Requirements for a Real-Time Risk Monitoring Tool to Reduce Grid-Plant Vulnerabilities

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PSAM6 Conference

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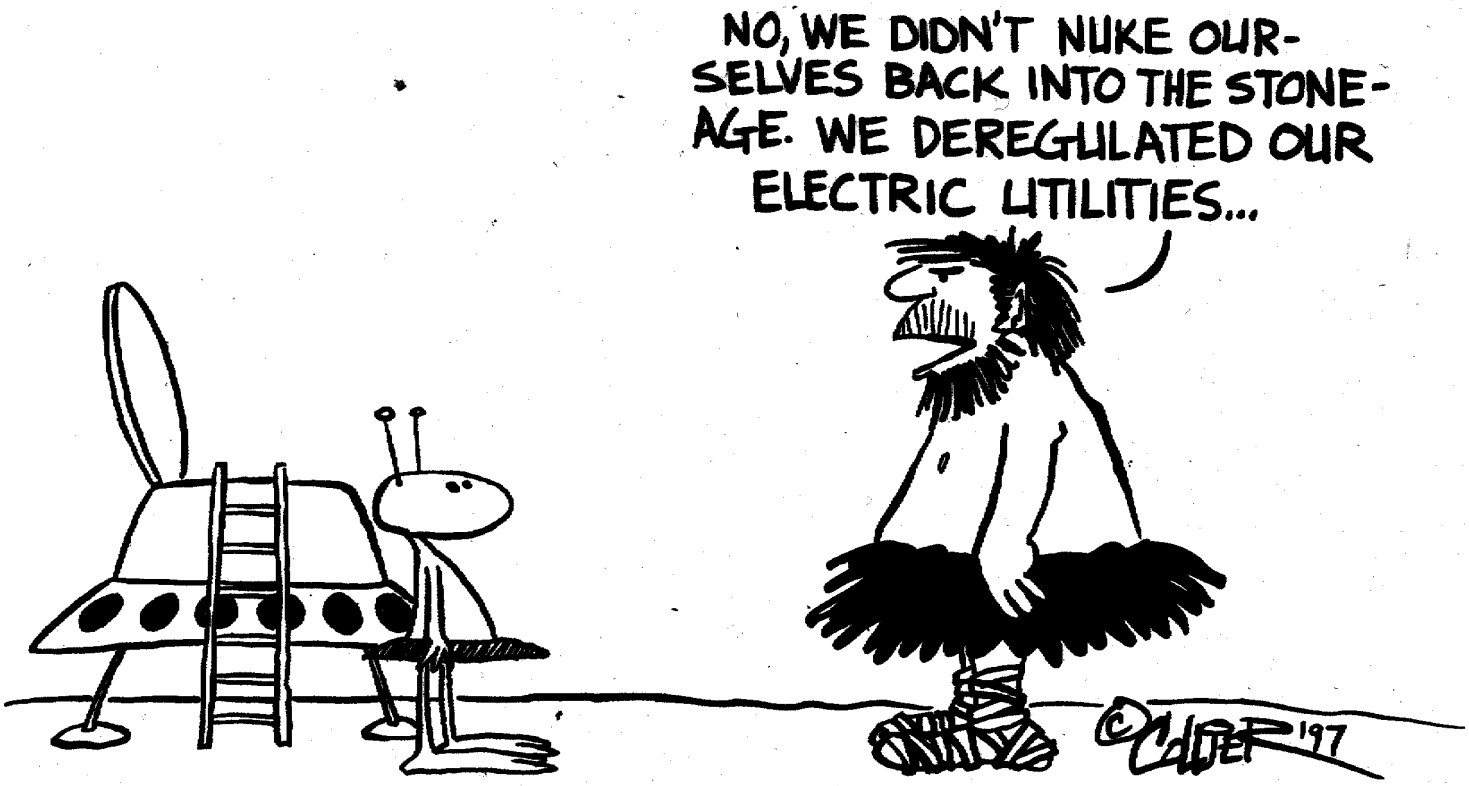

NO, WE DIDN'T NUKE OUR-
SELVES BACK INTO THE STONE-
AGE. WE DEREGULATED OUR
ELECTRIC UTILITIES...
©CALDER '97

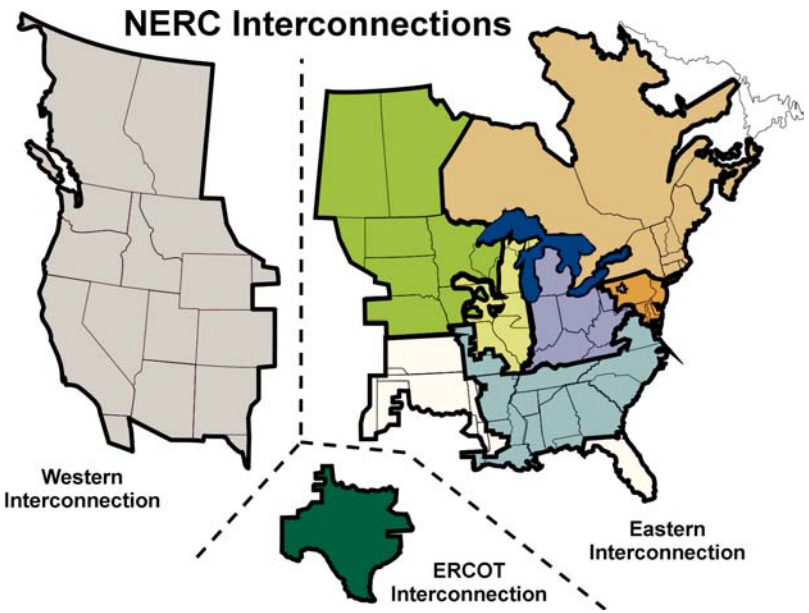
Objectives of a Grid Probabilistic Risk Assessment (PRA)

- Identify WHY a risk tool is needed
- Determine WHAT are the requirements of a real-time grid PRA tool
- Determine HOW to model the entire transmission system

Importance of a Real-Time Risk Tool

Major disturbance on the western grid occurred on Dec. 14, 1994

- Line fault in Idaho tripped a major 345-kV line
- Within ~40 s, three other 345-kV lines tripped
- Seconds later, three 500-kV lines in California tripped on overload
- Diablo Canyon 1 & 2 tripped
- 30 high-voltage lines, 29 plants, and 7000 MW(e) of load tripped
- Western grid splits into four islands



Why

- Problems on the transmission system affect nuclear power plants (NPPs) and customers (i.e., safety and economic concerns)
- Contingency analyses do not provide probabilistic measures of grid security
- Dynamic PRA-based models integrate plant operations with grid operations and conditions

Operating Experience Review of NPPs Found Numerous Adverse Grid-Plant Interactions

- Licensee Event Reports (LERs) for all nuclear power plants
  - High-voltage distribution systems
  - Plant transients
  - Actuations of engineered safety features
- Electric Power Research Institute
  - EPRI reports
  - Personal communication

He Said . . .

