OSCE Expert Workshop: Sharing Best Practices to Protect Electricity Networks from Natural Disasters

Experience of Nordic Region & Recent Developments in Risk Assessment for Electricity Networks

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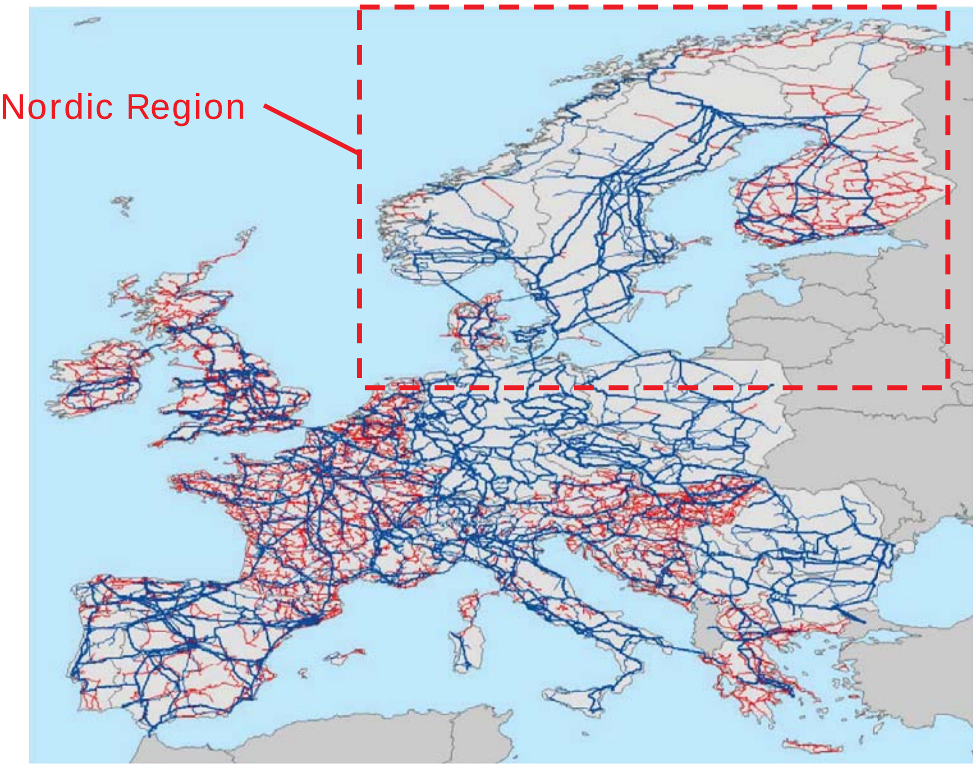


