Lightning Mitigation at National Grid

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nationalgrid

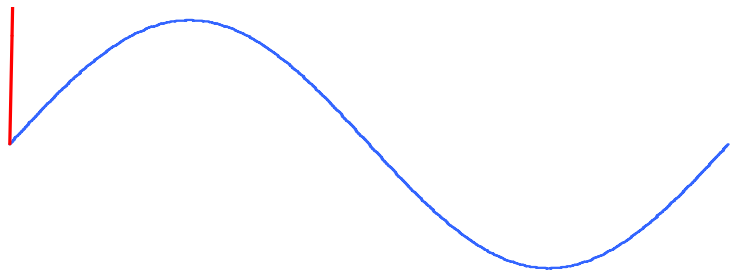
Overview

- Why Lightning?
- Protection strategies
- Mitigation methods
- Performance metrics
- Modeling and analysis
- Standards and construction practices

Why Lightning?
Lightning Characteristics

- Typical lightning stroke is -10 kA to -20 kA.
  - 50 times greater than load current !

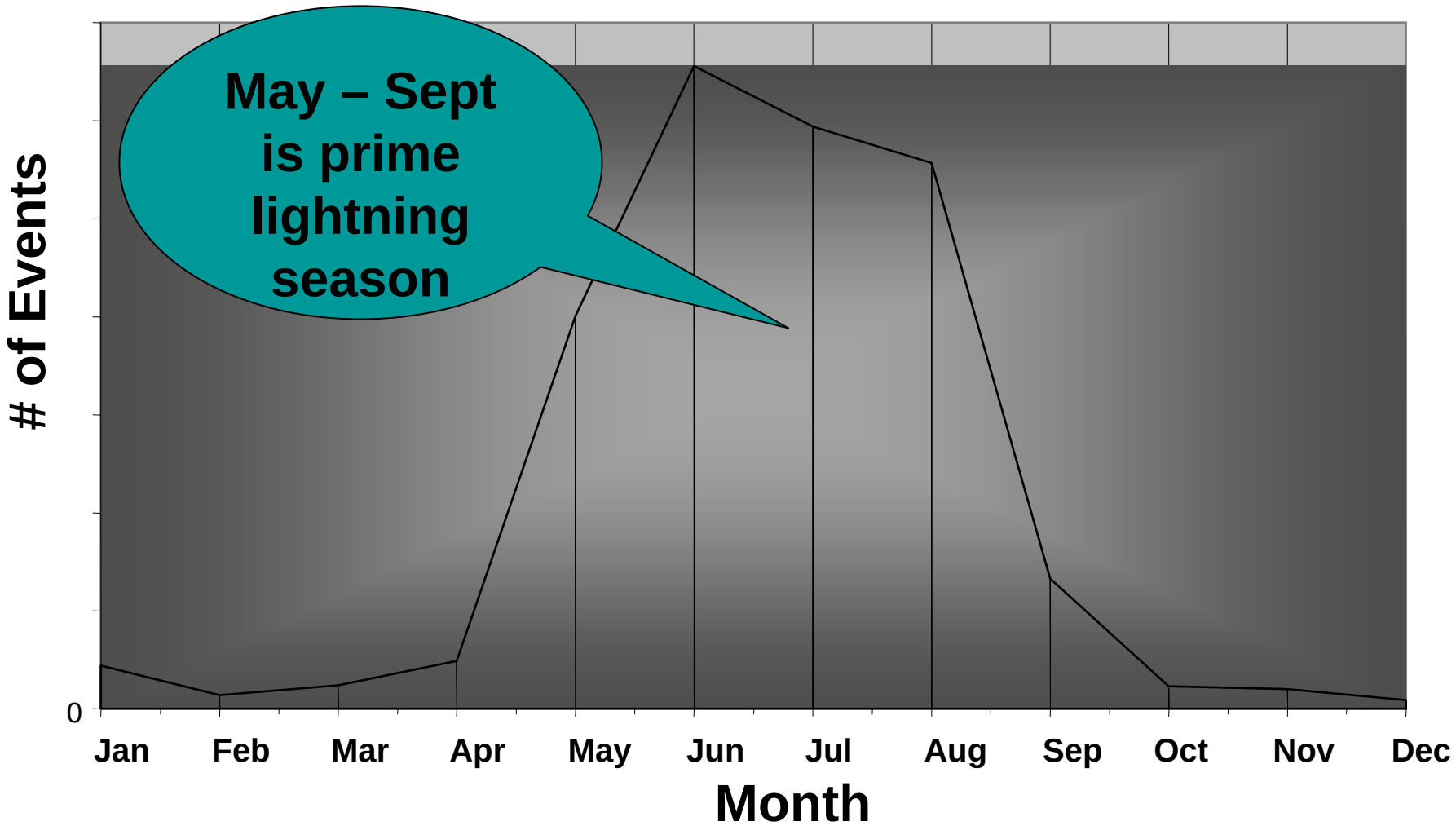
- Rise times are on the order of 1 to 10 μS.
  - 2000 to 3000 times faster than 60 cycle !
  - Far faster than fuses or breakers can operate.



