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THE STANDARD FOR ENERGY & POWER MEASUREMENT

Power Quality Monitoring
Seeing What's On The Wires

FMEA
FLORIDA MUNICIPAL ELECTRIC ASSOCIATION

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Today's Agenda

- Utility systems – yesterday & today
- Impact of Distributed Energy Resources (DER)
- Energy vs. power quality monitoring
- Fixed vs. portable tools
- Introduction to power quality – types of PQ issues
- Applicable PQ standards
- Types of PQ issues
- How to view PQ information – portable & fixed applications
- PQ data integration with SCADA/control software

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Utility Systems
Yesterday & Today

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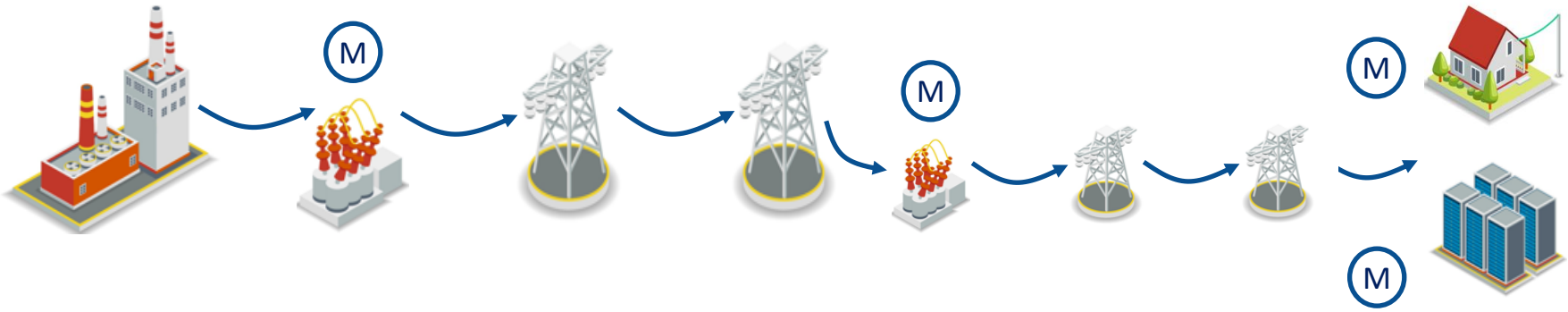
Traditional Utility System



Generation Transmission Distribution Consumer

Power Flow

M Metering – typically consumption/revenue

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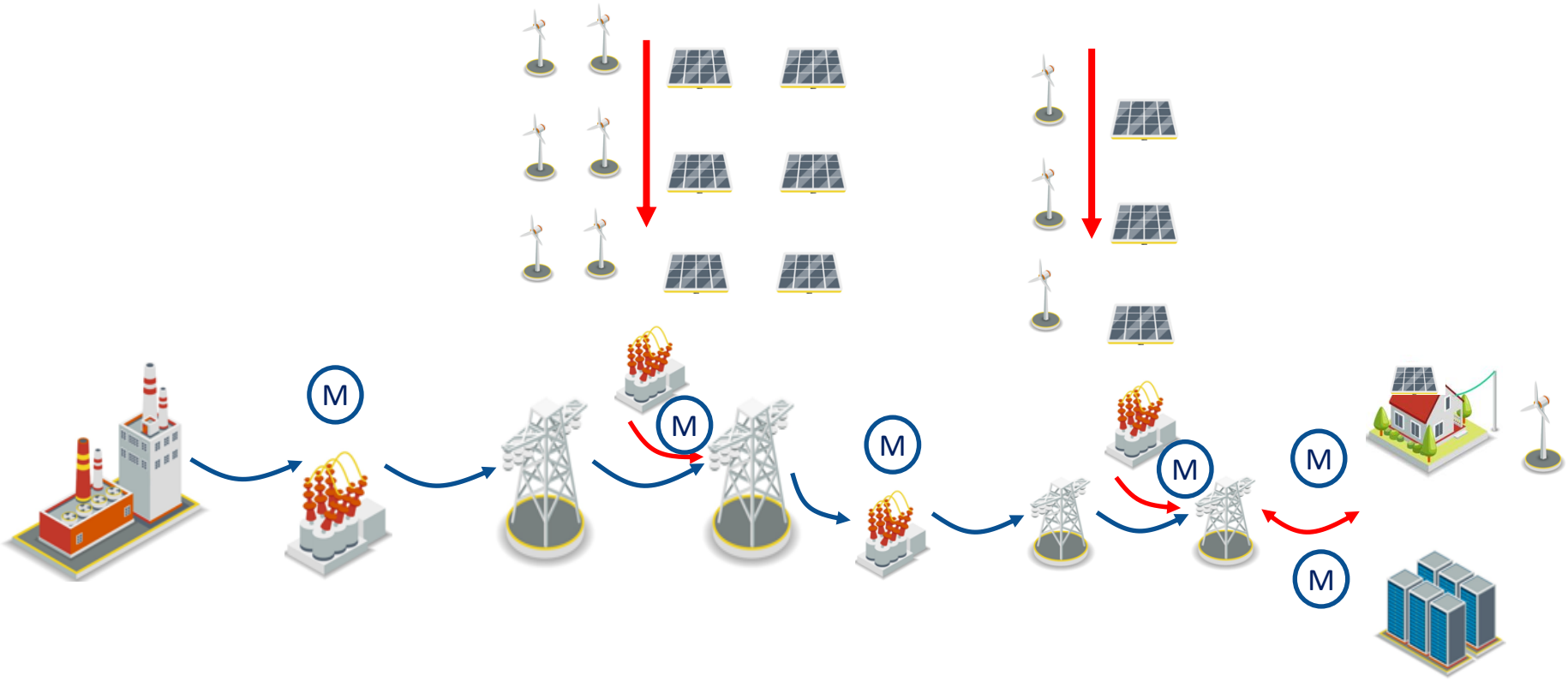
Utility System With DER



