# Quantification of the resilience of electric power distribution systems

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# Outline

- Aim
- Approach
- Case study
- Conclusion and outlook

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# Aim

The aim of this research is to establish a simulation tool that enables:

1. Power loss estimation

2. System resilience quantification

3. Informed investments

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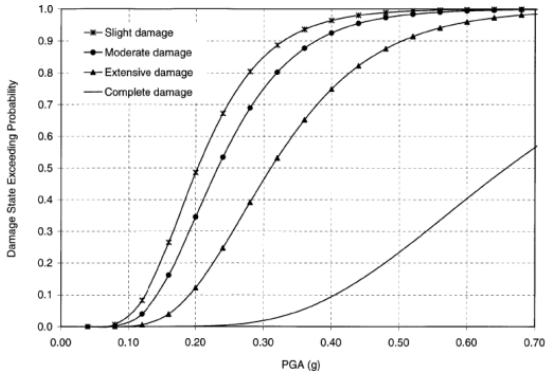
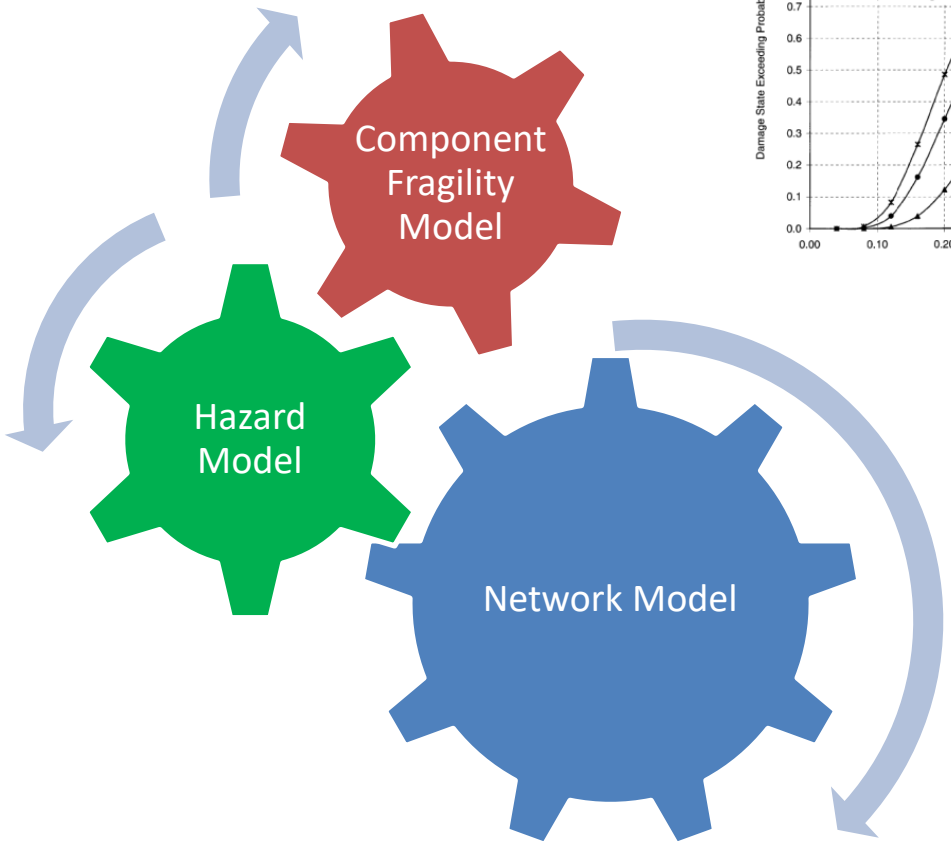
# Approach


Slight damage
Moderate damage
Extensive damage
Complete damage
Damage State Exceeding Probability
PGA (g)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70