Why Lightning?
Interruptions and Damage

- A large number of power failures experienced by customers are caused by
  - lightning or by
  - failing equipment damaged due to lightning
    - Large contributor to “Defective Equipment”
    - Lightning damage is CUMULATIVE
    - Failures happen moments, weeks, or months later

Why Lightning?
Lightning Exposure



Protection Strategies

- Direct strikes to line
  - Too much energy to protect from these
- Strikes near to line
  - Quickly reduce the amount of excess energy
  - Limit the voltage surge
  - Bleed the energy off via multiple paths

Mitigation Methods

- Lightning mitigation measures
  - Grounding
  - Bonding
  - arrester application
  - insulation coordination
  - construction standards

Metrics

SAIDI

System Average
Interruption Duration Index

$$\frac{\text{Sum of Cust. Interruption Durations (CMI)}}{\text{Total \# of Customers Served}}$$

CAIDI

Customer Average
Interruption Duration Index

$$\frac{\text{Sum of Cust. Interruption Durations (CMI)}}{\text{Total \# of Cust. Interrupted (CI)}}$$

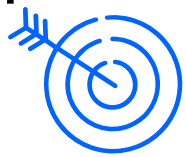
SAIFI

System Average
Interruption Frequency Index

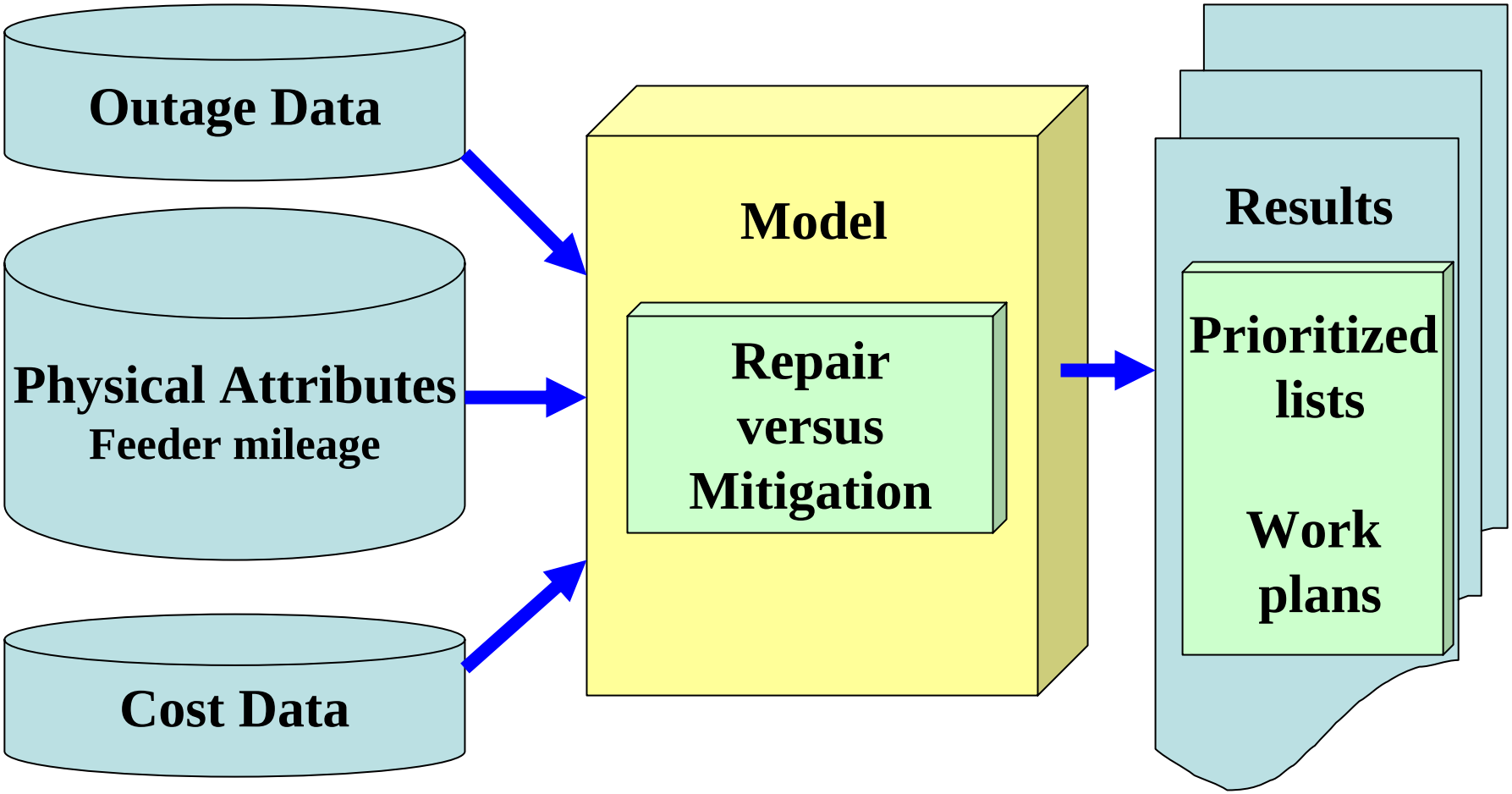
$$\frac{\text{Total \# of Cust. Interrupted (CI)}}{\text{Total \# of Cust. Served}}$$

