Significant Operating Experience Report (SOER) 99-1 “Loss of Grid”

SOER 99-1 “Loss of Grid”

- SOER issued in late 1999 because of events associated with loss of grid
- intent of the SOER recommendations is to help ensure barriers that protect nuclear plants from grid loss or degradation are in place (five recommendations)

Evaluation of SOER Implementation

- **began in June 2000**

  55 stations evaluated thus far
  - 16% of the recommendations are in progress
  - 82% of the recommendations are implemented
  - five recommendations at five different stations are not satisfactorily implemented
- **all stations to be evaluated (June 2002)**

Identified Weaknesses

- five recommendations at five different stations not satisfactorily implemented
  - Interface procedure and procedure implementation weaknesses existed at two stations.
  - A procedure was not in place at one station that addresses placing the plant in safe condition when significant threats to grid stability exist (night order in place).
  - One station had not completed review of the preventive maintenance for plant substation equipment.
  - One station had not completed simulator training on degraded voltage.

Recommendations in Progress

- updating interface agreements and guidance
- updating procedures to address degraded grid conditions
- maintenance responsibilities being updated because of restructuring and unbundling
- engineering analysis being updated and some design assumptions being verified with the grid
- training being developed and performed on degraded voltage and subsequent loss of grid

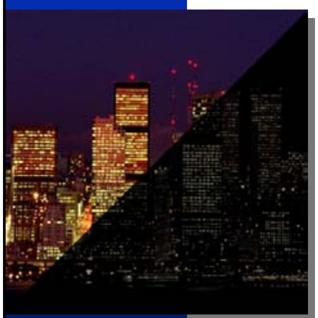
SOER 99-1 Implementation

- **conclusions based on evaluations**
  - Stations are actively addressing the SOER recommendations.
  - With few exceptions, the stations evaluated have completed implementation of the SOER recommendations or have satisfactory plans and schedules for completion.
  - Barriers that protect the stations from grid disturbances are in place. However, a few weaknesses in these barriers have been identified and are being strengthened.

Other Activities

- completed self-assessment in September 2001
- industry meeting in March
- update guidance as necessary
- continue to evaluate station implementation of the SOER

Discussion of LOOP Frequency and Degraded Grid Data



NEI / NRC Grid Reliability Meeting

Frank J. Rahn
Manager, PSA Applications
Stephen Lee
Area Manager, Power Delivery
March 15, 2002

EPRI Report 1002987
Losses of Off-Site Power at US Nuclear Plants - Through 2001

Single Year LOOP Events while at-power
-per generating unit year

Year	# of Events	Total Unit Calendar Years	Losses per Gen. Unit Year
2001	1	103	0.01
2000	1	103	0.01
1999	2	103	0.02
1998	3	103.2	0.03
1997	4	106.4	0.04
1996	5	108.0	0.05
1995	2	107.2	0.02
1994	0	107.0	0

*** because there are few LOOP events per year while on-line, and each adds 0.01 to the loss probability, the year to year experience will vary and can be be significantly impacted by the number of severe storms in a given year**

Loss of all Off-Site Power experience for Years 2000/1
-for events that occurred while at-power

- There was one LOOP event at U.S. nuclear plants while the plant was on-line during each year
  - Diablo Canyon 1 on 05/15/2000
    - The safety busses were without power for over 33 hours
    - The cause of the loss was an indoor 12 kV bus connection failure and fire
    - The plant tripped from 100% power and the 3 EDGs started and loaded
  - Quad Cities 2 on 08/02/2001
    - Lightning strike 2 miles from the plant
    - Relaying problem cause reserve aux transformer to isolate
    - Off-site power was available through a cross-tie approx. 15 minutes later, although the plant stayed on EDGs for 2:34
- All other LOOP-related events that occurred in year 2000 were either partial losses of off-site power or occurred while the plant was in an outage

Longer term average of LOOP events while at-power -per generating unit year

AVERAGE FOR DESIGNATED RANGE OF YEARS

Range of years	Duration of LOOP	# of Events	Total Unit Calendar Years	Losses per Gen. Unit Year
5 years (1996-2001)	Longer than 30 Minutes	11	516.6	0.021
	Less than 30 Minutes	1		0.002
	Total	12		0.023
12 Years (1990-2001)	Longer than 30 Minutes	32	1271.2	0.025
	Less than 30 Minutes	7		0.006
	Total	39		0.031

Loss of all Off-Site Power experience for Years 2000/1 -for events that occurred while off-line

- There were 3 LOOP events while the plant was off-line during the year 2000
- These occurred at
  - Brunswick 1 on 03/03/2000
  - Farley 1 on 04/09/2000
  - Davis Besse 1 on 04/22/2000

Loss of all Off-Site Power experience for Year 2000
-for events that occurred while off-line

In the following 3 events, the plants were in a condition and configuration, and had activities underway, that would not be permitted when at power

- Brunswick 1 on 03/03/2000
  - Unit was in 6th day of a refueling outage
  - During relay trip testing, a switch positioning error resulted in a LOOP
  - The EDGs started and loaded. Off-site power was restarted after 9:09 hours while the operators investigated the situation, but could have been restored much sooner if needed.
- Farley 1 on 04/09/2000
  - Reactor was defueled
  - The protection relay was activated during panel cleaning and de-energized a bus
  - An EDG started and loaded. Off-site power was restored after 19 min.
- Davis Besse 1 on 04/22/2000
  - Reactor was defueled
  - The inservice startup transformer tripped-off when a technician opened the case of a mis-identified relay during bus transfer tests
  - The EDGs started and loaded. Off-site power was restored after 10 min.

