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Why Remote Power Quality Monitoring

HOLDS THE KEY TO HIGHER PRODUCTIVITY AND COST SAVINGS

Let’s Summarize the

POWER QUALITY CHALLENGE

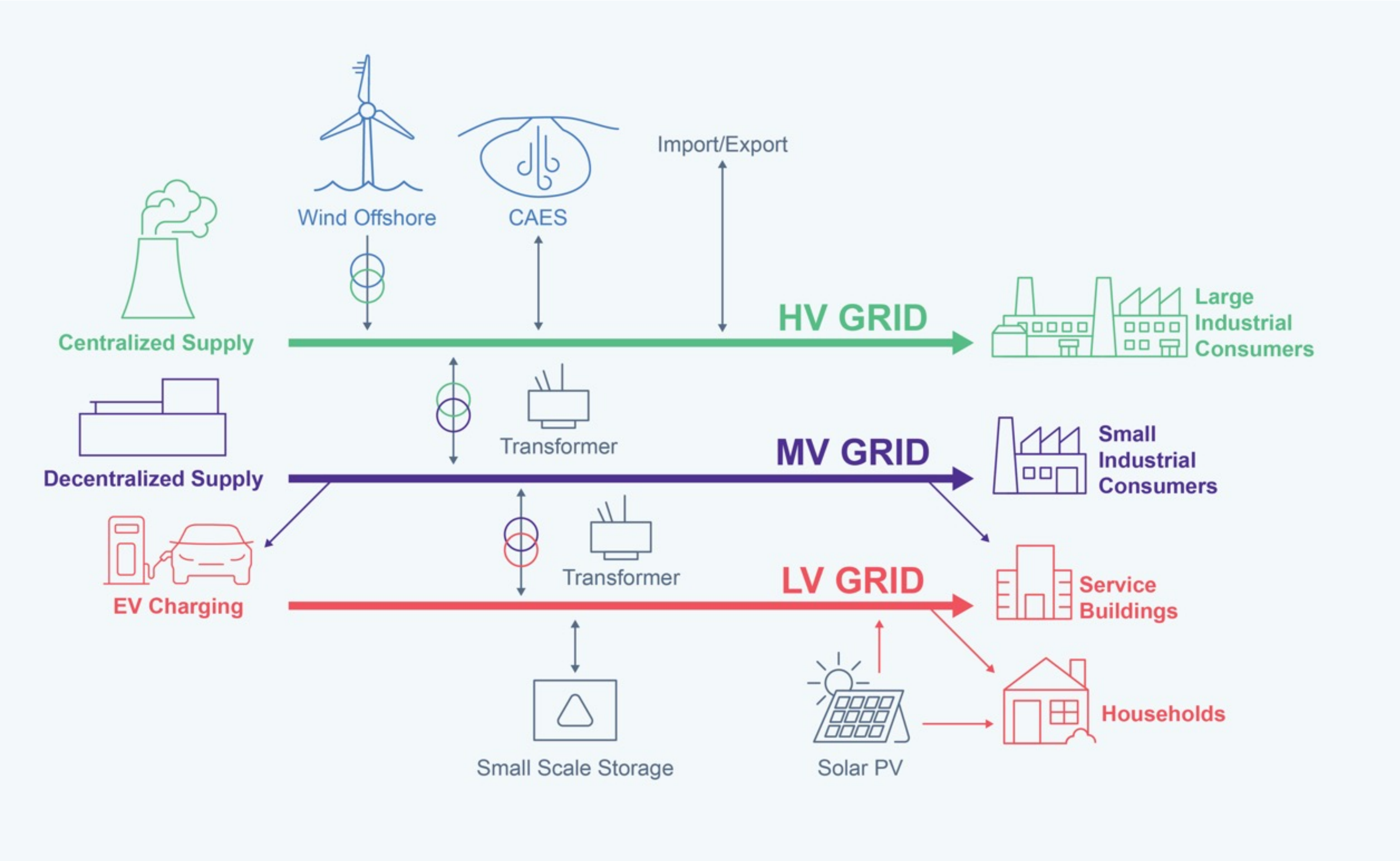
(Primarily as it Relates to the Distribution System)

Grid Overview and Our Supply & Demand Challenge

The largest area of focus for power quality is at the point of connection between the supplier of electricity and the consumer.

