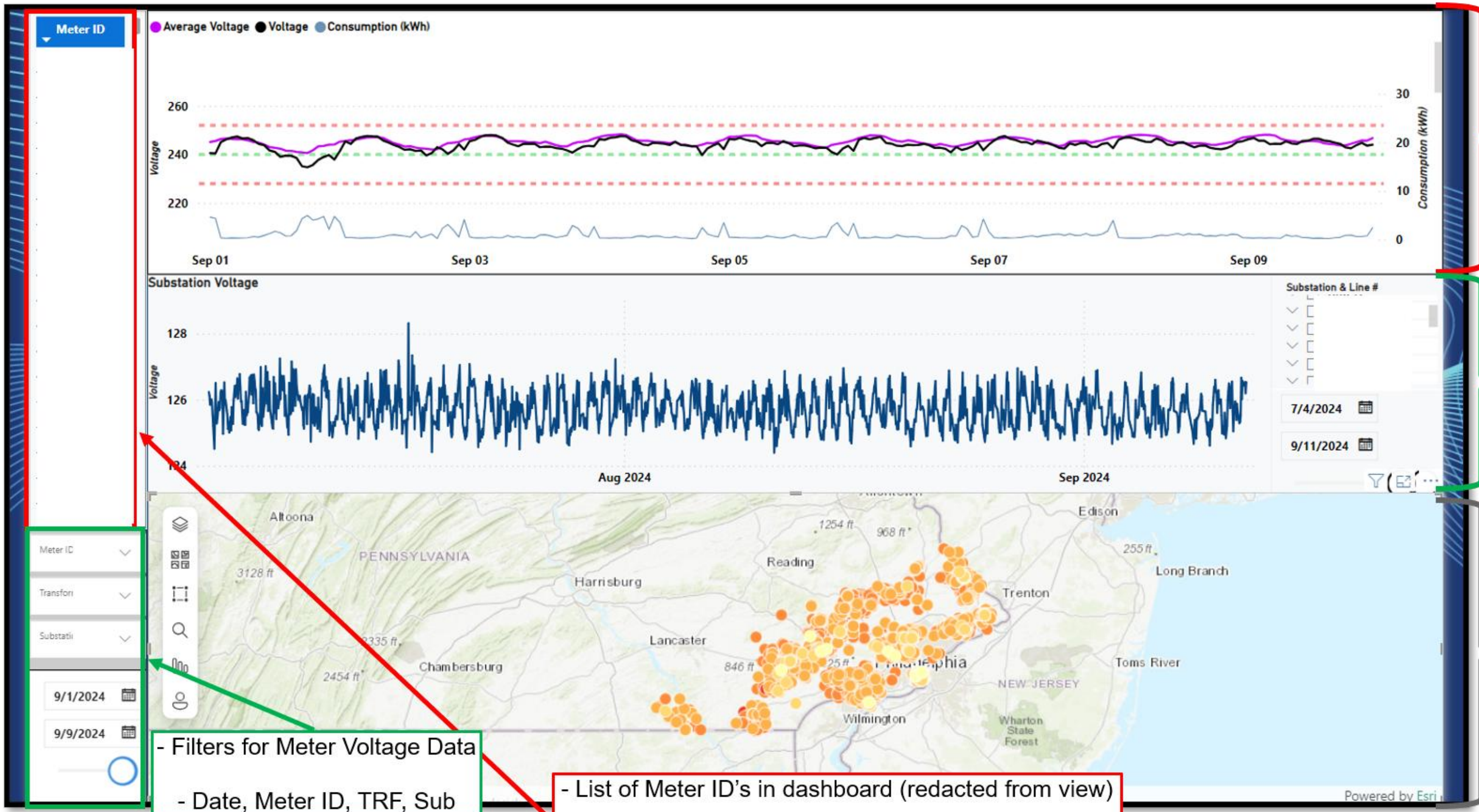
- You may be able to adjust an AMI meter configuration remotely to provide different (or more granular) data points for a period of time.

Leveraging Existing AMI Data for Power Quality

- At PECO all AMI meters provide instantaneous voltage.
  - Instantaneous snapshot of voltage data recorded and sent at time of transmission from the meter to the AMI headend.
- Designated some AMI meters to provide voltage data at 60-minute intervals from targeted locations.
  - The 60 min interval voltage, is a Root-Mean-Squared Voltage or RMS Voltage.
  - Injest RMS Voltage data and analyze in a PowerBI dashboard.
  - Currently a limited set of meters have the voltage channel enabled.



LEVERAGING EXISTING AMI DATA FOR POWER QUALITY



- Meter Voltage Data
- Legend top left
- **Red** dashed Line = Min(228 V)/Max (252 V)
- **Green** dashed line = Nominal Voltage (240 V)

- Substation Voltage Data
- Leveraging PI Data
- Stand-alone Filter

- Interactive point heat map of meter locations
- Integrated PECO Electrical Facilities Map
- Map filters with voltage data

