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EE 521: Analysis of Power Systems

Lecture 23
Power System Security

Fall 2009

Mondays & Wednesdays 5:45-7:00

August 24 – December 18

Test 216

Topics

- Power System States
- Total Transfer Capability
- Available Transfer Capability
- Blackout

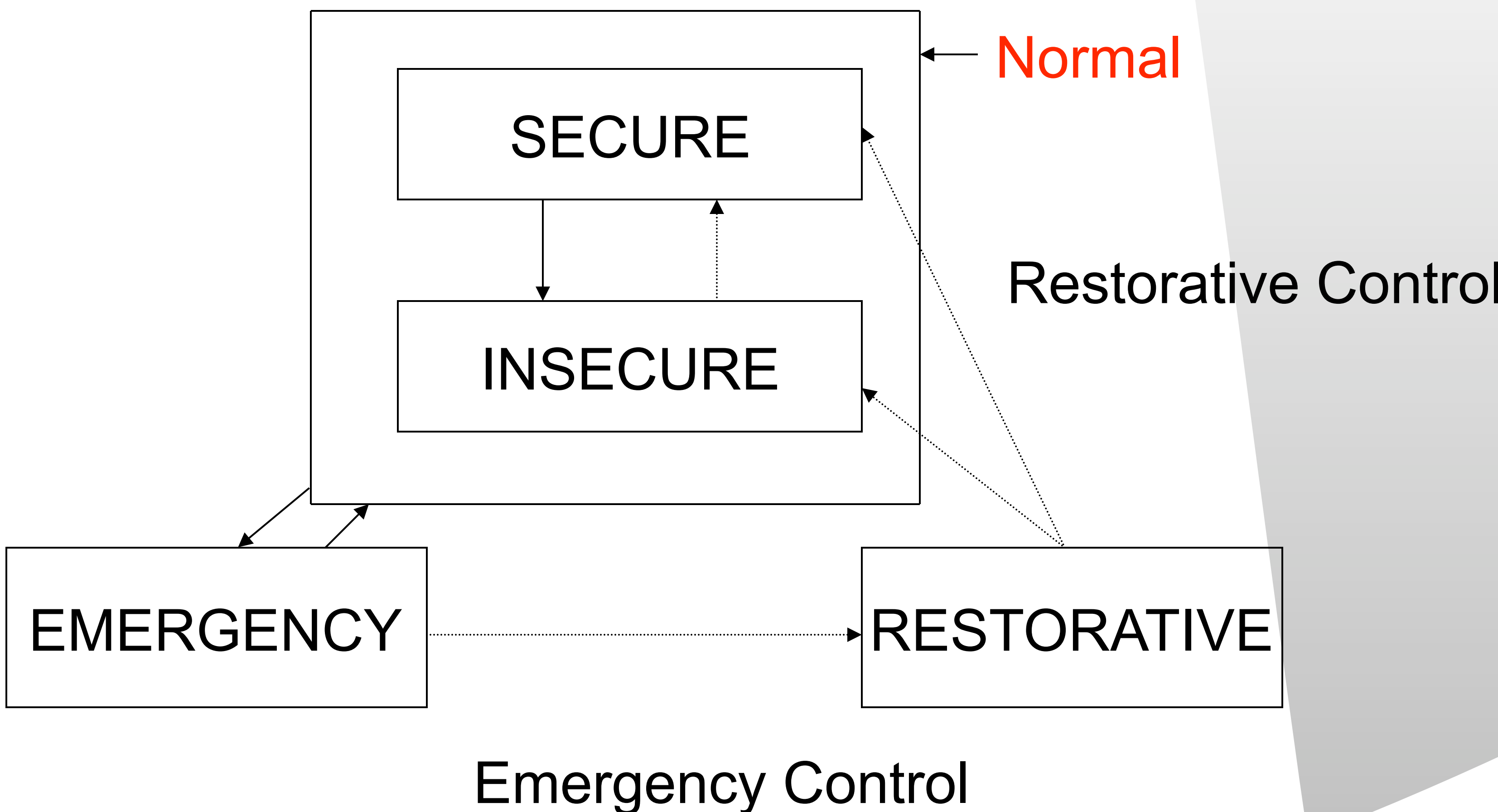
Power System Security

- The operation of a power system is not simply bounded by the ratings of individual pieces of equipment
- It is possible to operate every piece of equipment within the rated values and still have an unstable system
- Power system security is the ability of the system to withstand one or more component outages with the minimal disruption of service or its quality

System Operating States

- Normal - Load and operating constraints satisfied
- Emergency - Operating constraints not completely satisfied
- Restorative - Load constraints not completely satisfied