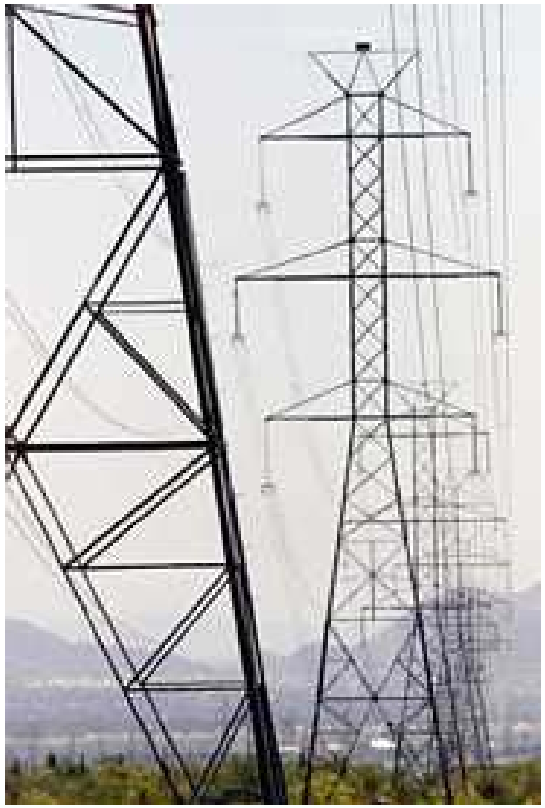
I'm sorry, I love you.

She Read . . .

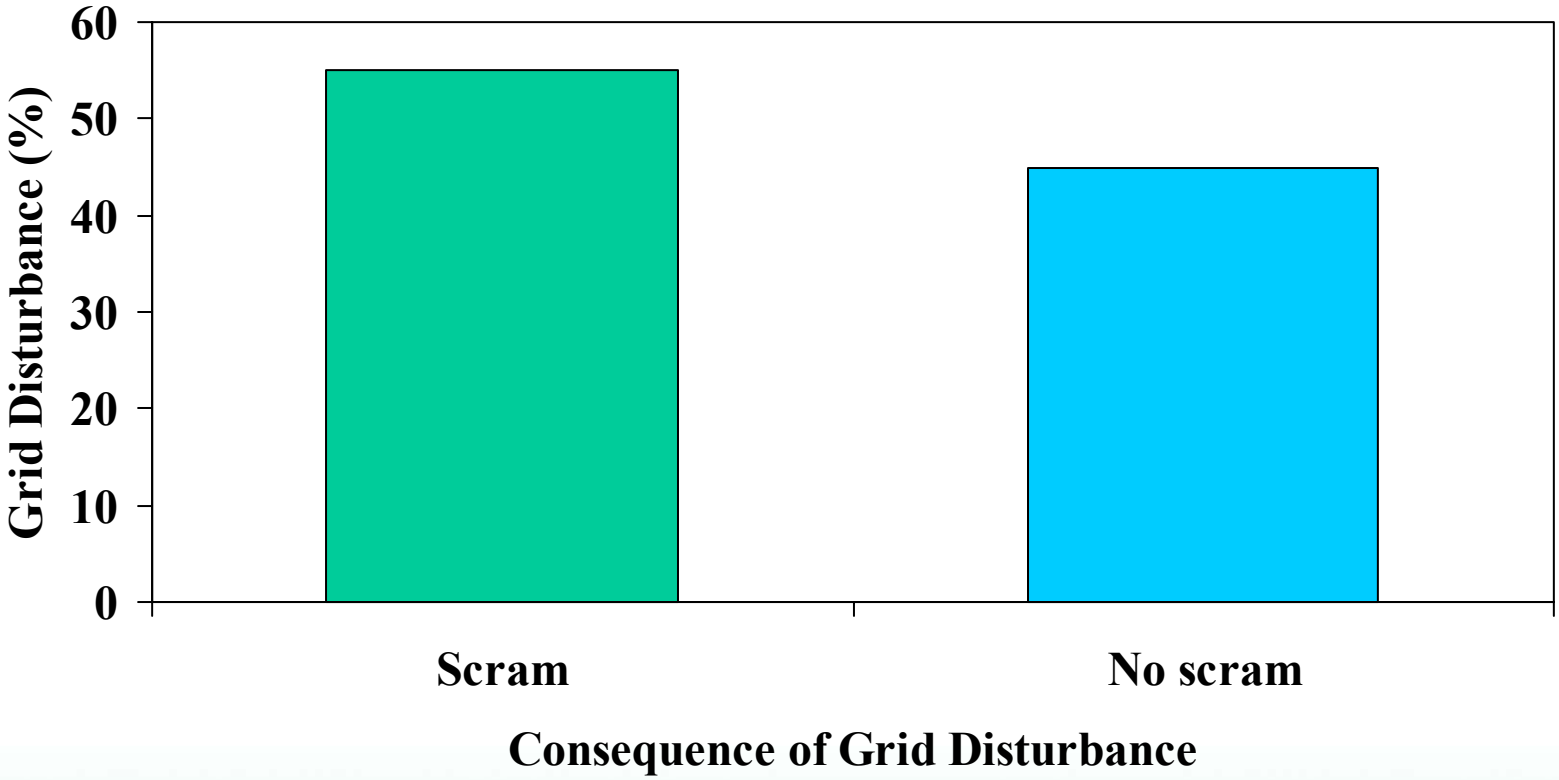
I'm sorry I love you!

