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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 16

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Today…

- Transient overvoltages
  - Lightning and lightning protection

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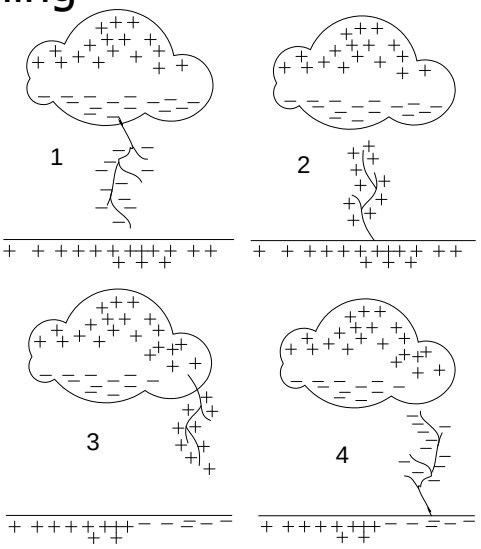
Anatomy of lightning

Four types of Cloud-to-ground lightning:

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



30s exposure/55mm

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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 and grounds
    - Raises local ground voltage by several kV
    - Induces voltages and currents in nearby equipment and systems

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How lightning damages electrical equipment

- Indirect strikes
  - Much more common
  - May cause transients in power and communication systems through conduction (resistive coupling), inductive coupling, or capacitive coupling

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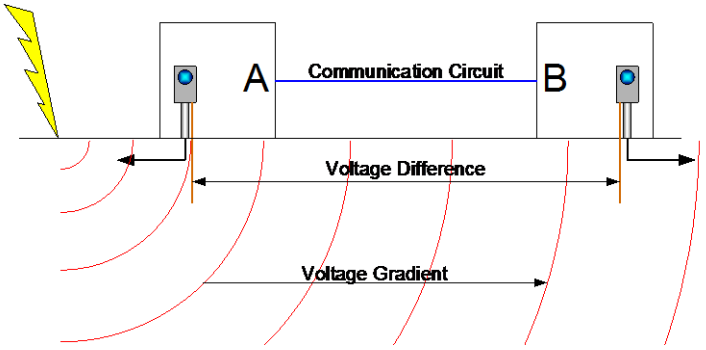
How lightning damages electrical equipment

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



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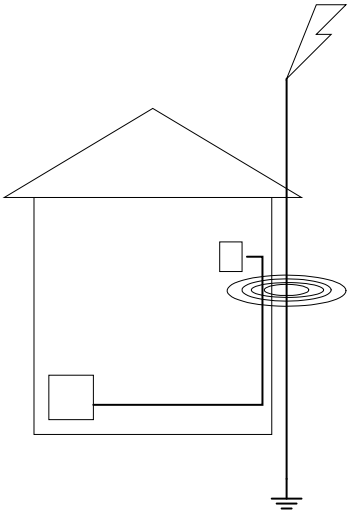
How lightning damages electrical equipment

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



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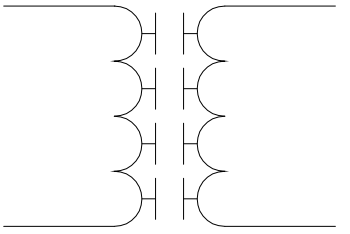
How lightning damages electrical equipment

Capacitive coupling of lightning-caused transient voltages

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



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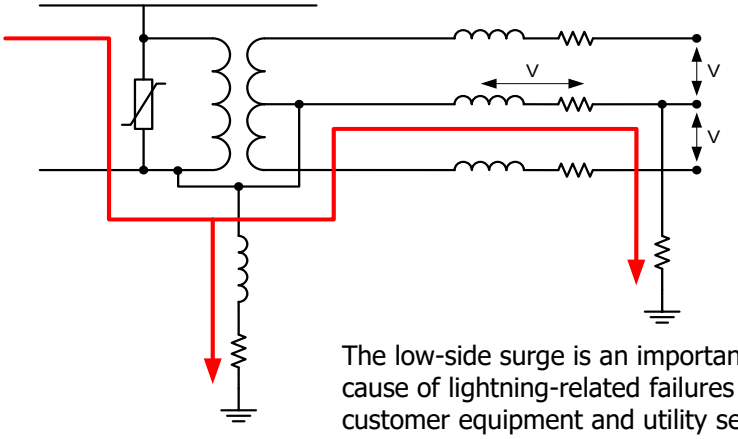
The "low-side surge"