Impact of DER On The Utility System

- By design, energy production is Distributed. Various locations, some large, some small
- Power production and revenue are the primary concern
  - However, don't take your eye off reliability
- As the proliferation of DER grows, so does the potential for reliability and PQ issues
  - Voltage quality
  - Harmonics
  - Flicker
- The DER may not be controlled or managed by the utility
  - Is the DER 'behaving' well?
- Monitoring for power quality throughout the system is becoming essential
  - Traditional generation interconnects
  - DER interconnects
  - Distribution interconnects
  - Key customers
- Quality of supply is now part of DER interconnect standards – IEEE 1547
- Power quality concerns are now system-wide

Historical Monitoring Objectives

- Energy consumption & revenue were the primary focus
  - Primarily fixed metering
  - Purchased power
  - Distribution capacity/flow
  - Customer billing
- PQ is typically an afterthought
  - Primarily portable metering
  - Reacting to customer complaints
  - Problem solving

Today's Trends - More Proactive Monitoring Approach

- Energy consumption & revenue – continued focus
  - Primarily fixed metering for
  - Purchased power
  - Distribution flow
  - Customer billing
- PQ – important focus
  - Fixed metering to be more proactive
  - Monitor at key generation, DER, distribution and customer points
  - Key accounts
  - Overall grid reliability
  - Portable metering remains valuable for reacting to customer complaints and problem solving
- Combined Energy & PQ metering in one
  - Fixed
  - Portable metering
- Lower cost metering is available

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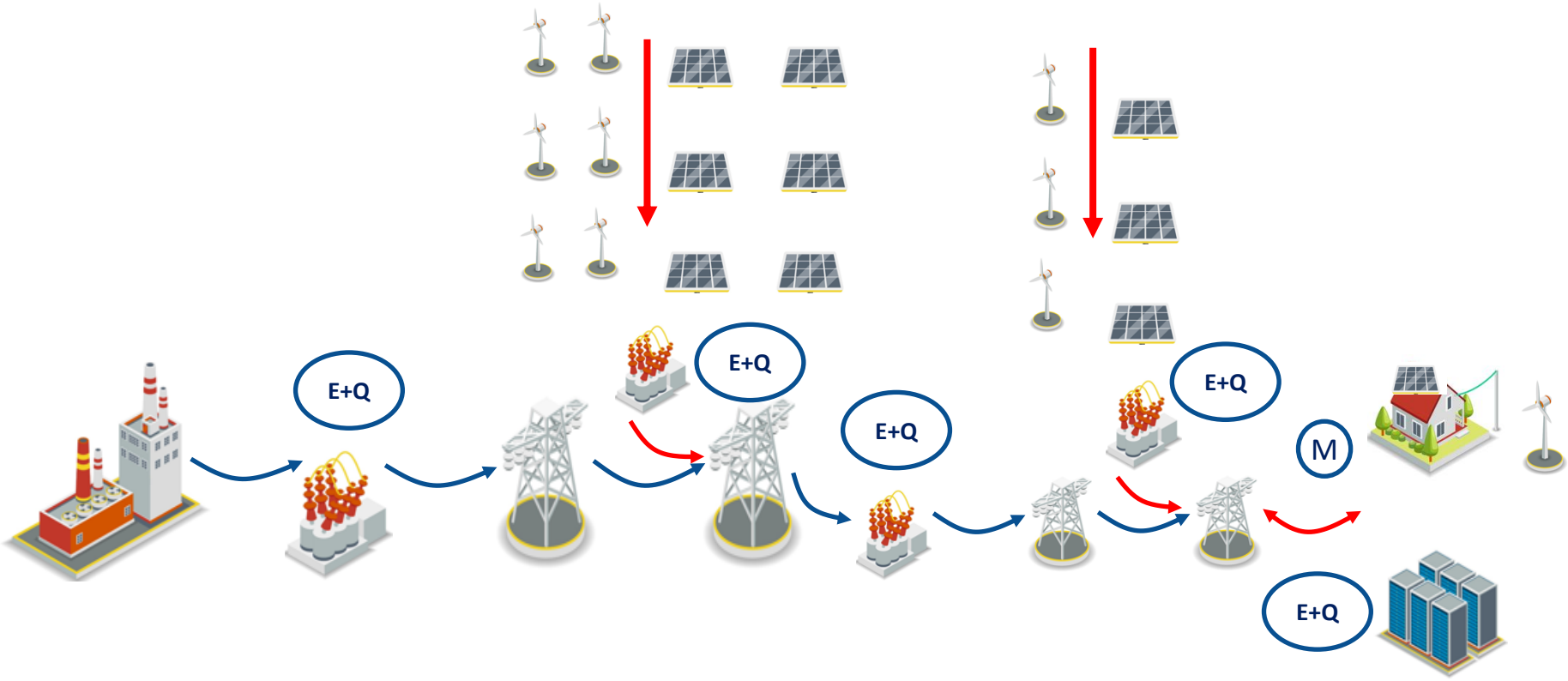
Metering Points + PQ