Modeling and analysis

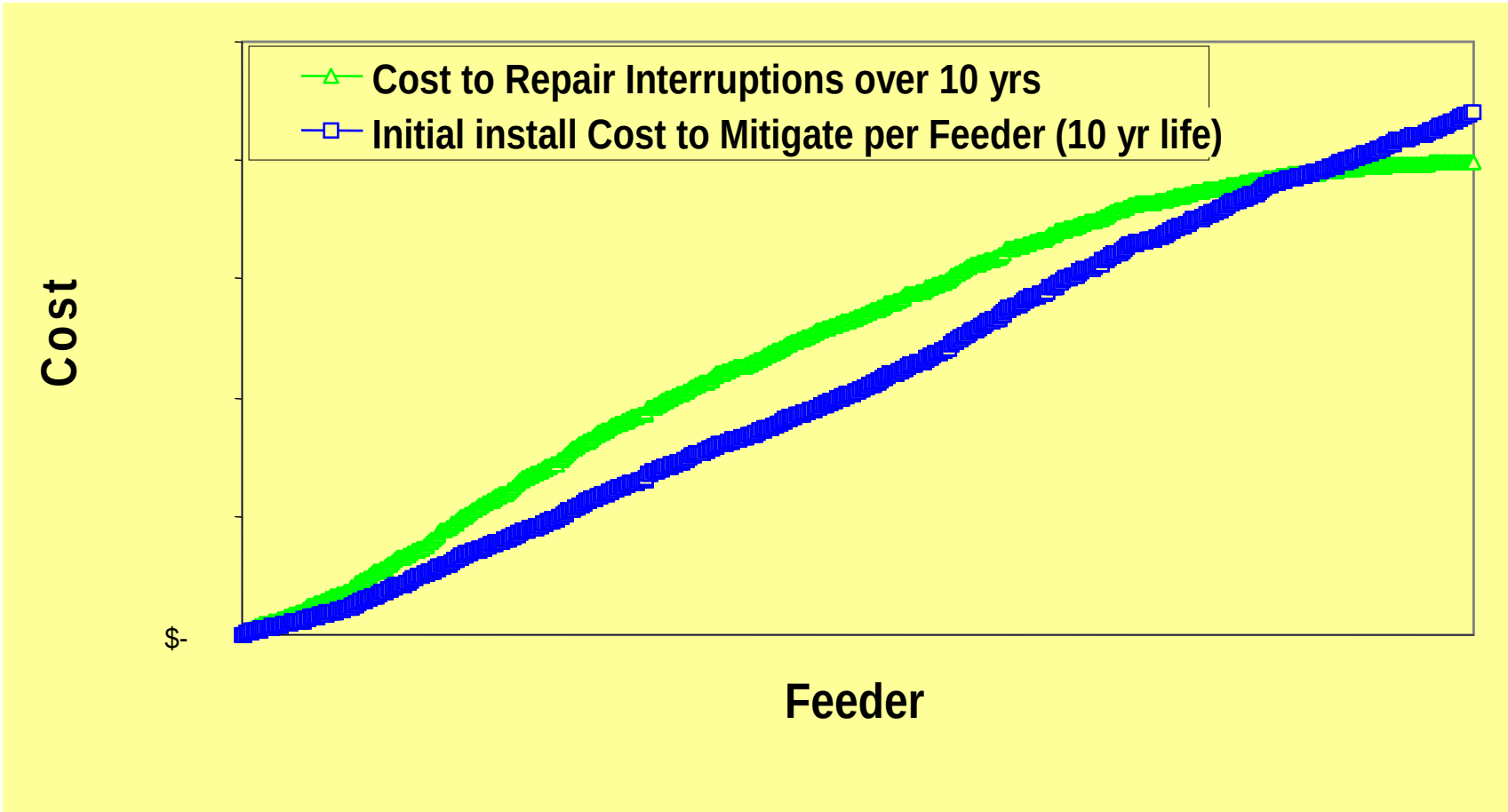
- In the past mitigations were implemented on a program basis using a “ 

” approach.
- It is now possible to enhance the application of these techniques to create targeted  implementation that improves performance and keeps costs as low as possible.

Lightning Model



Lightning Model Results



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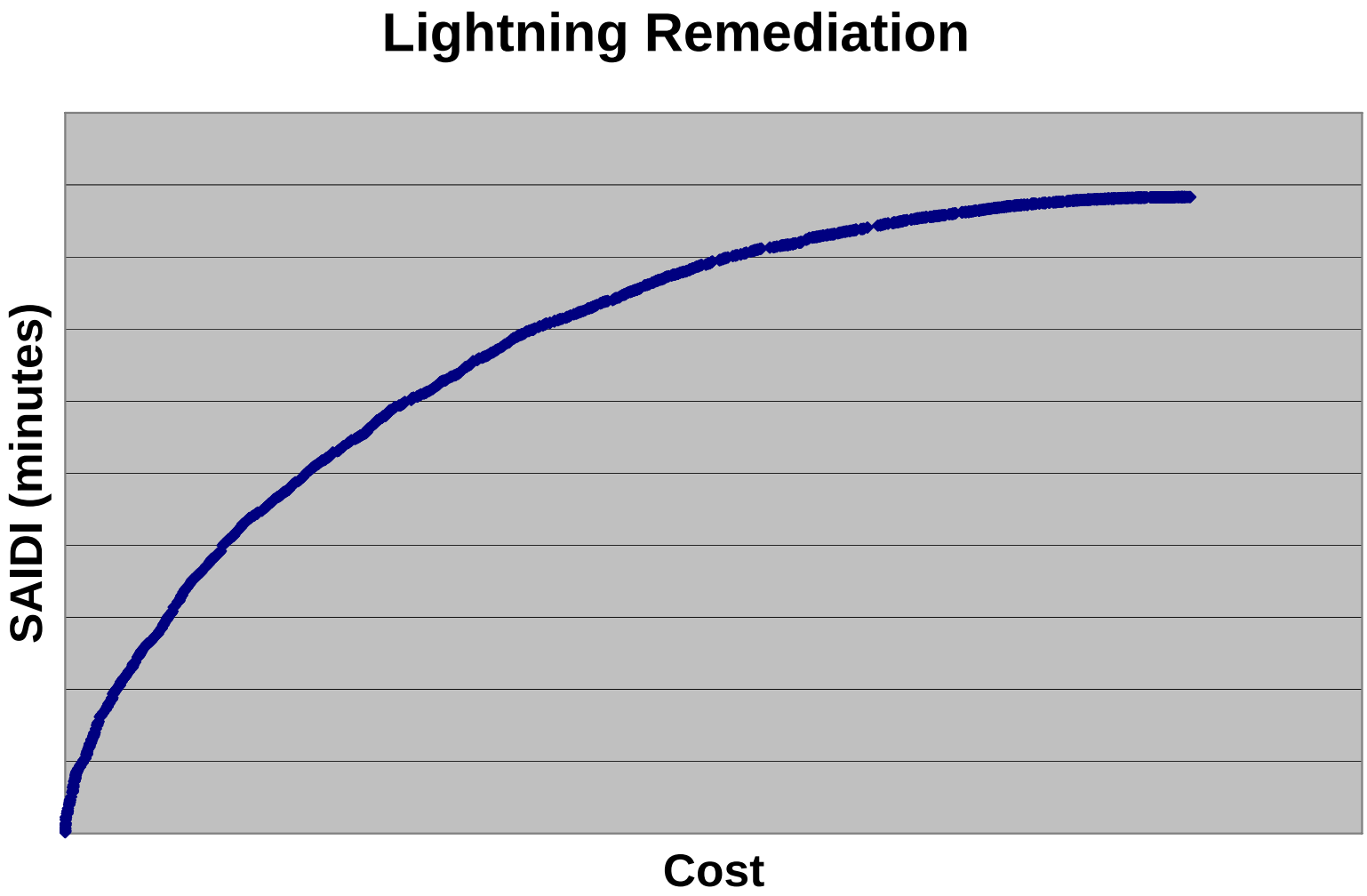

