How We Learn That *It Depends* In Protective Relaying

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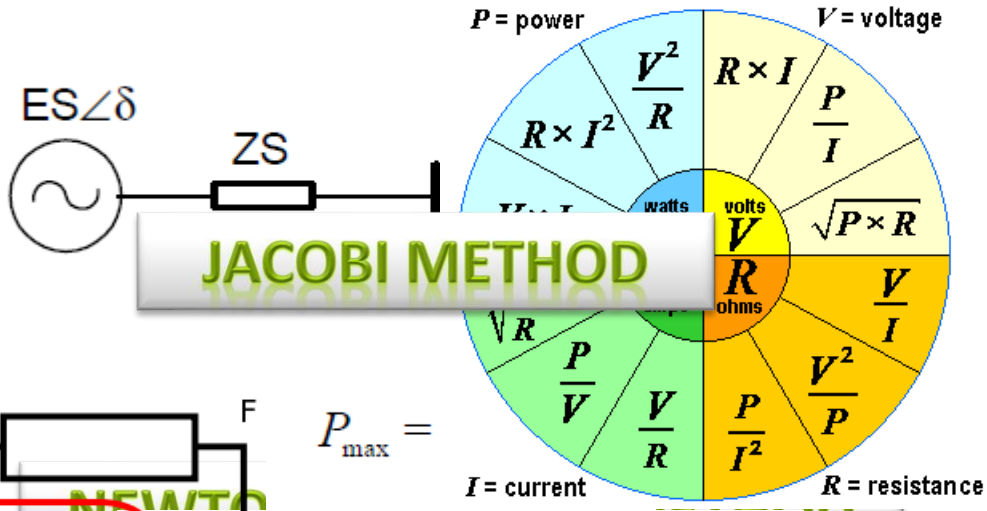
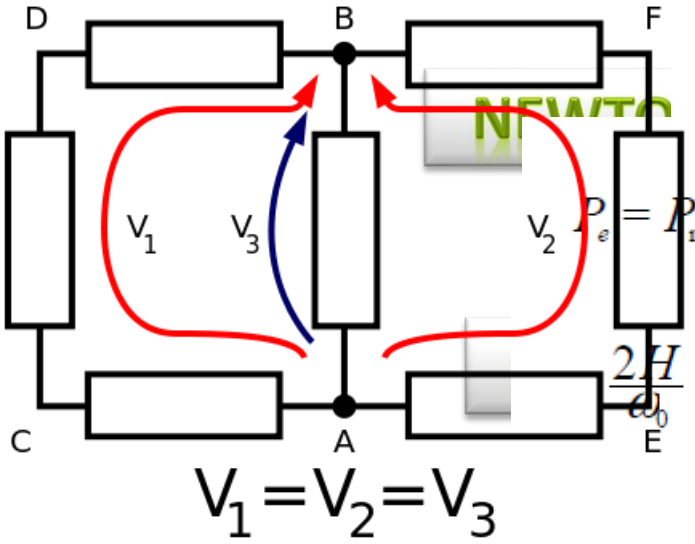
The Beginning

