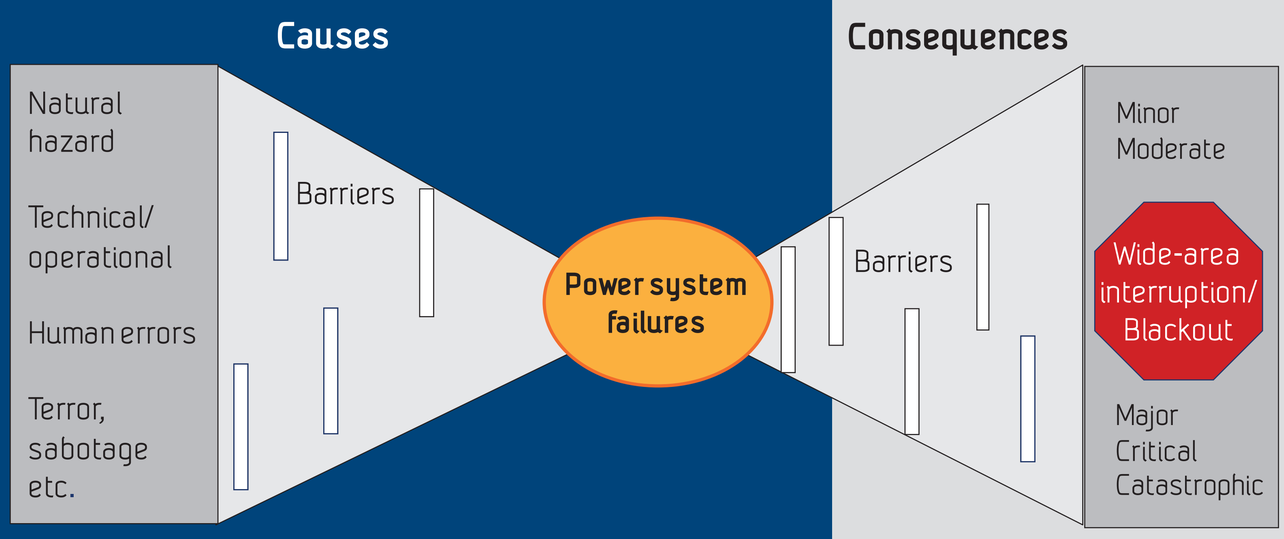
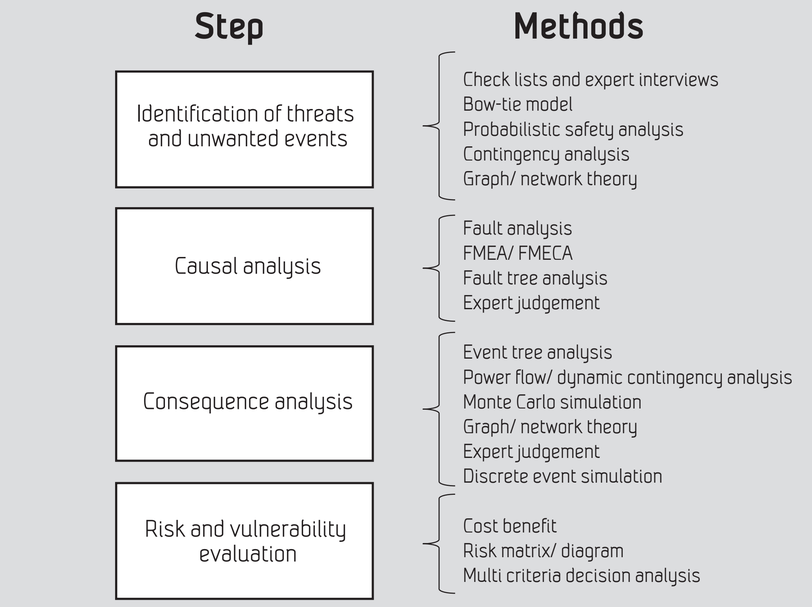
PowerTech
Paper 285

## Risk and vulnerability analysis of power systems including extraordinary events

# Vulnerability analysis

## Vulnerability framework



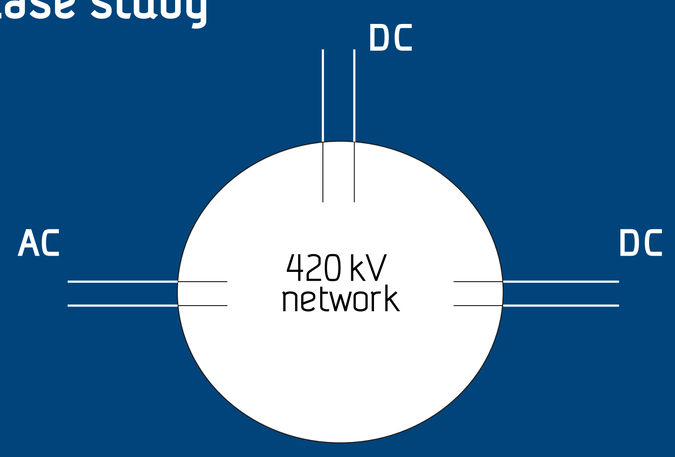




- Bow tie structure for identified threats, unwanted events, barriers and consequences
- Threats might lead to power system failures through a chain of events
- Barriers exist to avoid threats to develop into unwanted events and to prevent or reduce consequences