How Models Are Used

- Prioritization
  - On a common corporate base
  - By feeder

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- Prioritization
  - On a common corporate base
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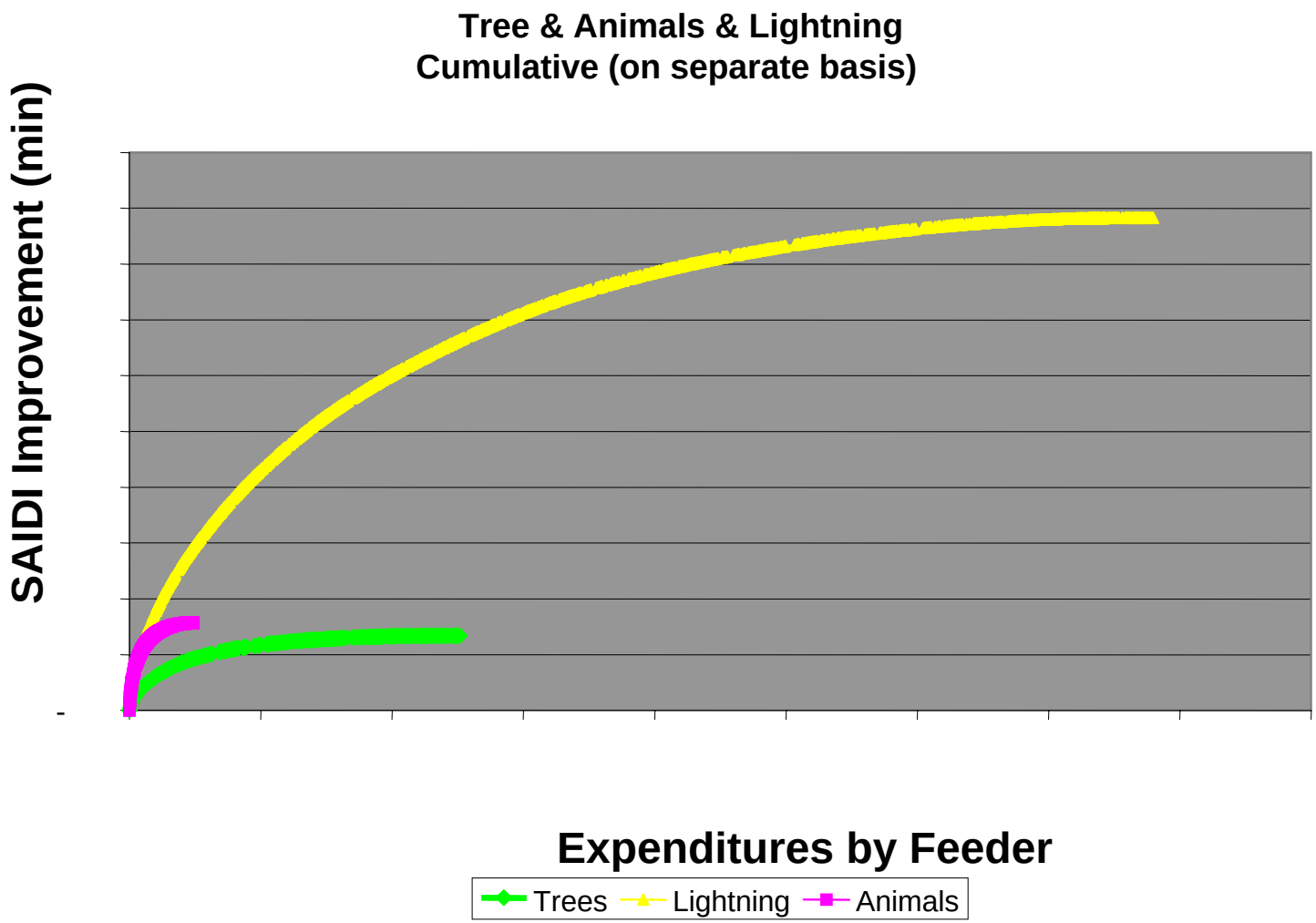
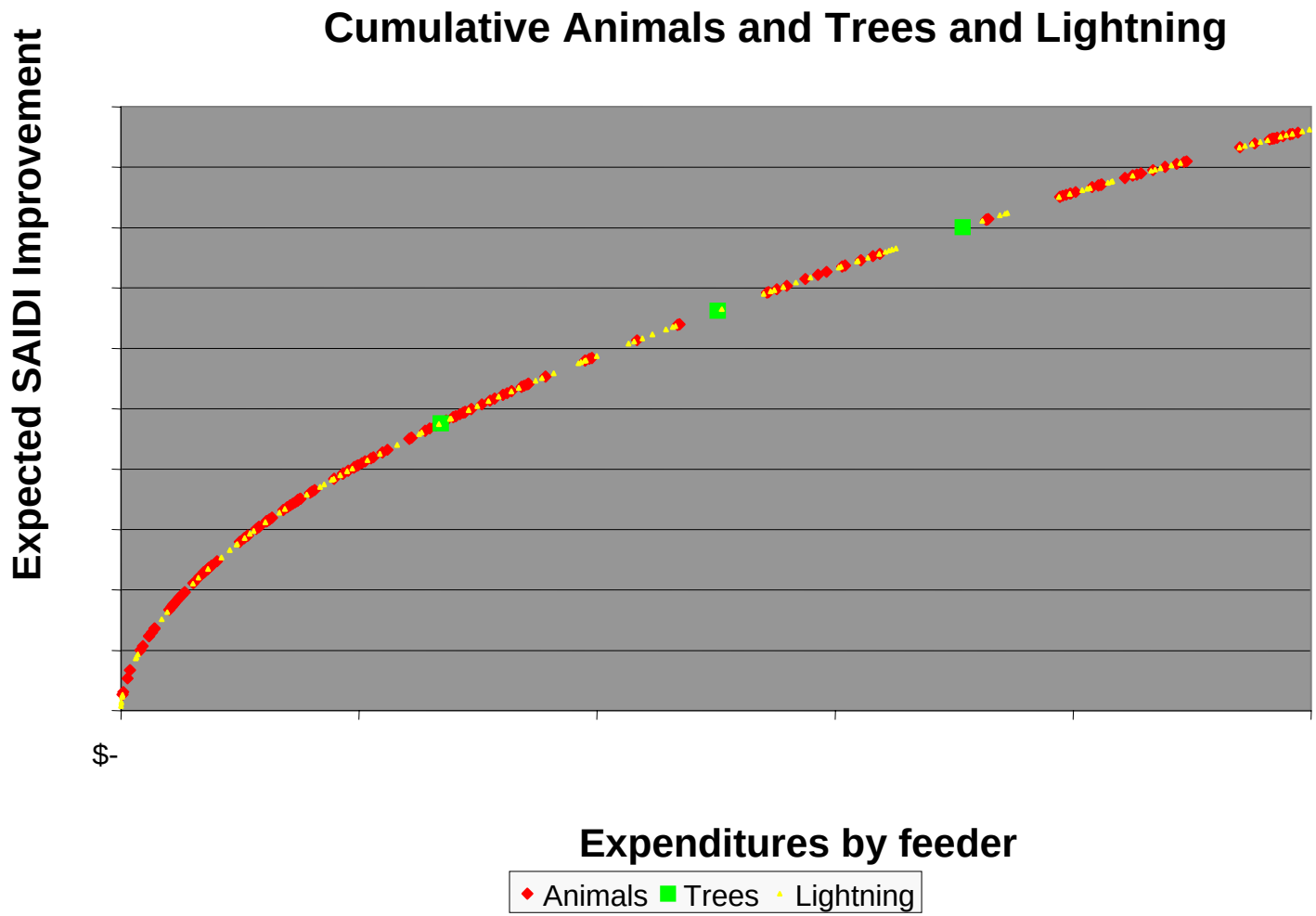
- Program creation or refinement
  - Business case
  - Show labor requirements for realistic work plans
- Budget
  - Predict changes in reliability due to funding changes