Grid Issues to Include in Vulnerability Assessments

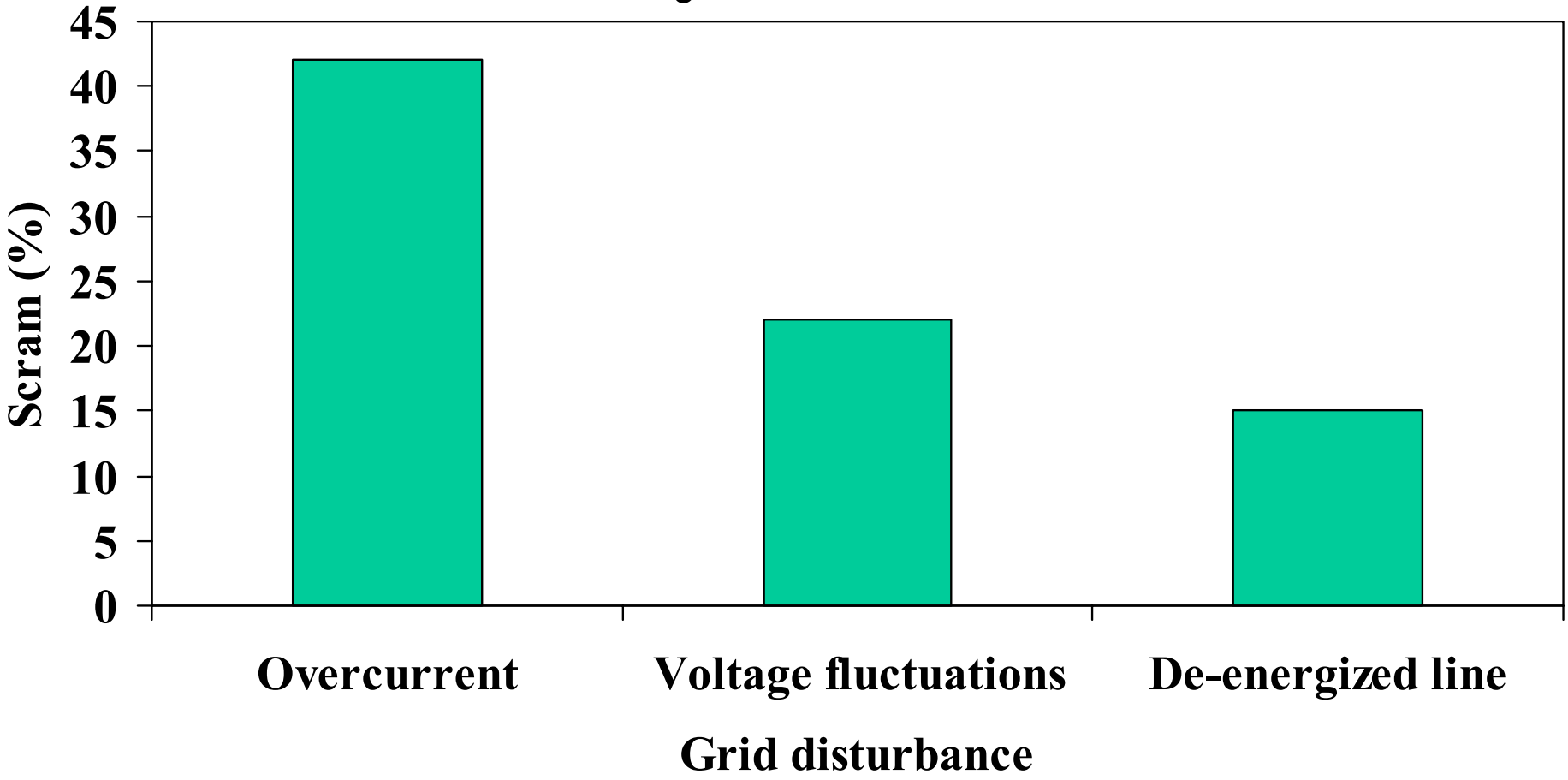
- Grid conditions
- Types of grid disturbances
- Causes of grid disturbances
- Individual power lines and equipment



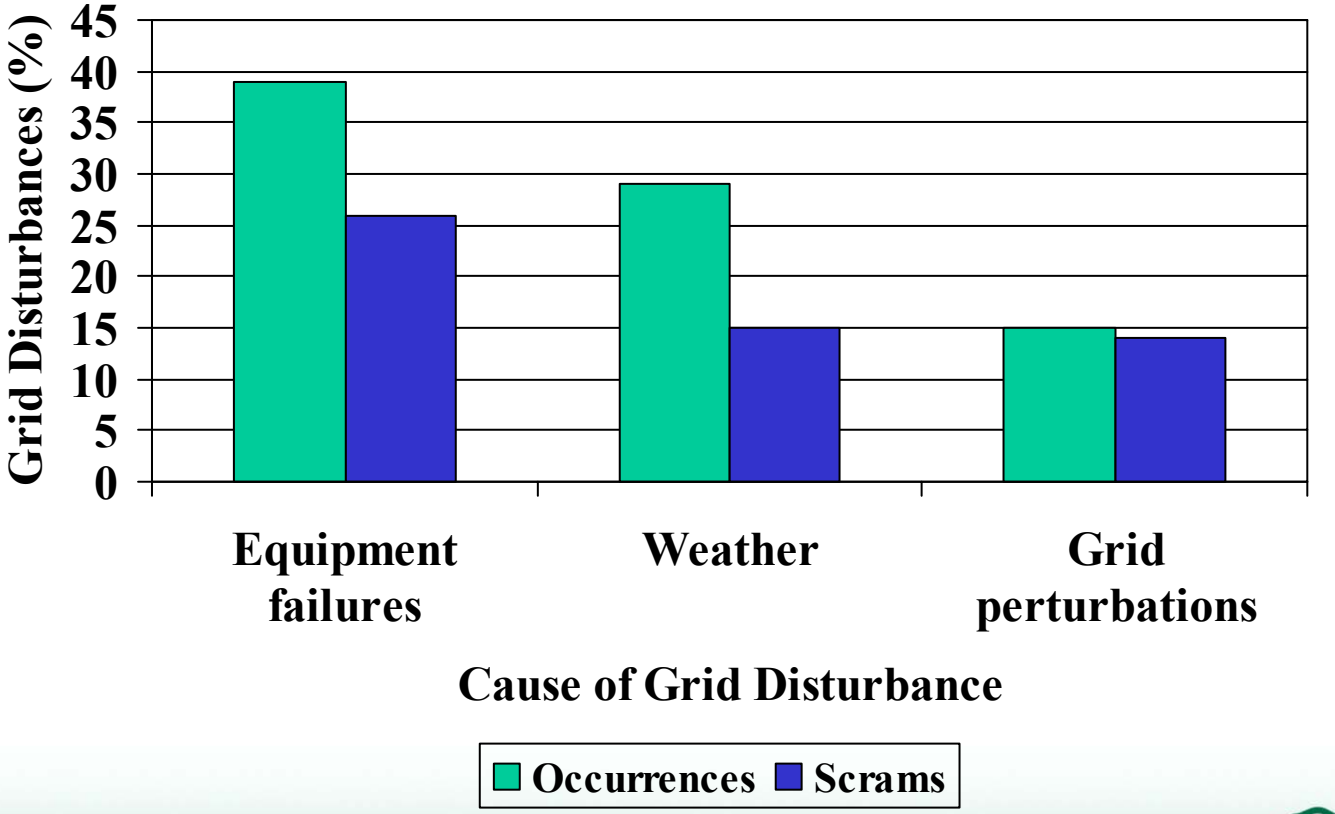
About ½ the Grid Disturbances Caused a Scram