IMPACT OF DEGRADED GRID ON LOOP EVENTS

Perspective

Industry and NRC Concerns

- Heightened awareness over potential transmission voltage instability and offsite power supplies due to:
  - Increased power transfers between regions
  - Lack of transmission capacity

The Reliability Challenge

- Increasing bulk power transactions strain grid capacity

- Grid expansion is not keeping up with growth. Incentives for expansion are lacking and Infrastructure needs to be upgraded.

- Deregulation and restructuring has increased the **uncertainty** of adequacy and security - data issues and looser control.

Recent Industry Steps Taken to Address Concerns

- INPO SOER 99-1
- Transmission Control Agreements
  - Impact of potential & subsequent loss of large generator
- Equipment upgrades and procedural changes to increase operating flexibility
  - Operational impact and measures to monitor for and address double sequencing, fast transfer problems, and voltage margin for starting large loads

Case Study - California 2001

CAISO Grid Operating Reserve Margin Events

	1998	*1999*	*2000*	*2001 (through 9/30/01)*
No Touch	8	12	77	**87**
Alert	7	2	34	**87**
Warning	8	6	85	**87**
Power Watch	-	-	0	**25**
Stage 1 Emergency	7	4	55	**53**
Stage 2 Emergency	5	1	36	**49**
Stage 3 Emergency	0	0	1	**36**

Stage 1 - Operating Reserve shortfall is unavoidable

Stage 2 - Operating Reserve shortfall of less than 5% is unavoidable

Stage 3 - Operating Reserve shortfall of less than 1 1/2 % is unavoidable

CAISO Grid Operating Reserve Margin Stage 3 Events

Month	No. of Hours in Stage 3 Emergency
January	392.8
February	384.0
March	14.4
April	----
May	3.6
June - December	----
YTD	795.9

Number of hours
CAISO Power Curtailments during Stage 3 Events

Although CAISO System spent many hours in Stage 3, actual power curtailments were limited and highly localized All curtailments were carried out in a controlled manner per pre-established ISO procedures

CAISO Stage 3		796 Hrs
PG&E	Non-Firm	233
	Firm	23
SCE	Non-Firm	202
	Firm	16
SDG&E	Non-Firm	200
	Firm	16

*** largest single hour curtailment of firm power on the entire CAISO system (including CDWR) was 1307MW at 10:00am on 01/18/2001. Most curtailments of firm power were a few hundred MWs**

Transmission Control Agreements (TCAs)

- Contract between SCE, SDG&E, PG&E and CAISO
- San Onofre and Diablo Canyon 'grid specs' have been incorporated into the TCA
- Operation of grid according to TCA improved grid reliability and operability after deregulation
  - meets NERC, WSCC, Local Reliability Criteria (TCA) and NRC criteria
  - in event of LOOP, priority return to service for nuclear plants
  - immediately communicate impaired/potentially degraded grid conditions

CAISO Grid Operating Strategy

- Although 2001 summer peak was below expectations due to cool weather severe operating conditions occurred in winter/spring due to lack of capacity
- Load was curtailed according to protocol in an orderly manner
  - first non-firm
  - next firm
  - critical ‘blocks’ were protected from service cutoff
- Year To Date there are zero instances of:
  - voltage sag
  - frequency below 59.6 Hz

Effects of 2001 California Grid Conditions on Nuclear Units

- SONGS
  - Unit 3 was out of service for an extended period following the fire event
  - No known issues that would have impacted the plant response to a Unit 2 trip, transient, or accident
    - Stations did not receive any “Degraded Voltage Notifications’ from load dispatcher
    - The station under-voltage protection system was upgraded in the early ‘90s
    - There are 9 transmission lines into the station providing widely diverse sources of off-site power

Effects of 2001 California Grid Conditions on Nuclear Units

- Diablo Canyon
  - Risk management policy for Stage 3, including
    - treating 500kV system as a trip risk
    - treating 230 kV system as a degraded trip mitigation system
    - 3 EDGs per unit were kept on high readiness
    - resulting operational decisions impacted maintenance
  - Prior preparations effectively executed
    - rolling blackouts provided sufficient reserve margin and capacity
    - CA ISO met its TCA commitments
    - Transmission lines into the station providing widely diverse sources of off-site power from both northern and southern, insulated from ‘Path 15’ issues
    - Analysis confirmed appropriate performance consistent with operational risk management policies

Power Delivery Initiative

- Closer relationship between EPRI and NERC
- Closer relationship between EPRI and EEI
- Closer relationship with nuclear power industry