3 Models On Separate Basis



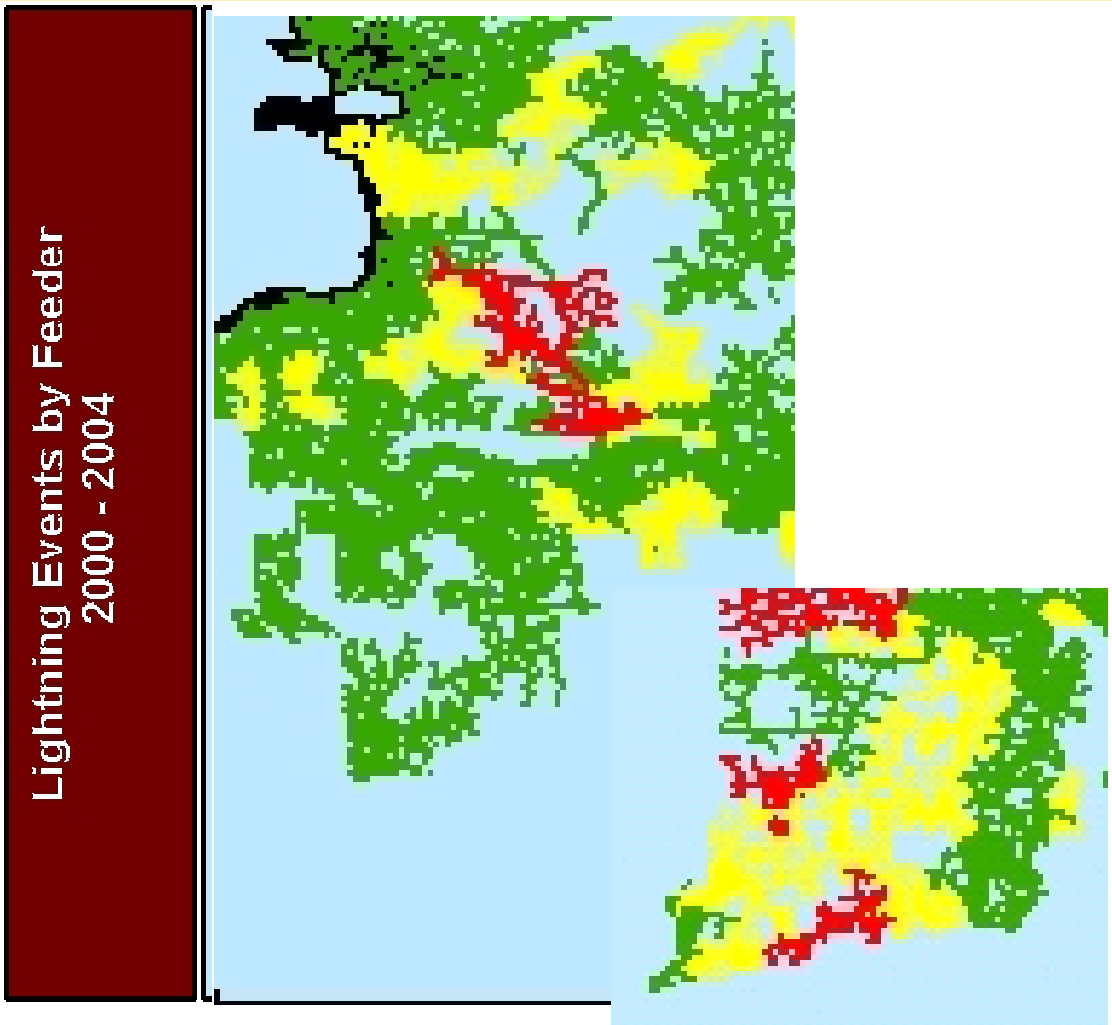
3 Models Same Basis



Results

- Faster corporate consensus reached
  - Able to show value of each program related to the others
- Enhanced credibility with regulators
  - Management by fact
  - Greater consistency throughout organization

