

Power Quality Data Analytics: An Emerging Direction of PQ Research

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Outline

- **Current status of power quality research**
- **What is PQ data analytics?**
- **Examples of PQ data analytics**
- **The big picture of PQ data analytics**



Current status of PQ research

- Active PQ research started in early 1980s
- Many key problems have been solved:
 1. Definitions, classifications, indices
 2. Measurement protocols & study methods
 3. Standards, disturbance mitigation techniques
- A few hard problems do remain
 1. Classic problems (e.g. disturbance source detection)
 2. New situations faced by society (e.g. impact of EV)
- There are also new directions emerging



What is power quality data analytics?

- PQ is the field of investigating all type of electrical disturbances (that affect PQ)
- Unexpected outcome 1 of PQ activities
 - Wide use of PQ monitors due to their generality
 - They are used to meet other monitoring needs
 - Additional applications of the monitors have been found
- Impact of outcome 1
 - The data have been used to solve issues beyond PQ
 - Example 1 - Feeder capacitor status monitoring
 - Example 2 - Feeder fault anticipation



What is power quality data analytics?

- (Unexpected) outcome 2 of PQ research
 - PQ community has built extensive expertise on disturbance analysis
 - The knowledge starts to support disturbance analysis needs of other areas
- Impact of outcome 2
 - The expertise has been used to solve other problems
 - Example 1: Disturbance source location
 - Example 2: Synchronization of measured data



What is power quality data analytics?

- Common characteristics of the 2 impacts
 - Applications are beyond PQ interest
 - Useful information is extracted from disturbance data
 - PQ engineers/researchers are the most suitable people for such tasks
 - We may call the tasks as **Power Quality Data Analytics**

Data analytics (DA) is the science of examining raw data with the purpose of extracting knowledge from them. It is originated from the activities of extracting “business intelligence” from market or consumer data. DA is a very hot topic in other disciplines.

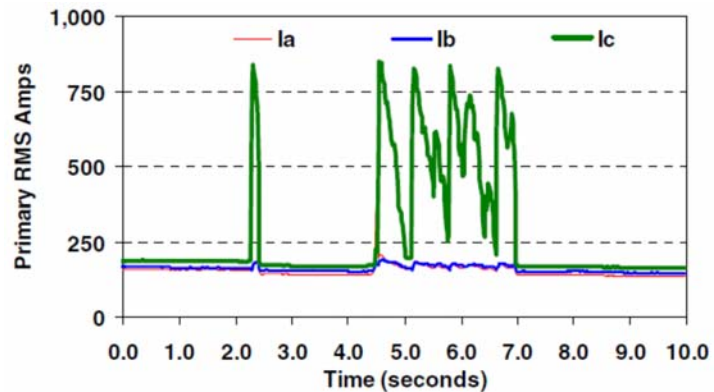
PQDA is a perfect area of smart grid research and development



Example of power quality data analytics

1. Distribution Feeder Fault Anticipator

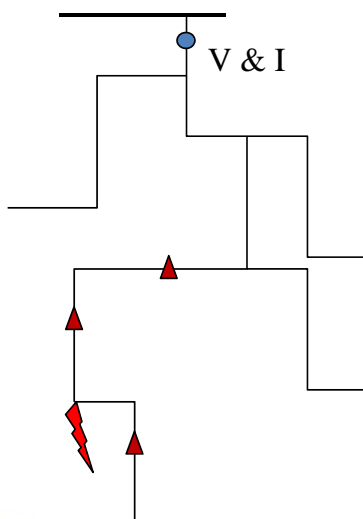
Fault anticipation is to analyze unusual V&I waveforms to determine if a potential fault could occur in a feeder



- Started from a PQ disturbance monitoring project by US-EPRI
- Texas A&M is leading the subject
- A lot more research is still needed in this direction, such as cause identification
- Fault anticipation has been labeled as a key feature of the smart grid

Example of power quality data analytics

2. Fault location



Idea 1:

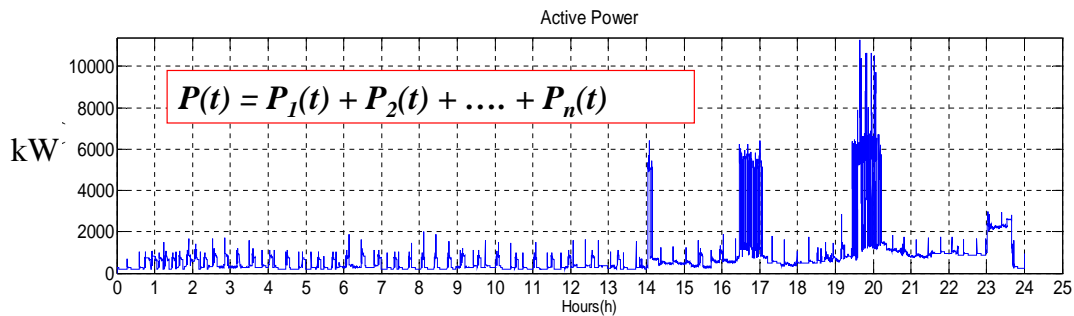
- Collect V&I at feeder terminal
- Calculate downstream Z using V&I
- Estimate fault distance using Z
- PQ monitor is used to collect data