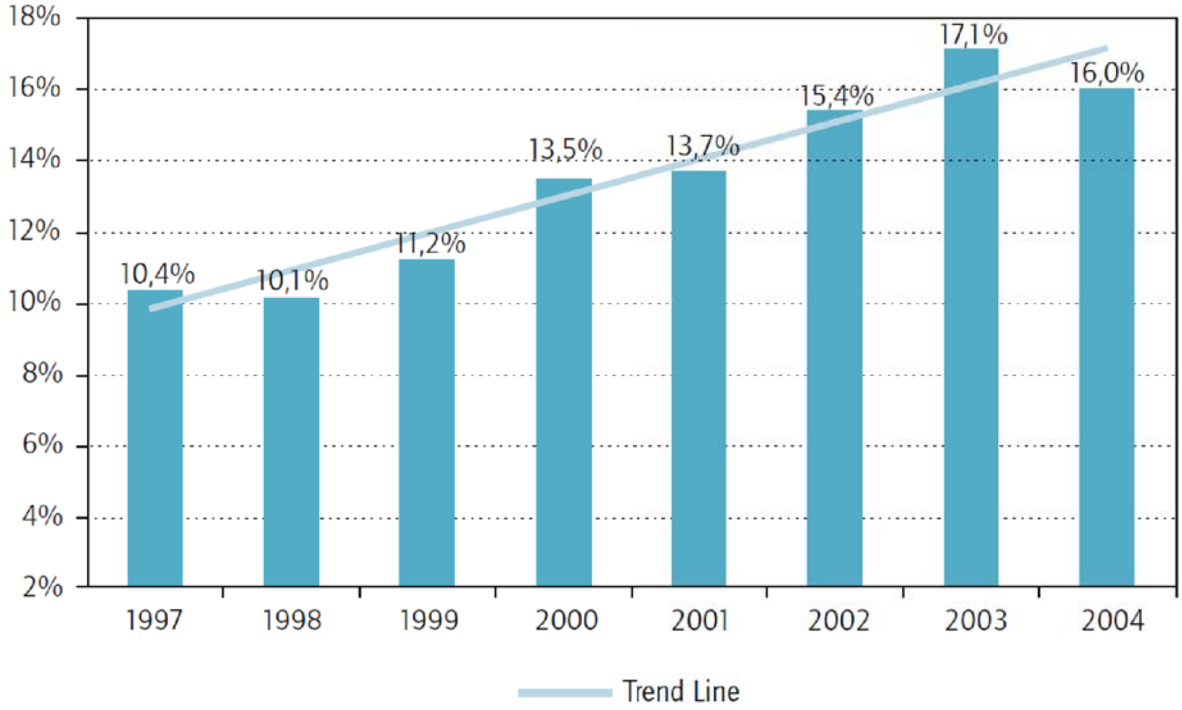
European high voltage transmission grid (V ≥ 220 kV).
Higher voltage lines in blue, lower voltage lines in red.
Line thickness is proportional to voltage.

Major transmission lines and area divisions in the Nordic grid

Overview of the Nordic power grid

- The power grids of Norway, Sweden, Finland and Denmark are highly interconnected, with significant power exchange.
- The interconnection of the individual subsystems into a common system has resulted increased security and lower costs. Consumers and producers can trade power over the whole Nordic power grid.
- As a result of the expansion of transmission capacity between the subsystems, the interconnected Nordic electric power system operates increasingly as a single entity.

Growth in inter-regional Power Exchanges in the Nordic Electricity Market 1997-2004

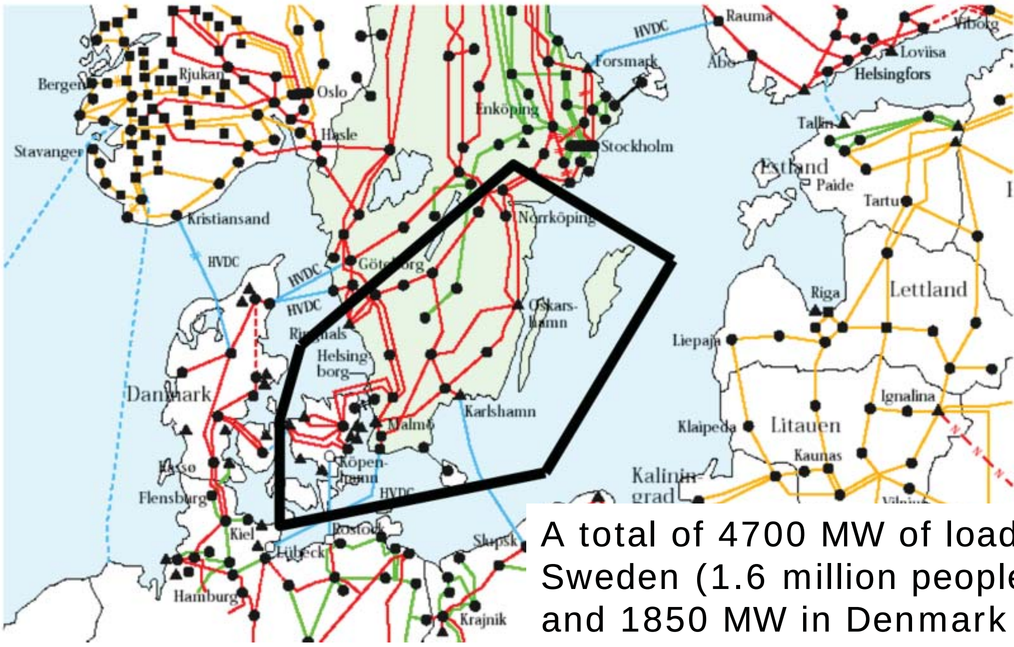


Blackout in Southern Sweden and Eastern Denmark – 23 Sept. 2003

- The system was moderately loaded before the blackout but several system components, including two 400 kV lines and HVDC links connecting the Nordel system with continental Europe, were out of service due to maintenance.
- Loss of a 1200 MW nuclear unit in southern Sweden due to problems with a steam valve.
- Five minutes after this outage a fault occurred about 300 km away from the location of the tripped nuclear unit.