Determining Deficiencies



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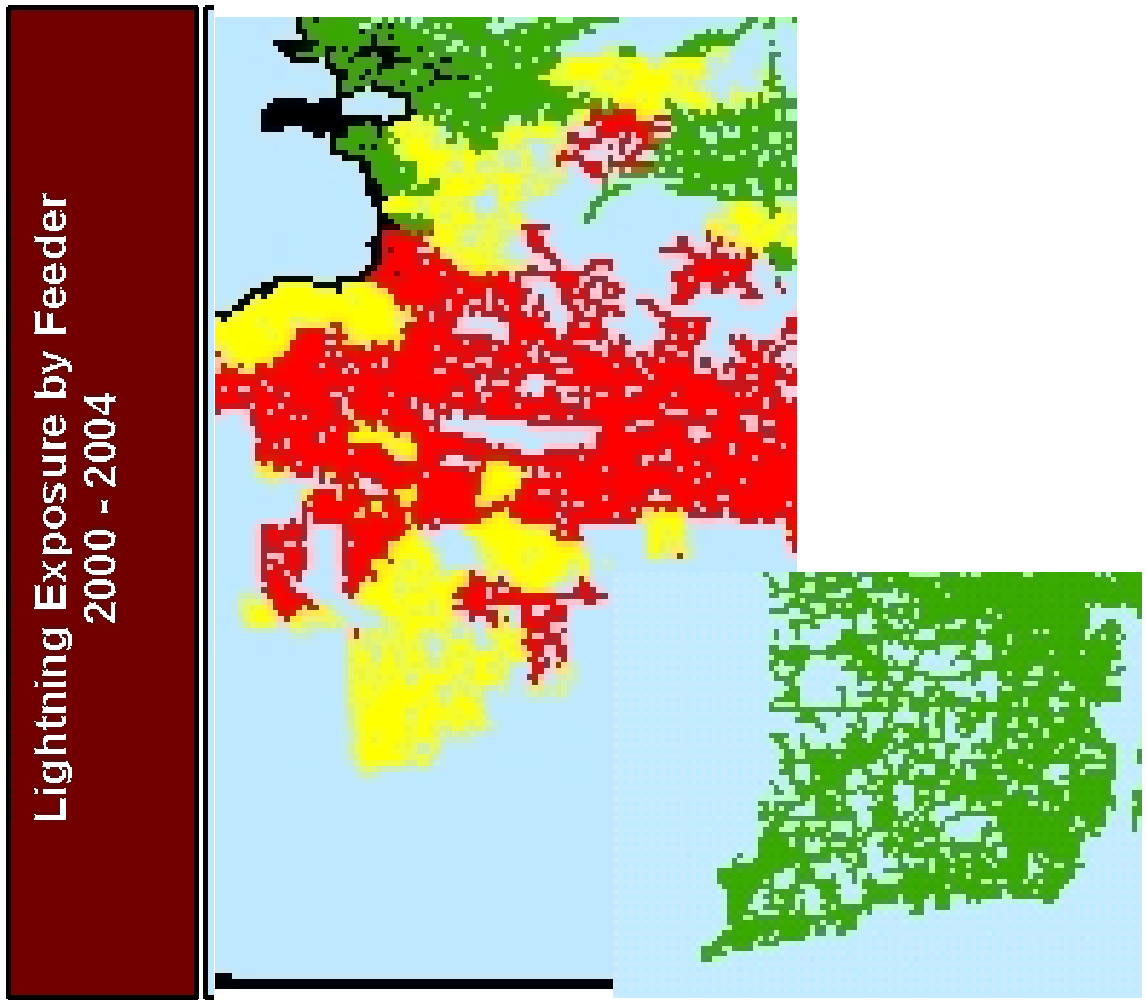