Industry Initiatives
To Enhance Transmission System Reliability

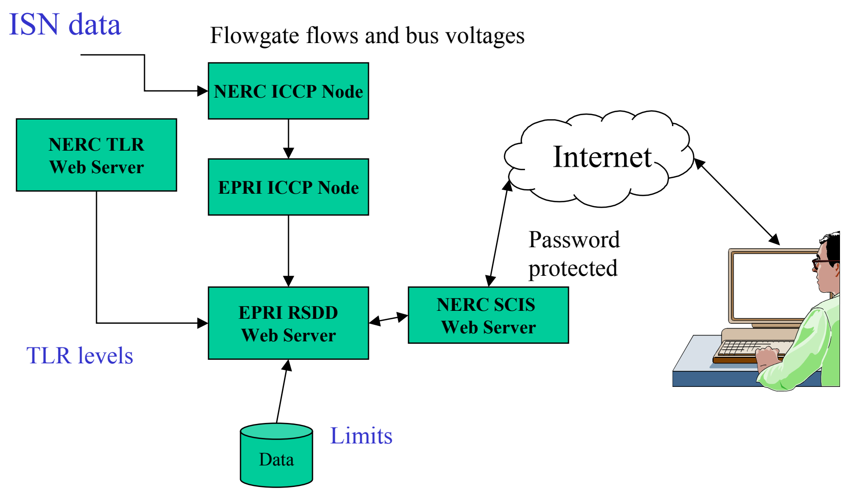
Objectives:

- Understand root causes of recent T&D system outages
- Identify and provide tools to minimize the risk of reliability disturbances
- Address Physical Security

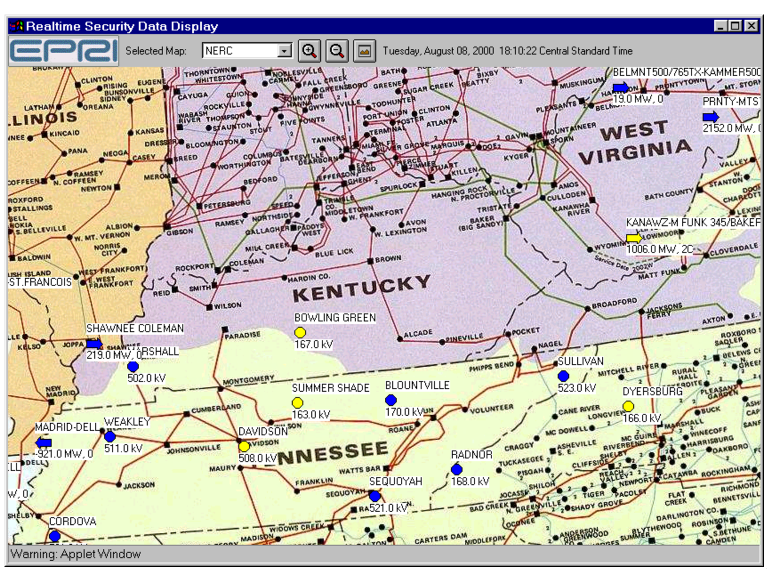
Real-time Security Data Display (RSDD)

- Purpose - to provide a bird's eye view of the grid reliability over a wide area (up to entire N. America)
- Data Displayed:
  - Flowgate flows and congestion status
  - Voltages at up to 300 buses
- Color code (Red, Yellow and Blue)

