ECE 528 – Understanding Power Quality

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

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Lecture 5

Today…

- Review important terminology
- Begin discussion of power quality investigation planning with some sample recordings

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Homework 1 questions

- Problem 1
  - See lecture 3 Your answer should include 18 to 35 values; the dc coefficient, and 17 a_k and/or b_k coefficients. If their value is zero, say so.
  - If you move zero on the time axis for symmetry, remember that the other times change too.
- Problem 2
  - It's a three-phase system. Power value given is 3-phase Watts, you'll need to use the power factor to calculate amps in each phase, and 3-phase reactive power (Q), before and after the capacitor is installed.

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Homework 1 questions

- Problem 2 continued:
  - I'm looking for total losses in the three phase line.
- Problem 3:
  - See lecture 2.
- Problem 4:
  - Make sure you evaluate the function over the whole frequency range (50hz to 400Hz).

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Terms and definitions

- Allow engineers to discuss issues, search for information, etc.
- Problem:
  - Most of the public including engineers outside of power quality are not familiar with power quality terms and their definitions.

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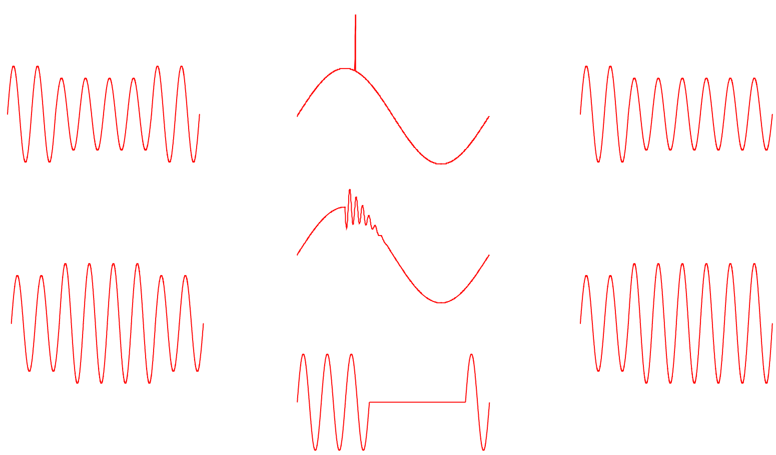
They all have names…



Ambiguous terms

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Brownout Dirty Power

Glitch Clean Ground Spike

Clean Power Surge

Blip Power Bump

Four general types of disturbances (IEC)

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- Conducted low freq.

Harmonics
Sags/swells/interruptions
Imbalance
DC offset

- Conducted High freq.

Transients
Induced high frequency signals

- Radiated low freq.

Electric and magnetic fields

- Radiated High freq.

Electric and magnetic fields

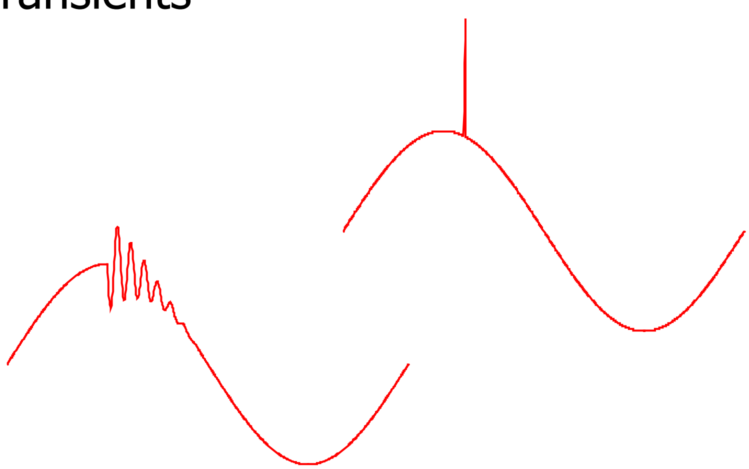
See FPQ p. 17 or PSQ p. 16

Categories based on duration (IEEE)

- Transients nanoseconds to 3 cycles
- Short duration
  - Instantaneous 0.5 – 30 cycles
  - Momentary 30 cycles – 3 seconds
  - Temporary 3 s – 1 minute
- Long duration > 1 minute
- Steady State