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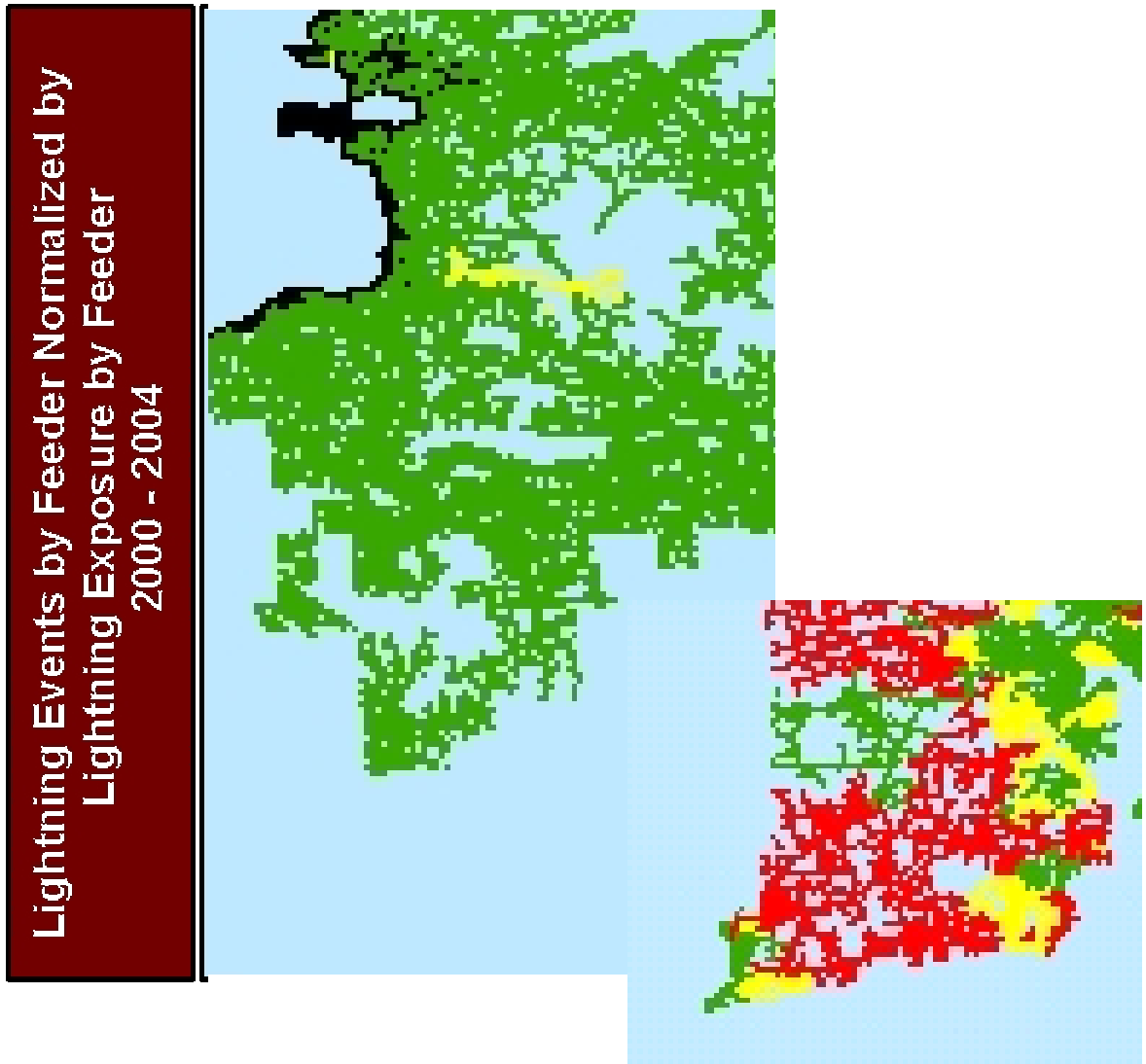

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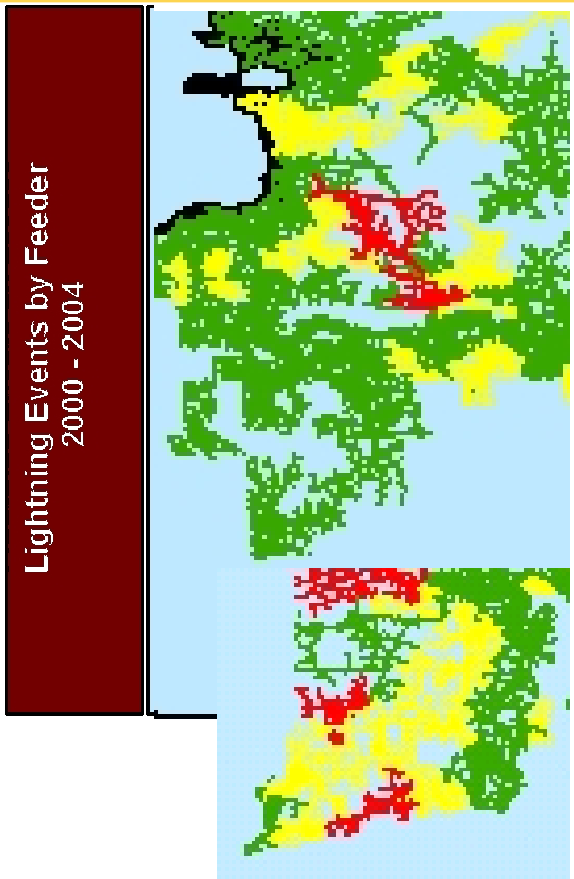
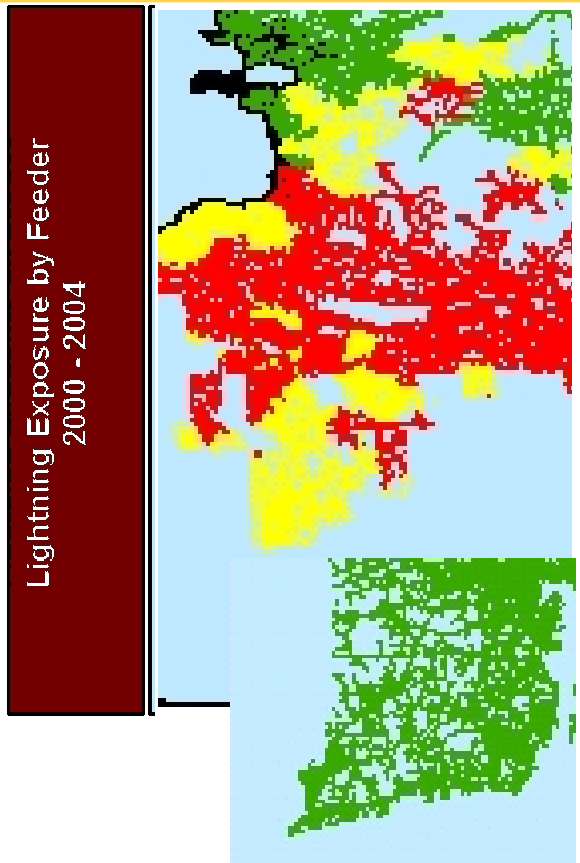
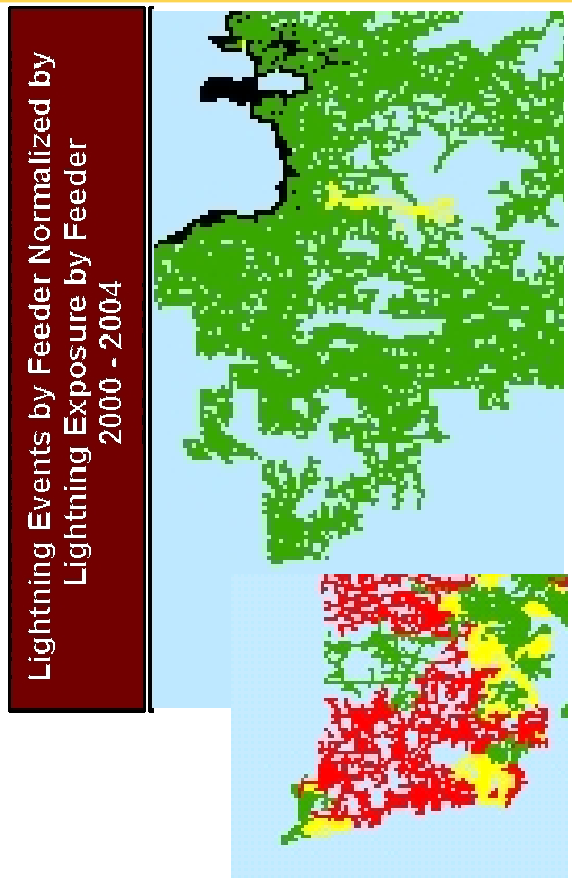