There are other critical points inside a consumer's facility where critical processes and machines operate and need consistent high-quality power.

Centralized supply and the HV grid have been stable and reliable for decades. **However, our grid is becoming less and less dependent on centralized power and more and more reliant on distributed renewable power** — which is not as dispatchable and consists of inverter-based technologies.



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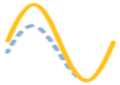
Power Quality Categories and Common Causes

WAVEFORM	DEFECT TYPE	DESCRIPTION	CAUSE
	**Power Factor**	Phase offset between voltage and current → reactive power	Inductive or capacitive loads (e.g., motors)
	**Harmonics**	Multiples of the supply frequency	Non-linear loads (e.g., power converters, VSDs)
	**Resonance**	Energy storage / voltage growth at a natural frequency	Matched capacitive and inductive impedance close to fundamental or harmonic frequencies (e.g., unplanned growth)
	**Transients**	Abrupt voltage or current disturbances	Switching large loads, lightning, arcing
	**Voltage Variation**	Includes dips, sags, swells, brown-outs	Network faults and overload, capacitive load switching
	**Unbalance**	i) Different network voltages ii) Different load phase currents	Mismatched single-phase loads (e.g., IT) and unbalanced three-phase loads (e.g., welding)
	**Flicker**	Random or repetitive voltage variation	High frequency loads: arc furnaces, welding, materials processing

Global Zero-Emission Objectives Drive Further Changes to the Grid

Before we even get to the V2G explosion…

- Acceleration of **DER deployment** around the world
- Huge **push** to electrify transportation (EVs)

Global warming

Electrify transportation

Decarbonize the grid

…Put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050.

"By 2035, 100% of new cars and light trucks sold in California will be zero-emission vehicles."

"EU agrees new cars must be emissions-free after 2035..."

"The Canadian Net-Zero Emissions Accountability Act, which became law on June 29, 2021, enshrines in legislation Canada's commitment to achieve net-zero emissions by 2050."

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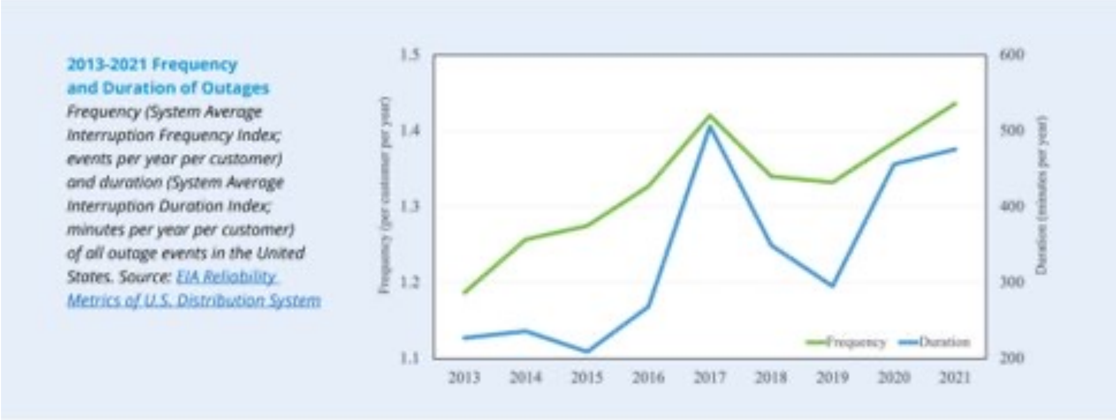
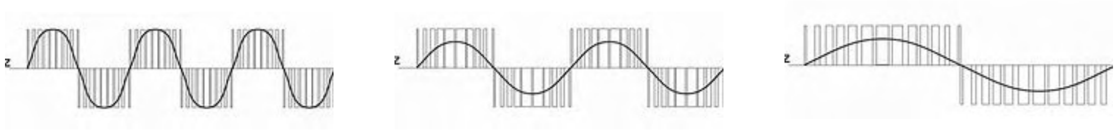
Inverter-Based Resources Growing On Both Sides of the PCC

Centralized power generation has dominated power generation, providing smooth, multiphase, sinusoidal AC power. If power then “switches” to DC (or has different rhythm and magnitude characteristics), **then we need to use power electronics to chop and reform the waves.** This is far from simple — especially when there are many different flavors on generation and consumption.