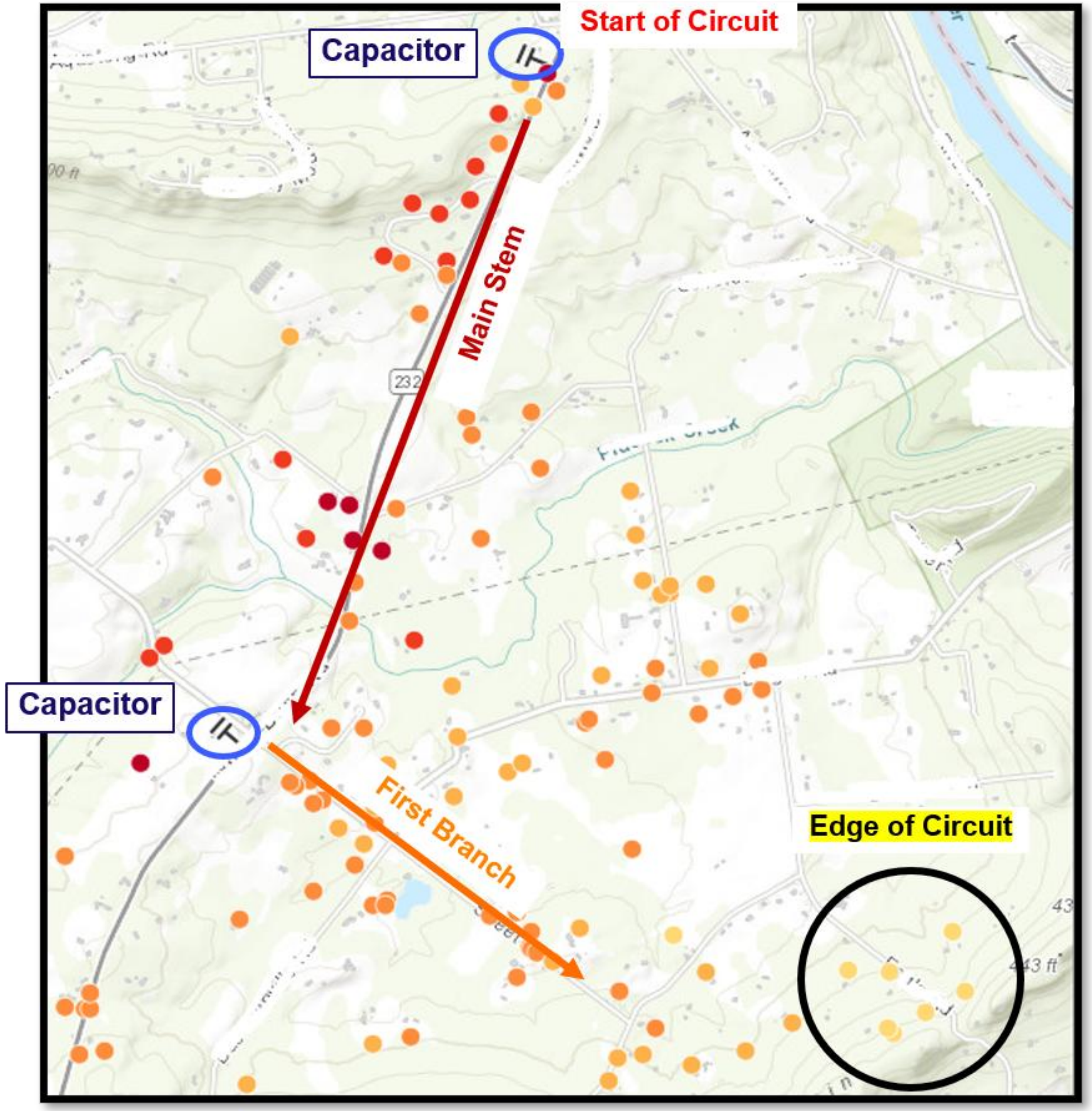
- Filters for Meter Voltage Data
- Date, Meter ID, TRF, Sub

- List of Meter ID's in dashboard (redacted from view)
- Blue highlight = SOLAR, Green highlight = EV

LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

Heat Map Analysis

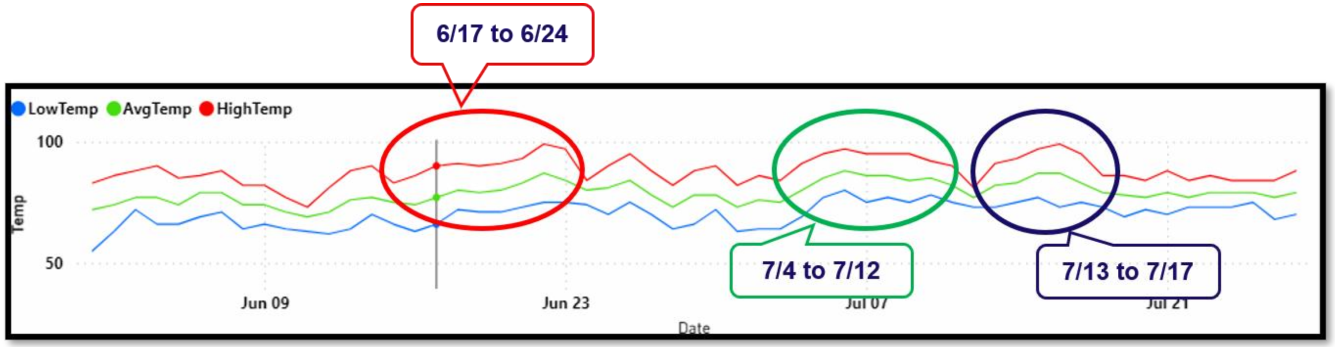
- By mapping the voltage of each meter, a view of how the electricity flows through the circuit can be generated such as the heat map shown.
- Color corresponds to voltage value:
  - **Red:** Higher Voltage
  - **Orange:** Median Voltage
  - **Yellow:** Lower Voltage
- Farther distance for electricity to travel = higher losses from resistance = lower voltage
- Identify the effects of electrical grid devices:
  - **capacitors** inject reactive power into the circuit which the voltage then draws on to "push" electrical current through distribution lines
  - Reactive power flows back and forth from source to load
- Can help a utility to plan efficient operation of energy delivery and to prevent voltage sags/surges
- Similar analysis can be done to see impact of buck/boost transformers (voltage regulators)