Equations and Solution Methods

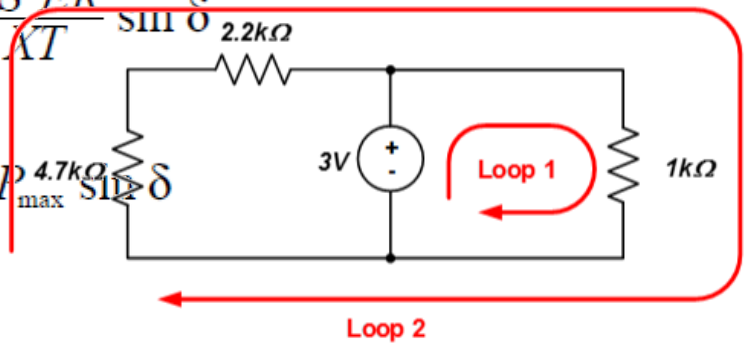




$$P_{max} =$$

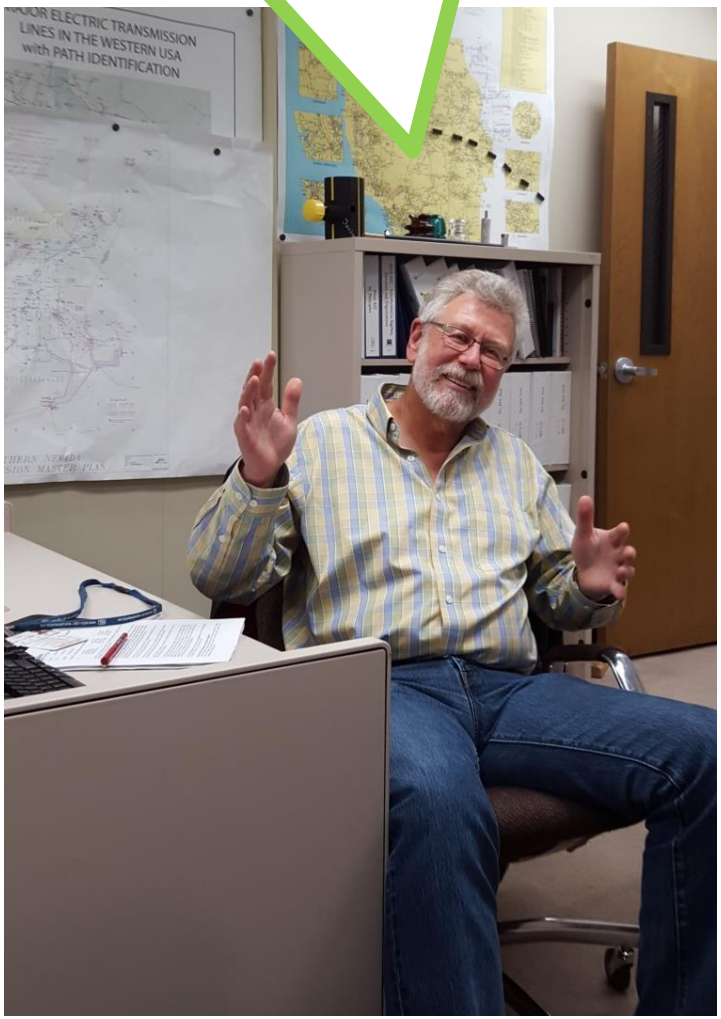
$$P_e = P_{max} \sin\delta = \frac{ES\ ER}{XT} \sin\delta$$

$$\frac{2H}{\omega_0}\frac{d^2\delta}{dt} = P_m - P_{max} \sin\delta$$



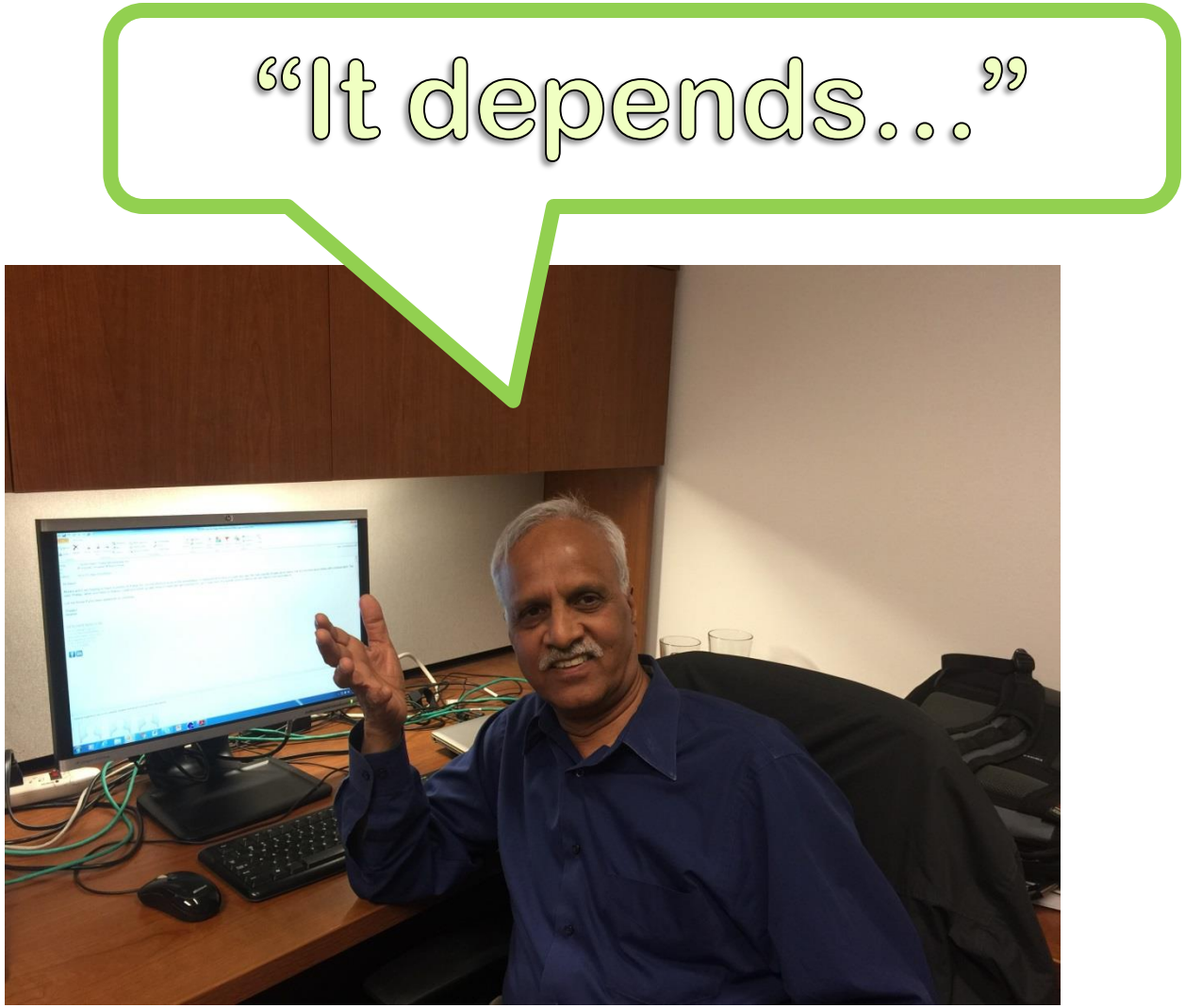
Power equations and one line figure – PSRC D6 Work Group Report, Power Swing and Out of Step Considerations on Transmission Lines, 2005