All of these resources need to adopt inverters to recreate an AC interface with our distribution grid:

PV solar facilities

Wind turbines

EV charging stations

Variable frequency drives

Battery storage

LEDs, UPS, data centers and even Bitcoin mining

So, Where Will the Priority Be for PQ Assessment?

Utilities/distribution grid operators will **measure/audit major consumers at their PCC.**

Major offtakers and developers will soon learn to **mitigate the PCC and ROI risk** (where IBR and risk assessment show likely problems).

Traditional areas policed by utilities/grid operators

PQ Assessment: Growth Areas

Utilities themselves have **rate-based commitments that must be adhered to** and must mitigate DER risks

Net metering and grid stability challenges will drive change

State estimation analysis verification

Microgrid monitoring

V and I profile monitoring to better map the distribution grid

And…where power monitoring can be enhanced by **PQ data**

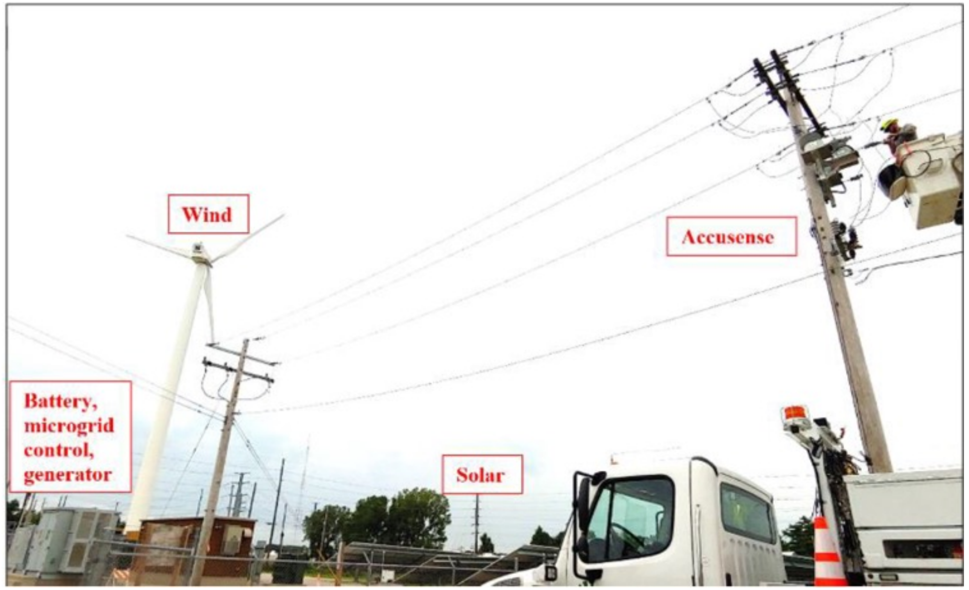
Growth areas at grid edge and beyond utilities where data can bring visibility and informed decisions, leading to improved grid resiliency

Some More Recent

EXAMPLES OF PQ ASSESSMENT

CASE STUDY

Microgrid Example: Both Industrial and Utility Driven



Microgrid site with PQube® 3 Power Analyzer

Midwest Utility: Typical Microgrid Experiment

125kW solar, 100kW Wind, 250kW battery storage, 1MW natural gas generators

Product

PQ Analyzer Pole Mount Package with MV Sensors

Applications/Experiments

- Monitor PQ and supraharmonics during islanded conditions
- 12–16kHz observed during islanded conditions
- 20% THD and flicker observed during islanding event

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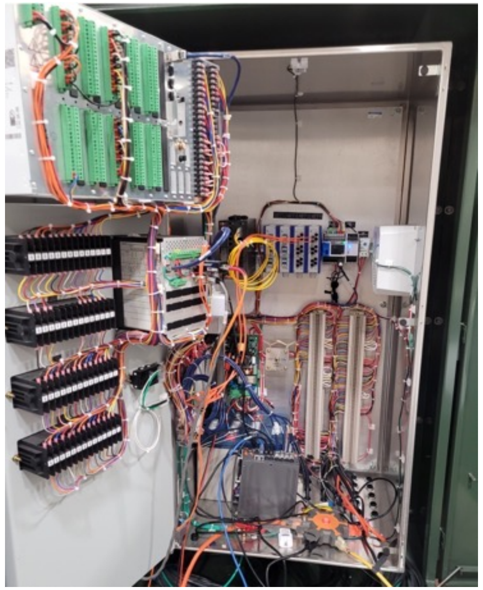
CASE STUDY