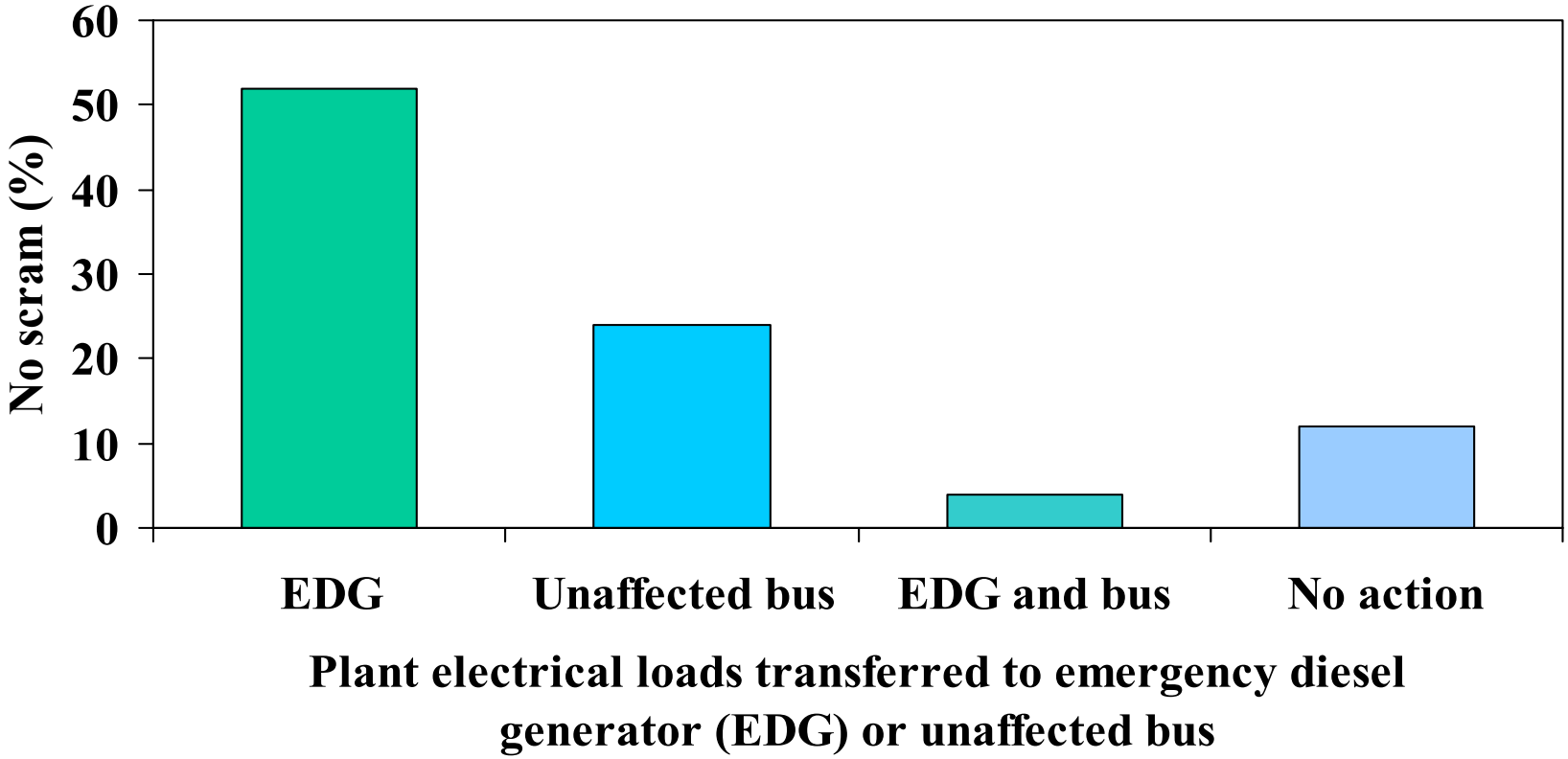
Grid Disturbances Affect the Safety of NPPs



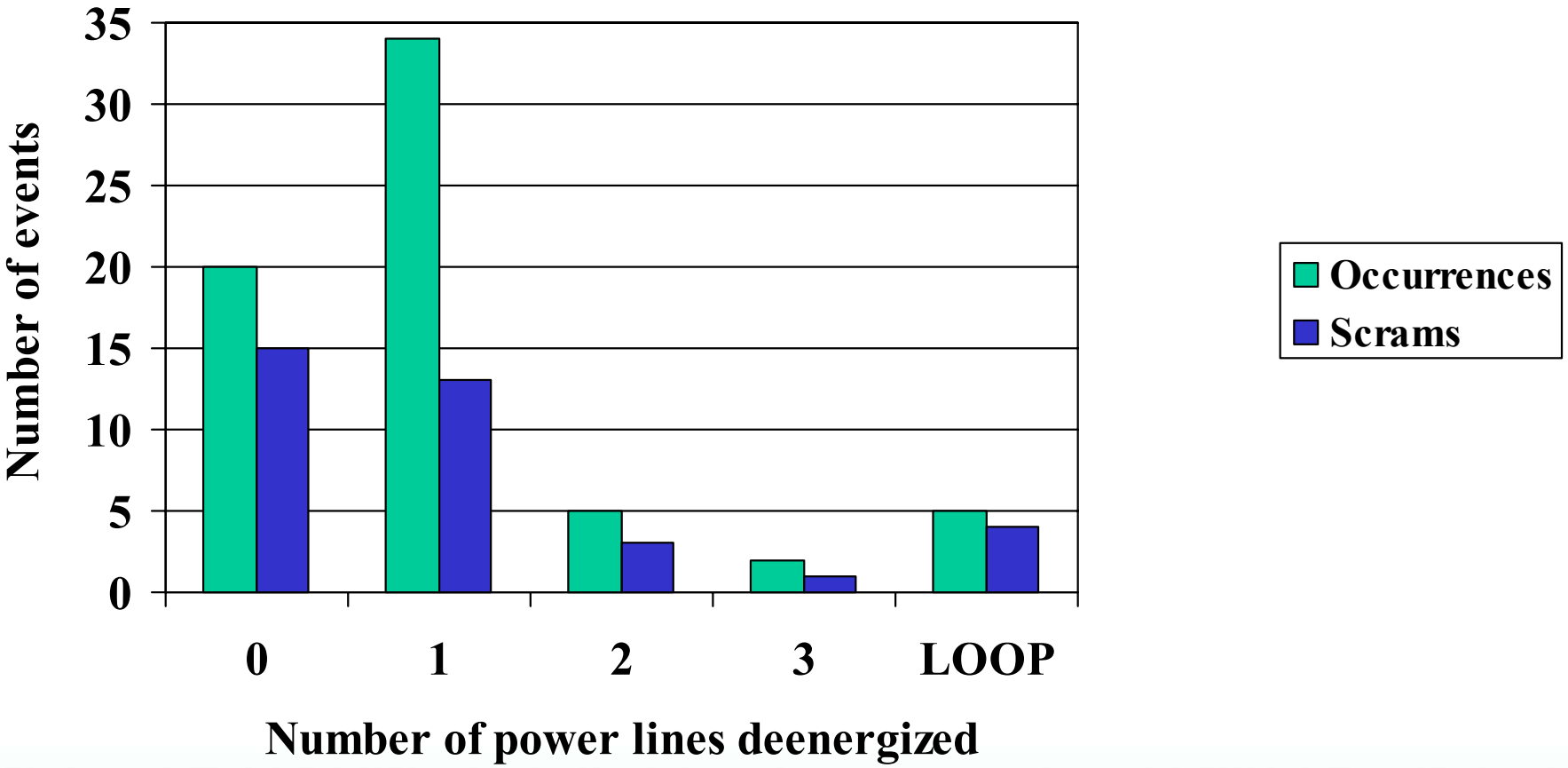
Causes of Grid Disturbances That Affect NPPs