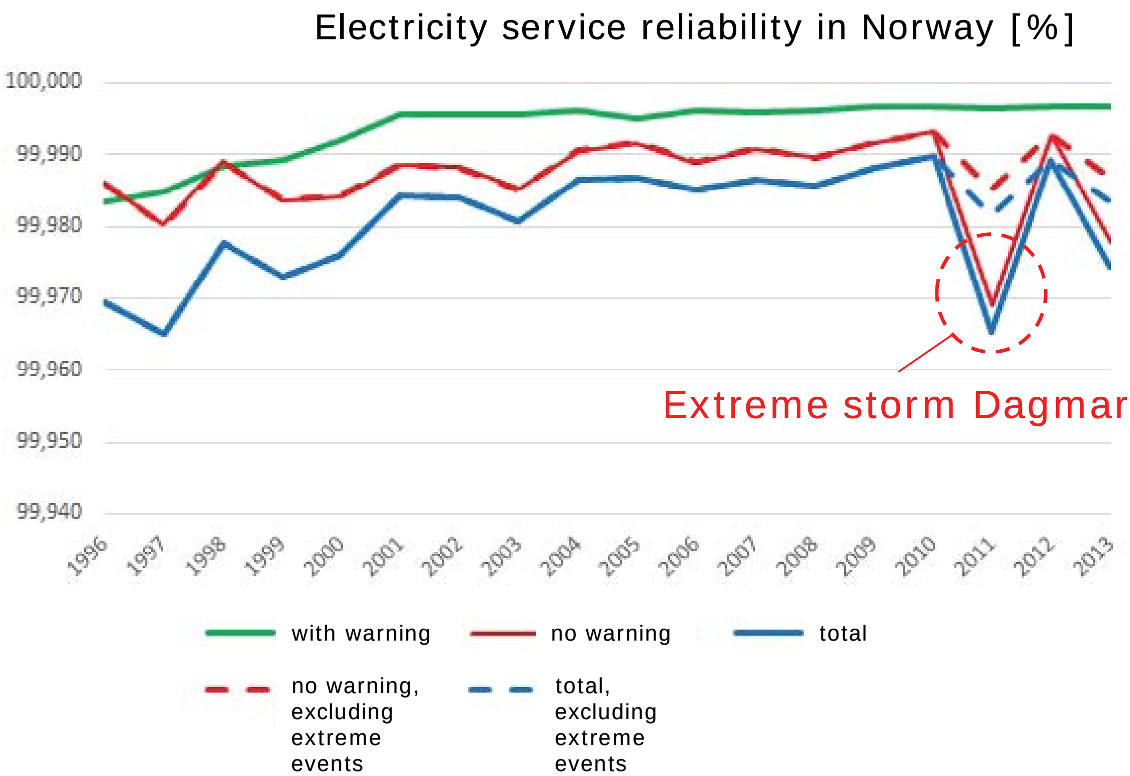
Area affected by Swedish-Danish Blackout on 23 Sept. 2003

The grid separation at 12.37



A total of 4700 MW of load was lost in Sweden (1.6 million people affected) and 1850 MW in Denmark (2.4 million people affected).

