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College of Engineering

ECE 528 – Understanding Power Quality

http://www.ece.uidaho.edu/ee/power/ECE528/

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Lecture 30

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Today…

- Power quality and reliability benchmarking
  - Definitions
  - Motivation
  - Issues
  - Trends
  - RMS Voltage variations

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Power Quality and Reliability Benchmarking: Defining terms (PSQ Ch. 8)

- Index or metric
  - A specific measured parameter
    - Voltage distortion, voltage unbalance, temperature, etc.
- Benchmark
  - A standard against which performance is measured
  - Typically a single value, a range, or an upper or lower limit
- Target
  - Goals for specific indices based on benchmarks, local constraints, and specific objectives
  - Typically a range, an upper or lower limit, or a probability
  - Rarely a specific value unless zero

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Defining terms

- Benchmarking
  - The process of evaluating performance against some standard level of performance
  - Uses one or more defined indices or metrics
    - For each index or metric, we need to know:
      - What is measured and how
      - How often it is measured
      - The benchmark for that index
      - The target for that index
- Aggregation
  - Grouping events within a time period or only considering the worst event in the time period

Some examples:

Index or metric	Benchmark	Target
Temperature (deg F)	Thermostat setting (68F)	Room at +/-1 deg. of setting
Speed in MPH	80mph (highway in Southern Idaho)	Cruise control – speed limit +/- 2mph.
Voltage THD	<8%	<8% for 95% of 10-minute average values over 1-week

A target may be more or less restrictive than the corresponding benchmark.

More restrictive target: The voltage benchmark is +/-5%. The distribution engineer designs the system to operate in a voltage range of +/-3%.

Less restrictive target: IEEE-519 allows harmonics to exceed the table values 5% of the time.

Motivation – why benchmark?

- Benchmarking helps drive improvement
  - Under-performing areas can be identified
  - "Best practices" can be determined
- Helps ensure fact-based decision making
  - The power quality may seem good or bad, but is it?
  - How good or bad is it, specifically?
- Benchmarking helps establish a common set of measurable expectations
  - Regulators, utilities, and customers can agree to, and document indices and benchmarks

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Motivation – why benchmark?

- Performance-based ratemaking
  - Links a portion of utility rates and profits to performance against specific benchmarks
- Power quality contracts
  - Contracts with individual customers that ensure a certain level of power quality and reliability, or refunds, in exchange for long-term contracts
  - Example: Sag Score

$$SagScore = 1 - \frac{V_A + V_B + V_C}{3}$$

    - Aggregation interval is 15 min.

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Benchmarking issues

- Power quality and reliability may be inversely related
  - Recloser fuse saving versus trip saving
- Customers do not classify events the same way that utility engineers do
  - Process interruption versus power interruption
- Impact of events may vary from customer to customer
- A single "event" main contain numerous "components" and they may be different on different phases
  - Simultaneous sags and swells during ground faults

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Benchmarking issues

- Not reasonable to expect the same performance across all transmission and distribution systems
  - Geography
  - Weather
  - System density/feeder length
  - Underground/overhead
  - Protection scheme
  - Animals/vehicles/vegetation

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Trends

- Standards have been and are being developed which combine power quality and reliability indexes and benchmarks
- In Europe, EN 50160: "Voltage characteristics of electricity supplied by public distribution systems"
- In the US – IEEE 1250-2011: "Guide for Identifying and Improving Voltage Quality in Power Systems"

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EN50160 (pg. 322)

- Sets limits for:
  - Frequency
  - Voltage sags
  - Interruptions (short and long (>3 min))
  - Voltage unbalance
  - Voltage harmonics, and more
- Generally specifies acceptable limits, measurement interval, length of recording, and acceptance percentage.
- Example: Voltage sampled every 10 minutes for a week will be within 10% of nominal 95% of the time.

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US Service Quality Benchmarking

- IEEE-1250-2011: Steady-state characteristics

Voltage Metric	Benchmark	Target
Regulation	+/-5% for normal conditions +/-10% for unusual conditions	CP95%
Unbalance	2% negative sequence	CP95%
Distortion	5% THD 3% individual harmonics	CP95%
Fluctuation/flicker	Pst < 1.0 Individual step changes less than 4%	CP95%
Frequency	+/-0.015Hz	CP95%

Targets are based on 10 minute sample intervals

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Existing US Power quality indices

- RMS variation indices
  - SARFIx: System Average RMS (variation) Frequency Index

$$SARFI_X = \frac{\sum N_i}{N_T}$$

customers experiencing event ($\sum N_i$)

total customers served (N_T)

  - Standard values:
    - 140, 120, and 110 – Overvoltage per ITI curve
    - 90, 80, and 70 – Undervoltage per ITI curve
    - 50 – motor contactors
    - 10 – IEEE interruption
    - CBEMA, ITIC, SEMI

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Existing US Power quality indices