Action Taken by NPPs to Prevent a Scram

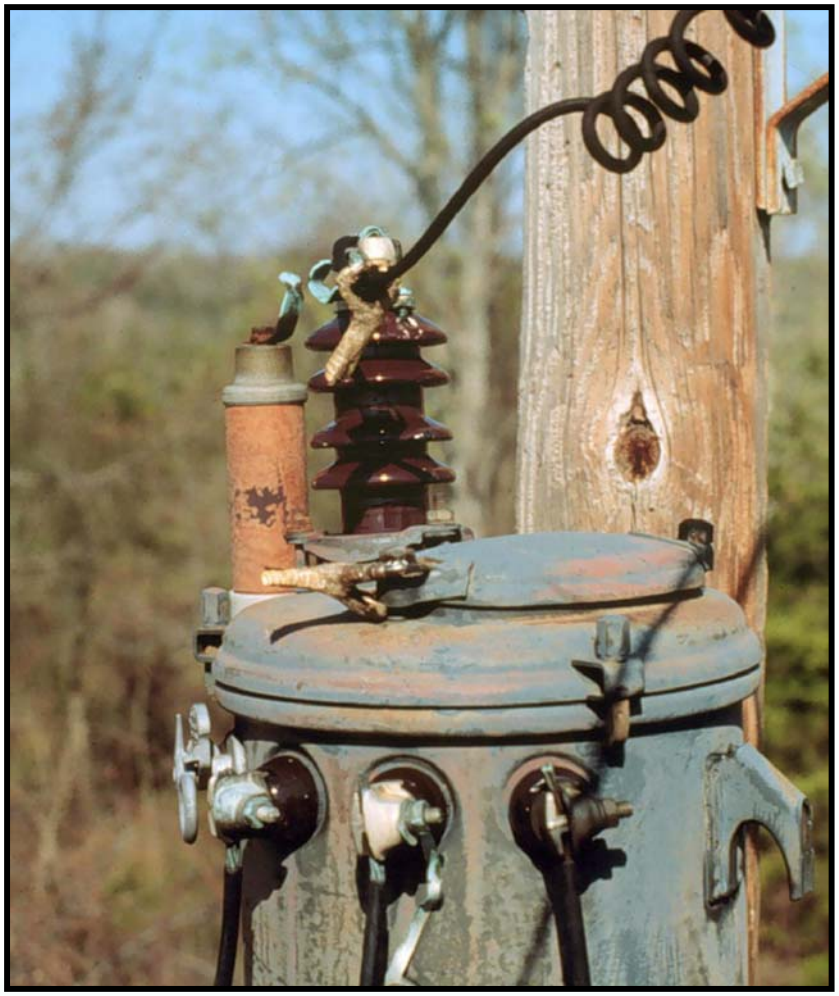


Traditional Focus on LOOPs Misses ~90% of the Problem



Grid Performance Affects the Safety of NPPs

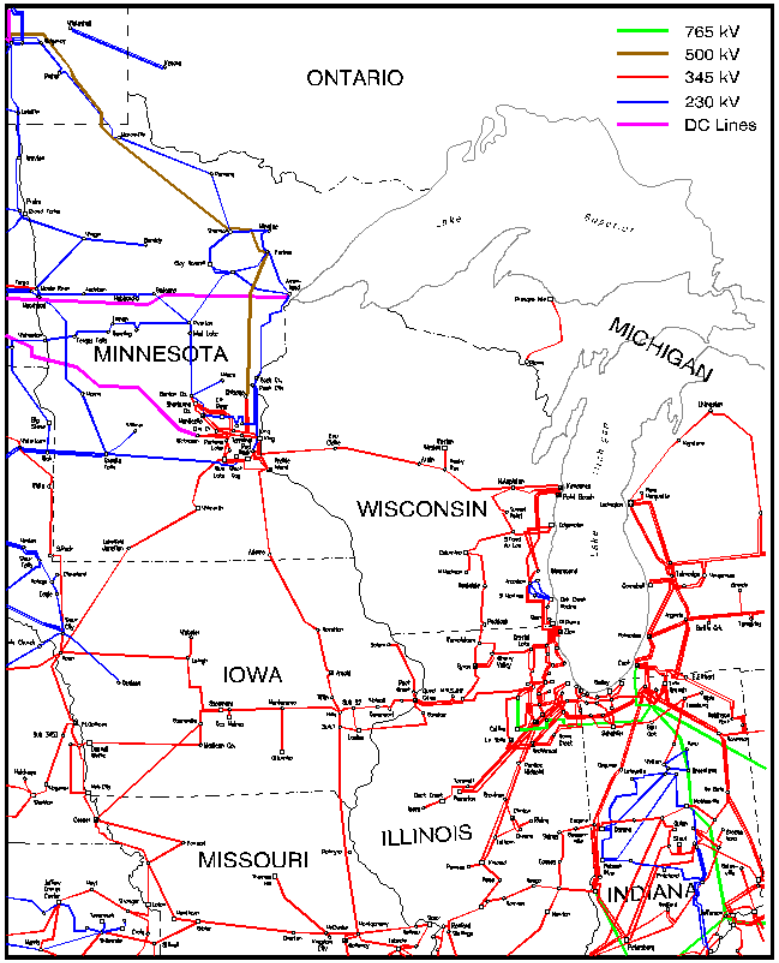
- About ½ the grid disturbances reported in LERs caused an NPP to scram
- Scrams are most likely caused by overcurrent (42%), voltage fluctuations (22%), or deenergized line (11%)
- Causes of grid disturbances are equipment failures on the grid (47%), weather (28%), and grid perturbations (25%)
- Scrams are typically prevented by transferring loads to an EDG (52%) or an unaffected bus (24%)
- Traditional focus on LOOPs misses ~90% of the problem