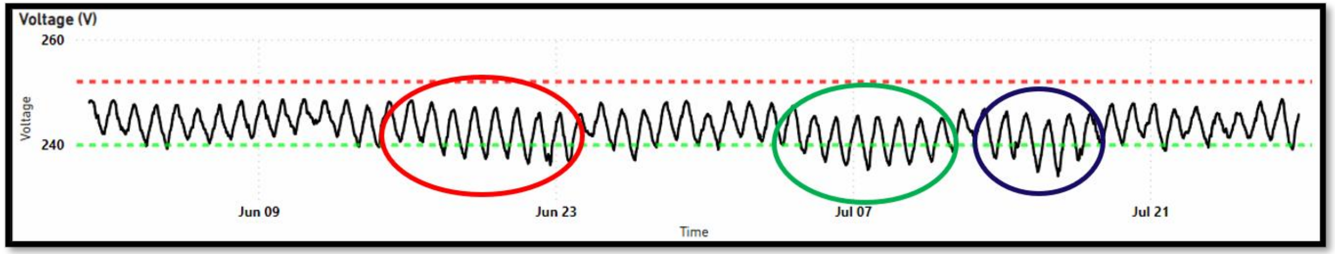


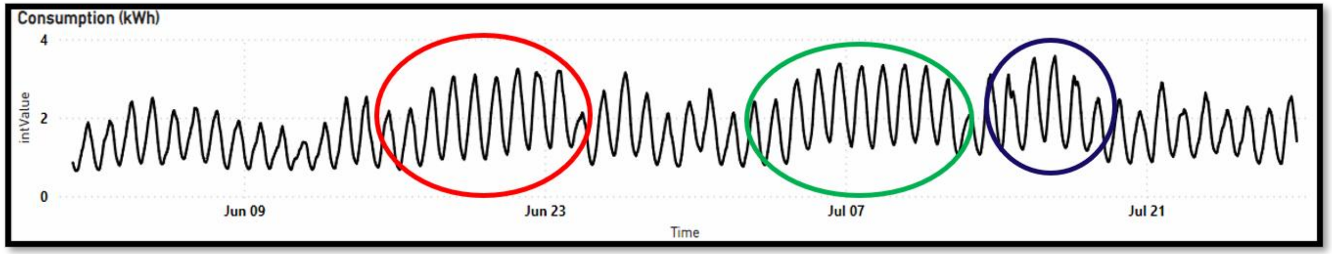
Leveraging existing AMI data for power quality

Effects of Heat Wave on customer voltage

- Multiple 2024 heat wave events:
  - 6/17 to 6/24, 7/4 to 7/12, and 7/13 to 7/17
- Temperature peaks of 99˚F
- Air conditioners and fans are running nearly non-stop day & night, plus fridges & freezers are working to combat the high temperatures
- This is all seen through voltage and energy consumption graphs
  - Energy rises as customers need to draw more power to stay cool
  - Energy rise driven by increased current (I) draw
  - Voltage (V) decreases due to higher resistance (R) loses caused by the increased current (I)
- Understanding environmental and consumer actions can help Power Quality analyzes.