Statistics of reliability of electricity service in Norway (Source: NVE)



Storm Dagmar – 26 December 2011

Hazards of concern for Statnett

(Statnett is the system operator in the Norwegian energy system, operating about 11 000km of high-voltage power lines and 150 stations all over Norway)

- Landslides, rockfalls and snow avalanche
- Flood zones, general hydrology of the area and drainage
- Encountering difficult ground conditions during construction, e.g. swamps, quick clay areas, etc.
- Encountering undetonated explosives during construction
- Existing ground pollution, either from natural sources or result of human activity
- Risk of polluting the environment during construction activities

Summary of Experience from Nordic Region and future challenges

- The interconnected Nordic electric power system operates increasingly as a very reliable single entity.
- Despite the high reliability, incidents and blackouts, sometimes major ones, still occur.
- Extreme natural hazard events pose a serious threat to the reliability of the Nordic electric power system.
- Climate and demographic changes, and extreme hydro-meteorological events may significantly affect the vulnerability of system in the future.

Transmission System Security Standards

OECD Report "Learning from Blackouts" (2005):

Operational standards applied to manage transmission system security have changed little since the introduction of electricity market reform, with great reliance placed on the N-1 standard*. The standard is typically applied in a deterministic way that does not take account of the probability of a failure occurring or the impact of potential failures.

* A power system can be described as being N-1 secure when it is capable of maintaining normal operations (i.e. reliably delivering electricity of a given frequency and voltage subject to technical limits) in the event of a single credible contingency event, like the loss of a transmission line, generator or transformer.

Recommendation of OECD Report "Learning from Blackouts" (2005)

Probabilistic methodologies, such as quantitative risk assessment, could be used to enhance existing standards, providing a more flexible and adaptable operational standard that better reflects more dynamic, real-time operating conditions.

Probabilistic approaches could be refined to incorporate a measure of the potential cost and benefits associated with a given level of system security. ...

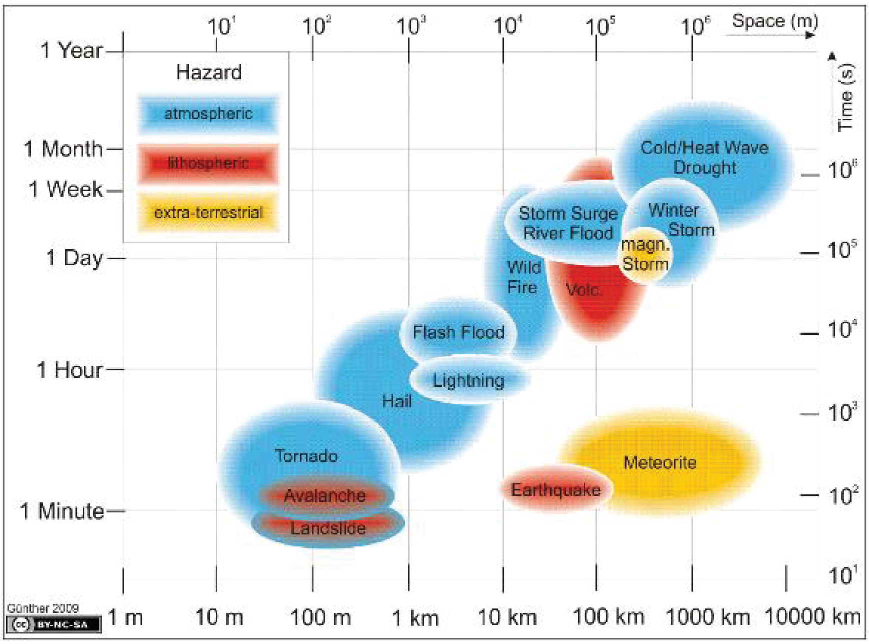
Hazard: Probability that a particular danger (threat) occurs within a given period of time.

Vulnerability: "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards"

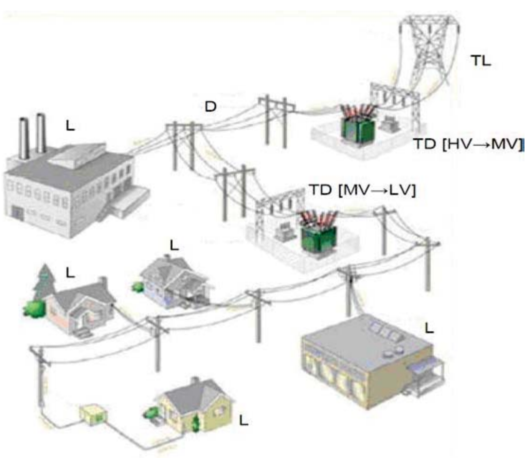
Risk: The combination of the probability of an event and its negative consequences.