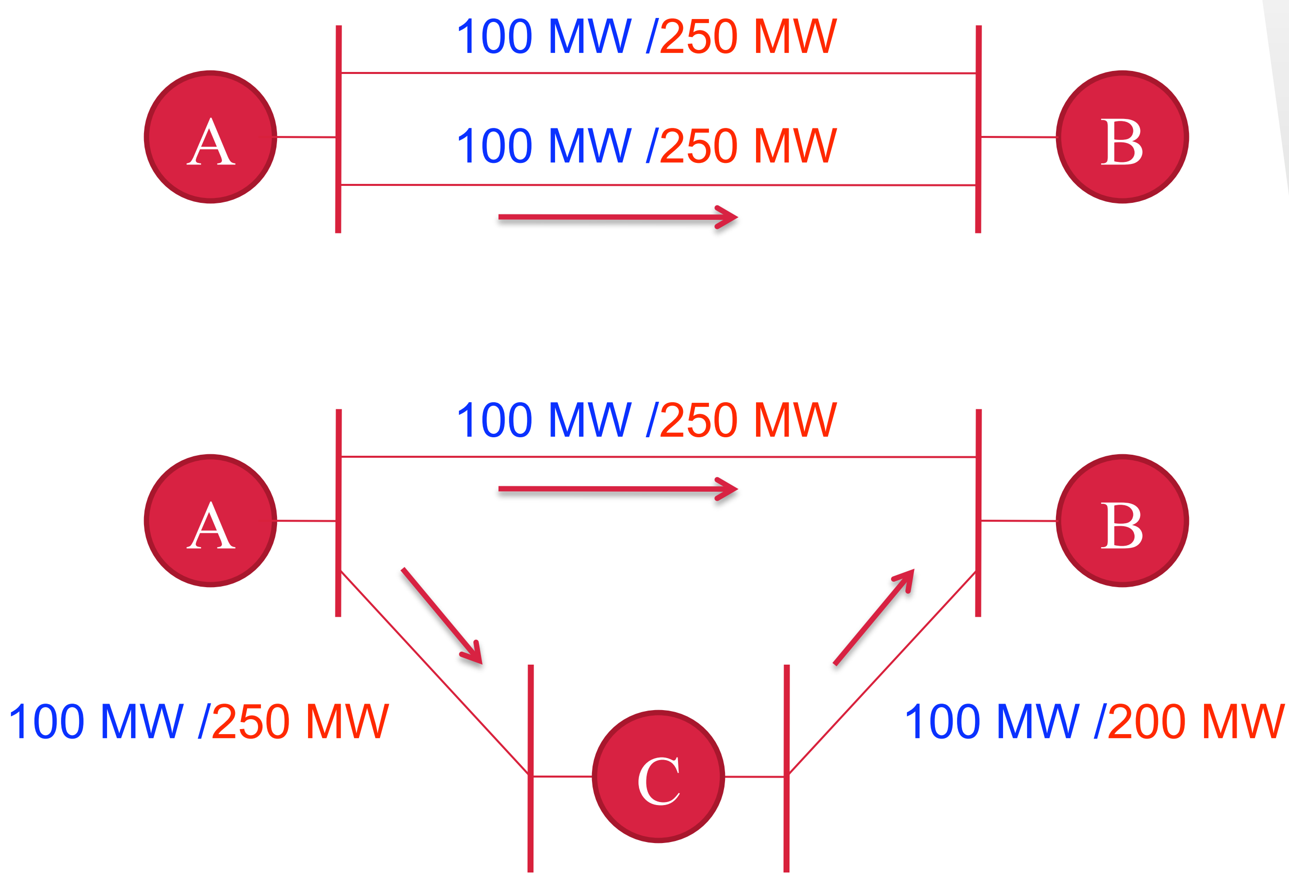
Security Assessment / Control



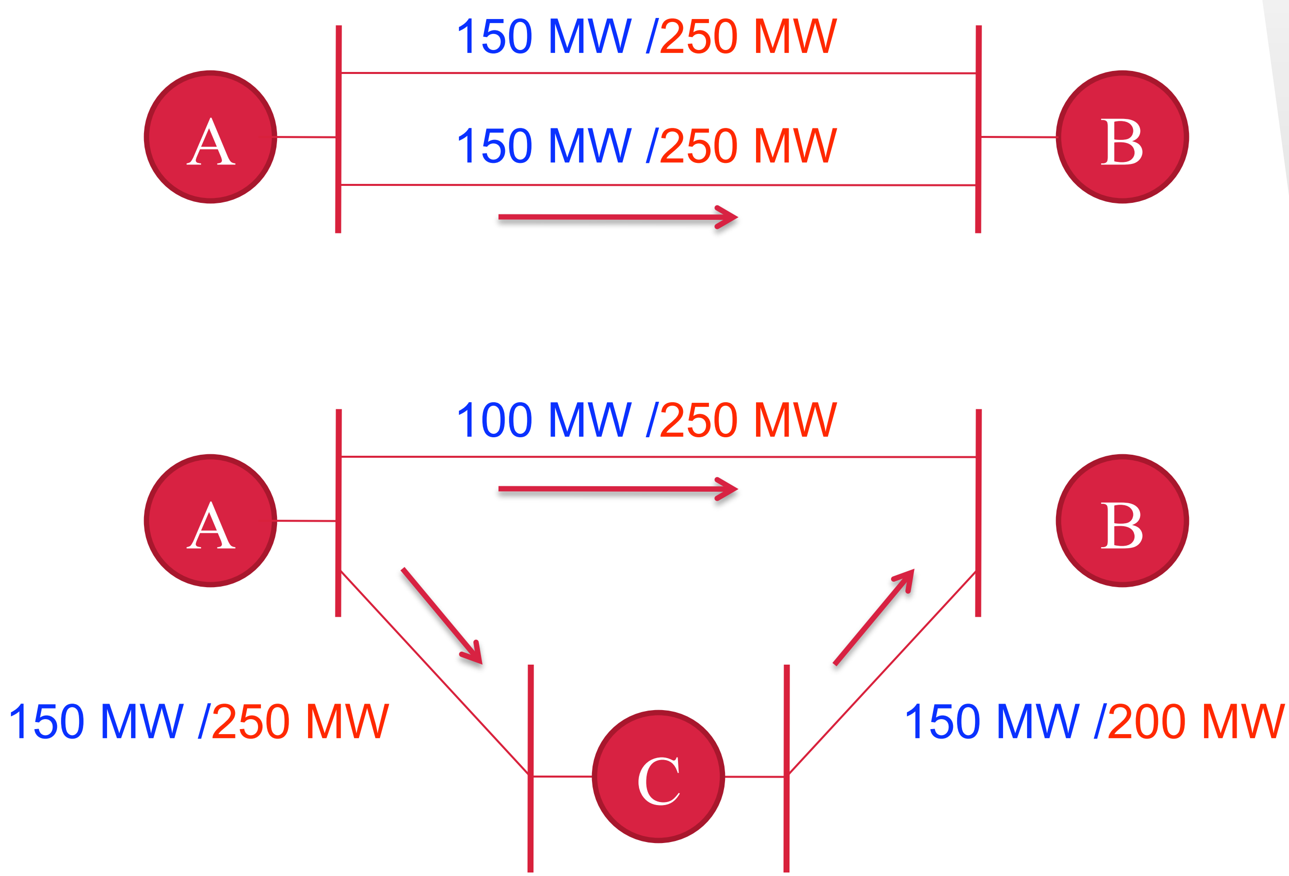
Security Assessment

- The operating state of a power system is “secure” if no disturbance in the next contingency list leads to an emergency operating condition
- The operating state of a power system is “insecure” if a disturbance in the next contingency list leads to an emergency operating condition
- This requires a list of contingencies that is appropriate for the system

Example: Secure State



Example: Insecure State



Contingency Analysis

- In general systems are required to be "N-1" secure
  - For a loss of any single piece of equipment, the system remains secure
- In addition to the N-1 criteria there are certain N-2 events that must be considered
  - Because of the geometric increase in combinations it is not feasible to examine all N-2 criteria
  - There are certain N-2 events that are more likely than others, i.e. the loss of two parallel lines at the same time