“It depends…”



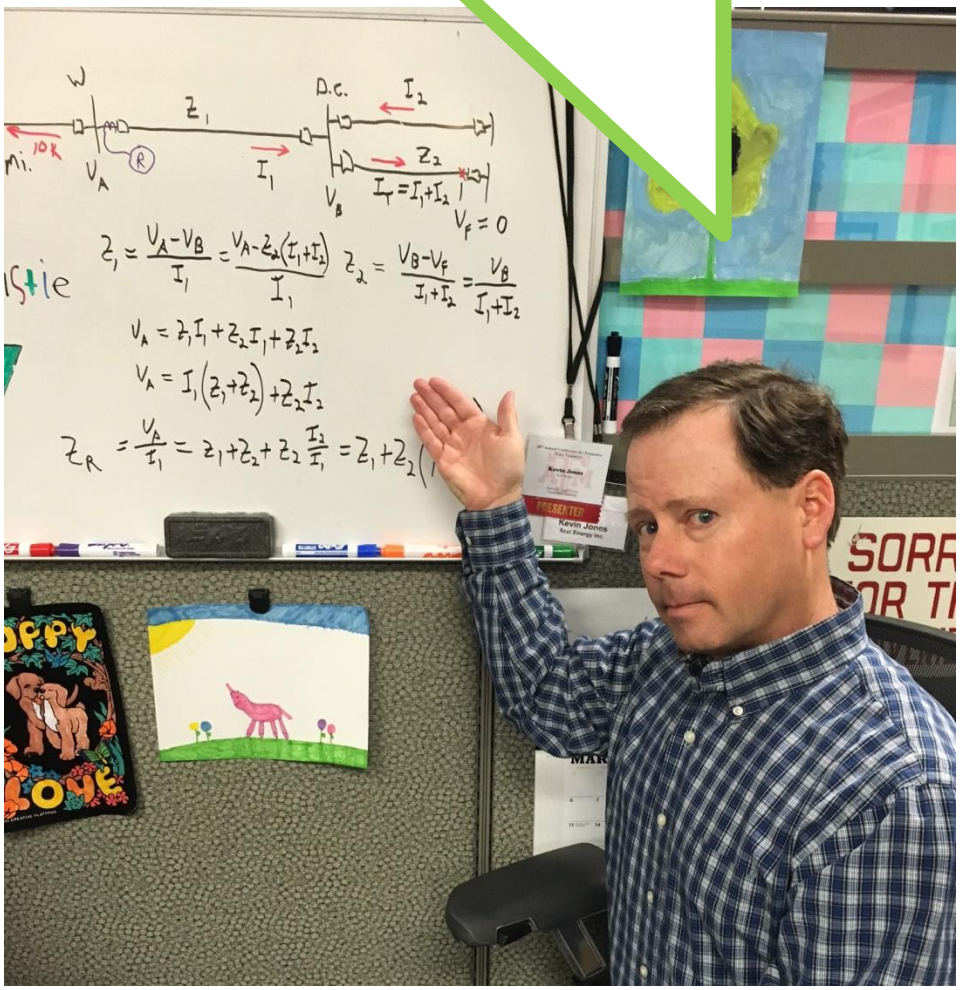
“Is the pick up for a ground element about 75% of the zone end ground fault?”

“Do we always block reclosing for bus faults?”