Can we “predict” extreme natural hazard events in a statistical sense?

Spatial and temporal characteristics of natural hazard events vary enormously

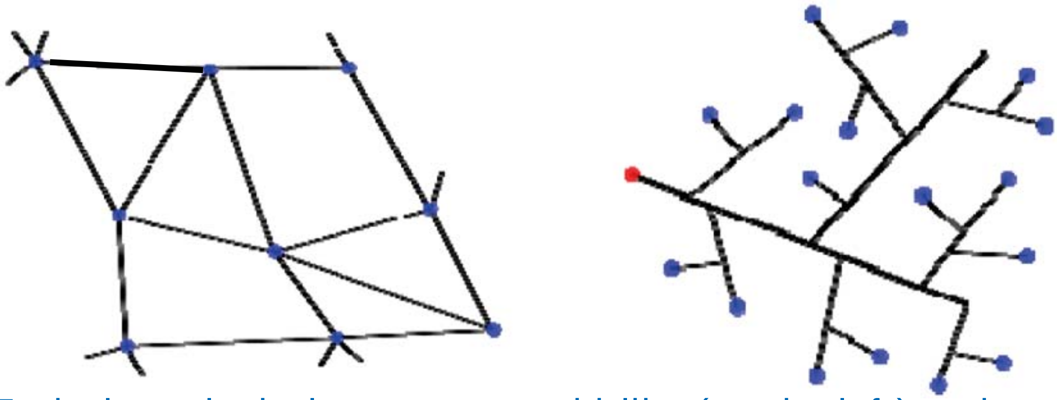


EU Project SYNER-G: Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain



Sketch of a T&D system for an EPN (TL = Transmission Lines, D = Distribution lines, TD [HV→MV] = Transformation (from high to medium voltage) and Distribution station, TD [MV→LV] = Transformation (from medium to low voltage) and Distribution station, L = Load)

Electrical Power Network model developed in EU Project SYNER-G



Typical topological structures, grid-like (on the left) and tree-like (on the right), respectively for transmission and distribution systems

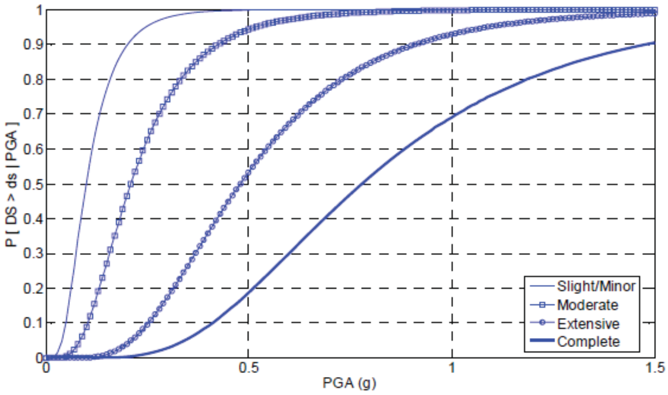
The SYNER-G model analyses power-flow changes that follow the short-circuit propagation. Within a power-flow analysis the target is to determine the voltage and power in all stations, as well as the current, power and power loss in all transmission lines.