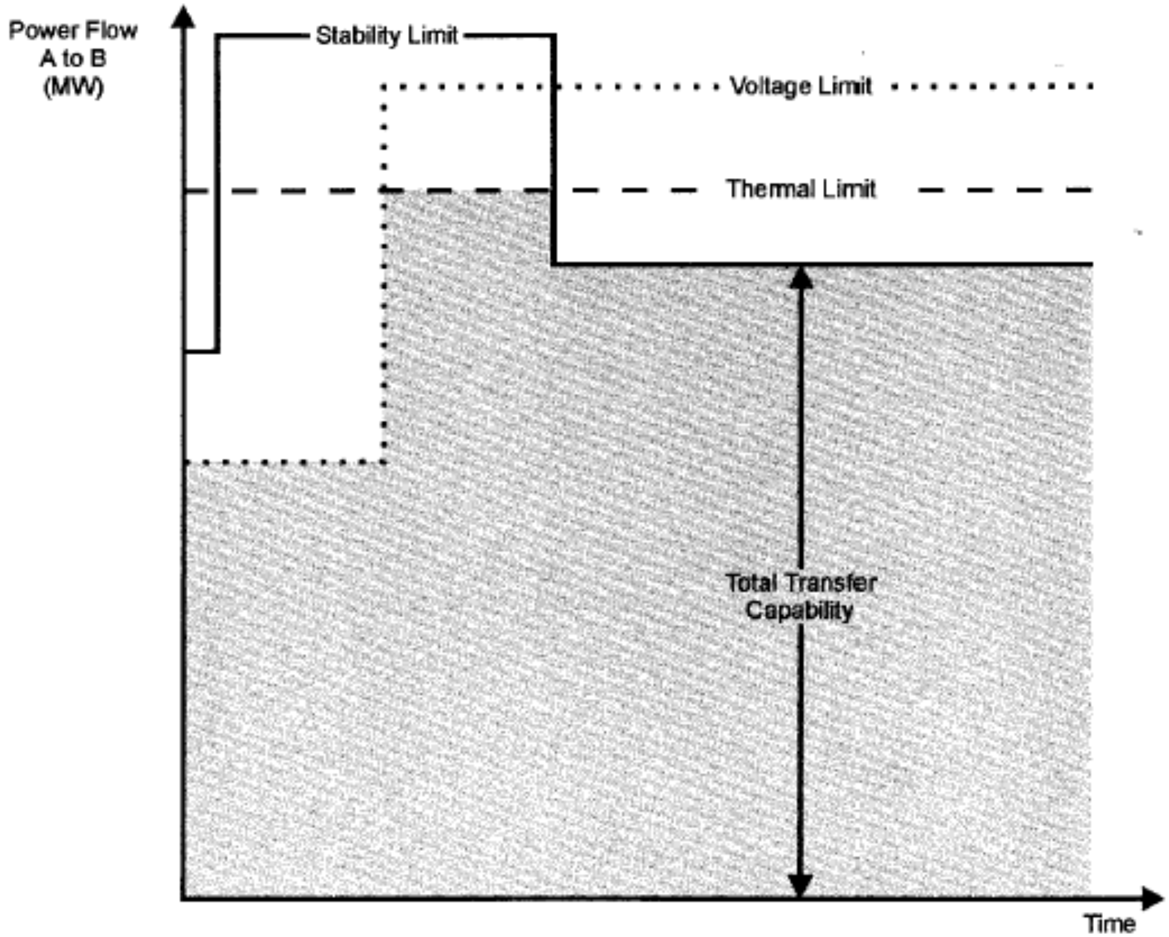
Contingency Analysis *cont'd*

- Contingency analysis is performed post state estimation
- The state estimation determines the initial operating point
- Multiple power flows are performed to see which, if any, of the contingencies results in the system becoming insecure
- Due to the computational requirements of the analysis only a limited number of contingencies can be assessed

Transfer Capability

- There is a difference between transmission capacity and transfer capability
- There are multiple limits that can impact the transfer capability
  - Thermal limits
  - Voltage limits
  - Stability limits
- Significant system studies are performed to determine system limits