See Table 2.2 in either text

Transients

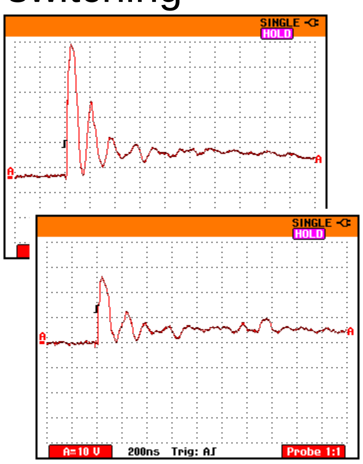


Describing transients:

- Impulsive
  - Peak magnitude
  - Time to rise/time to return to 50% of peak
  - *A 1.2kV, 1.2/50ns impulsive transient*
- Oscillatory
  - Frequency
  - Duration
  - Maximum absolute value
  - *A 720Hz, quarter-cycle, 1.3pu oscillatory transient*

Events have "signature" transients

Same device switching



Different devices switching

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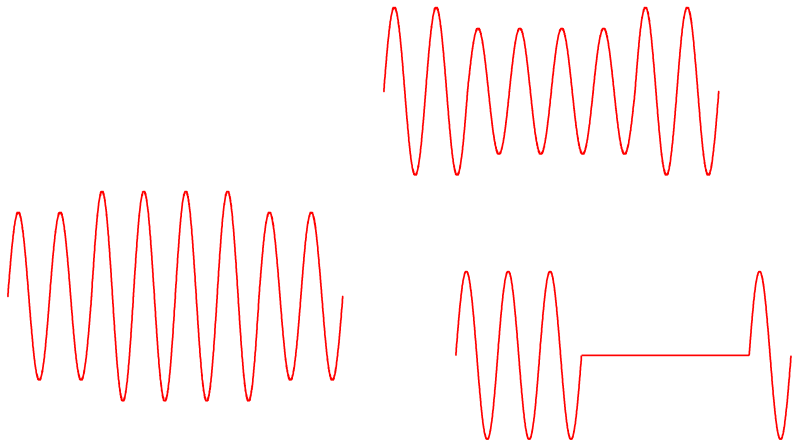
Short duration variations



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Clearly describing sags, undervoltage, swells, and overvoltage

- What is "a 40% voltage sag"? Is it more or less severe than a 60% voltage sag of the same duration?
- We'll use a remaining-voltage convention and describe sags, swells, undervoltage, and overvoltage carefully to avoid confusion.

A sag to 40% of nominal voltage.

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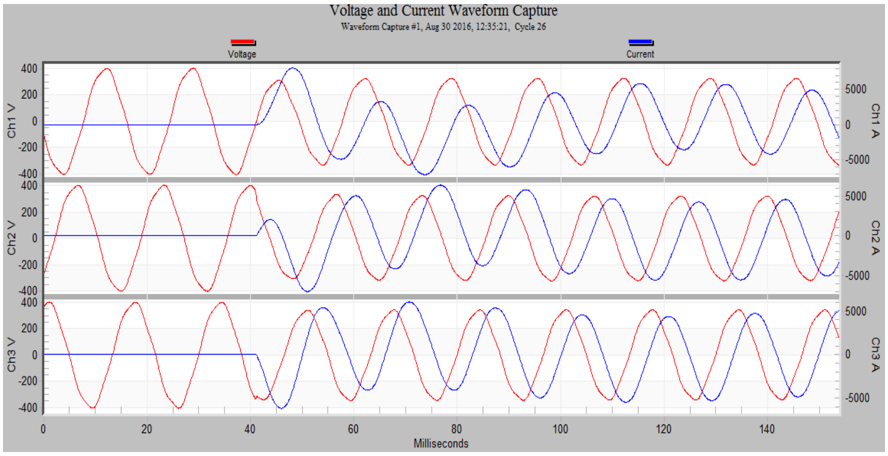
A real-world waveform…



Starting a 500hp motor “across the line” with no load connected.

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Describing short-duration disturbances

Duration	phases	Disturbance	Magnitude for sags and swells
Instantaneous	Single	Sag	Percentage
Momentary	Two	Swell	Or per-unit
Temporary	Three	Interruption	
Cycles			

A momentary single-phase sag to 70% of nominal.

A 4-cycle, three-phase sag to 50% of nominal.