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

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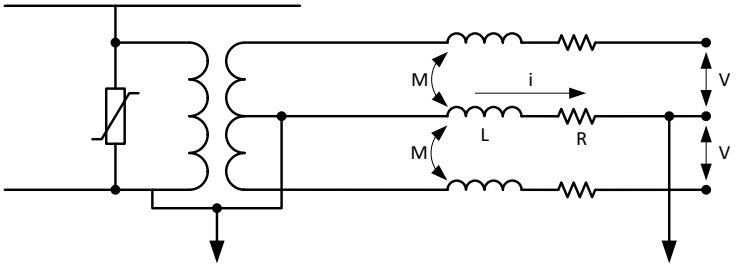
The "low-side surge"

- 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



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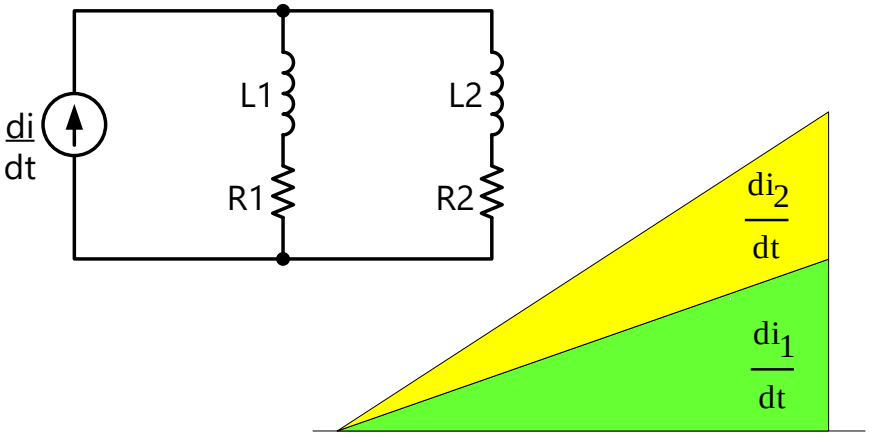
The simplified low-side surge circuit



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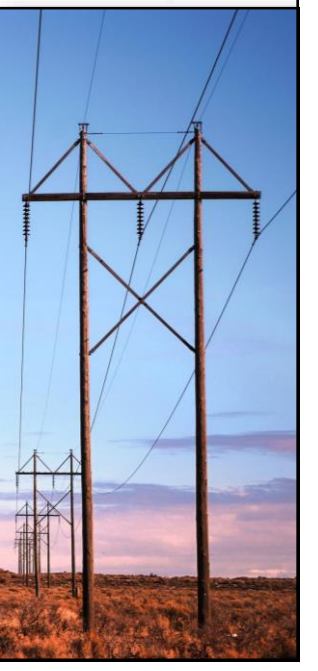
Lightning protection: Utility system

- 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



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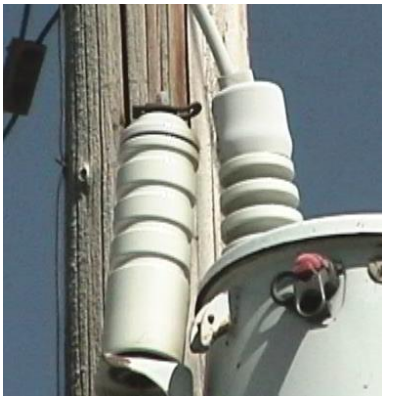
Lightning protection – Utility system

- 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 – at the transformer
  - 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 – successively reduce the current surge
    - Cable injection – helps restore insulation

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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

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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

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Finally - lightning detection

- A network of radio receivers in the US can help determine the precise time and location of lightning strikes.
- This can be used to 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.

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Next time…

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