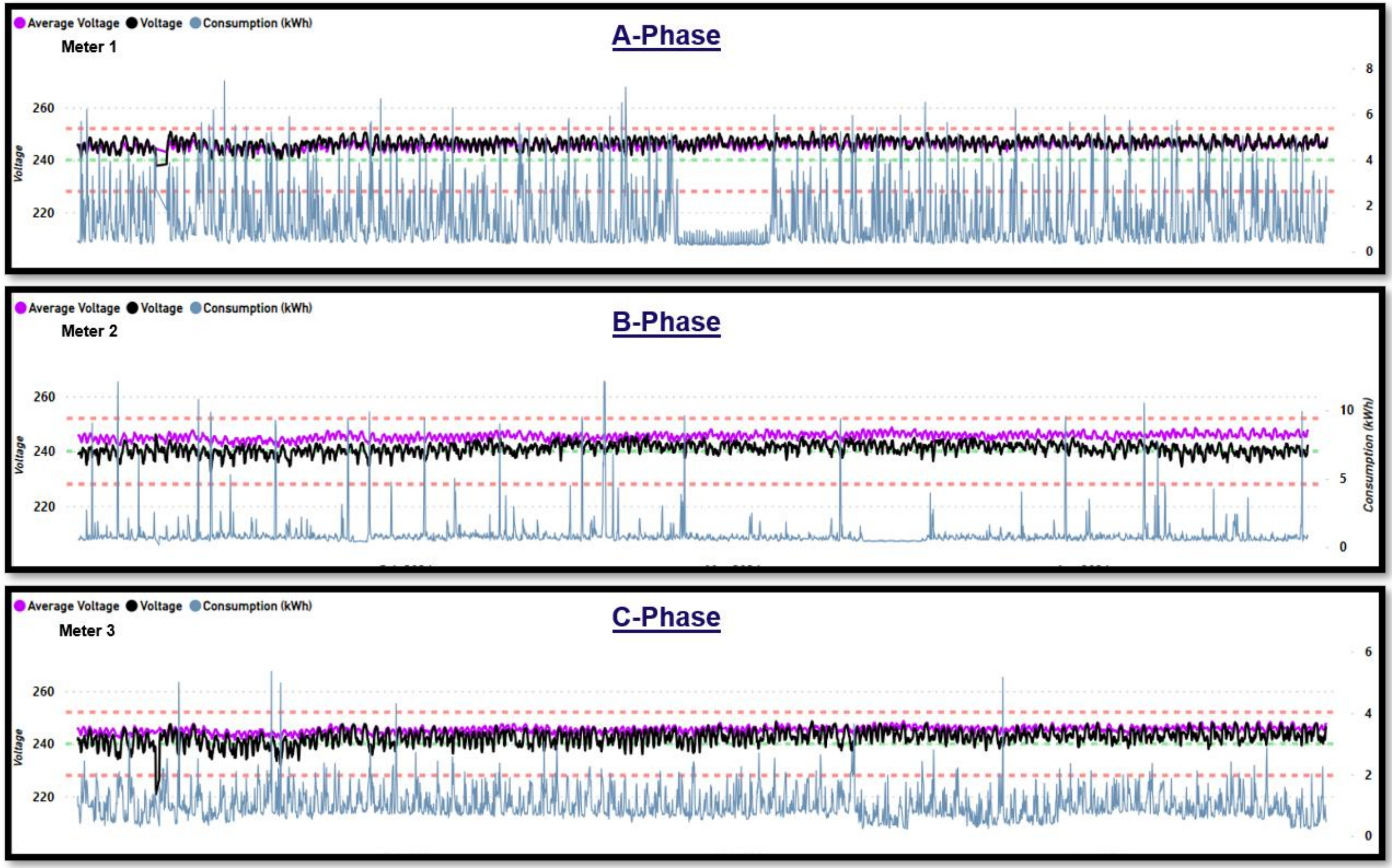


Remember: $E_P(kWh) = P(kW) \times t(h) = V(V) \times I(A) \times t(h)$

During a heat wave: Current (I) increase ≫ voltage (V) decrease

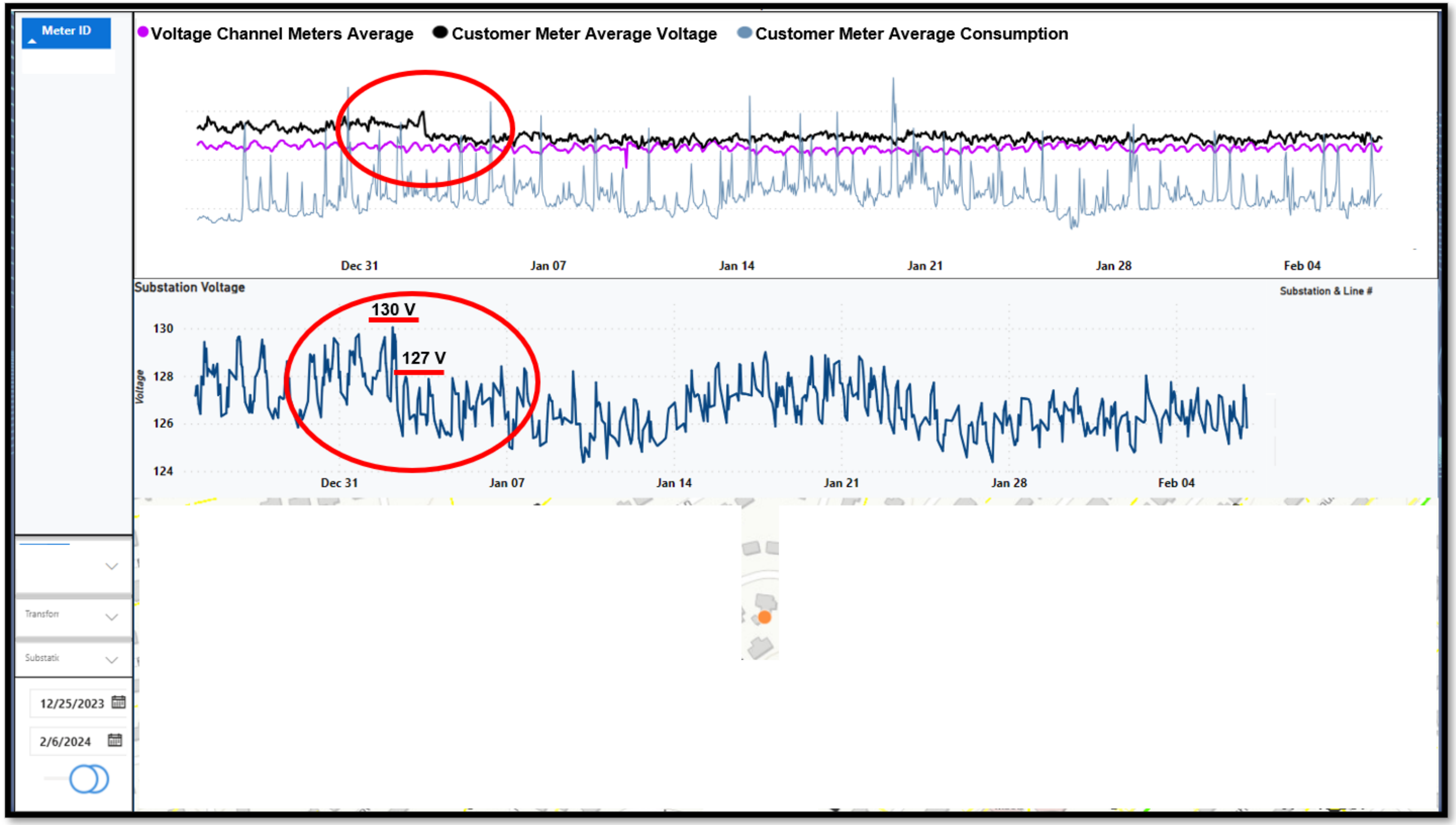
LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

