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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 11

Today…

- Mitigating voltage sags and short interruptions
  - Some Homework 2 questions
  - General mitigation principles
  - End user mitigation examples

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Some common Q & As on homework 2

1. Give the most likely cause of the variation in the power supply's vulnerability. Assume the sags all start and end at the same point on the waveform.
2. The fault is the same in both parts. Only the protection scheme changes. Pay attention to the locations of the fuse, recloser, and customers. "Fast" or "slow" operation refers to the recloser's curves. "Reclose interval" refers to how long the recloser stays open before re-closing.

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Some common Q & As on homework 2

3. Remember, it's a voltage division problem. MVA values, reactances, or current can be used. See lecture 8 and FPQ pgs 113-121+. In 3b, two answers are acceptable; the actual current when starting that results in 97% voltage at bus A, or the current based on a new value of X_m or KVA_{LR} and a supply voltage of 460V. Don't forget it's a 3-phase system.
4. The purpose is to help you see how different factors affect ride-through time in power supplies.
5. You can check your calculations against the values given in the paper before introducing new values from the problem statement.

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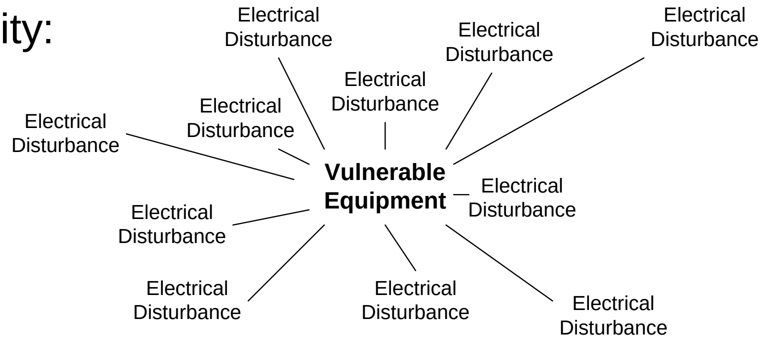
Work on disturbance or vulnerability?

The model:

Electrical Disturbance + Path + Vulnerable Equipment = Power Quality Problem

Reality:



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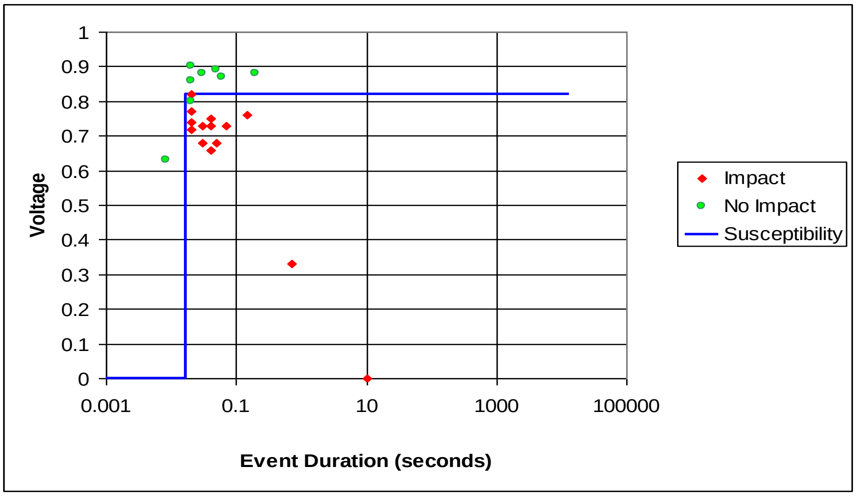
Mitigation principles

- Work as close to the vulnerable equipment as possible.
  - Establish a "Perimeter of Protection"
    - castle and moat analogy
    - *The environment is everything that isn't me.* – Albert Einstein
    - Minimizes impact from sags regardless of what causes them
    - Tends to minimize costs
    - Important for transient protection too
  - Equipment objective
    - Push the corner of the equipment susceptibility profile down to lower voltages, and out to longer durations, to provide an acceptable level of "ride-through".