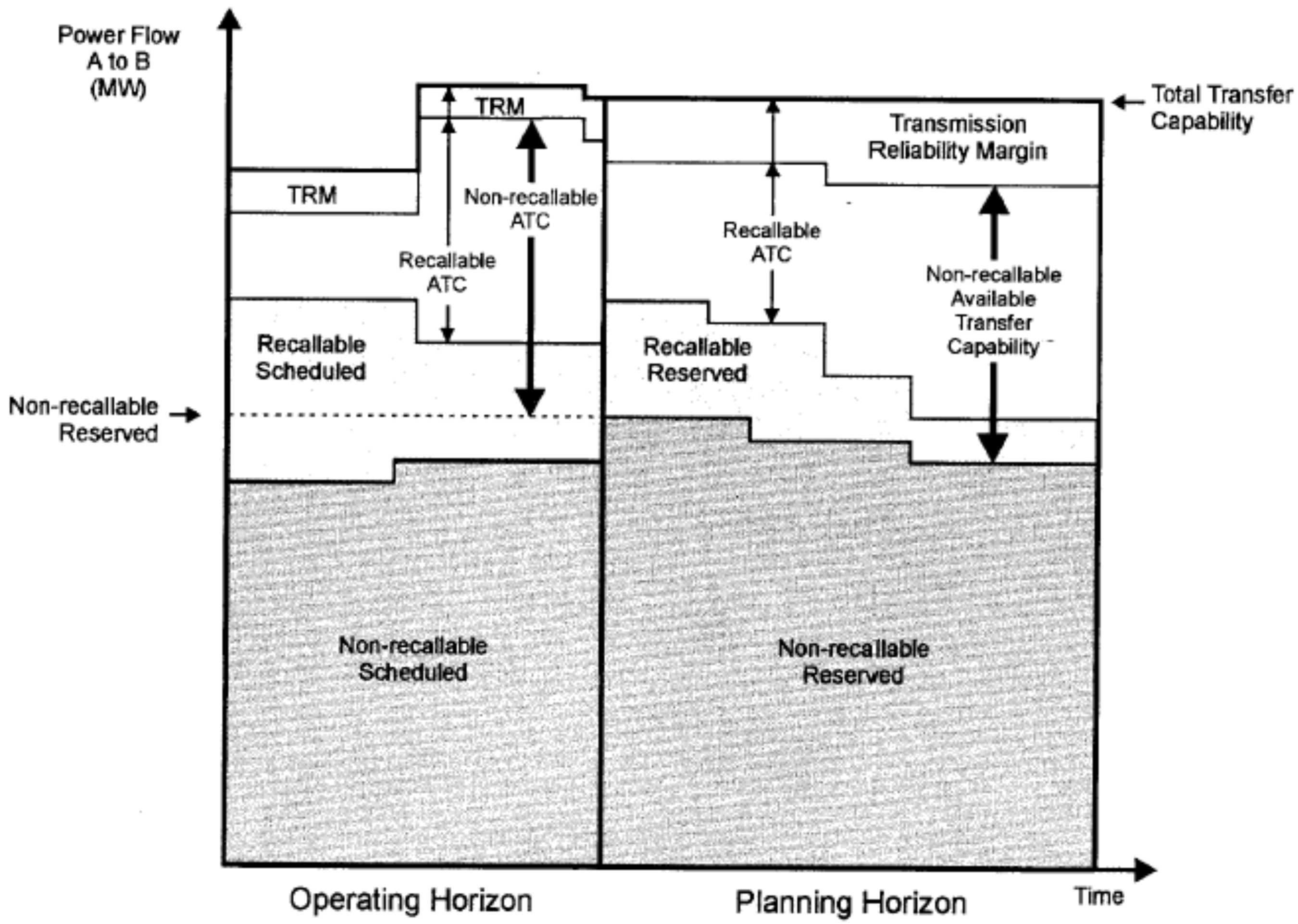
Total Transfer Capability (TTC)



Transmission Reliability Margin (TRM)

- Transmission Reliability Margin: the amount of transfer capability necessary to ensure that the interconnected transmission network is secure under a reasonable range of uncertainties in system conditions.
- The TRM represents available capability that is withheld for the event of a system disturbance
- TRM > 0 ➔ loss of revenue
- Competing interests: “revenue” and “reliability”

Available Transfer Capability (ATC)



Security Related Software

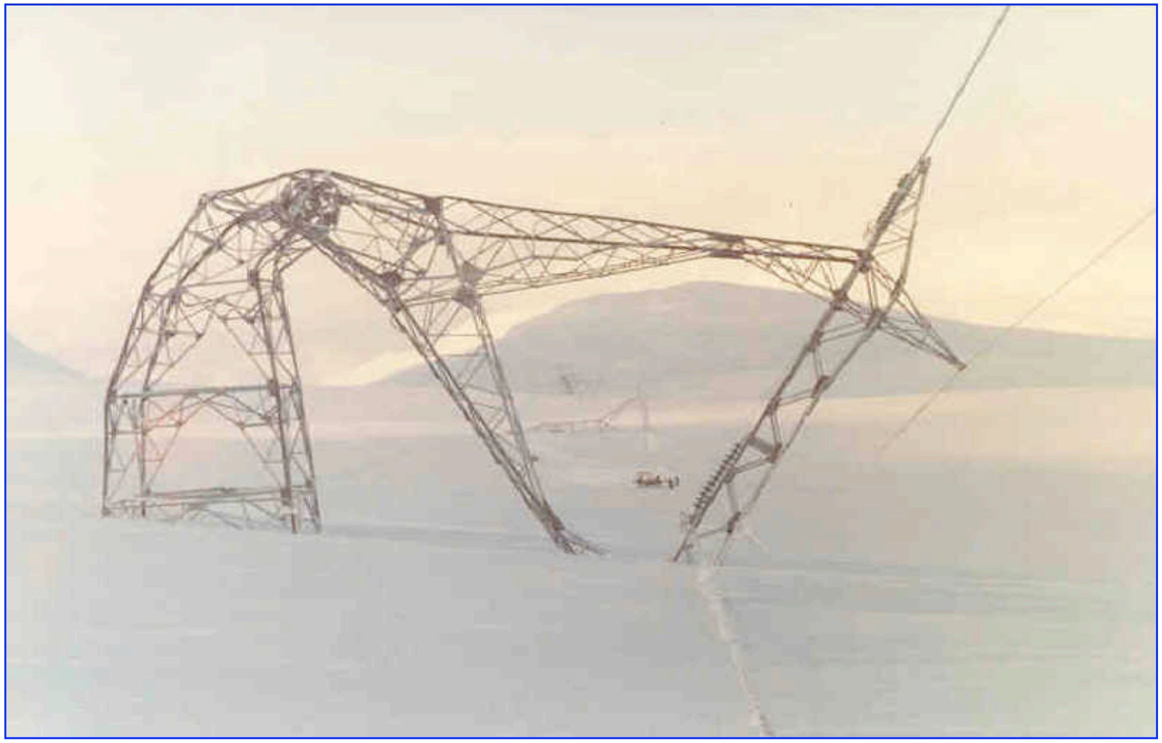
- State estimation
- Security monitoring
- Network topology processing
- On-line power flow
- Optimal power flow (OPF)
- Contingency screening
- Contingency analysis

