University of Idaho
College of Engineering

ECE 528 – Understanding Power Quality

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

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Lecture 10

Today…

- Sags and short interruptions
  - Evaluating voltage sag performance
  - Power Quality and reliability indices
  - Economic impacts

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Homework 2 clarifications

- Problem 2 – Clearly describe what each customer experiences: i.e. two voltage sags, each 0.42 seconds long, five seconds apart.
- Problem 5 – T_{60} is the period for one 60Hz cycle.

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Voltage sag impacts Example:

- Variable frequency drive subjected to multiple back-to-back voltage sags and short interruptions

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Inrush currents in rectifiers

- For voltage sags; 3-phase symmetrical sags cause the most severe inrush currents for 3-phase rectifiers [1]
- Switching transients can cause the same effect, but switching is usually an isolated event
- Multiple voltage sags can occur in a short period of time
- Drive manufacturers often limit how often a VFD can be powered up in a given time period
- Single-phase rectifiers are also vulnerable

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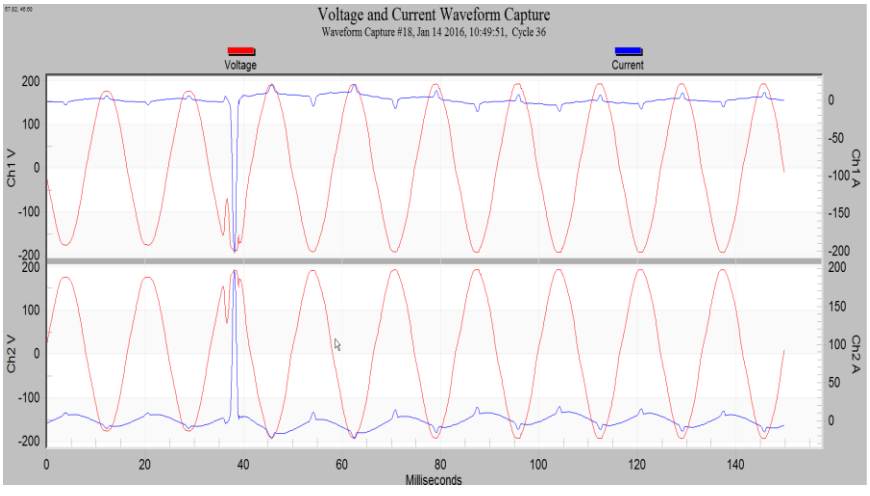
Drive inrush current…



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Evaluating voltage sag performance

- Voltage sag performance
  - Refers to the voltage sags a facility experiences and the impact of those voltage sags on the facility.
  - IEEE standard 1346 – "Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment"

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Evaluating voltage sag performance

- Objectives of the evaluation
  - Determine the expected number, depth, and duration of voltage sags
  - Determine equipment vulnerability to voltage sags
  - Identify and address incompatibilities

Electrical Disturbance + **Path** + **Vulnerable Equipment** = **Power Quality Problem**

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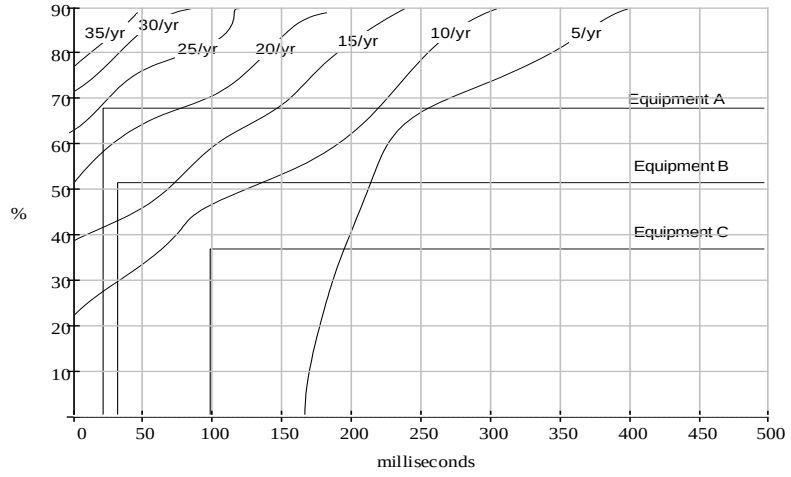
A "compatibility template"



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Building the compatibility template

- Power system data
  - Sources
    - Long term or permanent monitoring
    - Computer models and system records
  - Issues
    - Systems change
    - Long term monitoring takes a long time – customers want data quickly
  - Work-around – dealing with the issues
    - Use typical data from similar systems
      - Urban or rural, industrial or commercial, overhead or underground, etc.