Commercial Microgrid Example

Microgrid site with PQube® 3 Power Analyzer



PQube installed in PCC switchgear

Commercial Microgrid (Manufacturing Plant)

3MW: Solar, flywheel, 2MW flow battery, gas generators

Product

PQ Analyzers

Applications/Experiments

Power metering at 5 points:

- Point of common couple switch
- Service entrance at 2 locations
- Monitoring 2 inverters on the flow battery

CASE STUDY

Utility Microgrid: Synchrophasor Focus On MV

microPMU Package

microPMU

Midwest Utility: Microgrid Application

750 kW solar, 500 kW/2 MWh battery storage, 5MW natural gas generators

Product

microPMU Pole Mount Package with MV Sensors

Applications/Experiments

- Microgrid monitoring at critical loads and interconnections
- State estimation
- Voltage and current profile monitoring across the distribution system
- Root cause and post-mortem analysis with real time, 60–120 samples/cycle data
  - Higher resolution with continuous data vs. traditional 16 or 32 cycle event snapshot
  - Enables full picture of an event (e.g., through full reclose cycle)

microPMU Resolution and TVE

- Magnitude resolution: 0.0002% (2 PPM)
- Angle resolution: 0.001°
- TVE: ± 0.01% (2 orders better than transmission PMU)

CASE STUDY

Utility DER: Both PQ Analyzer + Synchrophasor

PQube® 3 + microPMU Package

Midwest Utility: DER Application

2MW battery storage, 1.6MW wind, 2MW solar

Product

Combined PQube® 3 PQ Analyzer + microPMU Pole Mount Package with MV Sensors

Applications/Experiments

- DER monitoring: Measure PQ and grid stability impact from DERs
- Use PMU information for voltage and current profile monitoring across feeder for real-time awareness and planning
- Low load current measurement (Rogowski coil)

CASE STUDY

Example of Level 3 DC-DC Fast EV Charging Station PQ Issues

Midwest Utility: DER Application

- Harmonic distortion exceeded utility provider limits
- Utility confirmed power quality issues included grid pre-distortion and EV-induced harmonics
- Data helped determine active harmonic filter spec
- Solution needed careful evaluation due to pre-distortion

Product

Active harmonic filter in voltage control mode

Applications/Experiments

- Solution was to operate the active harmonic filter in voltage control mode to help mitigate the distortion coming in from other sources on the grid
- This install improved the power quality issues on their distribution network from the use of 18 Tesla Superchargers, each with a capacity up to 150kW

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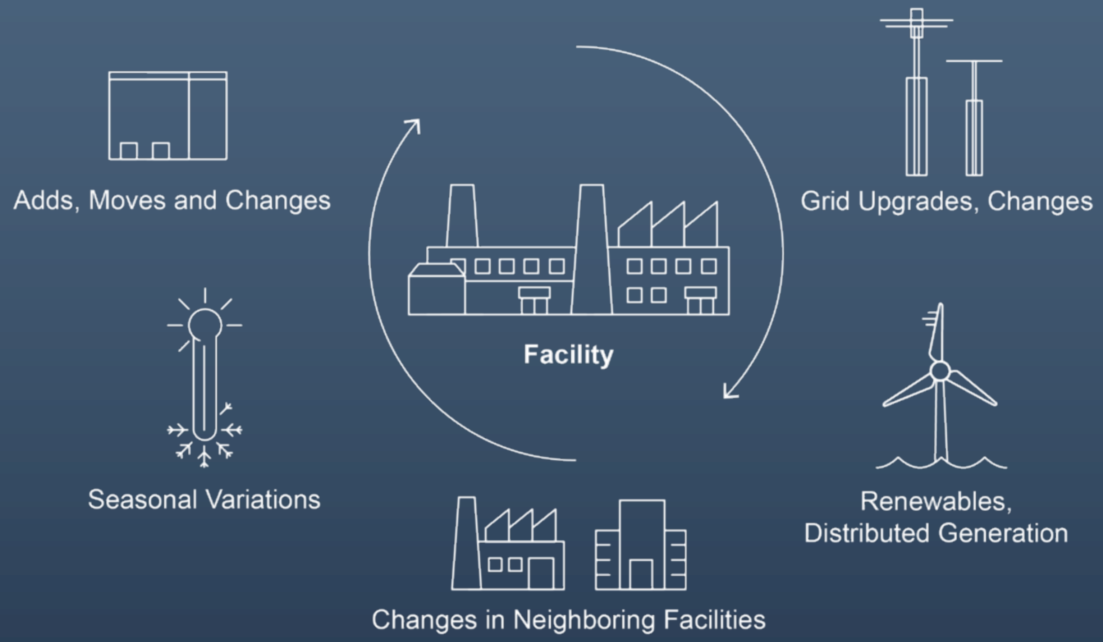
Is Power Quality