- The duration of the RMS variation can be incorporated into the preceding indices
  - SIARFIx
    - System Instantaneous Average RMS (Variation) Frequency Index
  - SMARFIx
    - System Momentary Average RMS (Variation) Frequency Index
  - STARFIx
    - System Temporary Average RMS (Variation) Frequency Index

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Applications of RMS variation indices
(see pg. 100+ of PSQ for reliability indices)

- SARFIx, SIARFIx, SMARFIx, and STARFIx can be determined for the system and for individual feeders or areas
- Feeders with below-average values can be targeted for improvement
- Feeders with above-average values can be studied for best practices

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Statistics

- Cumulative probability or frequency
  - Many standards, including IEEE 519-2014, EN50160, and IEEE-1250 allow the measured THD, voltage, frequency, etc. to fall outside the steady-state limits for short periods of time.
  - Cumulative probability
    - The sum of the probabilities of values above, below, or between specific points, depending on the limit in question
  - CP95
    - The point at which the "cumulative probability" equals 95%.

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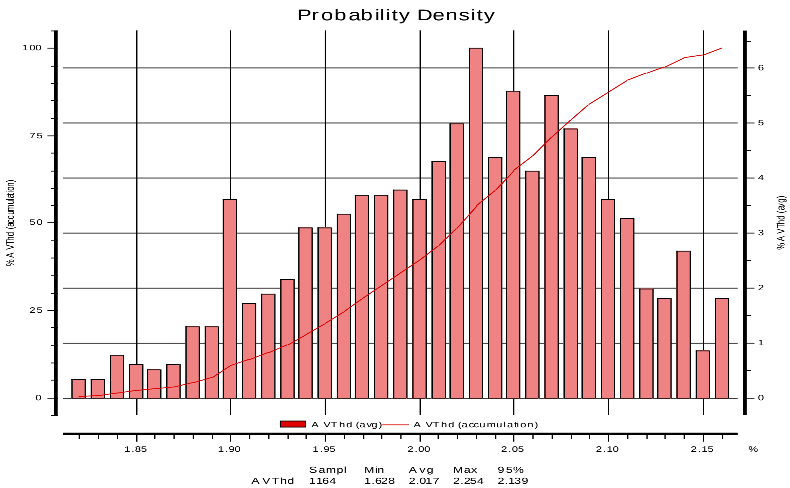
A CP95 example



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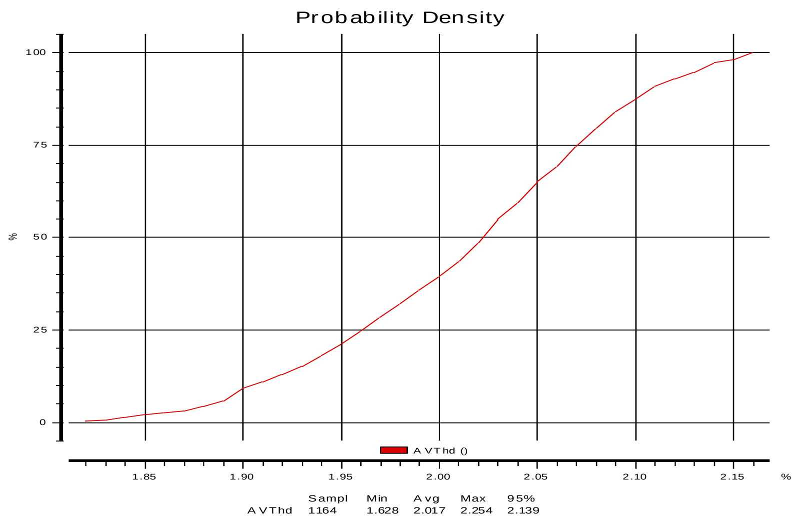
A CP95 example



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Real-world benchmarking
EN50160 report – application of CP95

EN50160 COMPLIANCE REPORT
Site: ECE 528 class 30a, Week #1 (08/02/2006 06:46:08.0 to 08/09/2006 06:46:08.0)
Nominal Voltage (Un) = 277 V

Power Frequency

Range	Threshold	Compliance	
60 Hz +1%/-1%	99.5%	100.0%	PASSED
60 Hz +4%/-6%	100.0%	100.0%	PASSED

Supply Voltage Variations

		Compliance:			
Range	Threshold	CHA	CHB	CHC	
277 V +10%/-10%	95.0%	100.0%	100.0%	100.0%	PASSED
277 V +10%/-15%	100.0%	100.0%	100.0%	100.0%	PASSED

Rapid Voltage Changes
Not available

Flicker

		Compliance:			
Range	Threshold	CHA	CHB	CHC	
<1	95.0%	97.5%	98.8%	97.5%	PASSED

Supply Voltage Unbalance

Range	Threshold	Compliance	
0-2%	95.0%	100.0%	PASSED

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Next time…

- More power quality and reliability benchmarking
  - Harmonic indices
  - Looking at real-world data
- Read PSQ section 3.8.6 (pg. 100+) and chapter 8