Standards implementation

Deterioration of grounding, bonding, arresters

Standards adequacy

Standards & Construction Practices

- Distribution equipment is usually designed to have a basic insulation level (BIL) of 60 – 150 kV.
  - Arresters generally used at equipment

- Pole tops are designed for 150kV BIL.
  - Based entirely on 20” of wood or equal
  - Arresters req’d on a pole when BIL is reduced

Standards & Construction Practices

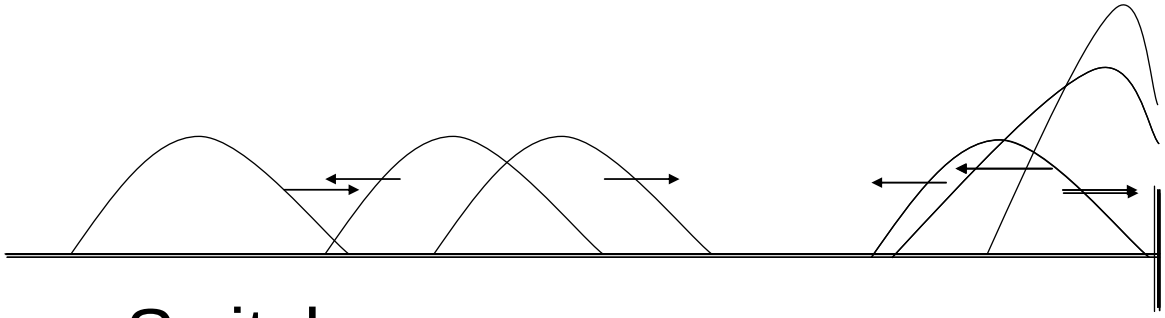
- Driven ground rod every 1300’ for open wire or 800’ for spacer cable.
  - Multiple ground paths provide low impedance path to ground so all the energy doesn’t have to go one way
  - NESC minimum: 4 grounds per mile
  - Insure good contact with earth
    - Do not put rod in pole hole!
    - Rod in tight contact with undisturbed soil

Standards & Construction Practices

- Install ground “loop” where req’d
  - When equipment is close to ground (8’)
    - Switch handles
    - Control boxes, etc.
    - Equipment should be bonded to loop to keep voltage difference across operators body as low as possible.

Standards & Construction Practices

- Arresters
  - Equipment
  - Dead-ends
  - Normally Open Switches
  - Junctions
    - Bare and covered/tree wire
    - Spacer and open wire
  - Risers
  - Pad-mounted equipment
    - As specified



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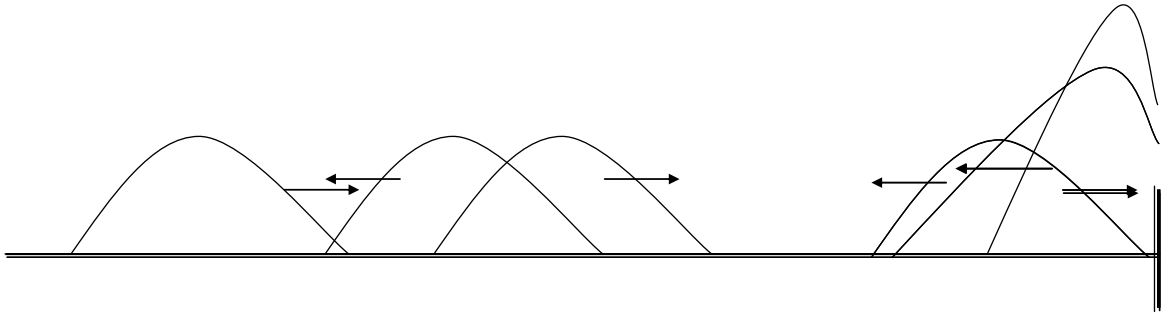

Arresters

- Install arrester where required on same pole as equipment
  - Arresters must be as close as possible to protect equipment
- Keep arrester ground leads as short as possible!
  - Arrester discharge voltage increases at a rate of 1.6kV for each foot of lead – long leads quickly reduce effectiveness of arrester.

Arresters Leads

- Remember:
  - 50x load current
  - 2,000x faster rise time
  - 100,000x greater voltage drop
  - ***v(t) = L (di/dt)***

What we covered

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