E+Q Energy + PQ monitoring

M Bidirectional energy metering

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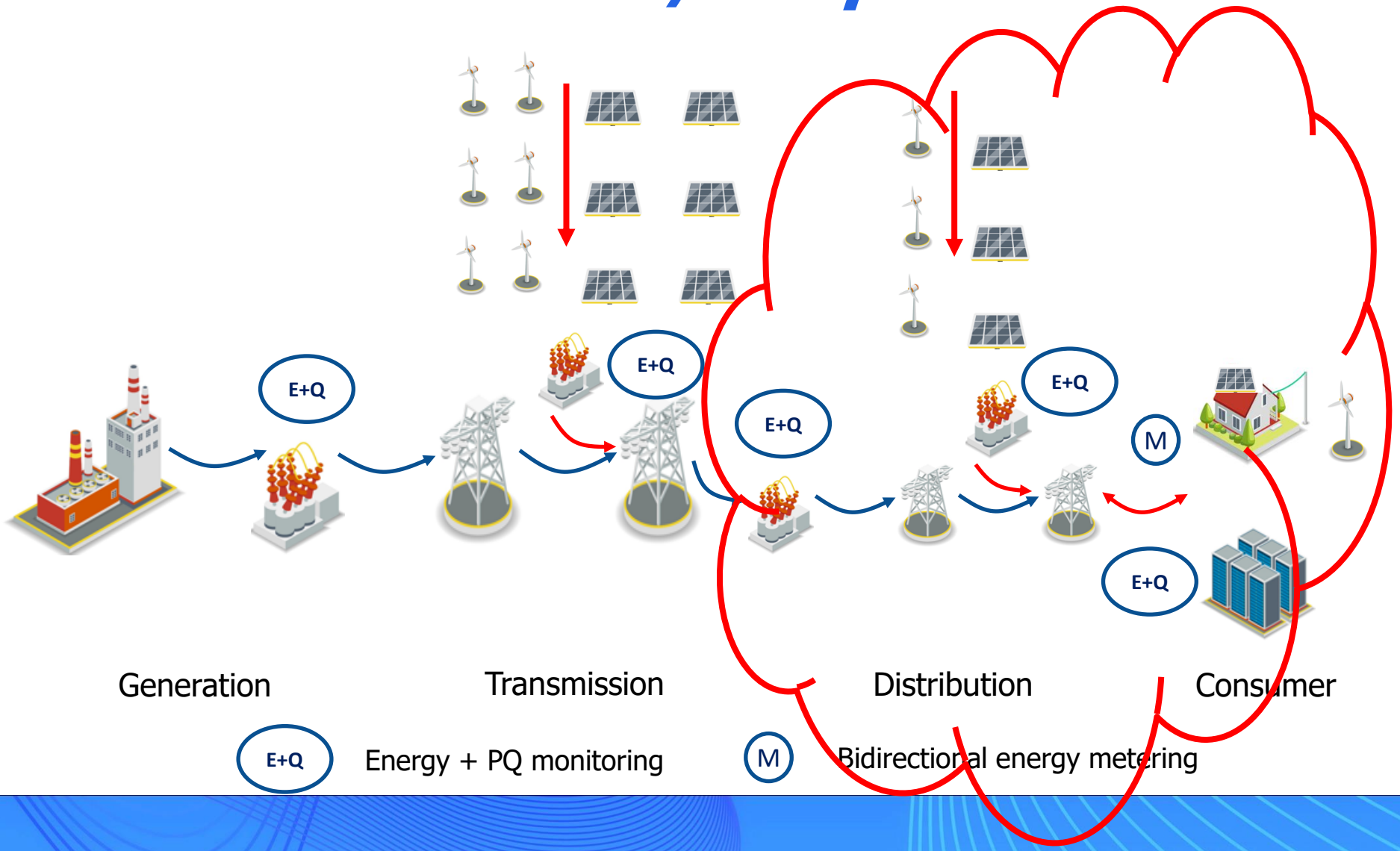
Potential Muni/Coop Concerns



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Energy & PQ
Monitoring Comparison

PQ vs. Energy Applications

- Energy
  - Where & when is energy consumed?
  - Customer revenue/billing
  - DER and other power production
  - Purchased power measurement
- Power Quality
  - Evaluate the compatibility between the power sources & loads
  - Determine the cause & source of problems
  - Evaluate the impact of PQ on the system. Costs, reliability, etc.
- Both Simultaneously