Electricity Infrastructure Vulnerabilities

- Natural disasters
- Human errors
- Gaming in electricity markets
- Informational and communication system failures
- Sabotage

Sabotage

Snowstorm



Significant North American Blackouts

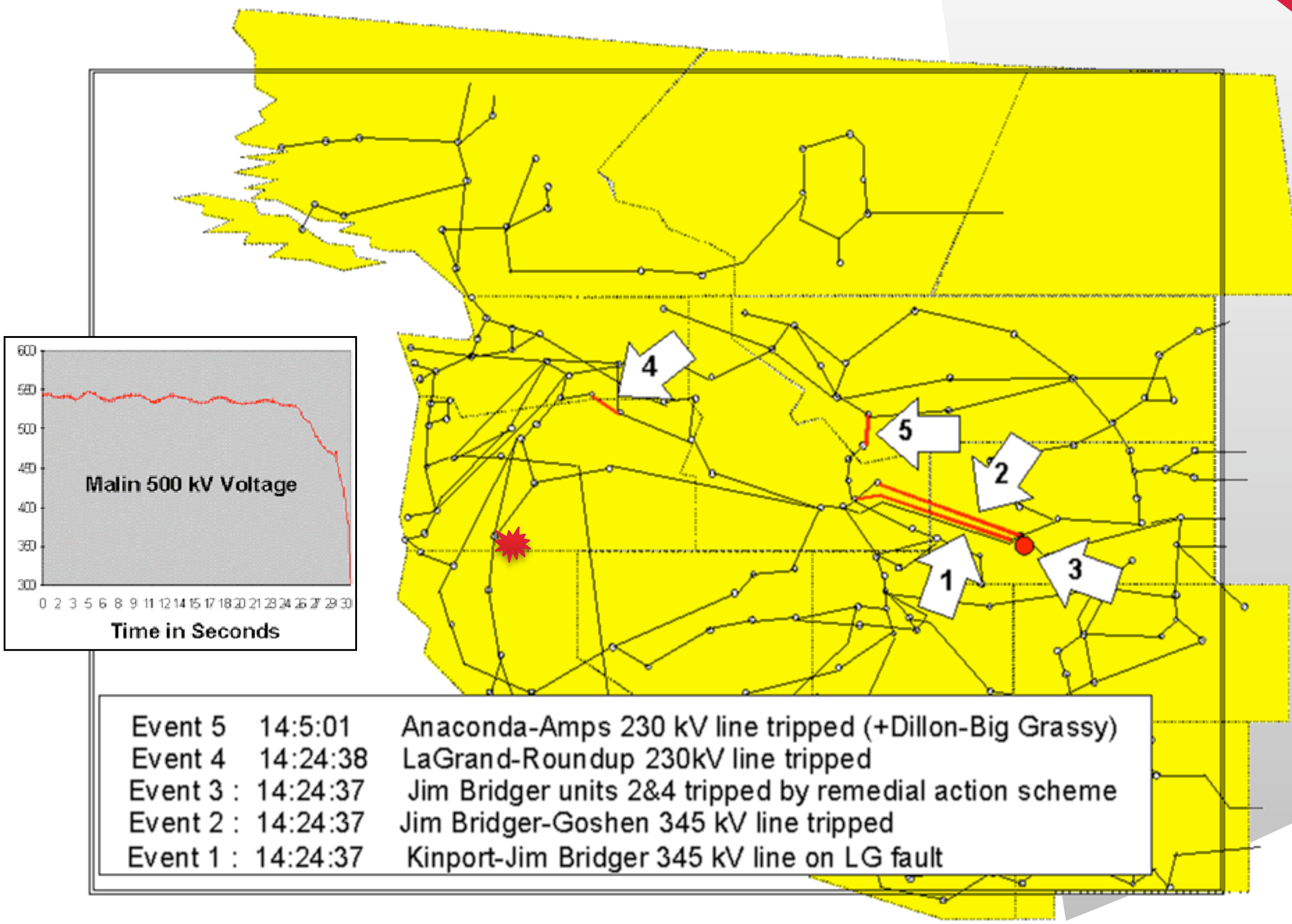
Date	Location	Load Interrupted
November 9, 1965	Northeast	20,000 MW
July 13, 1977	New York	6,000 MW
December 22, 1982	West Coast	12,350 MW
January 17, 1994	California	7,500 MW
December 14, 1994	Wyoming, Idaho	9,336 MW
July 2, 1996	Wyoming, Idaho, other	11,743 MW
August 10, 1996	Western Interconnection	30,489 MW
June 25, 1998	Midwest	950 MW
August 14, 2003	Northeast	61,800 MW

