University of Idaho
College of Engineering

ECE 528 – Understanding Power Quality

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

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Lecture 14

University of Idaho

Today…

- Some common midterm questions
- Homework 4 posted
- Transient overvoltage
  - General protection principals
  - Lightning

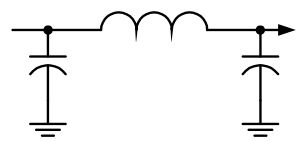
We're in PSQ chapter 4 and FPQ chapter 5.
You'll need them for HW4.

Principles of protection (PSQ pg. 157)

- Limit voltage at device terminals
  - Turn transient voltage into transient current
- Divert transient current
- Block transient current
- Bond grounds together at devices
- Reduce or prevent transient current flowing between grounds

What the protective devices do

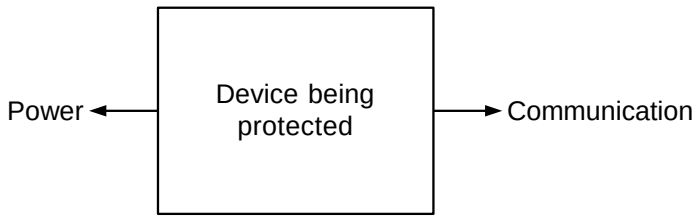
- Increase impedance as frequency increases
  - Low pass filters
  - Isolation transformers
  - Low impedance power conditioners



- Reduce impedance as voltage increases
  - MOVs (clamping)
  - Arc gap or electronic (crowbar)

Limit voltages at (and between) terminals

- This means excessive voltages on power circuits, on signal circuits, AND between power and signal circuits.



Diverted transients are still transients

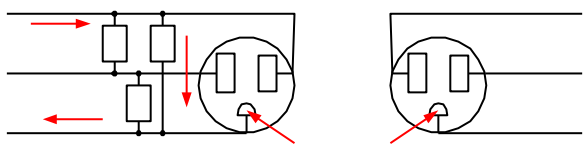
- Diverting transient current with clamping or crowbar devices "reroutes" the current to other conductors
- Ohm's Law still applies: I*Z=V
- May lead to voltage differences on grounding system
  - "Ground" is no longer a common reference

Blocked transients are still transients

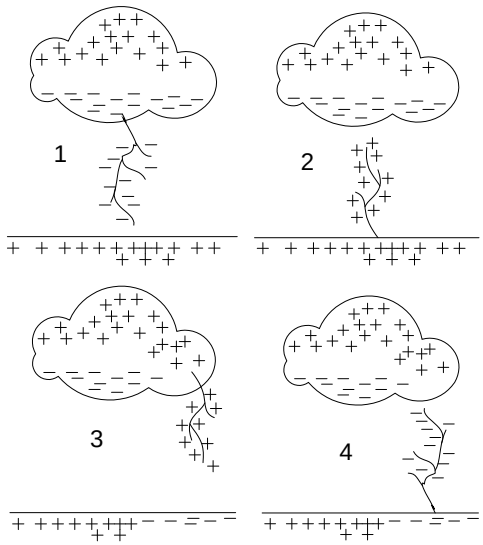
- Remember reflections and refractions
  - At an impedance change in the system, the transient may be reflected back into the “upstream” system.
  - Other nearby devices may be subjected to transient voltage magnification.

Grounding system voltage differences

- A transient on the left receptacle could result in voltage between the grounds at these two receptacles



Anatomy of lightning



Four types of Cloud-to-ground lightning:

1. Negative downward
2. Positive upward
3. Positive downward
4. Negative upward

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30s exposure

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How lightning damages electrical equipment

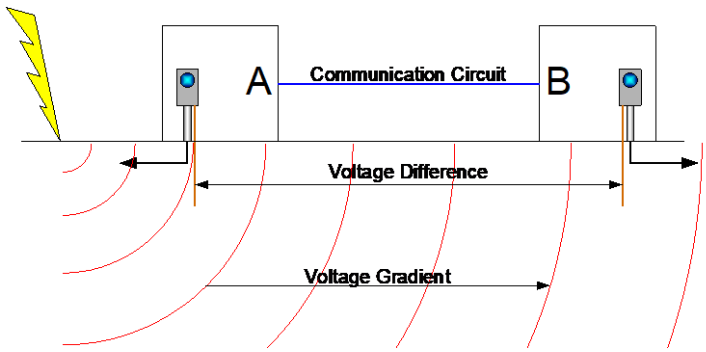
- Direct strike
  - Primary system
    - Conducted to grounding and secondary system through arrestors
    - Causes flashover – fault – sags and interruptions
    - Nearby arrestors may fail
    - May also cross into secondary system via interwinding capacitance in transformers or low-side surge
  - Secondary system: when lightning stroke current travels in the grounding system – two common issues:
    1. Raises local ground voltage by several kV
    2. Induces voltages and currents in nearby equipment and systems

How lightning damages electrical equipment

- Indirect strikes
  - Much more common
  - Many of the direct-strike impacts are still possible
  - May cause transients in power and communication systems through conduction (resistive coupling), inductive coupling, or capacitive coupling
  - Charge may build in the strong static electric field, then, when that field collapses, the charge rapidly redistributes – transient current