- Shown are 3 meters each on a different phase of the same circuit
- We can identify the voltage pattern related to each phase
- The average voltage of the whole group can be used as a baseline
- If a large density of meters on a circuit have granular voltage data, algorithms and/or applications can be used for phase & transformer misidentification
- Could help analytics for some specific customer concerns



LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

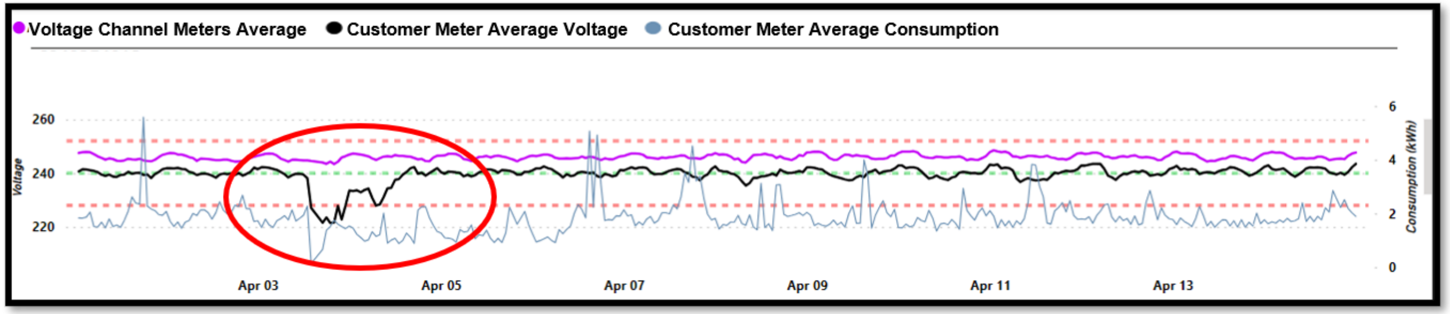
- Voltage Regulator adjustment made on January 2, 2024
- Previously operating between 128-130V, adjusted to 124-127V
- Adjustment to support new solar customers being added
- See positive affects for all customers downstream of voltage regulator

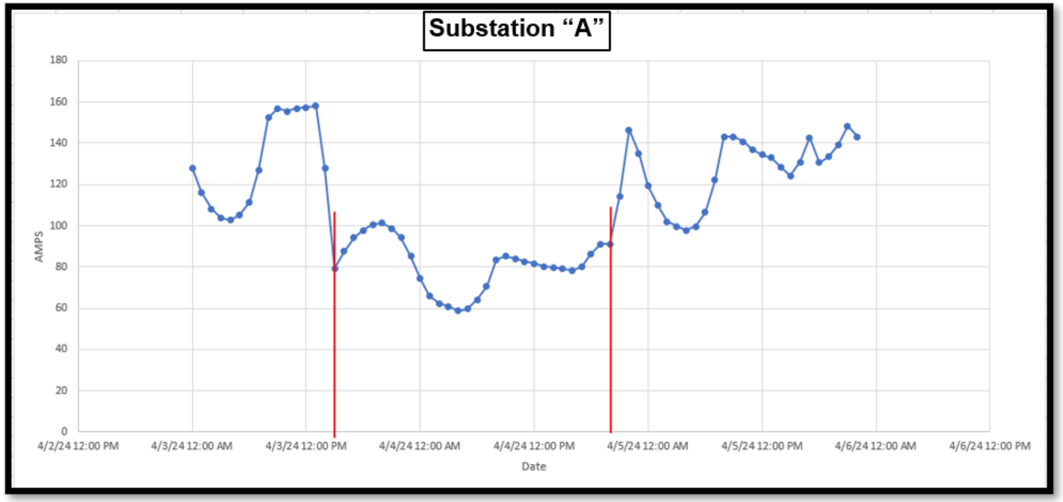


LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

Validate Power Quality in abnormal situations

- Circuit (feeder) “A” experiences outage on 4/3 at approx. 1 pm
- Affects a customer with the enhanced voltage channel enabled.
- Step restoration done moving load from Circuit “A” to other circuits
- Customer AMI shows power fail for approx. 2 hours, restored from another circuit “B”
- Loading on circuit “B” is higher than normal, Customer has lower than normal voltage
- On 4/4 at approx. 5pm repairs are completed on circuit “A” and circuit “A” and “B” configurations are returned to normal
- Customer voltage returns to normal levels