Characteristics of Cascading Blackouts

- Trees and faulty relays are common contributors to cascading events.
- Trees continue to be a cause of blackouts (cost of maintaining transmission right-of-ways).
- Relays have become more reliable and special protection systems have been designed to address issues that caused previous blackouts.

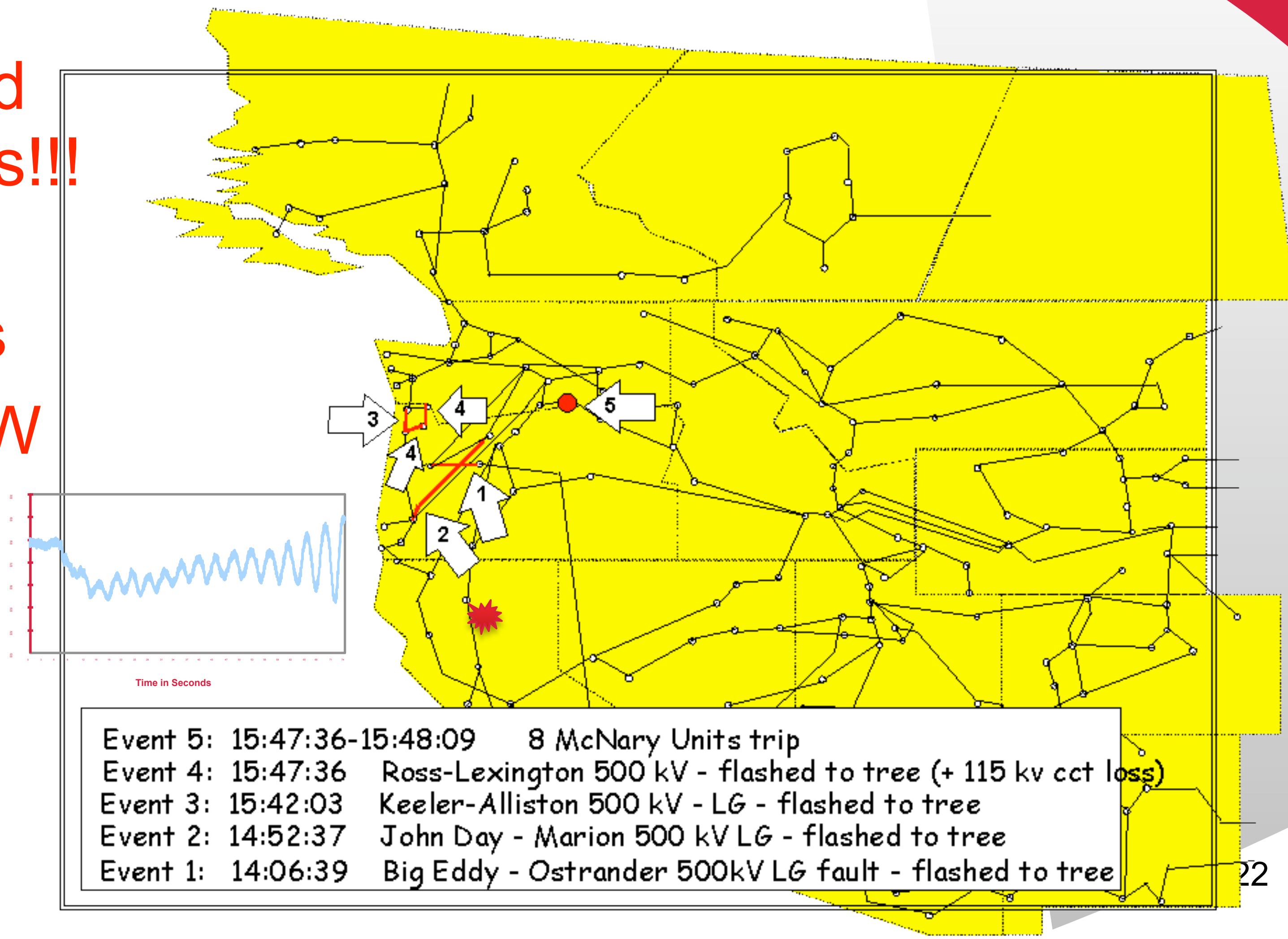
WECC July 2nd, 1996 Blackout