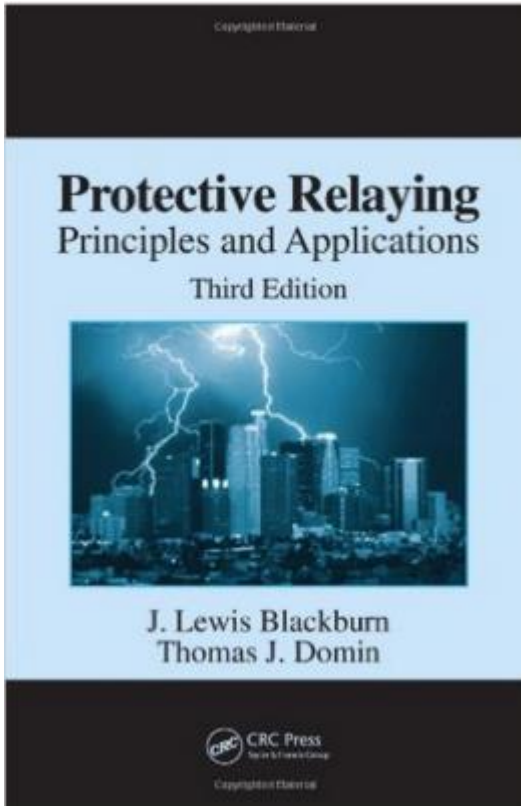
“Well, it depends…”

We both started working with Kevin and still heard…

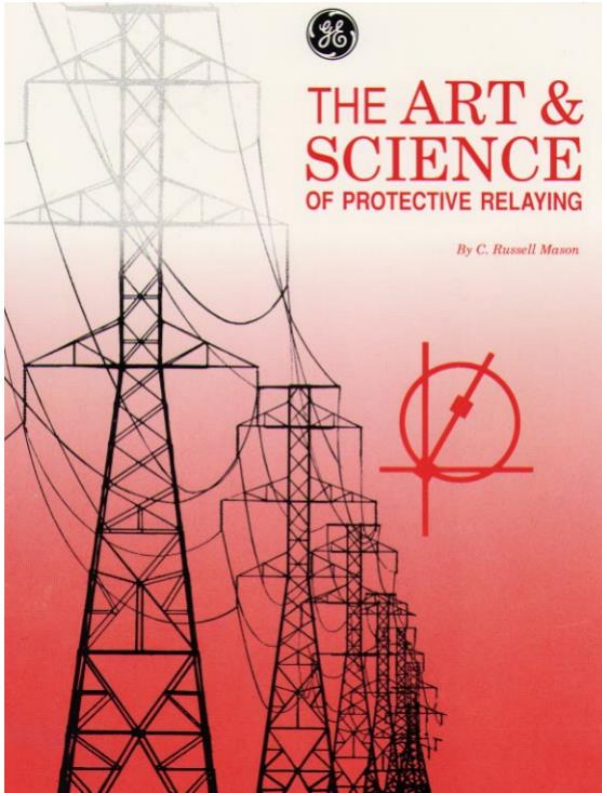


Protective Relaying Art and Science

- Mason and Blackburn



- Personality of the system and engineers
- Technology is common, practices are not



Blackburn book – Amazon.com, Mason book – gegridsolutions.com

Why *It Depends* is a Challenge for New Protection Engineers

- Issues
  - Math is precise and accurate
  - Student training and preparation is lacking
  - PE and FE formats
  - Protective relaying depends…
  - Workforce transition
- Teach the *why* with the *how* from the beginning

Protection Philosophy Challenges

ART vs. SCIENCE

Rule of thumb and application may vary

- Climates
  - Temperature Impacts on Loadability
  - Geomagnetic Effects on Ground Relaying
  - High Ground Resistances in Mountain and Arid Regions
- Biology – Plants & Animals
  - Birds, Snakes, and Mice