Energy vs. Power Quality Measuring/Monitoring

Similar, but different…

Energy and Power Quality measurement requirements may overlap but have different resolutions and accuracy needs

Energy

- Typically measured in seconds
- High accuracy especially if used for revenue or billing

Power Quality

- Typically measured in microseconds
- High accuracy important but not required. Note: Many of today's PQ instruments have revenue level accuracy

PQ instruments can often be used for energy applications but not vice versa

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Portable vs. Fixed Applications

Applications of Power Monitors

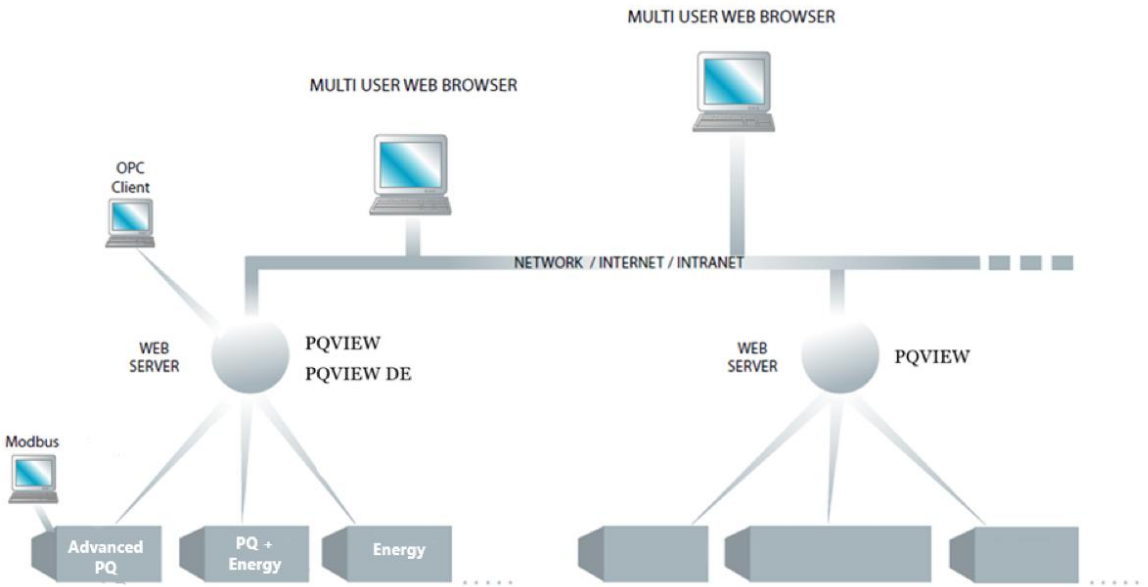
Portable vs. fixed – Main differences are in the packaging and use

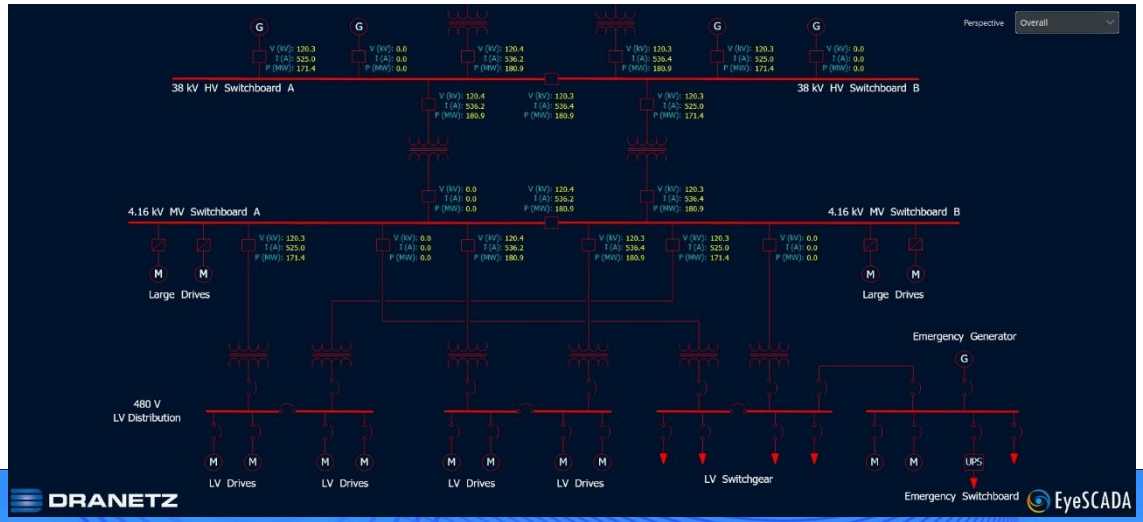
- Portable
  - ***Usually <u>reactive</u> for PQ – something failed, and a portable instrument is used in the hopes that it will occur again so it can be captured***
  - Single or a few meters for temporary use - handheld devices are typically used
  - Wiring connections are usually temporary – banana jacks for voltage, flex/clamp-on CT's for current
  - Trend is for strong remote connections for productivity and safety – Ethernet, Wi-Fi communications
  - Desktop application software for data analysis, reporting, etc.