ASSESSMENT EVOLVING? HOW?

Power Quality: A Moving Target That Needs a Black Box

The pace of current distribution grid development is changing the economics. PQ used to be non-scalable due to cost.

The Power Environment Is Dynamic



When does it make sense to analyze power quality via a short study, and **when does it make sense to incorporate the black box?**

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Power Quality: Do We Have and Set the Right Standards?

Regulation standards exist regionally

Power utilities agree on limits in some cases

Some verticals impose specific standards

Power quality measurement methods IEC 61000-4-30 – Class S/Class A exist

Consensus: Standards don’t tell the whole story and are also evolving.

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Is Power Quality

MOVING UP AS AN OPERATIONAL PRIORITY?

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Power Quality Analysis: The Importance of Useable Data

In most cases, **power quality analysis is used to understand system response, consequence and cause.**

The results can be used to validate improvement solutions and assessment of downstream effects. By doing so, longer term **grid resiliency measures can be put in place** either via correction solutions or system redesign.

It has been rare that power quality analysis is used for immediate control or protection response. Also, interlinked data via SCADA expansion just doesn't work economically.

Data is most powerful when events and trends can be manipulated and shared easily between experts across the network — whether this is harmonic or conducted emissions for one or origins of phase sags for another.

The ability, therefore, for a system to provide fleet, event or trended data in a **collaborative form** without limitation by software license, protocol limits or comms restrictions becomes important. Flexibility of data sharing — whether via DNP3, BACnet, Modbus, etc. — is an enabler, not a restriction.

The security standards defined for PLC comms, smart meter data collection or substation relay triggers also should be considered openly, considering the function we are trying to manage.

PQ Solutions: It’s Not Just About the Device

Multiple “compromise” products have been pushed on the market to hit the sweet spot ROI.

Do any of these stereotypes resonate with you?

Smart meters with PQ capability but poor storage capability

PQ meters with unique software, limiting data collaboration across companies and offices

Fleet power monitors that don’t have the granularity to catch important PQ transients

Excellent hand-held or portable devices that never seem to cover all the key events

Solid rack mount solutions in strategic locations that just don’t make “cents” to deploy at the grid edge

Putting sophisticated hardware in the hands of customers does not guarantee a winning solution.

But adding intelligent software can help!

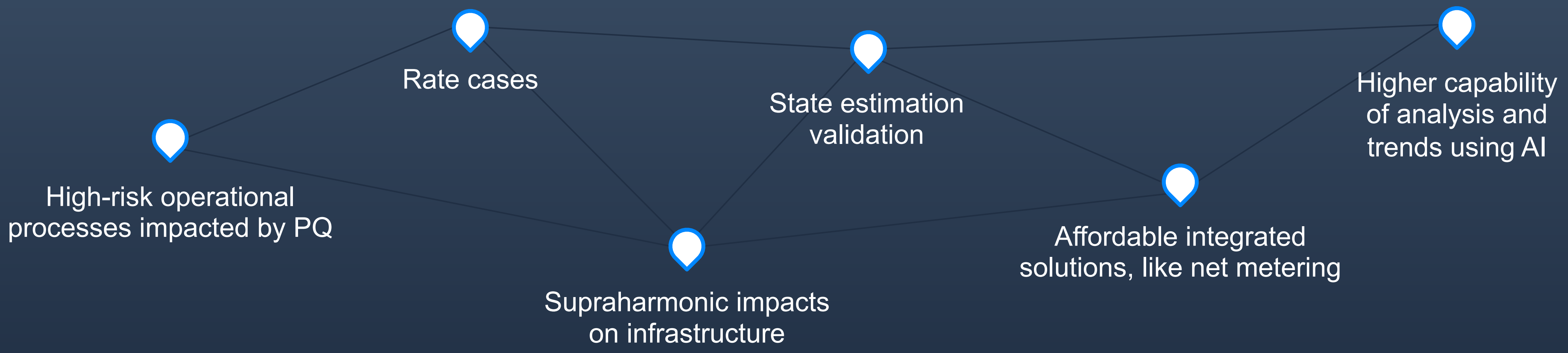
What Is the ROI of Fixing Power Quality, and How Do We Get There?