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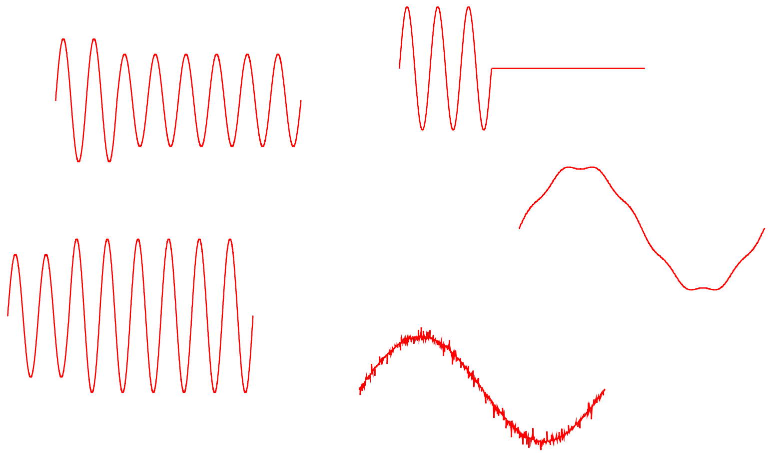
Long duration variations and steady-state conditions



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Describing long-duration disturbances

Duration	phases	Disturbance	Magnitude
Minutes and seconds	Single	Undervoltage	Percentage
	Two	Overvoltage	Or per-unit
	Three	Interruption	

A three-minute, single-phase interruption.

A 2-minute, three-phase overvoltage of 1.2 per-unit.

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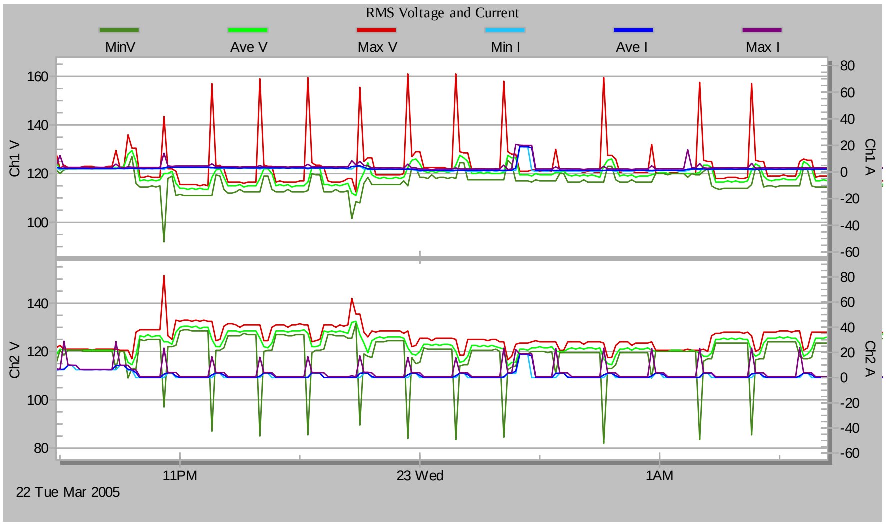
Let's use a stripchart of voltage and current to diagnose a problem...



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Other important terms

- A few in common usage:
  - THD – Total Harmonic Distortion
  - Triplen harmonics
  - CBEMA/ITI Curves
  - Flicker

Expectation: Students should be able to recognize or describe the disturbances or conditions described in table 2.2 in either text.

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Power Quality Investigations

- First Principles – The scientific method
  - Observe and describe phenomenon
  - Form hypothesis (or two or three!) to explain observations
  - Make predictions based on hypotheses
  - Test predictions with experiments - more observations
  - Refine hypothesis as necessary based on new observations
- Other principles –
  - Know what "normal" is before measuring
    - Use calculations, nameplate data, nominal values
  - Then every measurement becomes a test
  - A failed "test" (an abnormal measurement) can immediately change the course of the investigation

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A real-world example

- Reported problem:
  - Multiple customers on a single distribution feeder reported lights dimming and computers rebooting or switching to UPS.
- More information from discussion with customers:
  - Apparently random
  - Not associated with any activities of the customers

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A real world example continued

- More information from recording
  - Recorded voltage sags when symptoms occurred
  - Two to four per day
  - Not associated with load at monitored location
- Analysis
  - Pre- and Post- sag voltage is different – voltage goes up or down about 2 volts on a 120-volt system.

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A real-world example continued

- Hypotheses
  - Capacitors, voltage regulators, and substation transformer tap changing can cause step changes in service voltage
  - A problem at a capacitor, regulator, or the substation transformer is causing the voltage sags
- Tests
  - Review capacitor control logs: no correlation
  - Feeder has no regulators
  - Manually step the substation transformer: reproduced symptoms
- Results:
  - damaged transformer tap switching mechanism caused instantaneous open circuit when changing taps

Next time…

- More on the investigation process, and investigation examples.