RSDD - System Architecture



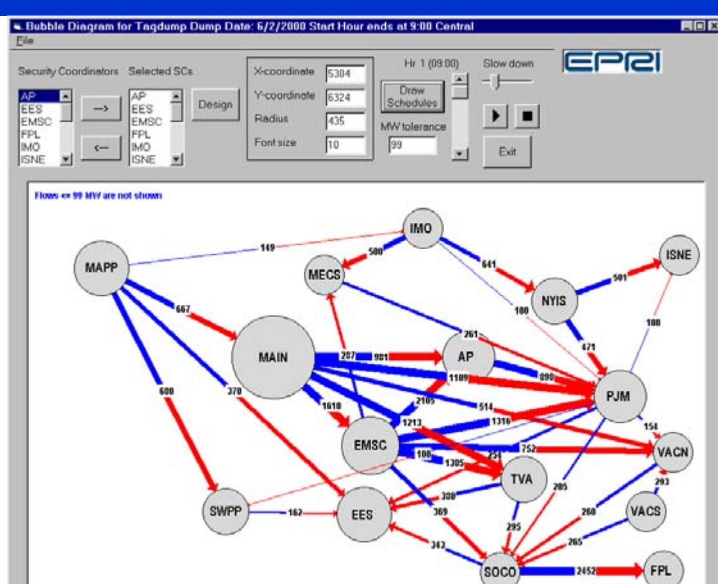
Sample Screen of RSDD

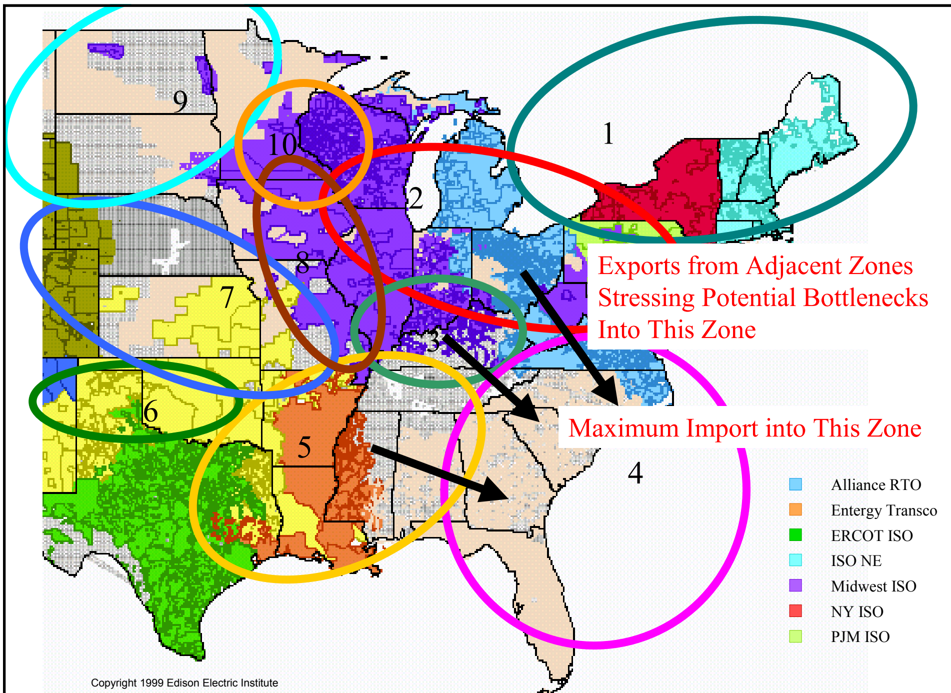


Tag Dump Program

- Purpose - to aggregate the historical and prospective E-tags into inter-regional total interchange schedules
- **Applications** -
  - To perform operational planning studies (e.g., for the next hour)
  - To compute system congestion for next hour or next da

Tag Dump - Bubble Diagram





Power Delivery PRA Study Conclusions

- Results
  - Voltage levels were of most concern
  - Load growth has a greater impact than transfers
  - Adding capacitors alleviate voltage constraints
- Probability indices provide useful insight to conditions and constraints that most impact transmission reliability

Applications of PRA

- Determining the relative impact of variables allow planners to identify the most effective reinforcements
- Reliability indices of adjacent areas can be compared to determine impact on combined area.
- Can be used in transmission operations analyses to prioritize critical contingencies and identify weak points for monitoring.
- Allows system operators to identify risks associated with transmission constraints

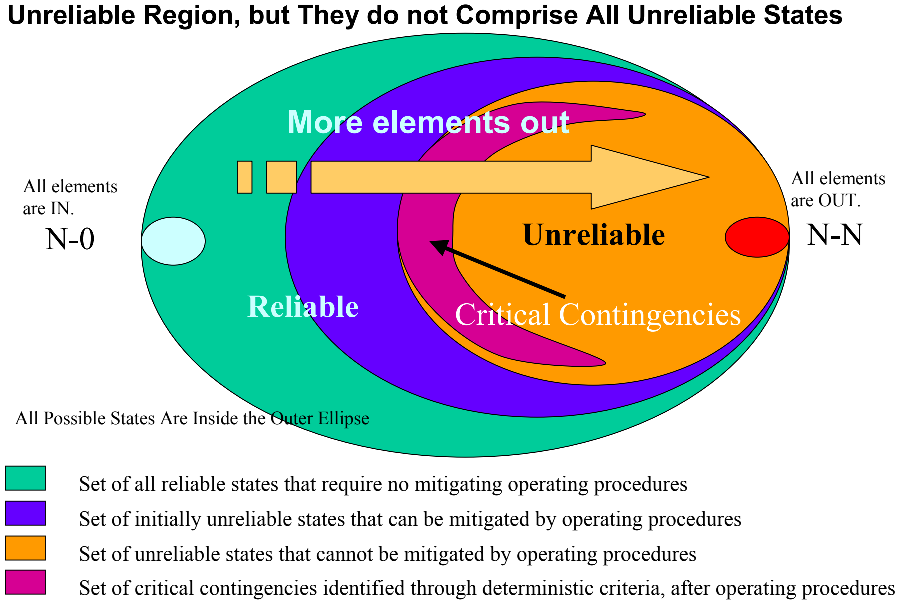
Definition of Risk / Reliability Index

- Risk/Reliability Index = Probability x Impact
- Probability is the probability of experiencing the Impact, that is, the probability of the contingencies that cause the Impact
- Impact is measured by severity
  - Thermal overload (MW)
  - Voltage violation (% V deviation from limit)
  - Voltage stability
  - Dynamic stability

Principle of Reliability Indices

- Voltage Index = Probability x (Deviation of voltage in p.u. below 0.92 p.u.) summed over outage situations and summed over buses with violations
- Overload Index = Probability x (Deviation of MVA/MW over the thermal rating) summed over outage situations and summed over branches with violations
- Voltage Stability Index = Probability x (Situations with voltage instability) summed over outage situations