Applications of Power Monitors

- Permanent/Fixed installed
  - ***Usually <u>proactive</u> for PQ and energy – capture data 24/7***
  - For permanent use – installed for the life of the power system
  - System with multiple meters of different types – Energy, PQ, both. Other types of metering
  - Panel, rack or wall mounted with/without a display
  - Wiring is permanent – screw terminal connections directly to circuit or PT's for voltage, screw terminals to fixed CT's for current
  - Strong remote communications – application dependent
    - Substation, end users, DER and other PQ and energy applications
    - Often Ethernet connected today, but older serial connections are still in use
    - Residential and industrial revenue meters may use other technologies
  - Server software that automatically communicates with each meter in the system to acquire data and for setups
  - Combine with SCADA and other enterprise management systems. Industry standard protocols

Typical Permanent/Fixed architecture





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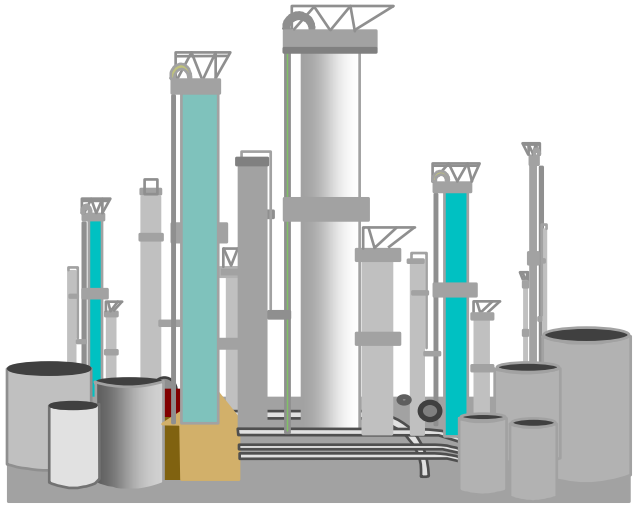
Introduction to Power Quality

Sources Of Power Problems

Referenced at the utility PCC (point of common coupling)

- **Utility**
  - lightning, PF correction caps, faults, switching
  - impact from other customers
  - Impact from DER
- **End user**
  - individual load characteristics, motors, ASDs
  - computers, microprocessors
  - wiring
  - changing loads



Question

Who is responsible for most PQ problems?

1) *Electrical Utility*
2) *End user*

Question

Who is responsible for most PQ problems?

1) *Electrical Utility*
2) ***End user***

Typically, 70% of all PQ events are generated within the facility

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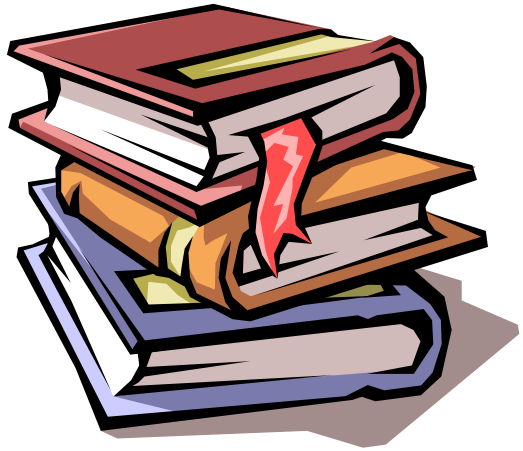
Power Quality Monitoring

References & Terms



Power Quality Measurement Standards

IEEE - Institute of Electrical & Electronic Engineers – US Recommended practices

- IEEE 1159 – Power Quality
- IEEE 519-2014 - IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
- IEEE 1453-2015 - Voltage Flicker -> Harmonized with IEC 61000-4-15
- IEEE 1250-2018 - IEEE Guide for Identifying and Improving Voltage Quality in Power Systems. Ties usage and standards together with application examples

IEC - International Electrotechnical Commission

- Europe, Asia, other areas
- IEC 61000-4-30 – Testing and measurement techniques – Power quality measurement methods. Edition 3. Edition 4 pending
  - Class A - full compliance with the standard. Repeatability of measurement
  - IEC 61000-4-7 - Harmonics
  - IEC 61000-4-15 – Voltage fluctuations (Flicker)

Europe

- EN 50160 voltage quality
  - Quality of supply
  - Within limits 95% of the time

Power Quality Measurement Standards

Why should you care?