Example – recorded voltage and impact data



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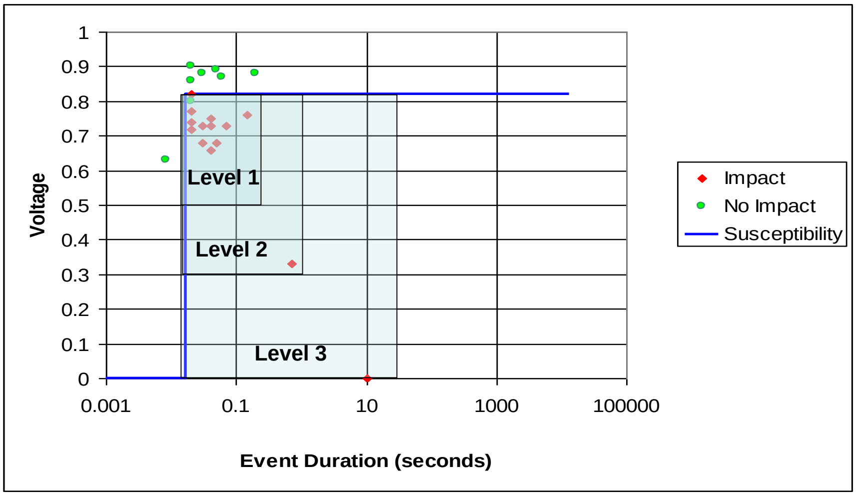
Objective – eliminate impact of typical sags



Giving customers options

1. Level 1: sags to 50% lasting up to 30 cycles. – 85% of recorded events.
2. Level 2: sags to 30% lasting up to 60 cycles. – 93% of recorded events.
3. Level 3: interruptions lasting up to 1 minute - 100% of recorded events.*

* We didn't necessarily record everything that might happen…

Mitigation options – Level 1

(Load is a PLC that draws up to 1kVA)

- Option 1: Dynamic Sag Corrector (DySC)
  (Active series compensator)
  - sag protection for sags to 50% for up to 2 seconds. Cost: about $250.
- Option 2: Ferroresonant Transformer
  - Must be oversized. For sags to 50% load may be up to 60% of rating. Cost: about $1,800.

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Mitigation options – Level 2

- Option 1: Ferroresonant Transformer
  - For sags to 30% load may be up to 25% of rating. Cost: about $4,000.
- Option 2: UPS
  - Typical unit provides 14 minutes of ride-through for 1000 VA for about $550. Batteries are approximately $200 and should be replaced every 3 years. There will be a labor charge to replace them.

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Mitigation options – Level 3

- Option 1: UPS
  - Same as level 2, option 2 – Cost: about $550 + $200 + labor to install new batteries every three years.
- Additional considerations for all options:
    - Ferroresonant transformer is "hard-wired" (installation costs) but has no electronic controls or batteries – very reliable, maintenance free, no switching disturbance.
    - UPS and DySC have similar electronics. Lower MTBF than Ferro. Both may be plug and cord connected – minimal installation time and cost.
    - UPS battery replacement requires technician and downtime or bypass.

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Some other devices

- Dip-proofing inverter
  - A UPS that uses capacitors instead of batteries for energy storage.
  - Small footprint – low or no maintenance
  - Can handle complete interruptions for about 3 seconds
- Voltage Dip Compensator
  - A multi-tap transformer with solid-state switching between taps
  - Can handle sags to about 50%

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Bigger loads

- Our load is four 15kVA industrial machines that press audio and data CDs
- Level 1 options: (cost per machine)
  - UPS: $7,500
  - DySC: $3,000
  - Motor-Generator: $25k

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Bigger loads

- Level 2 and 3 options:
  - UPS: $7,500/machine
  - Motor Generator: $25k/machine
  - Note that as the power requirements increase, technologies such as the flywheel-based systems may become cost effective.
  - We also may have opportunities for subsystem protection.

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Subsystem protection

- Remember the EMO circuit?
- In general, if we keep the controls “alive” motors, heaters, and other “high inertia” loads will continue to operate through a sag with no mitigation.
- Many industrial machines are simply assemblies of smaller machines that we may be able to address individually.
- This approach can significantly reduce costs.

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More mitigation examples

- DC contactors – stay closed longer, and may use inherent energy storage in power supply
- Coil hold-in devices – *(Coil-Locks)* will keep relays and contactors closed for sags to 25% of nominal voltage.

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Next time…

- Whole facility and utility options.