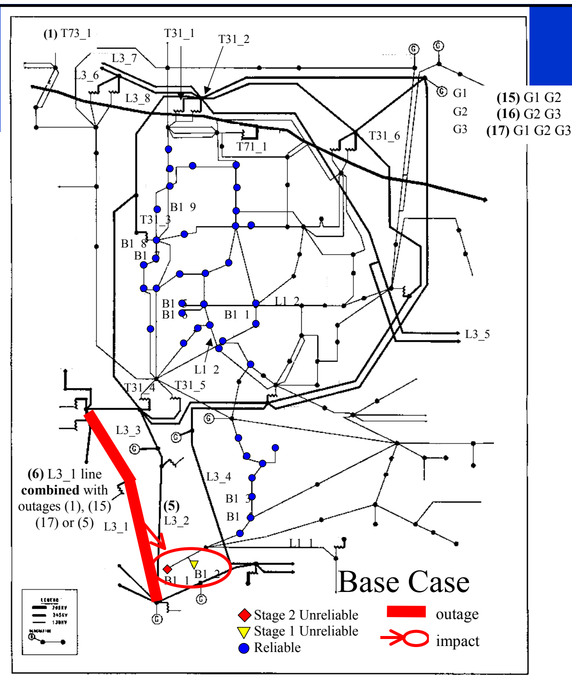
Deterministic Critical Contingencies Define a Boundary Between the N-0 and the N-N State to Separate the Reliable Region from the Unreliable Region, but They do not Comprise All Unreliable States



Determine Weak Points

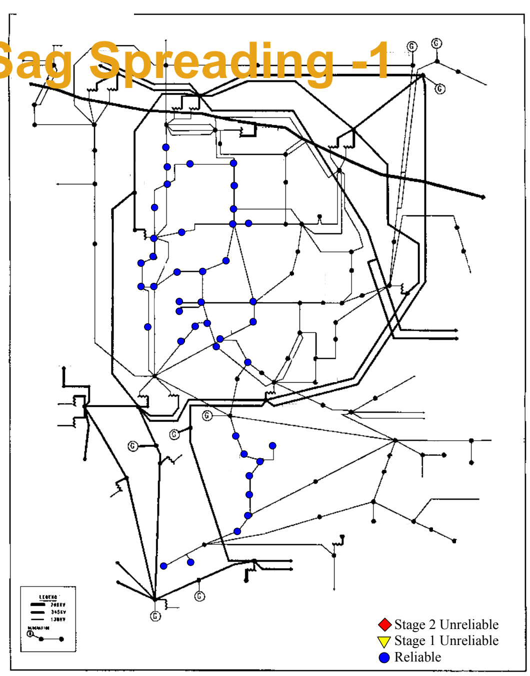
- Identification of the Buses where Voltage is most Unreliable

The measure of Unreliability is based on both occurrence probability and magnitude of violation