SYNER-G: Scale for vulnerability analysis of different typologies for EPNs

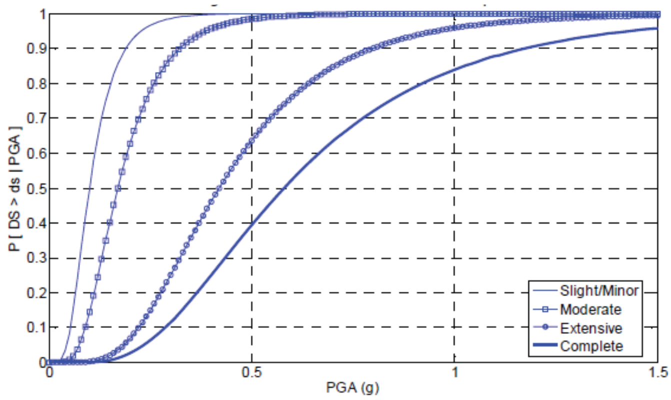
Typology	Vuln. analysis scale	Element code
Electric power grid	Network	EPN01
Generation plant	Station	EPN02
Substation	Station	EPN03
Distribution circuits	Distribution-system	EPN04
Macro-components	Substation's component	
Autotransformer line	Substation's component	EPN05
Line without transformer	Substation's component	EPN06
Bars-connecting line	Substation's component	EPN07
Bars	Substation's component	EPN08
Cluster	Substation's component	EPN09
Micro-components	Substation's component	
Circuit breaker	Substation's component	EPN10
Lightning arrester or Discharger	Substation's component	EPN11
Horizontal disconnect switch or Horizontal sectionalizing switch	Substation's component	EPN12
Vertical disconnect switch or Vertical sectionalizing switch	Substation's component	EPN13
Transformer or Autotransformer	Substation's component	EPN14
Current transformer	Substation's component	EPN15
Voltage transformer	Substation's component	EPN16
Box or Control house	Substation's component	EPN17
Power supply to protection system	Substation's component	EPN18
Coil support	Substation's component	EPN19
Bar support or Pothead	Substation's component	EPN20
Regulator	Substation's component	EPN21
Bus	Substation's component	EPN22
Capacitor bank	Substation's component	EPN23
Transmission or distribution line	Line	EPN24

Example of seismic vulnerability functions developed in SYNER-G

Anchored components



Unanchored components

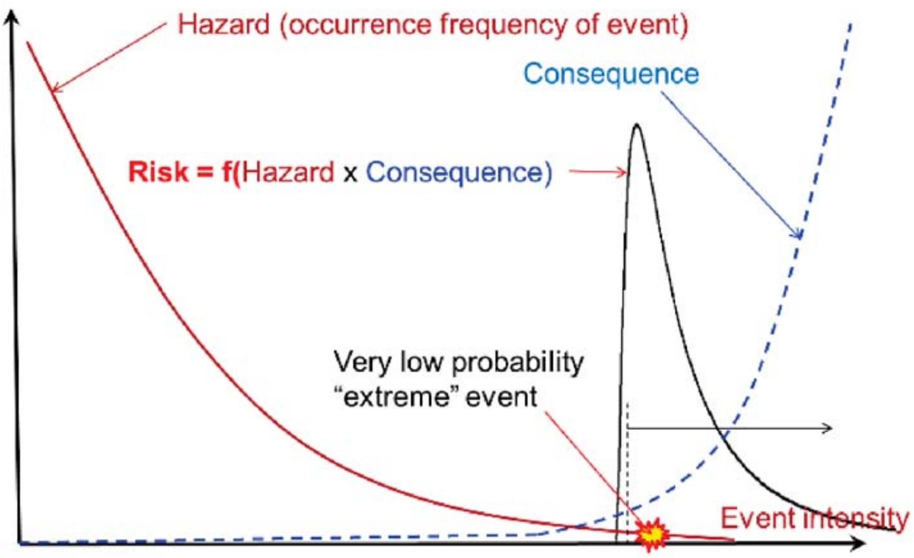


Element at Risk: Medium Voltage Substation (150-350 kV)

Comments:

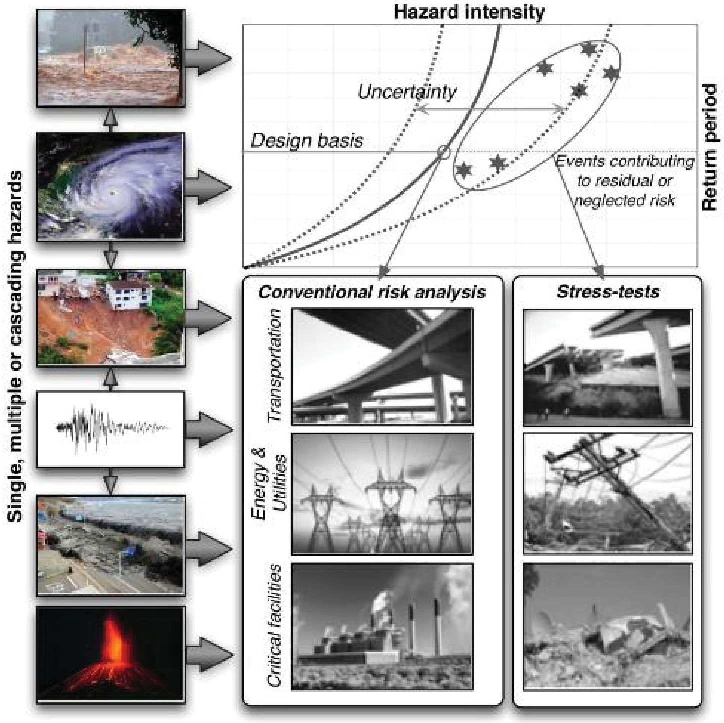
- Risk assessment of electricity networks for extreme natural hazard events is technically challenging and by no means straightforward.
- Research and development projects in recent years have produced promising tools for modelling the response of complex power grids to extreme natural hazard events.
- New ideas, such as stress testing, may also be useful for identifying the weaknesses in the electricity networks.

Traditional risk assessment may not be adequate for dealing with extreme events. "Residual" events can account for much of the risk



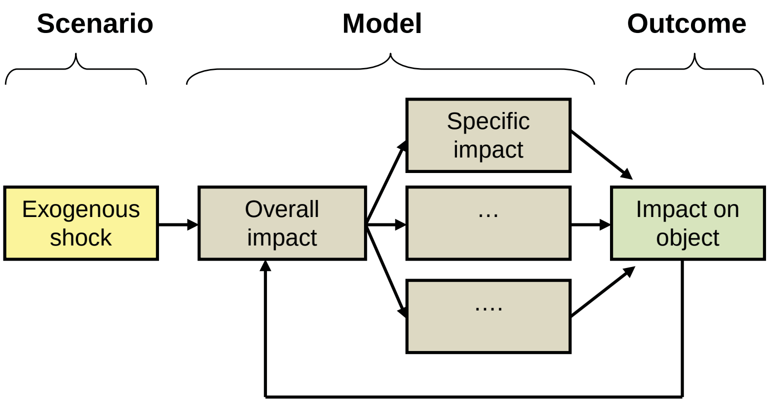
Uncertain / unverified models can produce "neglected" risks?

$$\frac{3\ (number\ of\ major\ accidents)}{400\ (active\ nuclear\ plants) \times 30\ (estimated\ lifetime)} = 2.5^{-4}$$

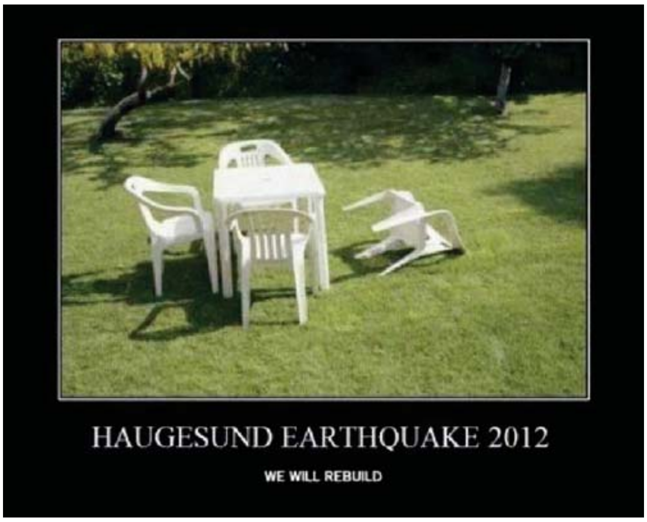


How can the system be made more robust under extreme events and the society be better prepared?