Idea 2:

- Monitor downstream sag levels
- Determine location from sag profile
- Assume distributed PQ monitors exist

Example of power quality data analytics

3. Home appliance monitoring



Given time series $P(t)$, Find key components: $P_1(t), P_2(t), \dots, P_k(t)$

- Each component represents an appliance. The target is to extract major appliances in a home, there are about 10 to 20 of them
- Must rely on the unique signatures of each appliance
- Success of this research will create truly smart meters

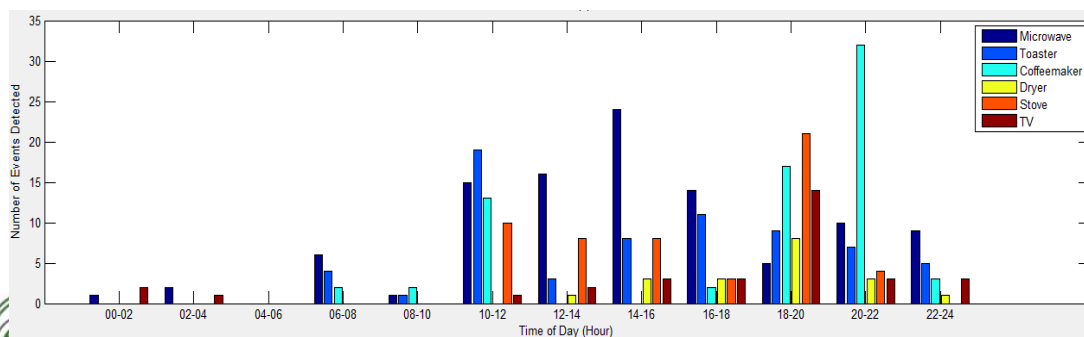
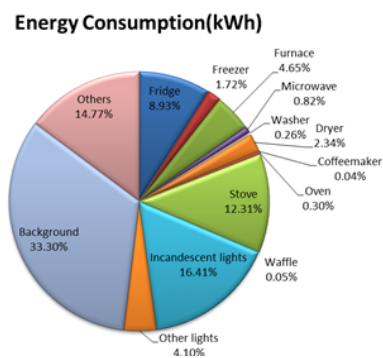


Example of power quality data analytics

3. Home appliance monitoring

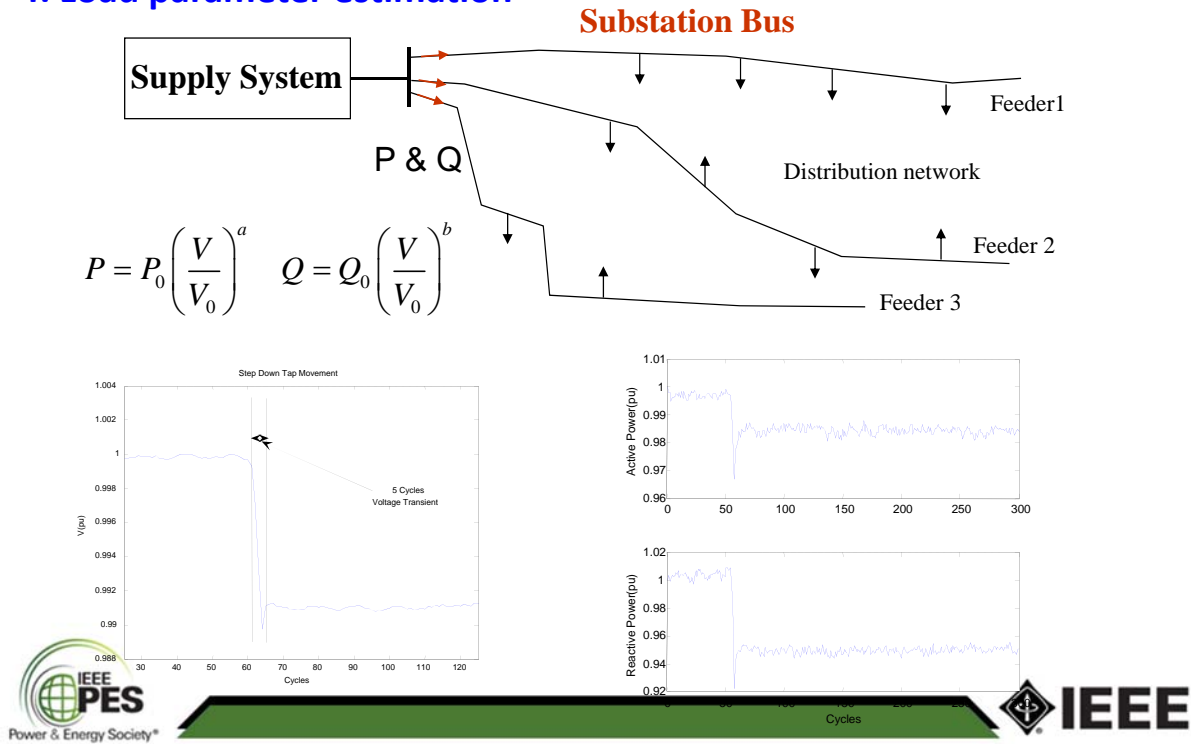
What are the benefits?