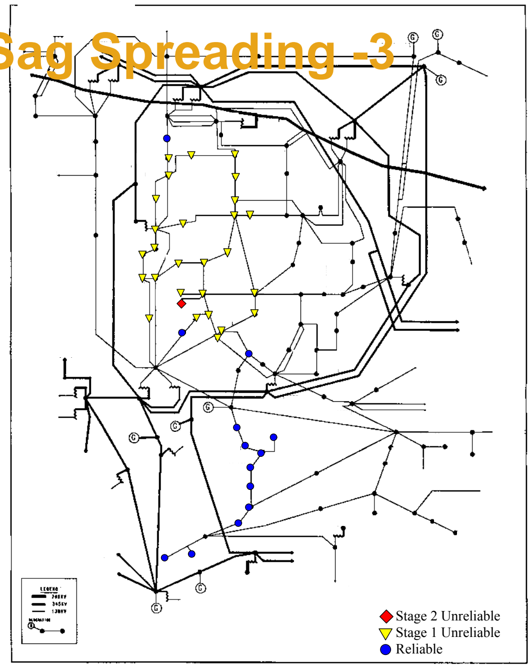
Voltage Sag Spreading -1

Load Level: +400MW



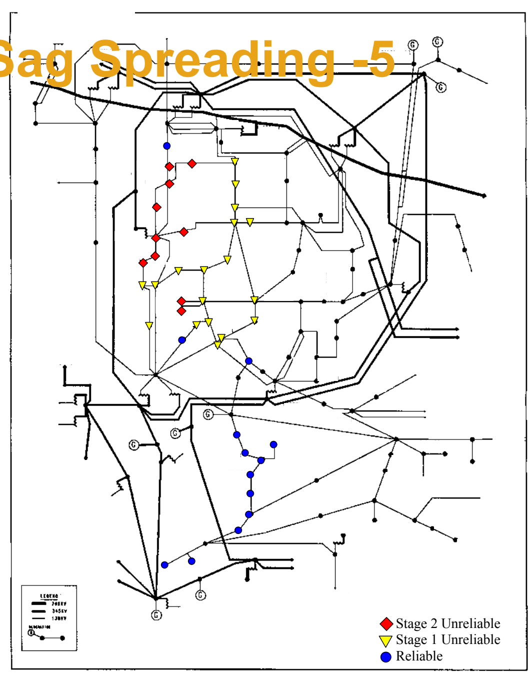
Voltage Sag Spreading -3

Load Level:
+600MW



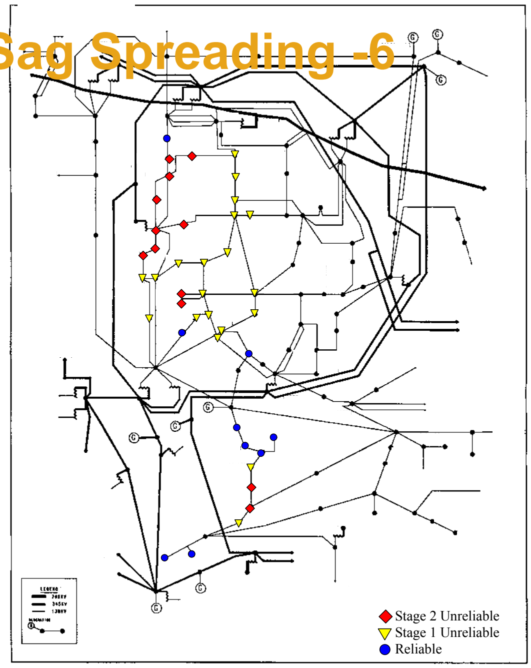
Voltage Sag Spreading -5

Load Level:
+900MW



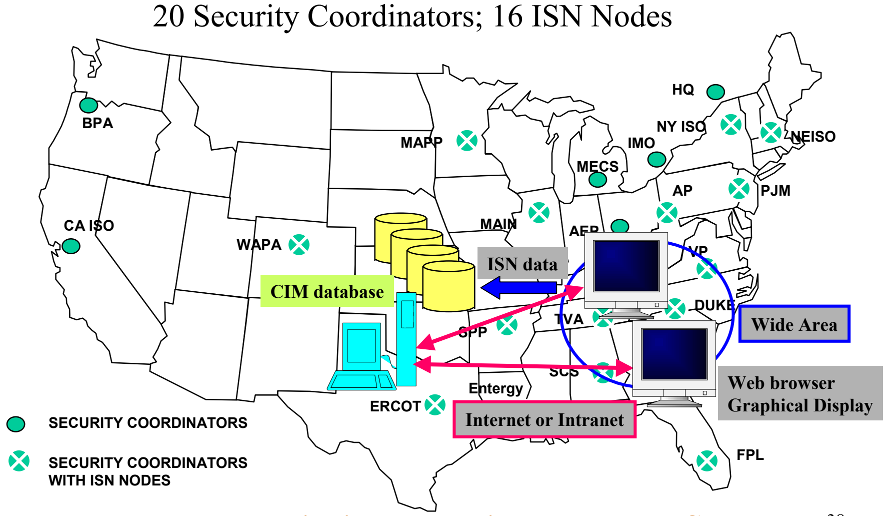
Voltage Sag Spreading -6

Load Level:
+1200MW



Wide-area Security Monitoring and Display (WSMD)