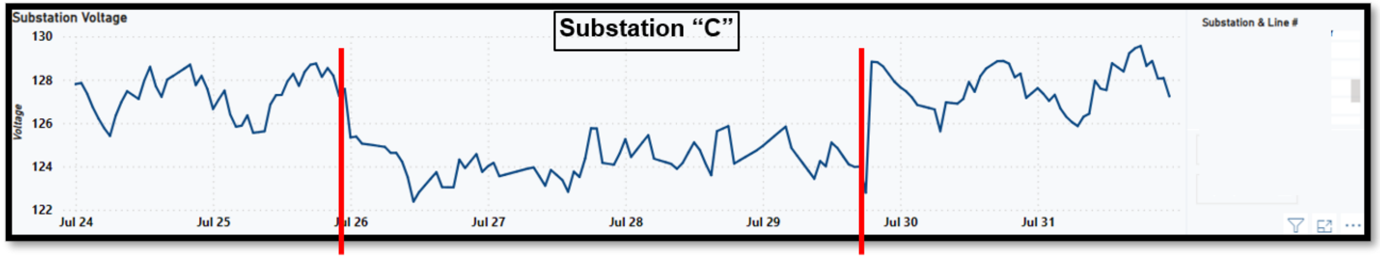


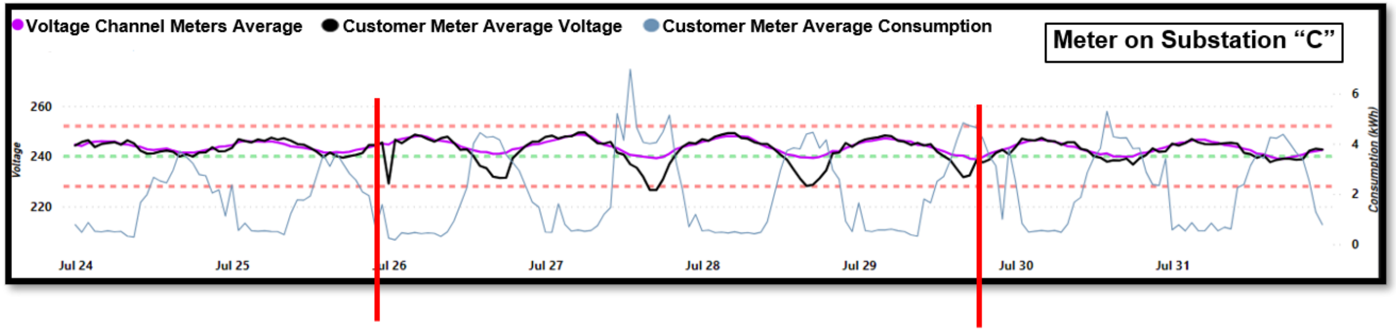


LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

Validate Power Quality issues due to temporary utility configurations

- There is a voltage drop at Substation “C” that lasts from 7/26 to 7/30
- This was due to a circuit breaker failure at Substation “D”
- Load was picked up by Substation “C” to restore customers
- Substation “C” levels increase 7/30
- Circuit breaker was repaired and closed at Substation “D”
- We now see higher voltage minimums that conform to the values before the substation voltage drop

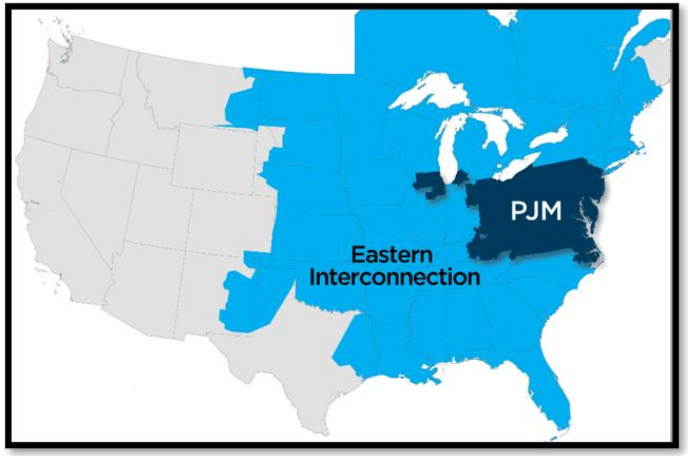


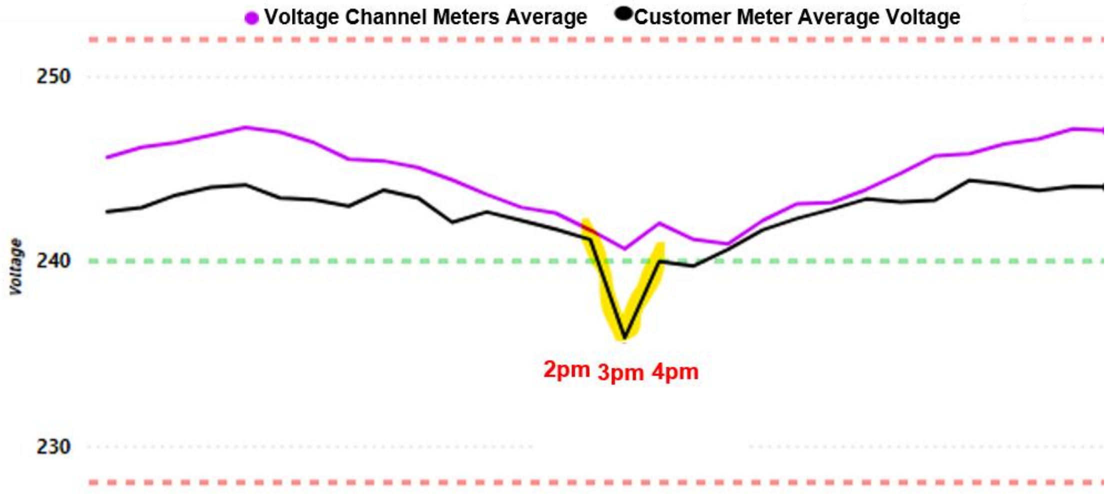


LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

PJM Voltage Reduction Test

- The PJM Interconnection is a regional transmission organization. In 2025 PJM conducted a 5% voltage reduction test for the Mid-Atlantic region from 2-2:30pm.
- Using the capabilities of RMS voltage channel enabled AMI meters the event was analyzed.
- On average service points saw a slight voltage drop (purple) with some customers exhibiting a more significant RMS voltage pattern shown to the right