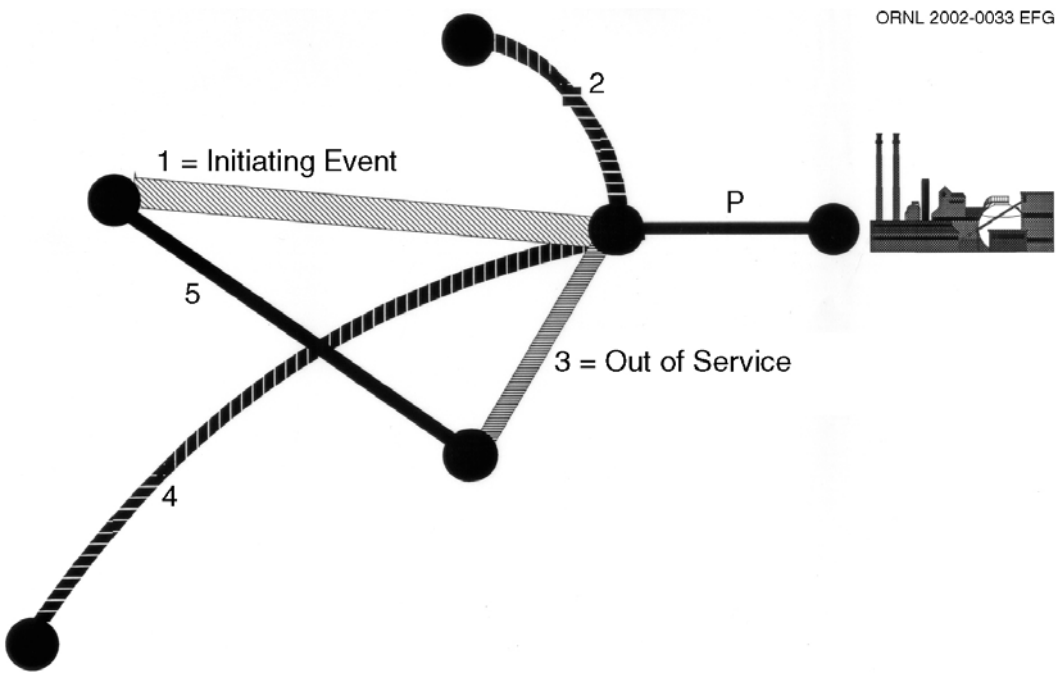
Model Considerations

- Plant-specific conditions
- Failure probabilities of individual lines and equipment
- Transmission lines and equipment out-of-service or undergoing repair
- Not only loss of power, but degraded conditions too
- Voltage, current, and frequency fluctuations
- Different failure rates for different conditions (e.g., weather, power flows)
- Constantly changing grid conditions

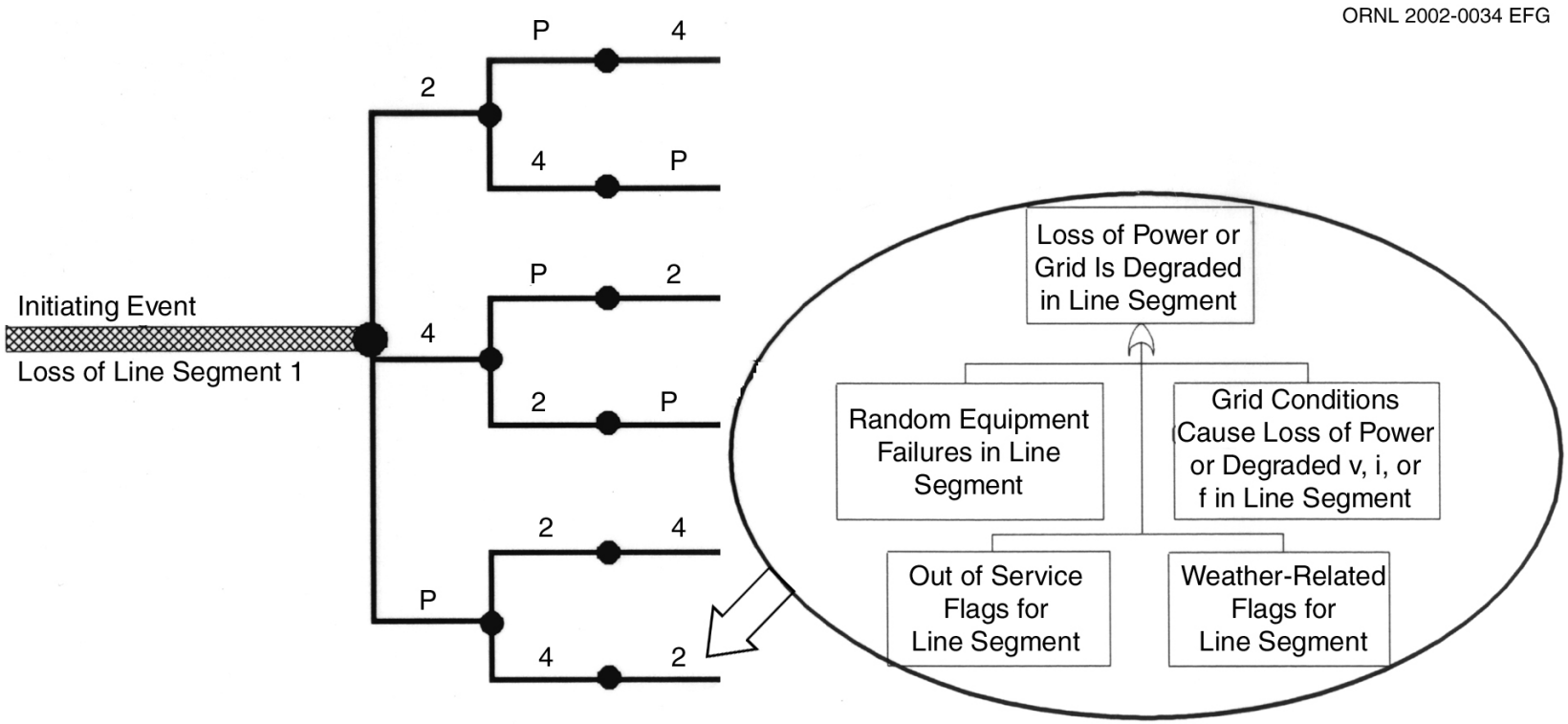
Where Do You Start?