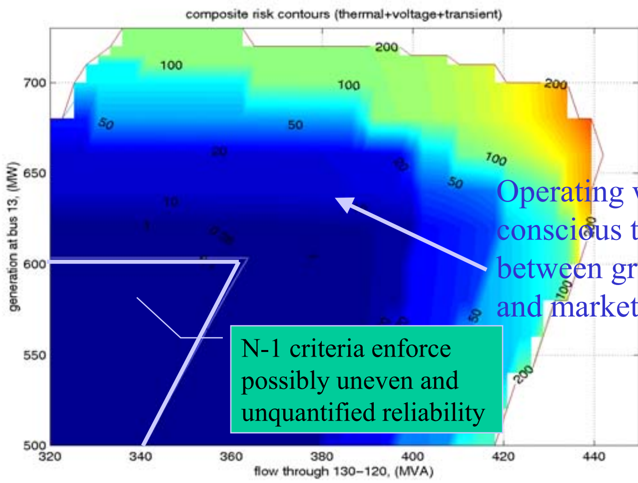
20 Security Coordinators; 16 ISN Nodes



The communication network is known as NERCnet

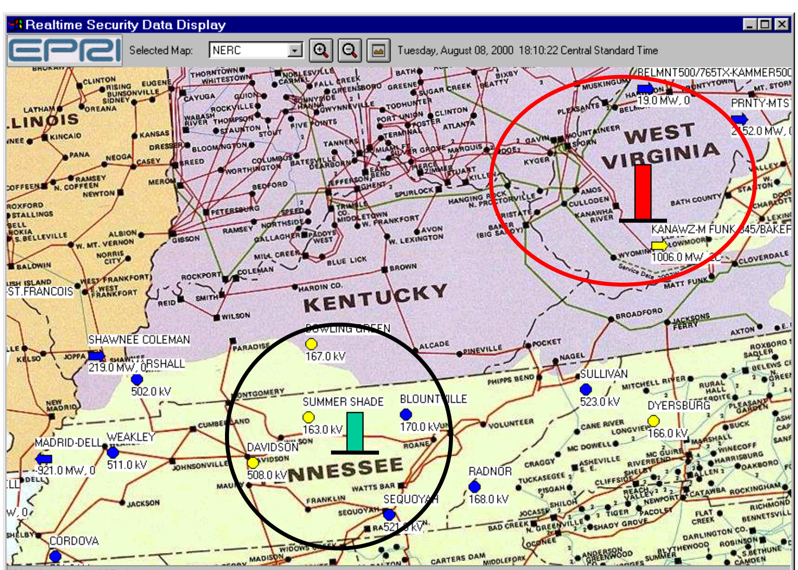
PRA Risk Contours

Market Activities Affect Reliability

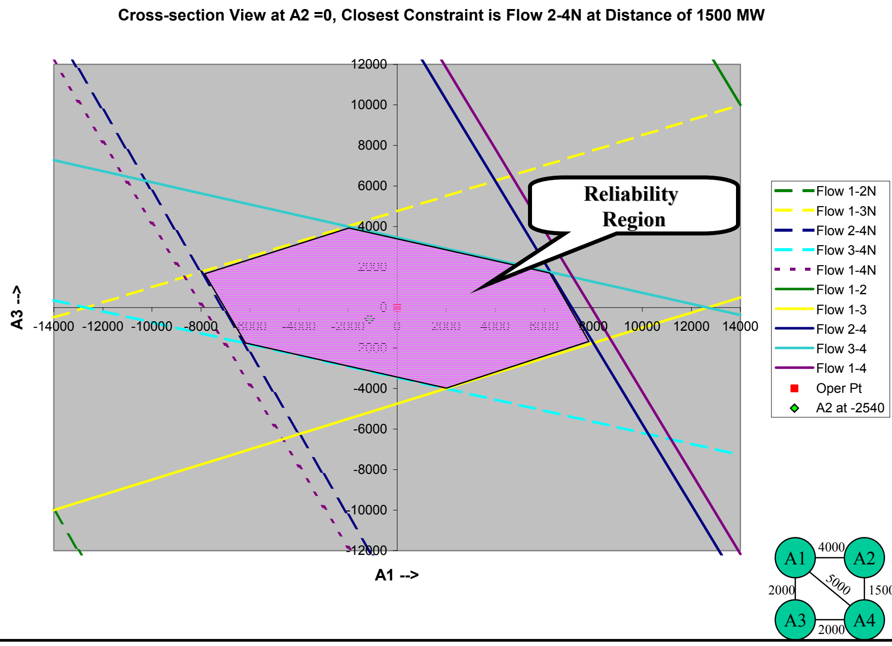


Operating with conscious tradeoff between grid reliability and market efficiency

"On-line" Probabilistic Reliability Indices Displayed by Zone - Concept



Concept of Displaying Reliability Region with TagNet Data

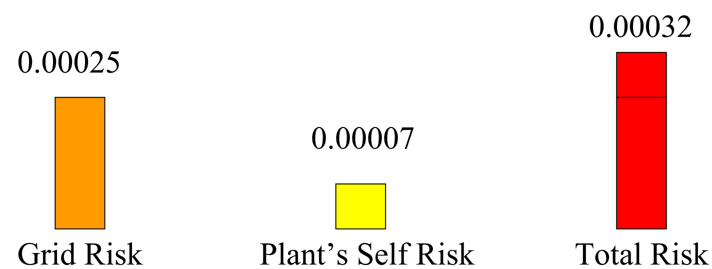


VRI (Voltage Reliability Indices) from Grid's PRM

- Grid PRA model provides critical grid contingencies (branches or generators) that would result in Degraded Voltage at the nuclear plant's switchyard, their probabilities and their voltage degradations
- Grid PRA model can also provide the post-contingency voltage at the switchyard given a loss of nuclear unit at the plant
- These two sets of data may define a risk index of LOOP for the plant

Critical Contingencies

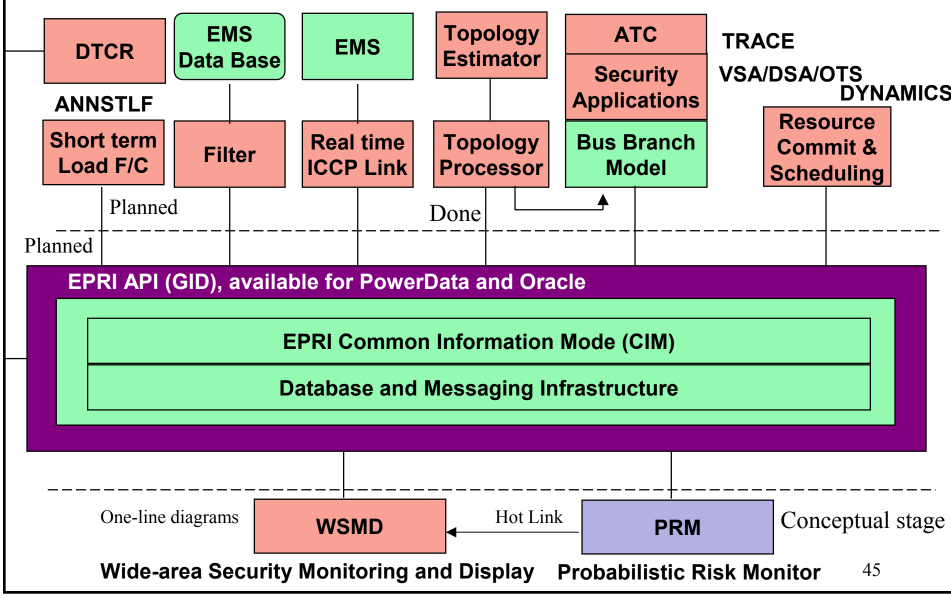
Contingencies	Probability (P)	Voltage drop below Degraded (I)	Risk (PxI)
1	0.01	0.02 pu	0.0002
2	0.001	0.05 pu	0.00005
Total Grid			0.00025
Loss of unit	0.001	0.07	0.00007
Total Risk			0.00032