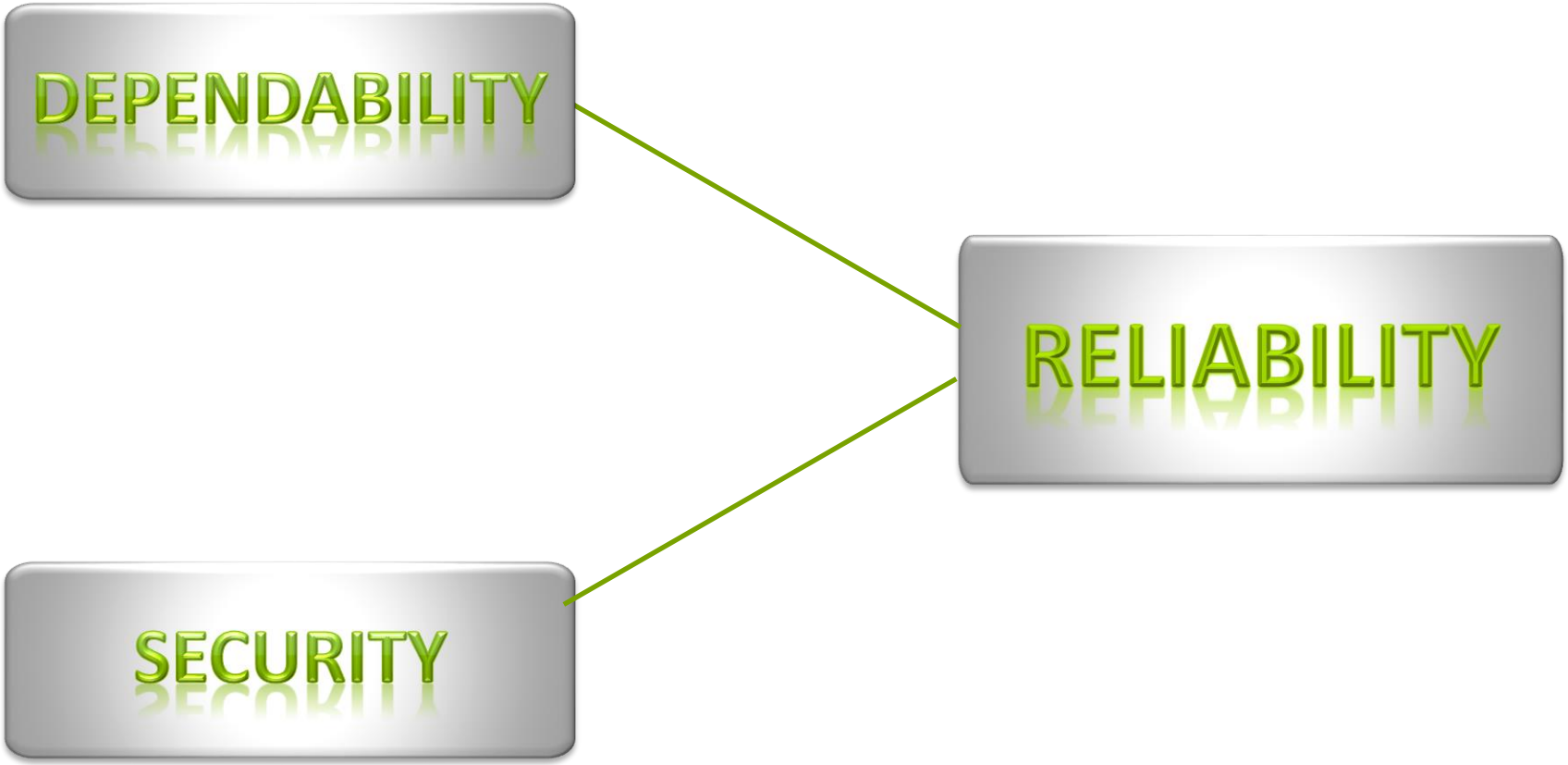
Major Tree-related Outages

- July 2, 1996
- August 10, 1996
- August 14, 2003

Tree Image - seattle.gov

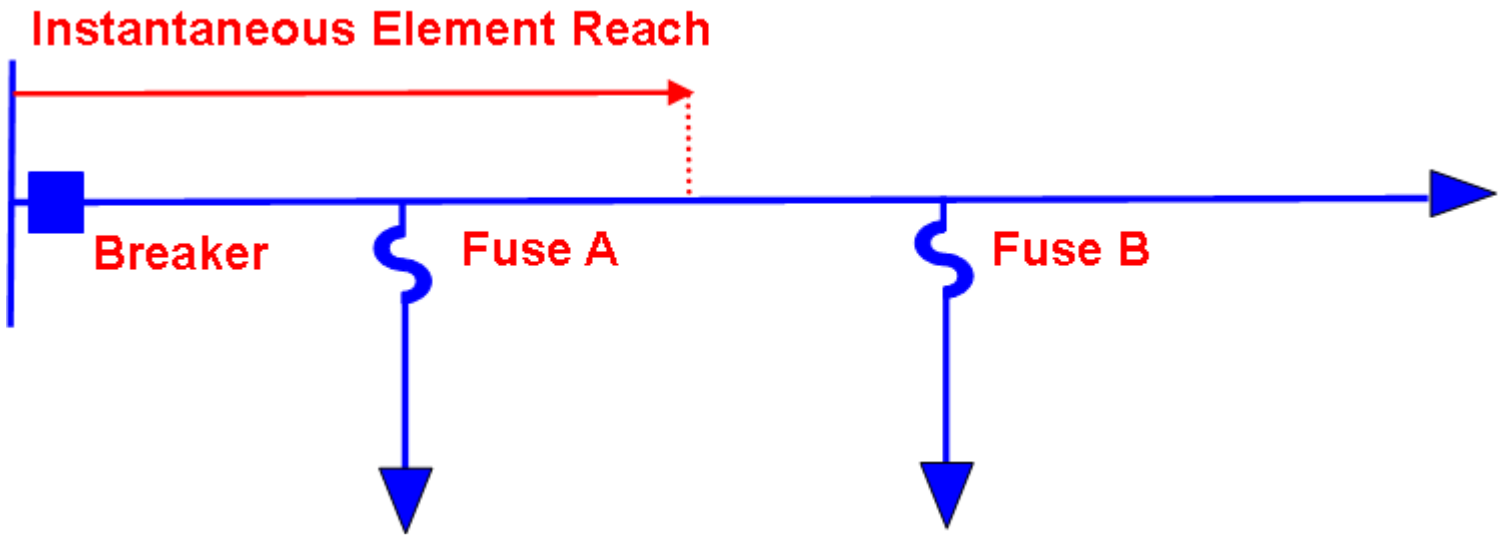
Protection Philosophy Challenges

- Dependability, Security, and Reliability



Protection Philosophy Challenges