- Voltage Instability!!!
- 2.2 million customers
- 11,900 MW load loss



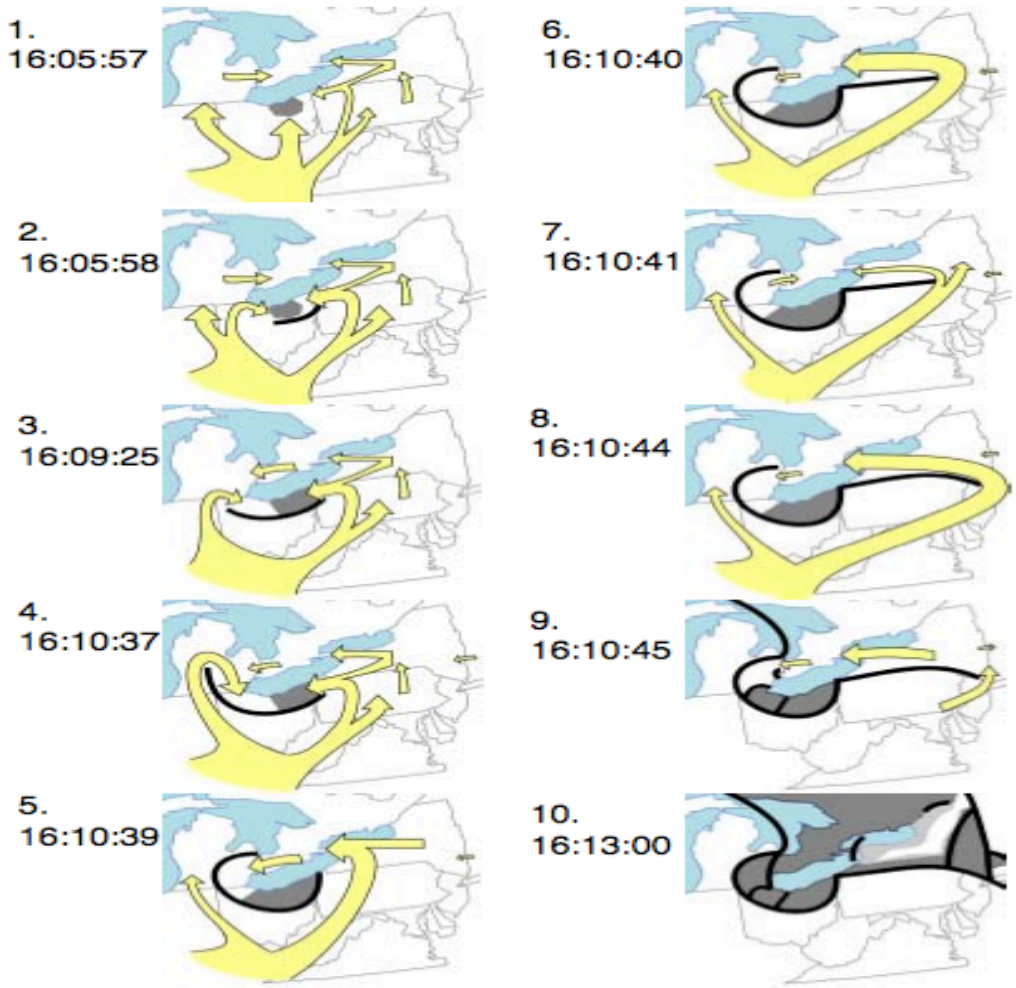
WECC Aug 10th, 1996 Blackout

- Undamped oscillations!!!
- 7.5 million customers
- 30,500 MW load loss



Northeast Aug 14th, 2003 Blackout

- Cascading failures!!!
- 16 million customers
- 62 MW load loss



Questions?

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