- Electricity bill split to appliance level
- Power cost per use of an appliance
- Verifying energy efficiency claims
- Comparing energy use of similar appliances
- Simulating the replacement of appliances

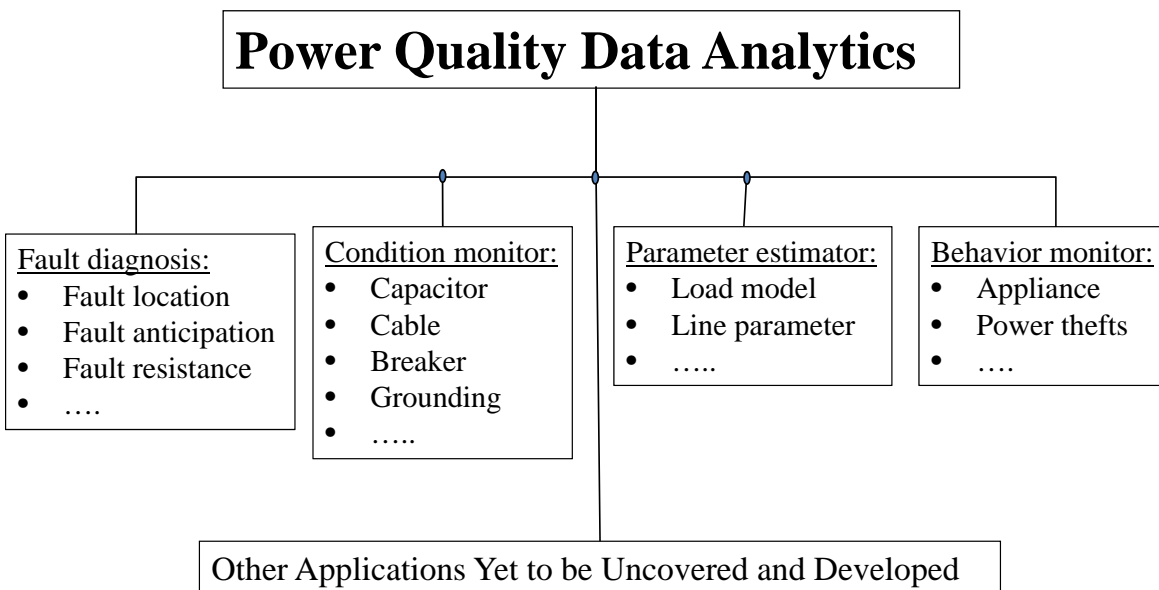


Example of power quality data analytics

4. Load parameter estimation



Summary of PQDA areas



The big picture of power quality data analytics

Major monitoring networks in current power systems

SCADA network: 60Hz magnitude data;
For load flow, state estimation & other applications

PMU network: 60Hz magnitude & phase data;
Some applications have been identified

AMI network: Interval E, P, V & I data;
For billing purpose and demand monitoring

PQ network: **Waveform data;**
For PQ monitoring and, in the future, for **PQDA**

The PQ monitoring network provides a unique set of data with significant amount of information on the performance of a network



The big picture of PDA

Monitoring devices providing waveform-level information:

- Modern relays – mission critical, hard to access data
- Digital fault recorder – specialized for fault recording
- Condition monitors – specialized/customized devices
- PQ monitor – general purpose monitor

It can be seen that the PQ monitoring network is the best candidate to collect and provide waveform-level data.

It is just a matter of time that large-scale waveform-level data will be made available to utility companies. [The goal of PQ data analytics is to create killer applications for such data.](#)



Summary

- Power disturbances are a PQ concern, but they also contain unique and useful information;
- Utilities have found that the information is quite useful and its applications go beyond the traditional PQ activities;
- At present, the PQ monitoring network is the most general platform to provide the waveform level disturbance data;
- It is likely that the waveform monitoring networks will emerge as a powerful platform for power system monitoring, in parallel with SCADA, WAMS and AMI;
- Power quality data analytics is the brain for the upcoming waveform-level monitoring networks