- Industry challenge – consistency and repeatability of measurements
- Confidence in instrumentation to appropriately detect and report issues. Can you trust the data?
- IEC measurement methods are applicable in the US without compromises
- Most reputable PQ meter/instrument manufactures offer compliance with IEC methods. Low end meters may not – you get what you pay for
- IEC methods are now being called out in the US by the IEEE

The IEEE has harmonized with some of the related IEC standards

- Voltage flicker
- Harmonics measurement methods

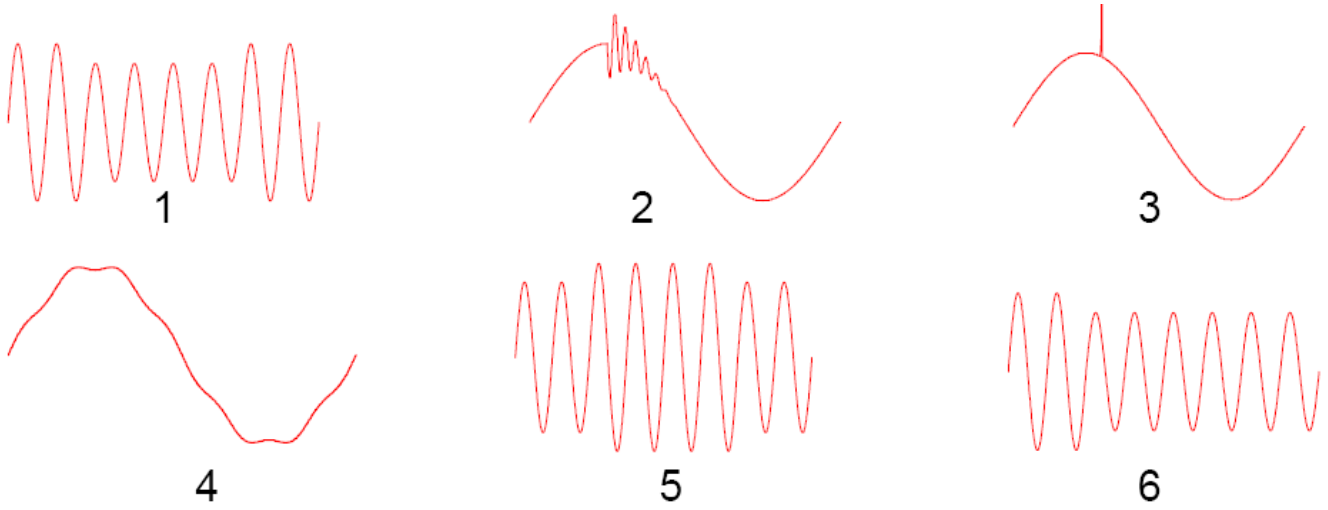
US compliance standards are starting to call out IEC compliant PQ monitoring

- Example: IEEE 1547 – Interconnection of Distributed Energy Resources (DER). IEEE 1547 references IEEE 519-2014 and IEEE 1453-2015 which are based in IEC standards. The committee is working on a PQ section that may reference IEC 61000-4-30

Common Types Of Power Quality Disturbances (per IEEE 1159)

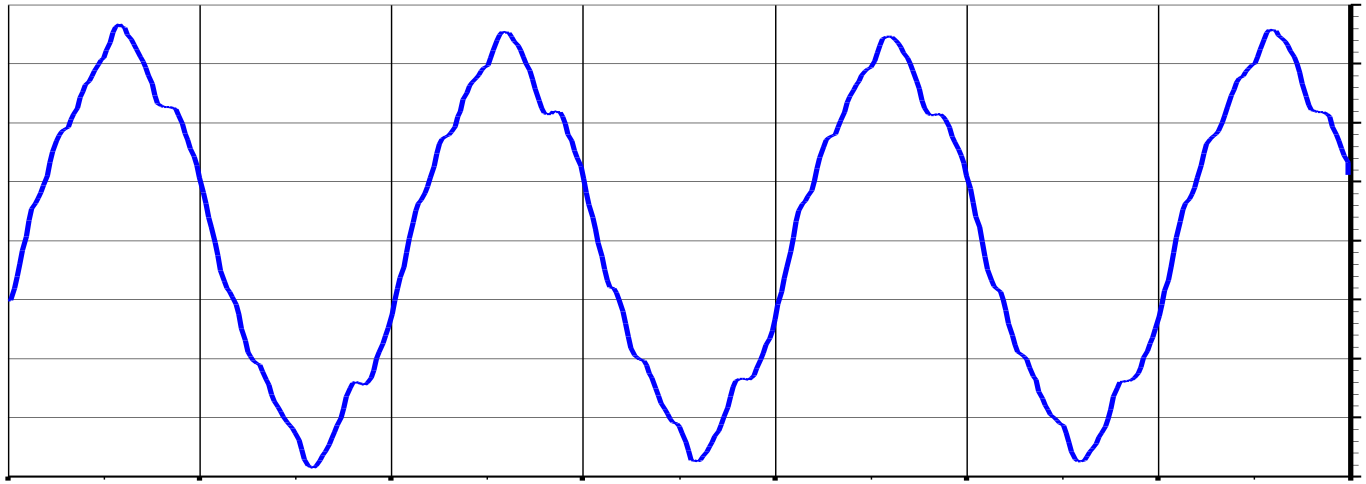
- Transients
- RMS Variations
- Waveform Distortion (harmonics)
- Voltage Fluctuations (Flicker)
- Power Frequency Variations

Potential PQ Issues



Harmonics

- Distortion
- Primarily originate from loads
- Inverters/DER



Why are managing harmonics and IEEE 519-2014 important?