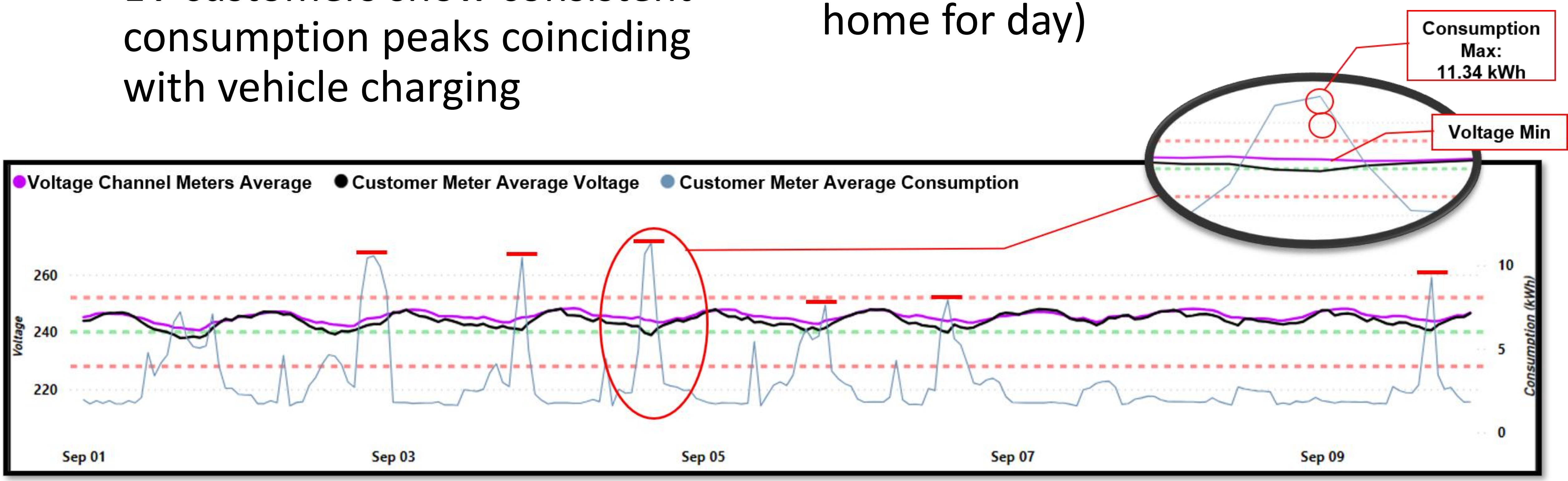




LEVERAGING EXISTING AMI DATA FOR POWER QUALITY

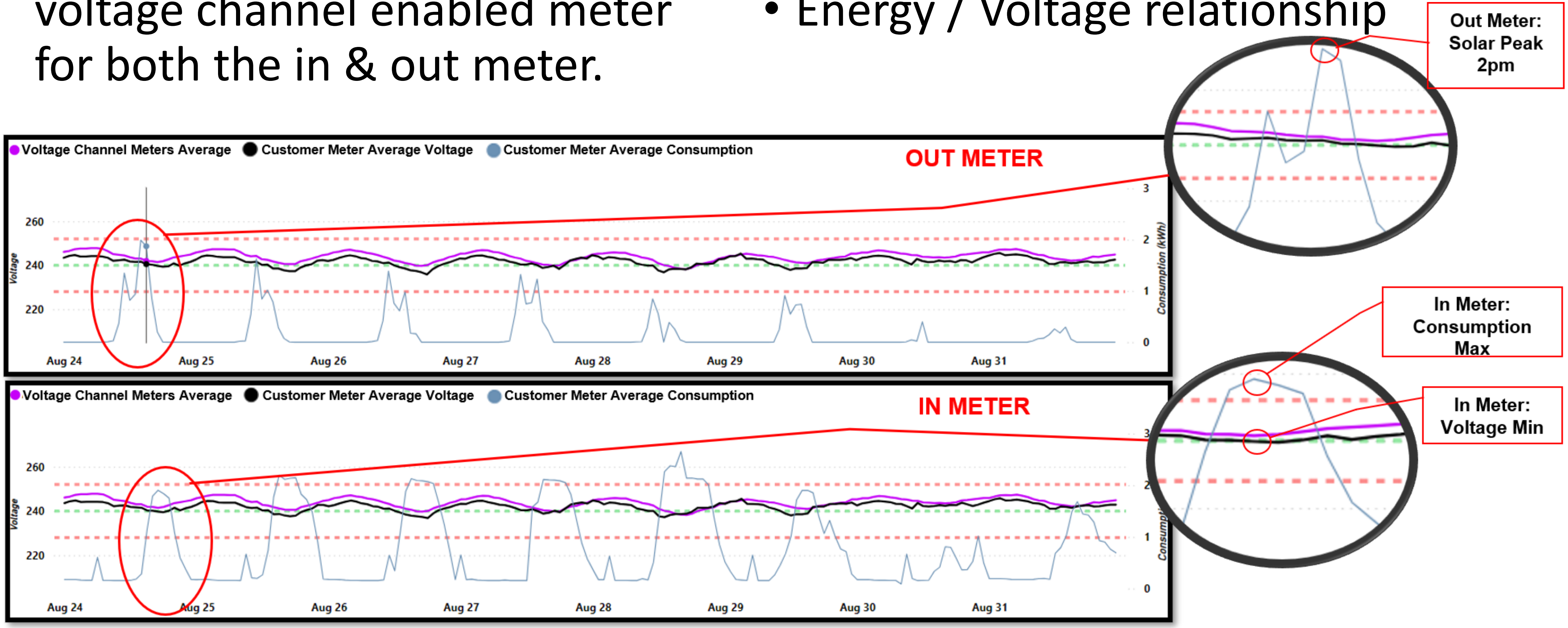
- Customer insights/impacts
- EV customers show consistent consumption peaks coinciding with vehicle charging