## Approach

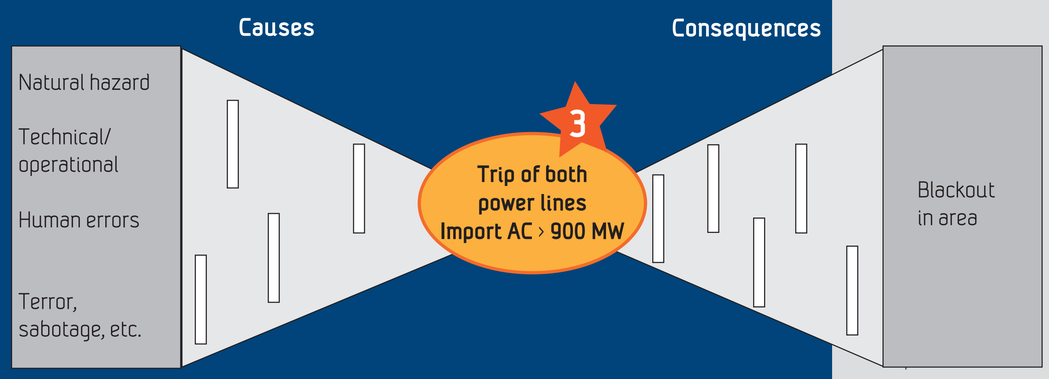
- Combining qualitative and quantitative techniques:
  - Bow-tie model
  - Based on expert judgement
  - Supported by power flow and dynamic analyses
- Close cooperation with the power system operator

## Case study



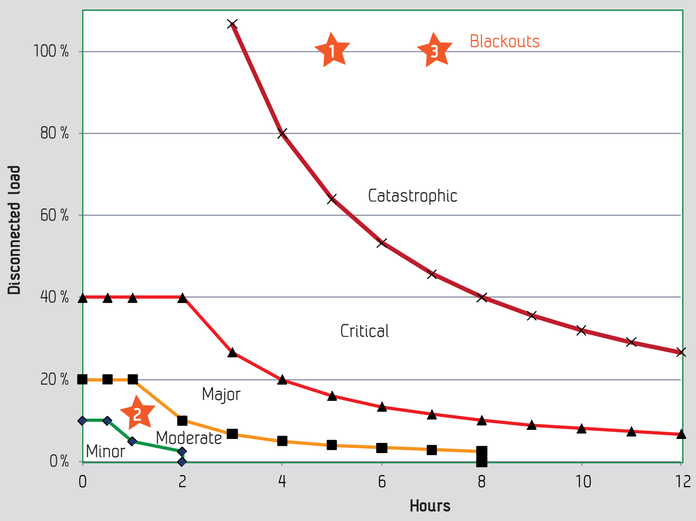

- 420 kV transmission network
- Connected to neighbouring areas via one AC and two DC connections

## Bow tie model

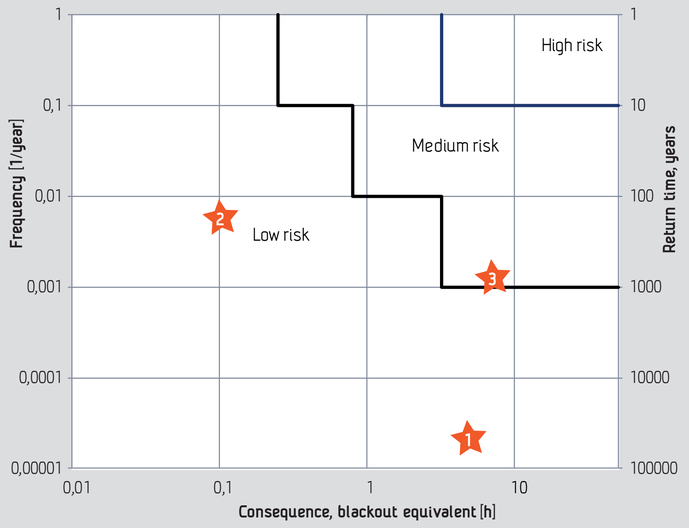



- N-1 operation
- Component protection/ relay plans
- Poser system operation
- Surge arresters installed
- Marking of spans
- Adequate mechanical dimensioning
- HVDC emergency power
- Load shedding
- Controlled islanding

## Consequences




## Risk




## Conclusions

- Describes a framework for power system risk and vulnerability analysis
- Illustrated with a simplified real case study with three identified unwanted events
- It is hard to think of the unthinkable – one of the main challenges is to identify the vulnerable operational states and extraordinary events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