- IEEE 519-2014 is the current US recommended practice for harmonics measurement and compliance
- Compliance limits referenced to the Point of Common Coupling (PCC) between the utility and end user. Limits for voltage and current harmonics vary by system voltage level
- Applications in:
  - DER/Alternative energy
  - Utility management
  - Facility management
- The intent is to manage the harmonics at the interface point between utility system owners and end users. The specified limits are only at the PCC and not for individual loads, but are often used for individual loads

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IEEE 519:2014 Reports – PASS & FAIL

Harmonics Statistics

Reports for 31 days prior to and including: Apr 17, 2017

Date	Interval	Statistic	Compliance	Channel
Apr 17, 2017	Daily	Very Short (99th)	Pass	
Apr 16, 2017	Daily	Very Short (99th)	Pass	
Apr 15, 2017	Weekly	Short (99th)	Pass	
Apr 15, 2017	Weekly	Short (95th)	Pass	
Apr 15, 2017	Daily	Very Short (99th)	Pass	

Event Details/Waveforms

Date:	Interval:	Statistic:	Compliance:
10/25/2017	Daily	Very Short (99th)	Fail
Nominal voltage:	Nominal current:	Max.Demand Current:	Max.ShortCir Current:
230.00	10.33	10.00	100.00

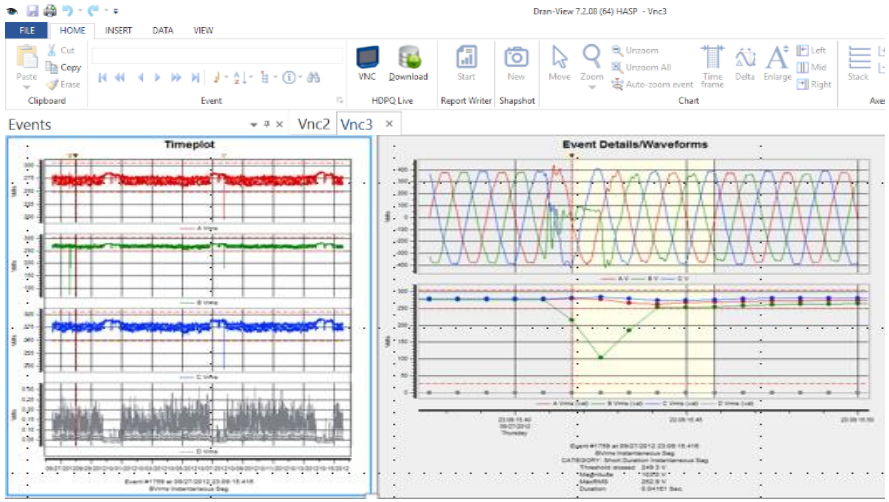
Harm.	AV	AI	BV	BI	CV	CI	DV	DI
THD	39.403		39.399		39.404			
TDD		0.023		0.033		0.030		
2	0.008	0.007	0.010	0.006	0.011	0.007		
3	16.092	0.007	16.090	0.006	16.094	0.006		
4	0.006	0.006	0.008	0.005	0.009	0.005		
5	16.089	0.006	16.088	0.005	16.090	0.006		
6	0.006	0.005	0.007	0.005	0.008	0.006		
7	16.088	0.006	16.086	0.005	16.088	0.006		
8	0.006	0.005	0.007	0.005	0.008	0.006		
9	16.088	0.005	16.087	0.006	16.089	0.006		
10	0.009	0.005	0.010	0.005	0.010	0.006		
11	0.007	0.006	0.008	0.006	0.009	0.006		
12	0.007	0.006	0.009	0.005	0.009	0.006		
13	0.007	0.006	0.009	0.005	0.010	0.006		
14	0.007	0.005	0.006	0.006	0.009	0.006		
15	0.007	0.005	0.007	0.005	0.010	0.006		
16	0.007	0.005	0.006	0.005	0.009	0.006		
17	0.007	0.005	0.008	0.005	0.010	0.006		
004		0.007		0.005		0.010	0.005	
007		0.012		0.008		0.009	0.007	
004		0.012		0.005		0.009	0.005	
005		0.010		0.006		0.009	0.005	
004		0.009		0.007		0.009	0.006	
004		0.009		0.006		0.007	0.006	
004		0.009		0.006		0.006	0.006	
005		0.010		0.007		0.008	0.006	
004		0.017		0.006		0.016	0.005	
005		16.084		0.006		16.085	0.006	
004		0.017		0.005		0.017	0.005	
004		0.010		0.005		0.009	0.005	
004		0.007		0.005		0.007	0.005	
005		0.008		0.005		0.007	0.005	
005		0.006		0.006		0.006	0.005	
004		0.005		0.006		0.005	0.005	
004		0.005		0.005		0.005	0.005	
004		0.005		0.005		0.006	0.005	
005		0.004		0.005		0.004	0.005	
005		0.005		0.007		0.005	0.006	
005		0.006		0.006		0.005	0.005	
005		0.012		0.006		0.004	0.005	
005		0.007		0.006		0.004	0.005	
005		0.007		0.006		0.004	0.006	
005		0.005		0.006		0.004	0.005	
005		0.006		0.006		0.005	0.005	
006		0.007		0.006		0.005	0.006	
006		0.007		0.006		0.007	0.006	
006		0.009		0.006		0.009	0.006	
005		0.013		0.006		0.013	0.006	
005		0.028		0.006		0.027	0.007	
006		16.077		0.009		16.078	0.008	
003		0.031		0.006		0.031	0.006	