PQ trends and customized alerts can be used qualitatively rather than analyzing each wreck/event.

Compliance at the PCC is still important, but industry has a stake now, not just the utility.

Power quality devices can do more than analysis of fault behavior and **pull ROI from elsewhere.**

Where?



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Barriers to Fixing Power Quality

Aging infrastructure (Who?)

Cybersecurity (Don’t touch my data!)

SCADA (All of it! Let's boil the ocean.)

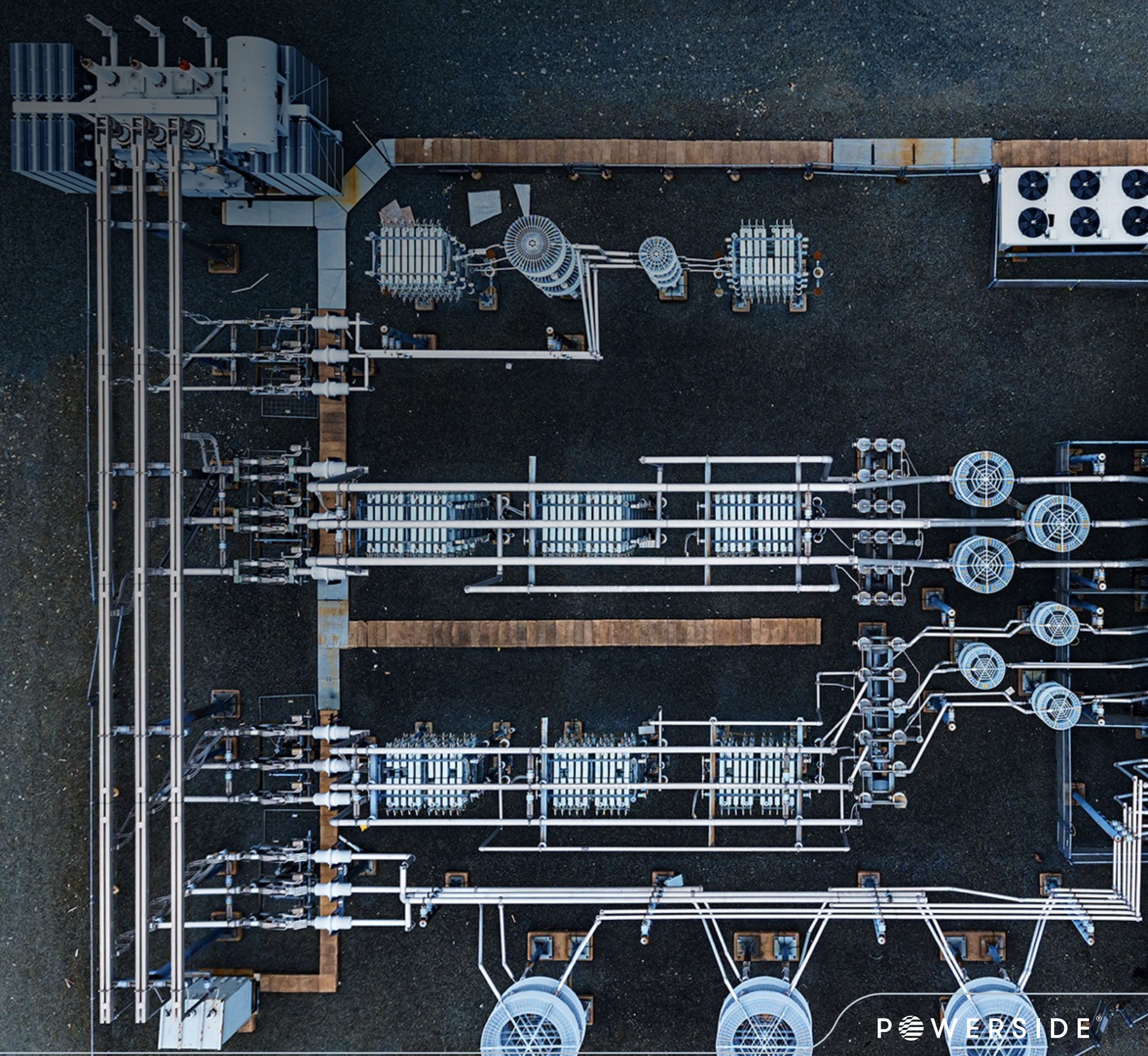
And lock it down

No collaboration between experts, municipalities or co-ops

Believing it’s statistically unimportant and we better chase other fires