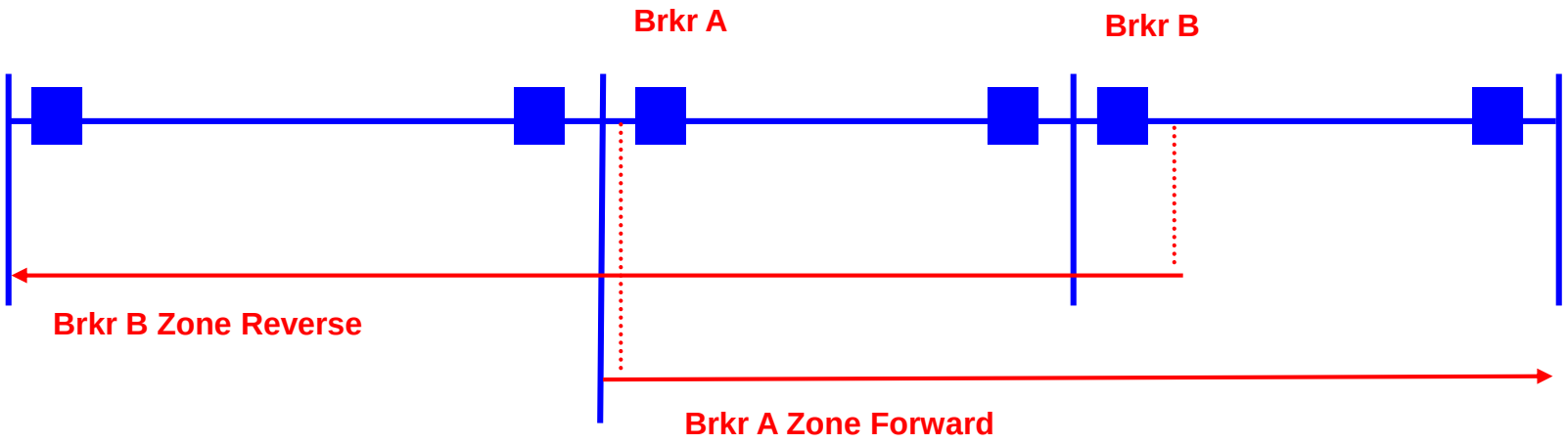
Fuse-Saving Schemes (A)	Non Fuse-Saving Schemes (B)
Toward Dependability	Toward Security
Fault Location Lessened	Fault Location Improved
Increased Fast Trip/Close Cycles	Increased Tap Outages and Durations
Clear Temporary Faults Faster	Fewer Feeder Outages