- Peaks occur when the vehicle is plugged in around 7-9pm (Arrive home for day)



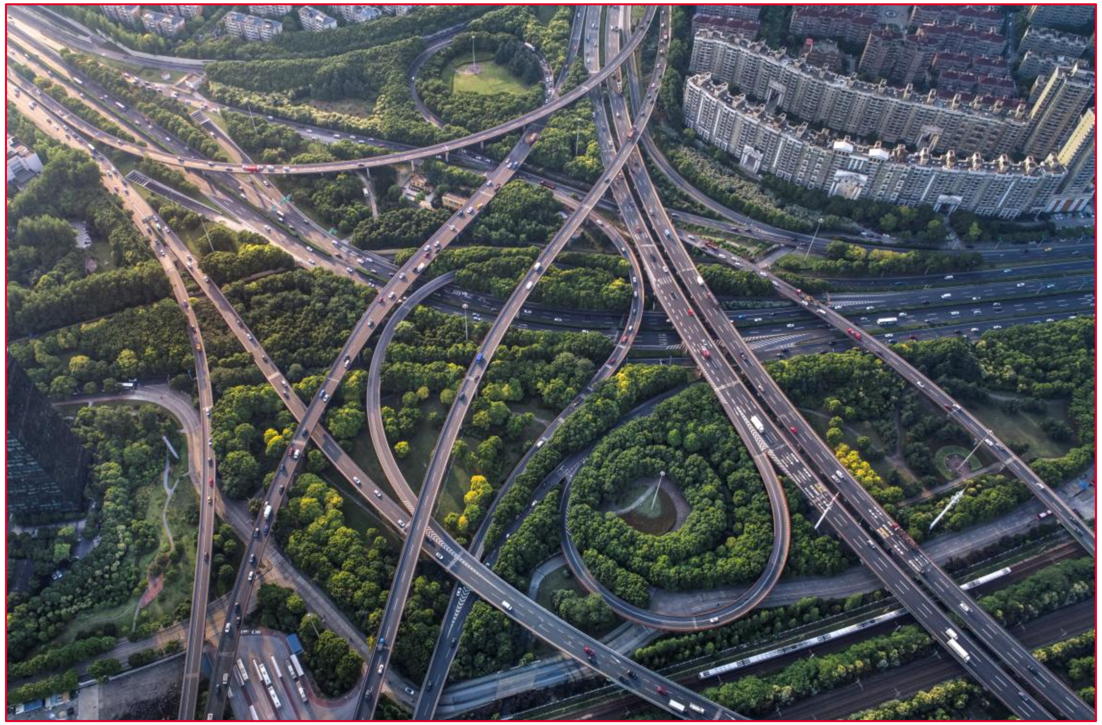
Leveraging existing AMI data for power quality

- Customer insights/impacts
- A solar customer with RMS voltage channel enabled meter for both the in & out meter.
- Consumption graphs help understand solar generation
- Energy / Voltage relationship



Impact of Power Quality Data on AMI Network

- Can we just make all AMI meters capture and communicate Power Quality measurements?
- Network engineering!
- More data is like more cars or larger tractor trailers
- Likely your network will NOT want every meter sending detailed waveform capture data hourly or even daily!



The evolving grid, power quality and AMI

- More distributed energy resources
  - Inverter based resources have different power outputs than traditional rotating generation technologies
  - Volt-Var optimization of inverters
- More advanced electronics needing more precise power requirements, compared to motor loads
- Increasing battery back-up and power conditioning systems used by commercial & industrial customers with sensitive equipment
- Newer utility programs: CVR – Conservation of Voltage Regulation
- Comparing voltage regulator or capacitor set points and operations with AMI meter data

Potential Large Scale Data Analytics and AI

- Consider the granularity of PQ data on the AMI network
  - Challenges / opportunities
    - More granular necessary for effective PQ
    - Impact on AMI network: Consider targeted AMI meter configurations
    - Availability of AMI alerts (who/how/where routed)
- Understanding the evolving grid and how AMI data can help
- Predict issues that are contributors to Power Quality issues
  - Examples: Transformer failure or cable failure
- Use of AI and other ML tools to support at scale analytics
  - Predict issues at meter / home level

Reminder of Key Learning Outcomes

1. AMI data can be leveraged to help in broad power quality analysis
2. Localized or focused power quality analysis still requires more specialized tools
3. Evolving data analytics coupled with “temporary” meter configurations with higher power quality data resolutions on the AMI network may help augment the need for #2 above.

QUESTIONS AND DISCUSSION

Nathaniel Nichols

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