Event #115 at 10/25/2017 00:00:00.000
Harm Percentile Daily 99'th

User Interfaces

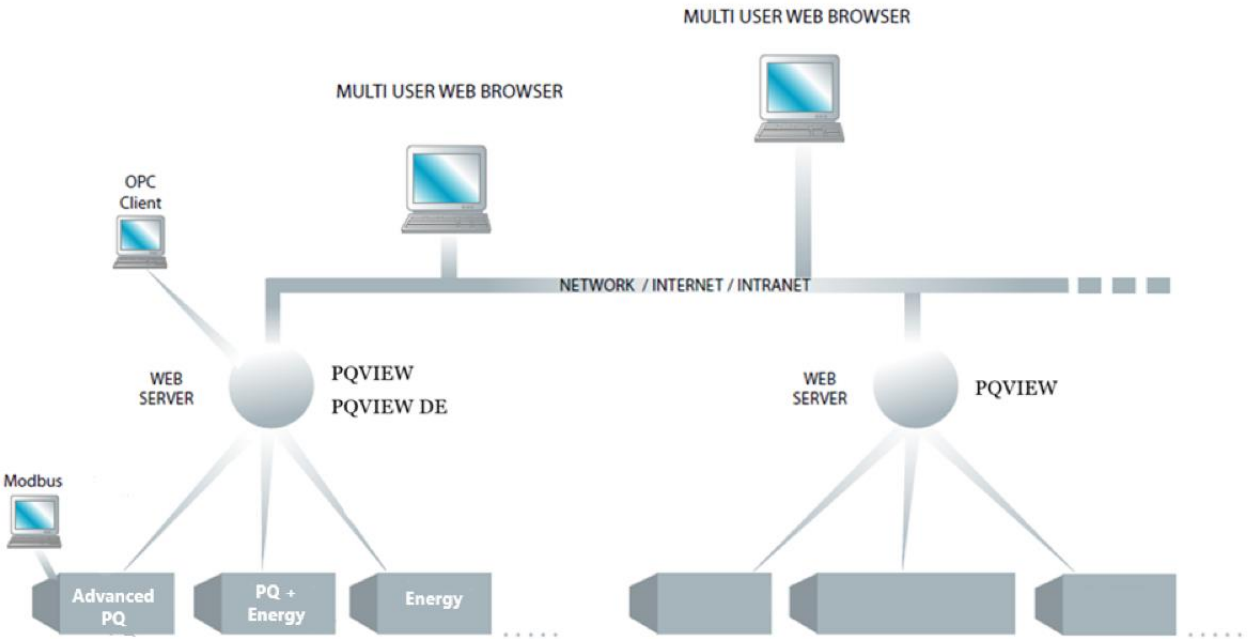
How Do We View Portable PQ Information?

- Usually single meters
  - Real time meters, PQ event lists and timelines are often available on instrument displays, if available
  - Desktop application software is typically provided by the manufacturer and is often used for more detailed analysis and reporting
  - Data is transferred to the software via jump drives, memory cards (SD, µSD) or by remote communications via Ethernet, Wi-Fi, cellular or Bluetooth
  - Software capabilities vary greatly by manufacturer



How Do We View Fixed PQ Information?

- Usually a monitoring system with multiple meters
  - PQ meter manufacturer provided server-based software collects data from remote meters
  - Manufacturer agnostic, independent software providers
  - Desktop or web-based software - manufacturer dependent
  - Software capabilities vary greatly by manufacturer



Fixed PQ Data Integration – Smart Grid

- PQ meters are just one type if Intelligent Electronic Device (IED) used in utility systems
- Modern protection and control devices can be IED's, and their data can be acquired by PQ software, SCADA and other monitoring/control systems. Examples are
  - Energy meters – wide range of capabilities
  - Relays
  - Breakers
  - Inverters
- PQ software is available that can acquire data from a variety of PQ meters from different manufacturers, and other types of devices such as those listed above. Benefits include
  - Understand the system dynamics during a PQ event – correlation with breaker, relay, protection operations
  - Advanced PQ for fault analysis. Include upstream and downstream metering/IED's

Fixed PQ Data Integration – Smart Grid

- PQ data can be integrated into existing SCADA and other monitoring/control systems
- Generally speaking, there are two approaches
  - PQ software database integration. PQ software acquires data from the meters. SCADA reads the PQ software SQL (or other) database
  - PQ meter integration. SCADA software reads the meters directly
- Direct meter access is enabled by industry standard communications protocols
  - Modbus
  - DNP3
  - PQDIF
  - Comtrade
  - IEC 61850
- A hybrid approach is common
  - PQ software handles the PQ reporting and analysis. Can notify SCADA of events
  - SCADA software reads metering data from PQ and other meters

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Thank you!

Questions?

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