Building the compatibility template

- Equipment data
  - Sources
    - Manufacturer data or typical industry data
    - Customer Logs
    - Monitoring at the equipment
    - Sag generators
  - Issues
    - Equipment availability
    - Facility is not built yet – no history
    - Other impacts – phase shift, point-on-wave, phase unbalance – Similar sags may have different impacts
    - Time

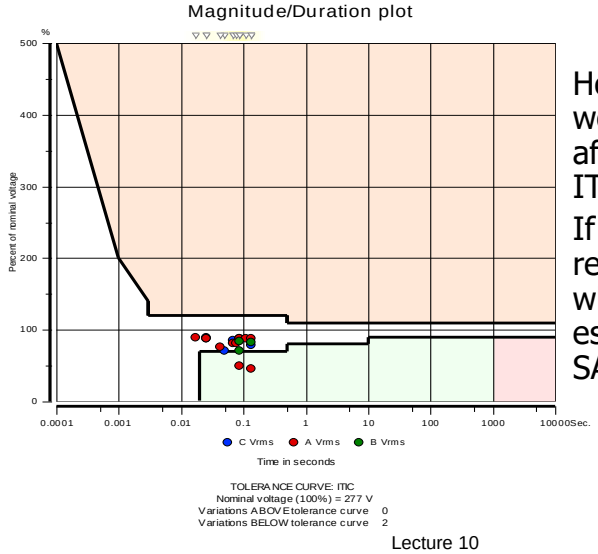
A practical approach with limited data

- Use any applicable monitoring data available
  - Past monitoring for other issues
  - Monitoring at other locations in the area
- Use customer's impact-frequency data
  - Customer logs
- Correlate customer data with system logs
- Use system logs to estimate long-term impact frequency
- Use system logs and computer models to estimate voltage sag depth and duration
- Preventing impact from one or a few events may justify the cost of mitigation

Other ways to specify sag performance

- SARFIx – (PSQ pg. 365) System Average RMS variation Frequency Index. The "x" is a specified voltage level, such as $SARFI_{70}$
- Standard voltage thresholds are 140, 120, 110, 90, 80, 70, 50, and 10 % of nominal
- May be specified as a curve; $SARFI_{ITIC,}$ $SARFI_{SEMI}$
- Standard time period is one year, so these indices are an estimate of the number of events per year that satisfy a particular criteria

Voltage variation data on the ITI curve



How many events would you expect to affect unprotected IT equipment?

If this data represents 1 month, what would we estimate for $SARFI_{ITI?}$

Reliability indexes

- Used to evaluate interruptions, but the definition of "Interruption" varies
  - SAIFI – System Average Interruption Frequency Index
    - number of times an average customer is interrupted per year
  - SAIDI - System Average Interruption Duration Index
    - total time that an average customer is interrupted per year
  - MAIFI – (not in texts) – Momentary Average Interruption Frequency Index (for trip-close events)

$$MAIFI = \frac{total\ customer\ momentary\ interuptions}{total\ customers\ served}$$

    - See more: PSQ pg. 101, 364-336, FPQ pg. 130-134

The costs of voltage sag events

- How can a voltage sag lasting only a few cycles result in losses of several million dollars?
  - Lost work – idled labor – starved processes
  - Lost production – makeup production - overtime
  - Repairs
  - Increased buffer inventories
  - Product quality issues
  - Customer satisfaction – lost business
  - Fines, disposal fees

Mitigation principles

- Mitigation is any equipment or modification that sufficiently resolves a voltage sag incompatibility issue.
- Mitigation should be "the simplest thing that could possibly work."*
- "Perfect Power" is not necessary.

*from "Make" magazine, Vol. 7 – Merlin Mann, 43folders.com

Next time…

- Mitigation alternatives
  - See PSQ pgs 66-86.
- To do:
  - Catch up on reading
  - Work on homework 2
- References:

[1] A.M.Shewale, et.al., *Effect of Voltage Sag on Ageing of Front End Rectifier Diodes of ASD, IEEE, 2013.*