Distribution Line with Load Taps

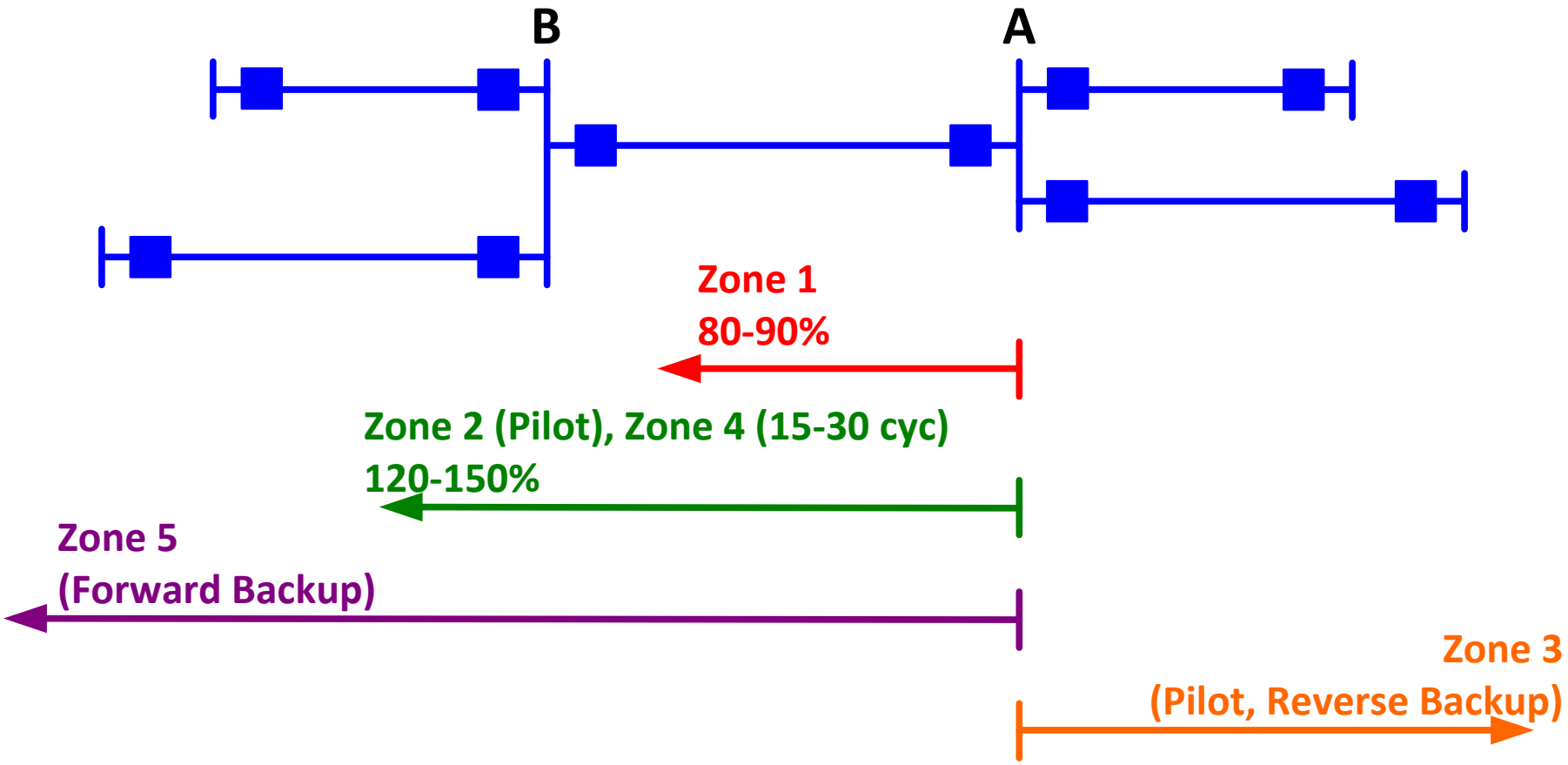
Protection Philosophy Challenges

- Distance Over-Reaching Zones – Forward or Reverse?
  - Advantages
  - Disadvantages



Examples Where It Depends

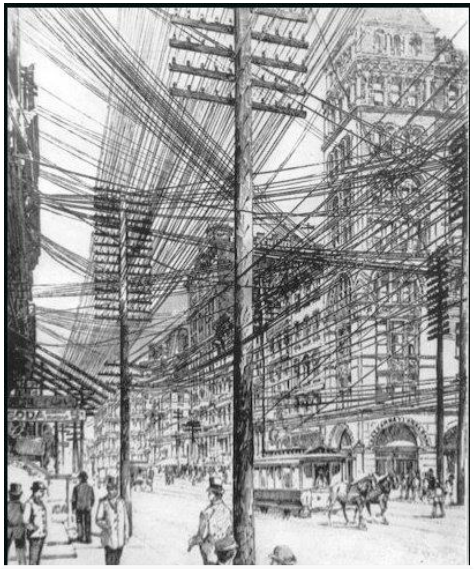
- Distance Relaying Philosophy



Examples Where It Depends

- Distance Relaying Challenges
  - System Design & Connected Equipment

- Multi-terminal lines
- Tapped distribution transformer
- Line terminated by transformer
- Series-compensated line



1890 NYC – CHAOTIC OVERHEAD POWER LINES

1910 NYC – SAFER UNDERGROUND POWER LINES

Examples Where It Depends

- Distance Relaying Challenges
  - Mutual coupling in parallel lines
    - Fault study with contingency to determine reach
    - Reduce Zone 1 reach & increase Zone 2 reach
    - Set zero-sequence compensation

PARALLEL SINGLE-CIRCUIT LINES

DOUBLE-CIRCUITS ON A TOWER

  - Time Coordination
    - Depends on adjacent protection schemes

Examples Where It Depends

- CT Ratio Selection Considerations
  - CT size (rating and class)
  - CT burden
  - Fault currents

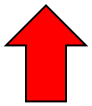
  - Maximum load
  - Relay application
  - Relay elements sensitivity