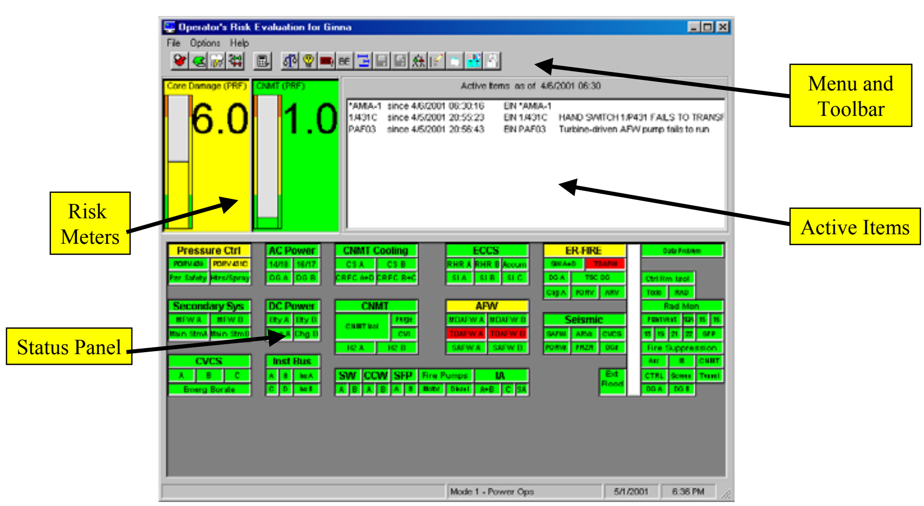
Interface between Plant Trip and Grid Security Monitors

- Sponsored by joint DOE / EPRI funding
  - A plant trip meter, based on EOOS, has been developed by the Risk and Reliability Users Group
    - Plant Metrics
    - Modeling Needs
    - Displays
  - A software interface between the TRIP MONITOR and the Grid PRA
    - Specifications have been developed
    - Prototype software exists
    - Considering pilot sites

Flexible Open Architecture for Application/Data Integration Using CIM



EOOS Operator Screen



Reactor Trip Monitor Objectives

- Augment current R&R Workstation capabilities
  - EOOS, Safety Monitor
- Provide initial consideration of safety and economic indicators
- Provide key risk parameters
  - Probability of a trip or runback in the next "x" hours
  - Instantaneous trip frequency
  - Expected generation loss in MWH and revenue ($$)
  - Important initiators and plant configurations/conditions
- Additional specific objectives
  - Communicate with transmission grid providers to prevent LOOP/Voltage events
  - Address cost-benefit-risk issues associated with plant upgrades

Occurrences where offsite event initiated on the grid affected NPPs (i.e., events initiated OUTSIDE of NPP and its switchyard)

Number

1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
8	10	13	10	9	5	2	6	4	67

Number of offsite lines without power to NPP

0 lines	1 line	2 lines	3 lines	LOSP	Total
18	36	5	3	5	67

NSSS vendor

B&W	CE	GE	W	Total
3	4	28	32	67

Region

1	2	3	4	Total
29	8	11	19	67

Source ORNL Project

Summary of scrams or trips caused by offsite disturbances

Result	Cause of "TRIP"	Plant "sees"	Full or partial LOOP
Scram or trip (36)	Equipment (18)	Overcurrent (11)	1 line (6)
			0 lines (3)
			2 lines (2)
		Current imbalance (3)	1 line (2)
			0 lines (1)
		Voltage drop (2)	0 lines (2)
		Undervoltage (1)	1 line (1)
		Voltage fluctuation (1)	1 line (1)
	Grid perturbation (9)	Undervoltage (2)	0 lines (2)
		Undervoltage / underfrequency (2)	0 lines (2)
		Overcurrent (2)	1 lines (2)
		Swings on load demand (2)	0 lines (2)
		Underfrequency (1)	1 lines (2)
	Weather (9)	Power lost (3)	LOSP (2)
			3 lines (1)
		Overvoltage (2)	0 lines (1)
			1 line (1)
		Voltage fluctuation (2)	LOSP (2)
		Undervoltage (1)	2 lines (1)
		Voltage drop (1)	1 line (1)

Source ORNL / NEPO Project

Conclusions

- 2001 LOOP experience lower than, but consistent with, 10-year average of 0.03 losses per generating year
- Recent experience with degraded transmission grid environment suggest that INPO recommendations and ISO/RTO protocols to protect nuclear units are working (both for voltage support and LOOP)
- Industry is taking proactive steps to increase the reliability of the transmission grid