Where can technology help mitigate the current risks of both manpower availability and inefficiencies in the current process?

Identifying, interpreting and resolving these ever-increasing power quality impacts are **key to our distribution grid resiliency.**



Situational Awareness That Helps Solve This Challenge

Alternatives to power line comms (PLCs): Cellular capabilities to transfer more data effectively, more quickly

Heat map representation of data, interactive trend graphs and higher band harmonics

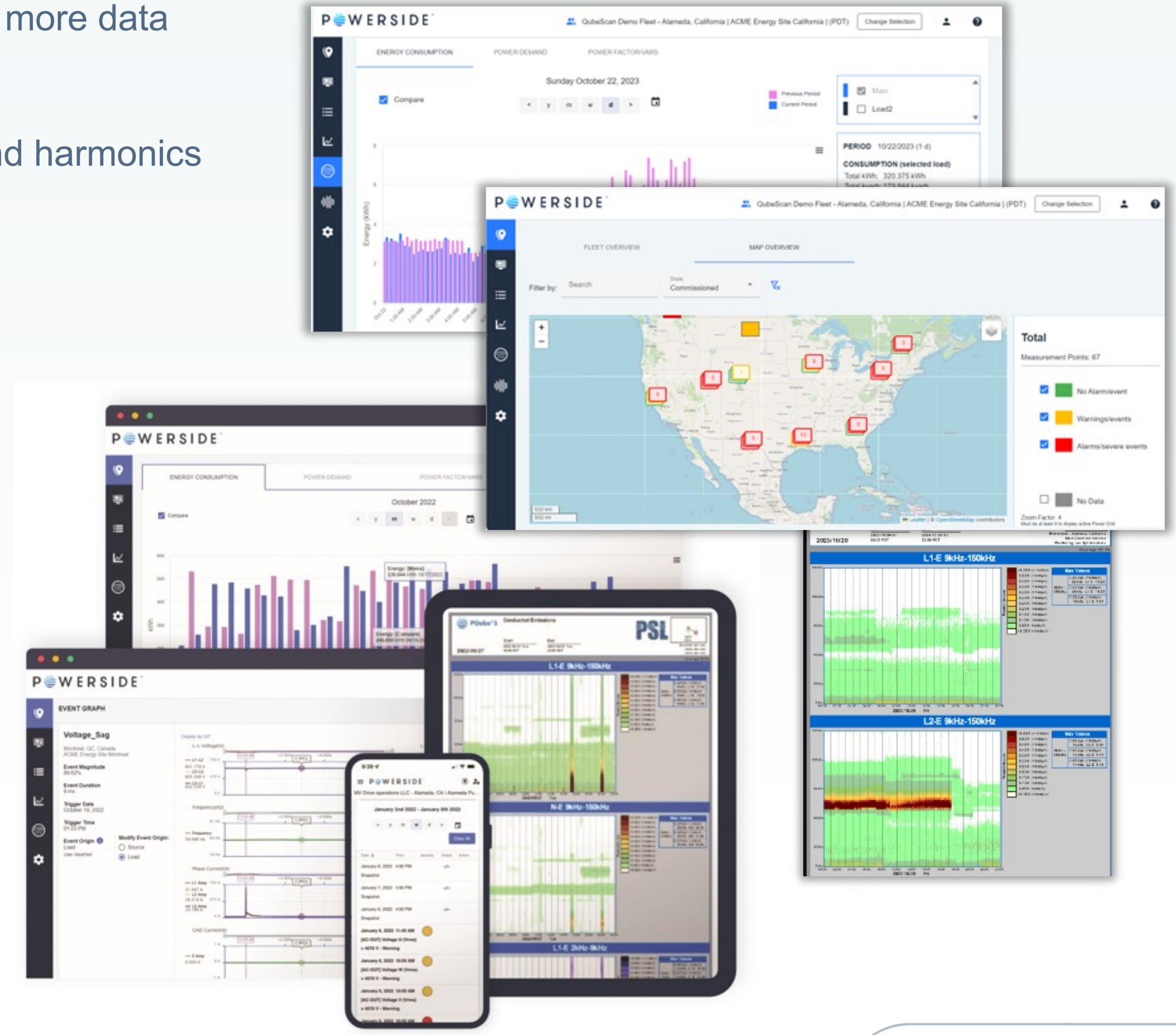
System data alignment via secure system protocols or via external time clocks/GPS/GNSS parameters