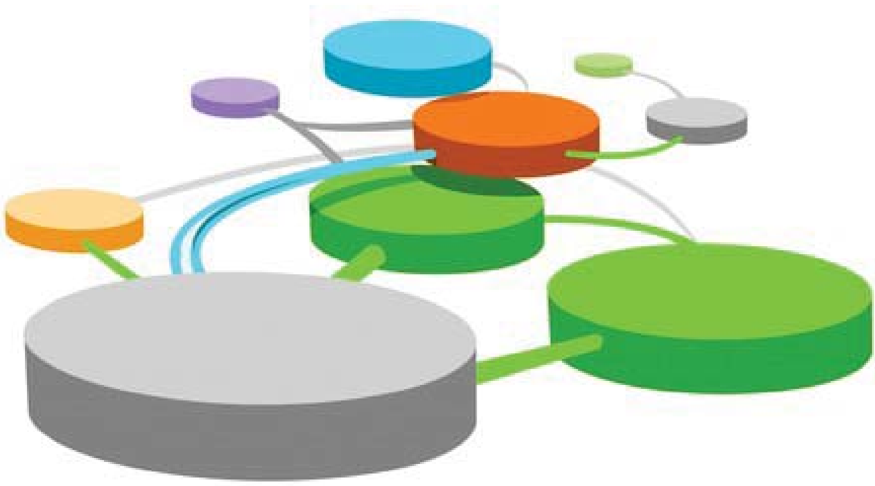
Basic concept for stress test



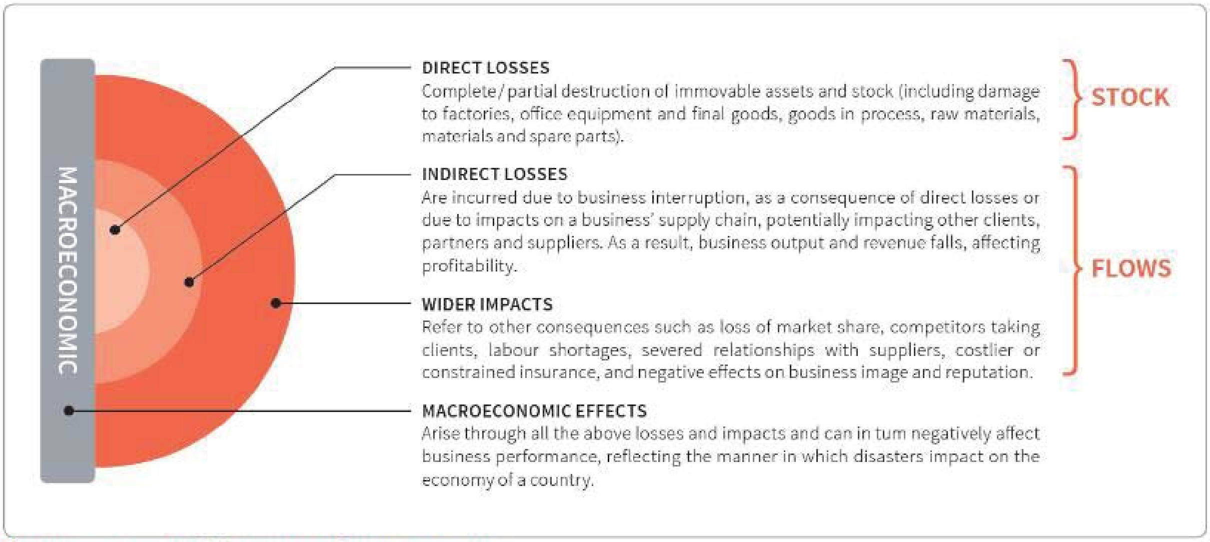
Major challenges – I. What scenatio to test for?



Major challenges – II. Coping with complex systems (and systems of systems)



Major challenges – III. Are we willing to accept the answers?



The growing impact of disasters on the private sector

GAR 2013 report

Concluding Remarks

- *Reliability of Electricity Networks under the action of natural hazard events can be improved by using probabilistic methods like quantitative risk assessment.*
- *Conventional Quantitative Risk Assessment (QRA) may not be adequate for dealing with low-probability, high impact (extreme) events.*
- *Stress testing is not a substitute for conventional risk or safety assessments, but it provides additional valuable insight about system performance for extreme situations.*


Thank You for Your Attention