Electrically Interconnected Transmission Line Segments



Risk Model of Interconnected Transmission Line Segments



Increase in Risk Easily Evaluated

- Transmission line outages and plant outages automatically incorporated
- Differences in system operators, weather, plants, etc., incorporated into model
- Failure probabilities change as system conditions change
- System "learns"

Risk Tied to Operations

- Characterize likelihood of moving from stable to unstable network configuration (probability)
- Provide network metrics for effects of losses (risk)
- Test mitigation strategies and corrective actions

Benefits of a Real-Time Risk Monitoring Tool

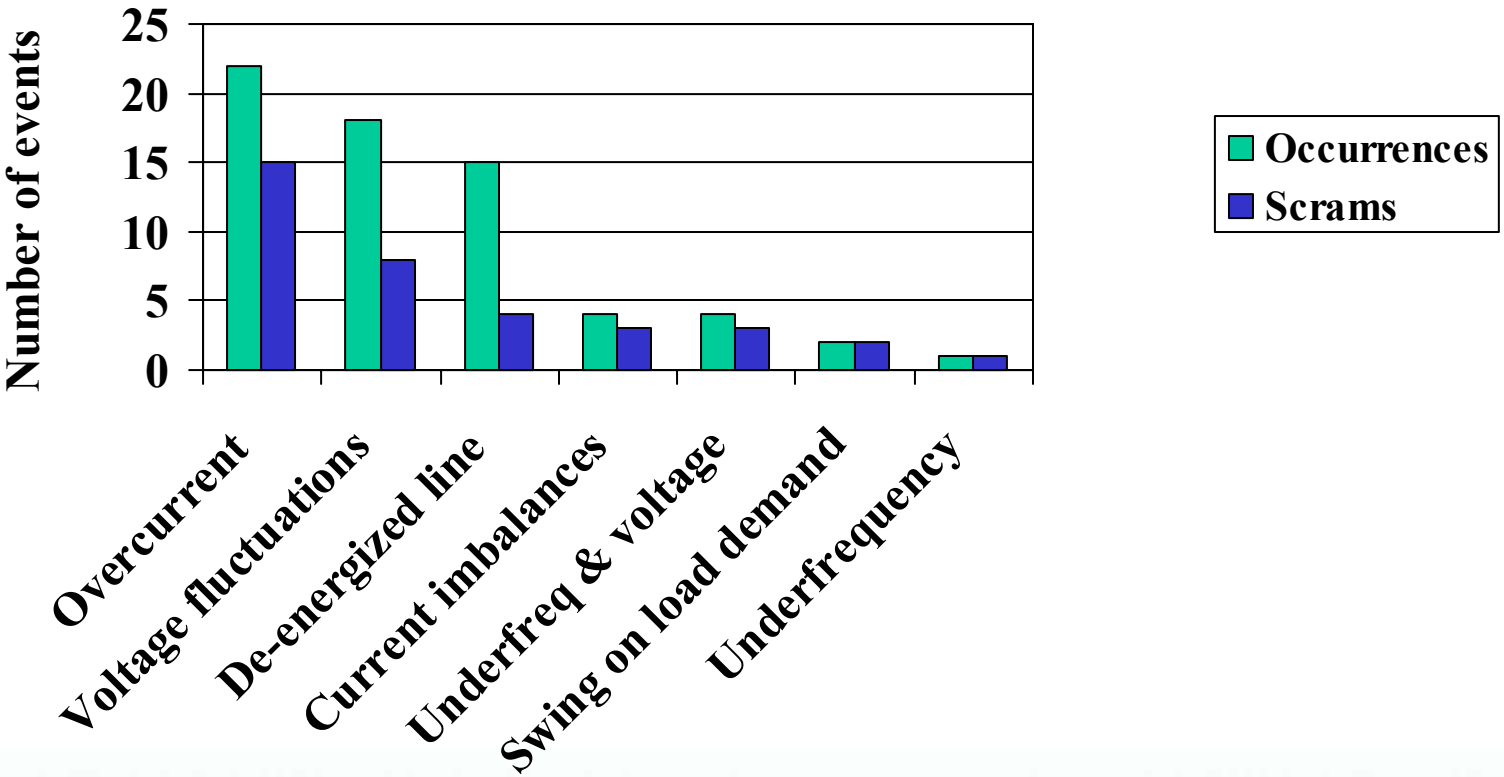
- Reduce the likelihood of a transient at a power plant
- Reduce the likelihood of an event cascading throughout the grid
- Reduce the economic consequences to generators, system operators, and the public

All slides after this point are extra slides to support the question and answer session