Examples Where It Depends

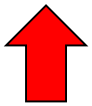
CTR Selection for Distribution Line OC Protection

Line Loading	675 A, pri	Relay Rating	5 A, sec
EOL Phase Fault	313 A, pri	Relay Minimum Tap	0.5 A, Sec
EOL Ground Fault	117 A, pri	Maximum CTR	1200/5 A

	Maximum CTR = 240	Reduced CTR = 120
Line Loading →	675/240 = 2.81 A, sec	**675/120 = 5.62 A, sec**
Phase Faults →	313/240 = 1.30 A, sec	313/120 = 2.61 A, sec
Ground Fault →	**117/240 = 0.49 A, sec**	117/120 = 0.98 A, sec



Ground fault below relay minimum tap of 0.5A, sec



Phase Pickup Below Load

Examples Where It Depends

- Breaker Failure Protection Design
  - Cost
  - Equipment
  - Bus Configuration
  - System Topology
  - Redundancy
  - System stability
  - Communication
  - Local philosophies

Breaker Image - electrical-engineering-portal.com

Examples Where It Depends

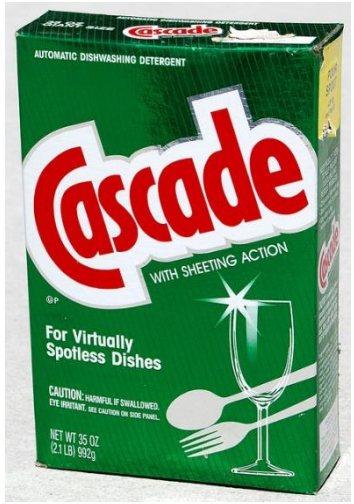
- Breaker Failure Relay Settings
  - Factors to consider

Critical Clearing Time (CCT)
Trip Timer
Active Control Timer
Fault Detectors
BF Initiate
Re-trip
Reset

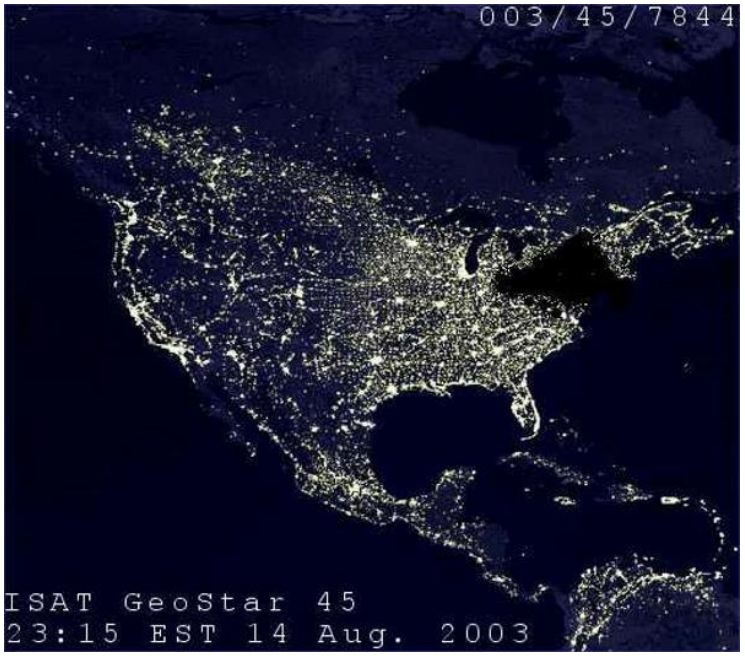
Breaker Image - hydroworld.com

Examples Where It Depends

- Load Encroachment and NERC PRC-023
  - Why do we have PRC-023?



  - August 2003 Blackout
  - Load Encroachment
  - NERC PRC-023 Methodologies



“It Depends” is a Valid Answer

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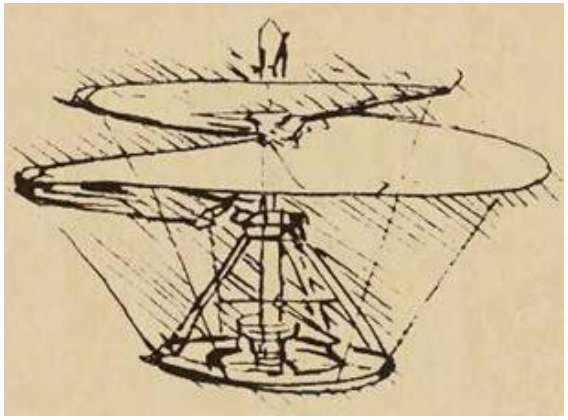
The noblest pleasure is the joy of understanding. –
Leonardo Da Vinci



DaVinci helicopter and Mona Lisa

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