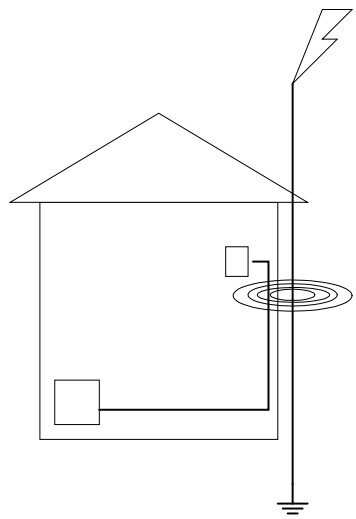
How lightning damages electrical equipment:
Lightning stroke current in the grounding system

Resistive coupling (conduction) between devices or buildings due to change in local ground voltage



How lightning damages electrical equipment:
Lightning stroke current in the grounding system

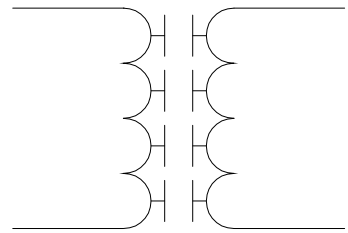
Inductive coupling to power or communication circuits due to current in the lightning protection system or other lightning current paths



How lightning damages electrical equipment

Capacitive coupling of lightning-caused transient voltages

Voltages may couple to any nearby conductors, and across transformer windings



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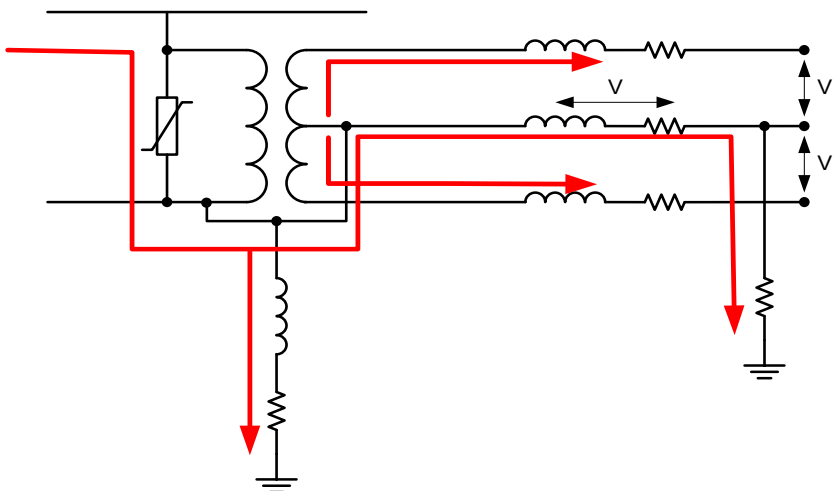
The “low-side surge”



The low-side surge is an important cause of lightning-related failures of customer equipment and utility service transformers

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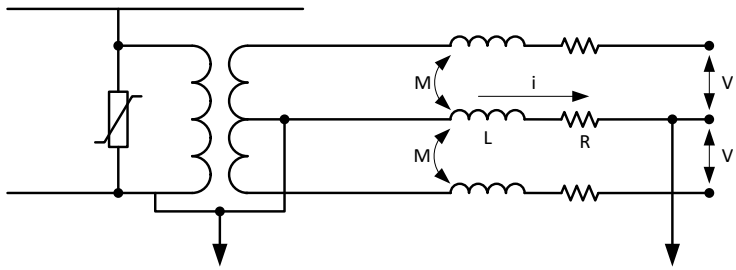
The “low-side surge”

- Current in service neutral creates resistive and inductive voltage drop. V = Ri+(L-M)(di/dt)
- Mutual inductance can reduce the effect.
- A short at the load end will cause the surge voltage to appear at the transformer secondary



Lightning protection: Utility system

- Shielding – installing a grounded conductor above the phase conductors
  - Common in transmission and substations
  - Not common in distribution
  - Goal is to prevent lightning from striking the phase conductors
  - Ground lead must be kept well away from phase conductors and be as straight as possible
  - Grounding resistance needs to be as low as possible

Lightning protection – Utility system

- Line arrestors
  - Crowbar or clamping device
  - Usually installed at transformers
  - In less populated areas, arrestors may be required on poles without transformers
  - It may take several arrestors working together to sufficiently "bleed off" the stroke current

Lightning protection – Utility system

- Low-side surge protection
  - Arrestors on the low voltage side of the transformer – <u>at the transformer</u>
  - Interlaced secondary windings on the transformer
    - Only protects the transformer
    - Only effective for balanced surge currents
    - Does not reduce, and may increase surge current into the load

Lightning protection – Utility system

- Underground cable protection
  - Underground cable failures may result in extended outages
    - Open point arrestors – reduce reflected voltage
    - Scout arrestors – arrestors at poles on either side of a riser pole - successively reduce the current surge
    - Cable injection – helps restore insulation

Lightning Protection – Customer side

- Lightning rods
  - Provide a more prominent target than the protected structures
  - Generally used to avoid catastrophic damage
  - Must consider ground voltage gradients, and routing of grounding conductors

Lightning Protection – Customer side

- Basic approach
  - Arrestors at the service entrance
  - Transient voltage surge suppressors at individual loads
  - Establish common ground point at devices to prevent damaging voltages between power and communication systems at devices

Finally - lightning detection

- A network of radio receivers is used to help determine the time and location of lightning strikes.
- This can be used to help rule-in or rule-out lightning damage.
- This system can also be used when planning new systems to determine the lightning environment in a particular area.
- Topography and lightning behavior can produce spatial bias in results.

Next time…

- Ferroresonance
- Capacitor switching
- General issues with switching inductive or capacitive loads