Engineering remote collaboration is improving via share of case study data and documentation of findings

Better software tools to distinguish and link PQ trends to fault analysis via AI

Automated and intelligent conformance report capabilities to improve prioritization of analysis

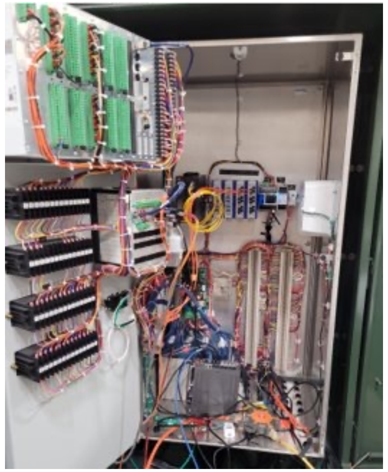
Fleet views and dashboards

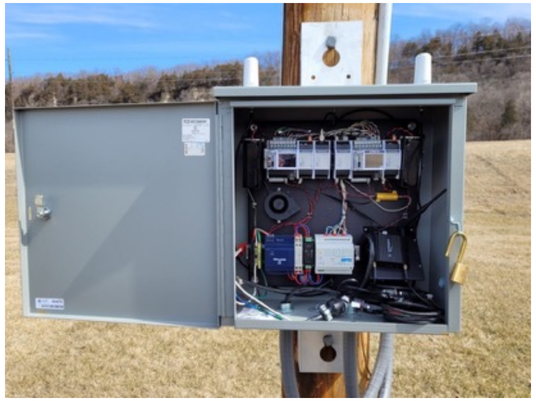


New Equipment and Solutions That Enable Scaling Up

- Power quality analyzer **advances in form factor**: Compact yet high performance for easy integration
- **Increased capacity** for distribution systems to ingest high volumes of synchrophasor data to secure cloud
- PQ analyzers **designed to interface** with new, high-accuracy MV sensors
- DNP3 and GNSS interface development advances to better **align multiple sources of grid data**

- Fleet-based and user-determined **custom trend alert systems available** for high-performance troubleshooting
- **Fleet management capability** with dashboards, live meters and geolocation for rapid identification
- **Automated compliance reporting, better historic data and event history** annotation for better analysis
- Significantly improved power and harmonic analysis to better design corrective solutions for industrial clients





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Conclusions and an Opinion as to What We Face Next

Skilled human resources in power quality **is in decline**

PQ risks are increasing as the distribution grid complexity shifts

PQ events mistakenly translate to lower priority against fault/fire mitigation, or grid upgrades as data is hidden

Solutions exist to more effectively collect and analyze PQ data if proper instrumentation is put in place

Industrial and utilities are stakeholders now; **situational awareness is key**

Today's challenge is dragging **analysis to the edge of the grid**

Effective solutions come when data is securely shared with all the technical and operational stakeholders

We need a way to recenter our capabilities, and bring power to our data analytics and data analytics to our power

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THANK YOU