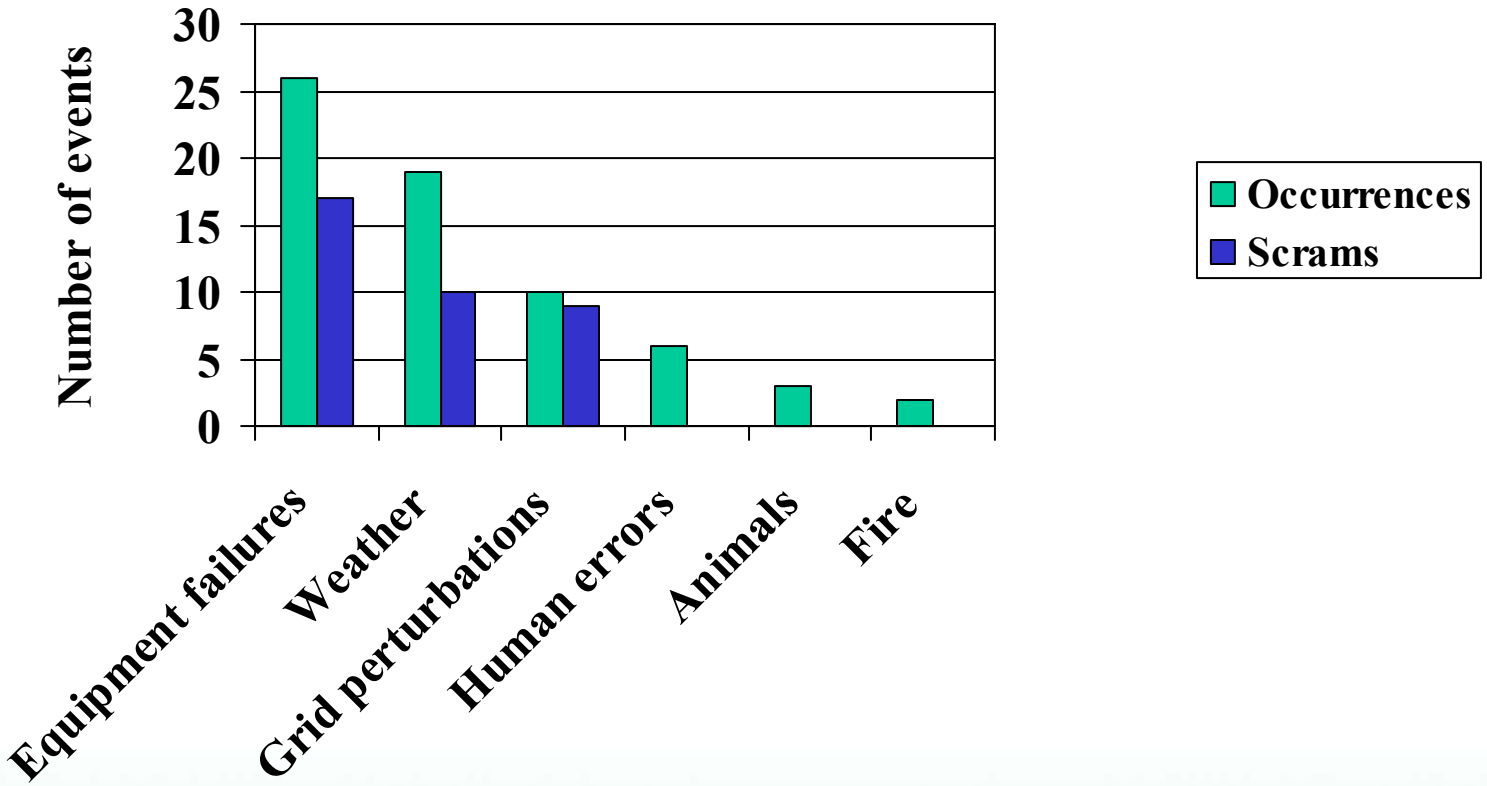
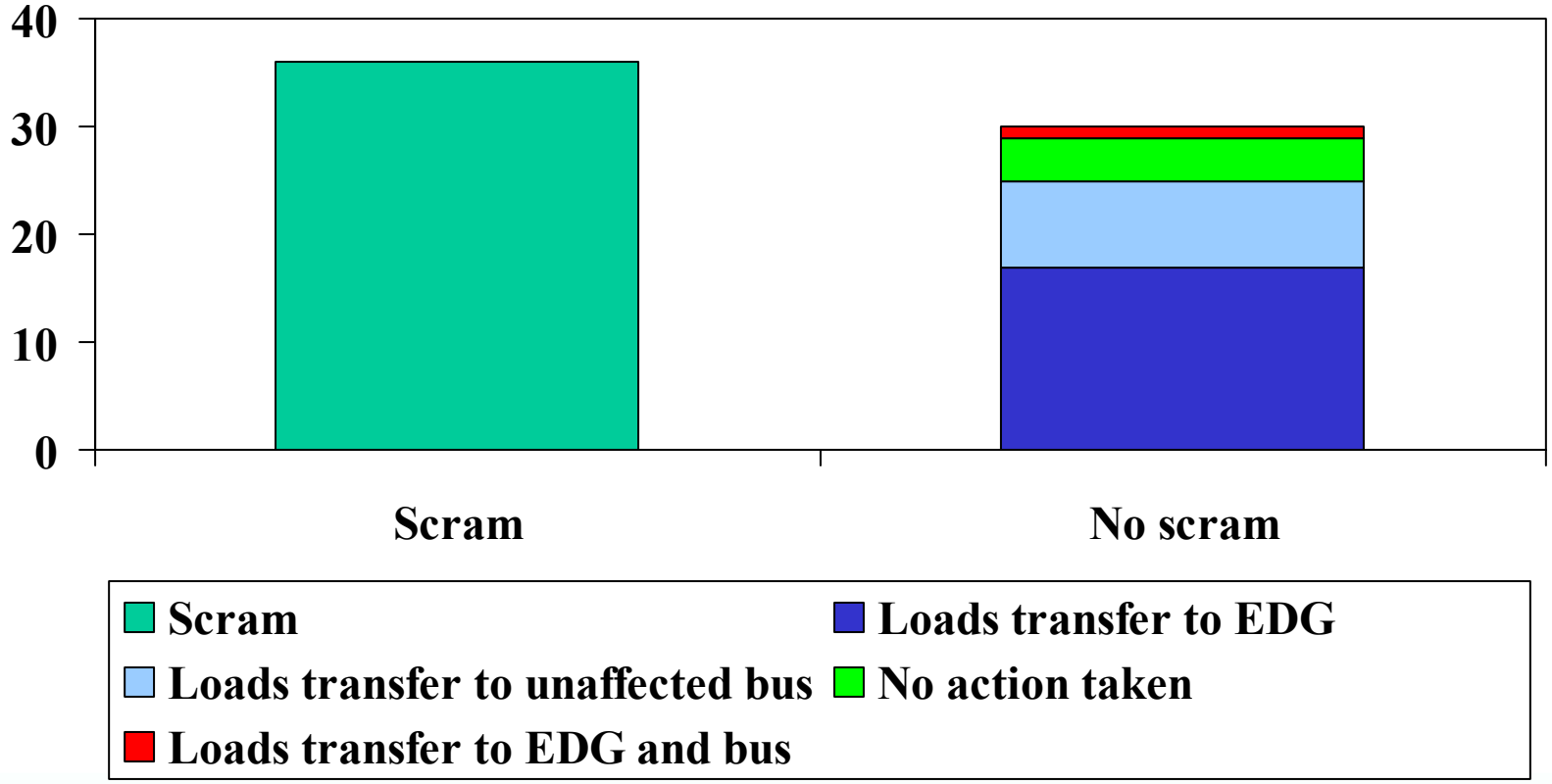
Not covered in Grid Model

- Operating conditions that exceed previously analyzed conditions (what if . . .)
- Plant-centered disturbances and loss of offsite power (LOOP) events

Grid Disturbances Affect the Safety of NPPs



Causes of Grid Disturbances That Affect NPPs



Action Taken by NPPs After a Grid Disturbance Occurs