ECE 528 – Understanding Power Quality

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

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Lecture 26

Today…

- Begin long-duration voltage variations
  - Definitions
  - Principles and practices
  - A simple example

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Overview

- Long-duration voltage variations are caused by voltage regulation problems
- Voltage regulation

$$\text{Percent\_Regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \cdot 100$$

  - A measure of the change in voltage compared to the change in load

NL=no load, FL=full load

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"Normal" voltage ranges

- Defined for the U.S. in ANSI C84.1
  - "American National Standard for Electric Power Systems and Equipment – Voltage Ratings (60Hertz)"
  - Describes nominal voltages and operating ranges for utility systems and end-user equipment

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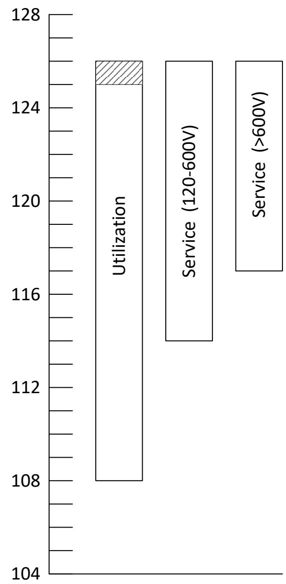
ANSI C84.1

- Range A – Normal operating conditions
  - Shaded area does not apply to systems of 600V or less

(Voltage scale is on a 120V base.)



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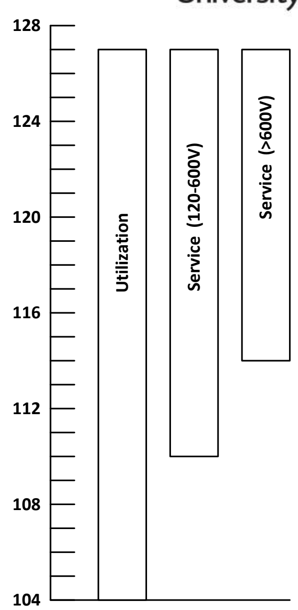
ANSI C84.1

- Range B – Unusual conditions
  - Unusual conditions are not specified
  - Utility must take corrective measures in a "reasonable time"



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Voltage rating example

- What is the range A voltage range for a 480V service?

  Answer:

- A motor designed for this system would be rated 460V, not 480V, and should operate satisfactorily at nameplate +/- 10%.

  Motor range (V):

  Motor range (% of nominal):

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Where is the issue? System, Service, or Facility Wiring

- System
  - Transmission System
  - Substation
  - Distribution Lines
  - Capacitors
  - Voltage Regulators
  - Switches
  - Reclosers
  - Fuses
- Service
  - Distribution Transformer
  - Service Conductors
  - Service Panel/meter
- Facility Wiring
  - All electrical equipment beyond the point of service

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Utility approach to voltage regulation

System Problem

- Change settings on existing regulators or capacitors
- Install regulators or capacitors
- Reconductor

Service point problem

- Increase service transformer size
- Increase service conductor size

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Investigating voltage regulation problems

- System or Service?
  - System problem
    - Service voltage is not significantly affected by load variations at the service point
    - Voltage is low (or high) with little or no load at the service point
  - Service problem
    - Voltage is significantly affected by load fluctuations at the service point
    - Voltage is normal with little or no load at the service point

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Resolving a local voltage-regulation problem

- Example:
  - Single phase, 120/240V customer reports lights are dim or flicker and UPS sometimes "beeps" when loads start.
  - Voltage measured at service panel is 122, 122, 244V with almost no load.
  - When well pump starts, current peaks at 160A RMS, and voltage drops to 112.5, 112.5, 225V.
  - Customer is served with a 15kVA transformer and 100' of #2 triplex aluminum cable.

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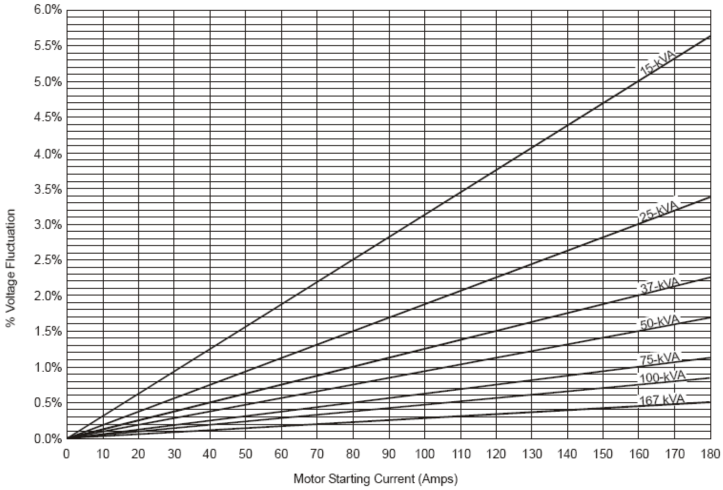
Resolving a local voltage-regulation problem

- Voltage drop for transformers, assuming 2% impedance:



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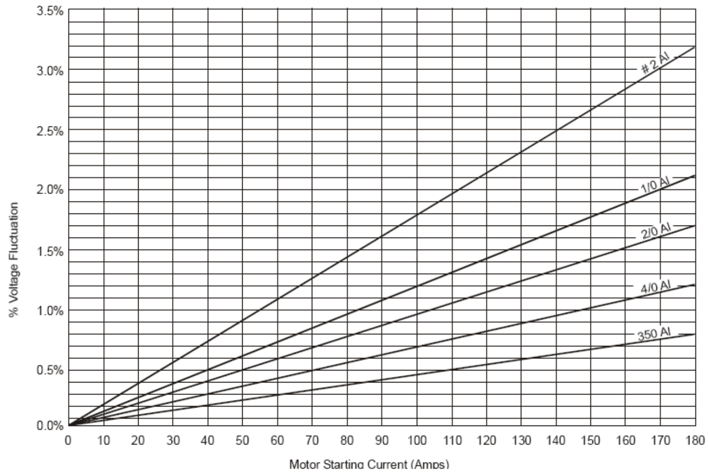
Resolving a local voltage-regulation problem

- Service cable voltage drop, per 100’ of service length:



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Resolving a local voltage-regulation problem

- From graphs, voltage drop for 160A is 7.8%, 5% for the transformer and 2.8% for the conductor.
- Design goal: <4%
- We can change the conductor, the transformer, or both.
- Suggestions?

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Customer-side mitigation

- Ferroresonant transformers
  - What do we know about them?
    - Very constant voltage output over a wide range of voltage input
    - Must be oversized
    - Best for relatively constant load – not suitable for motors
    - Inefficient

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Customer-side mitigation

- Magnetic Synthesizers
  - Similar to ferroresonant transformer
  - Normally no electronics or moving parts
  - Uses saturated reactors, transformers, and capacitors
  - Output voltage is relatively constant over a wide range of voltage input

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Customer-side mitigation

- Electronic tap-changing transformers or regulators
  - Use solid-state switches to quickly switch between taps
  - Can provide voltage in a narrower range than supplied by the utility
    - One example:
      - Input: +10% to -20% of nominal
      - Output: +/- 2.5% of nominal

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Customer-side mitigation

- UPSs
  - Generally not intended for long-term mitigation
    - Some models incorporate ferroresonant transformers or electronic tap-changing voltage regulators or transformers
    - Provides voltage regulation over a wider range of input without switching to battery

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Next time…

- Utility-side mitigation
  - Voltage regulators
  - Capacitors
  - Please read PSQ, sections 7.1-7.5