Component Fragility Model
Hazard Model
Network Model

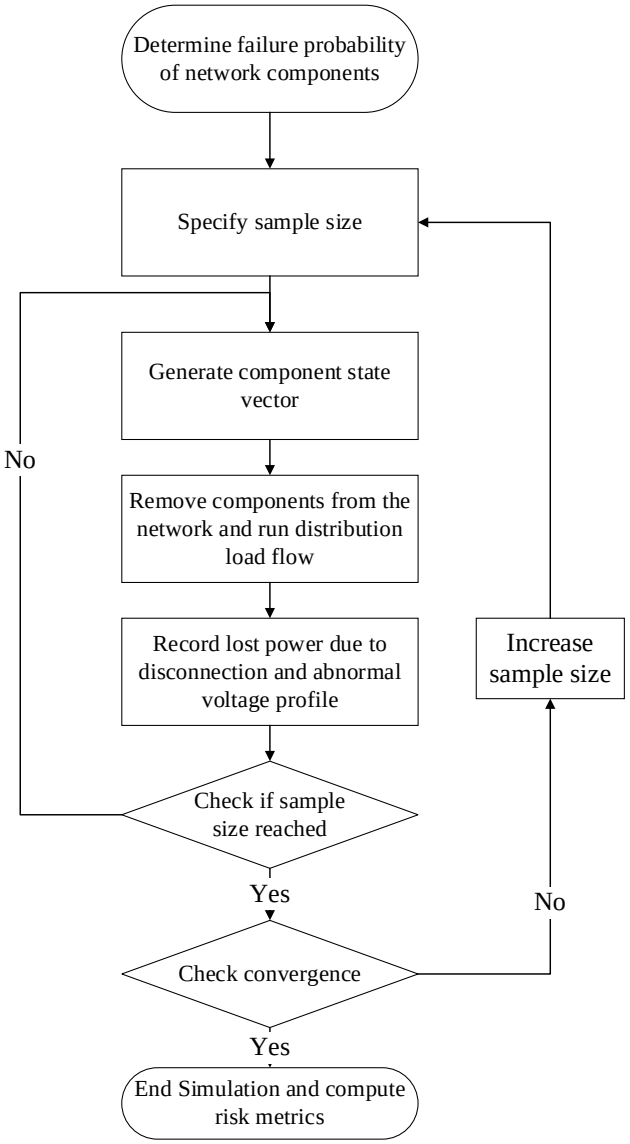
# Approach

Substation – Circuit breakers, disconnectors, bus bars transformer

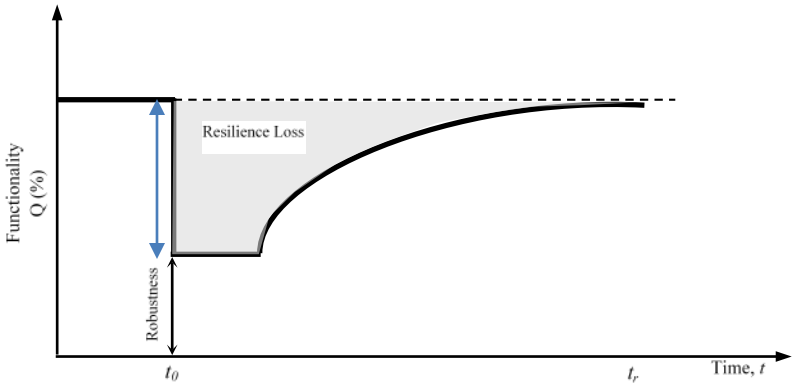
Network – Bus bars, underground cables, switches

Framework – Static

Variant – Dynamic, spatial-temporal impact of extreme weather events



# Approach -- Functionality metrics




Expected load not supplied:

$$E(P_{loss})$$

Load at risk:

$$VaR_\alpha(P_{loss}) = \min\{\gamma : P(P_{loss} \leq \gamma) \geq \alpha\}$$

Conditional load at risk:

$$CVaR_\alpha(P_{loss}) = E[P_{loss} | P_{loss} \geq VaR_\alpha(P_{loss})]$$

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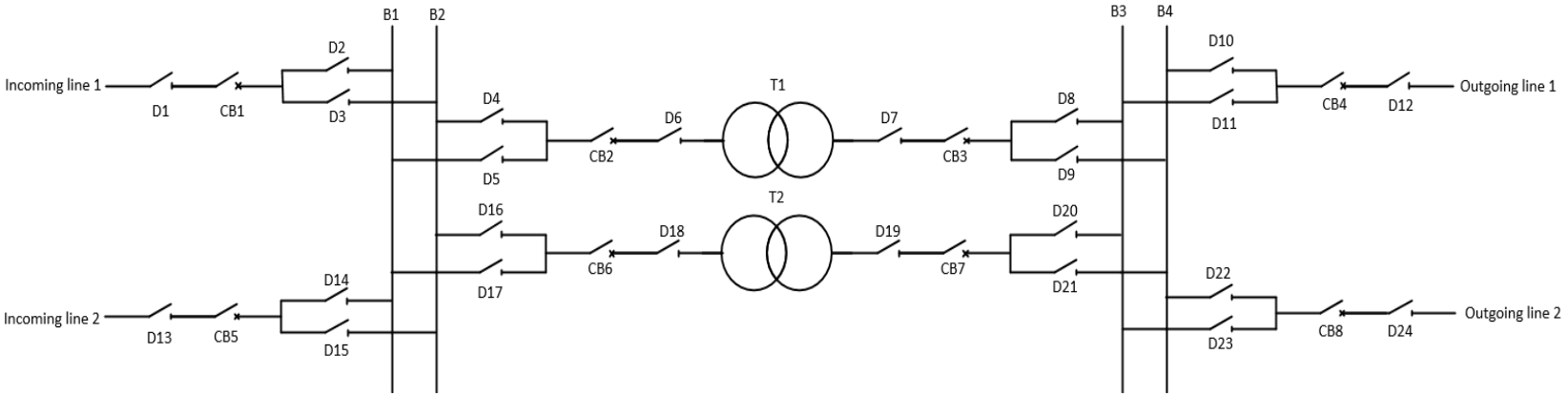
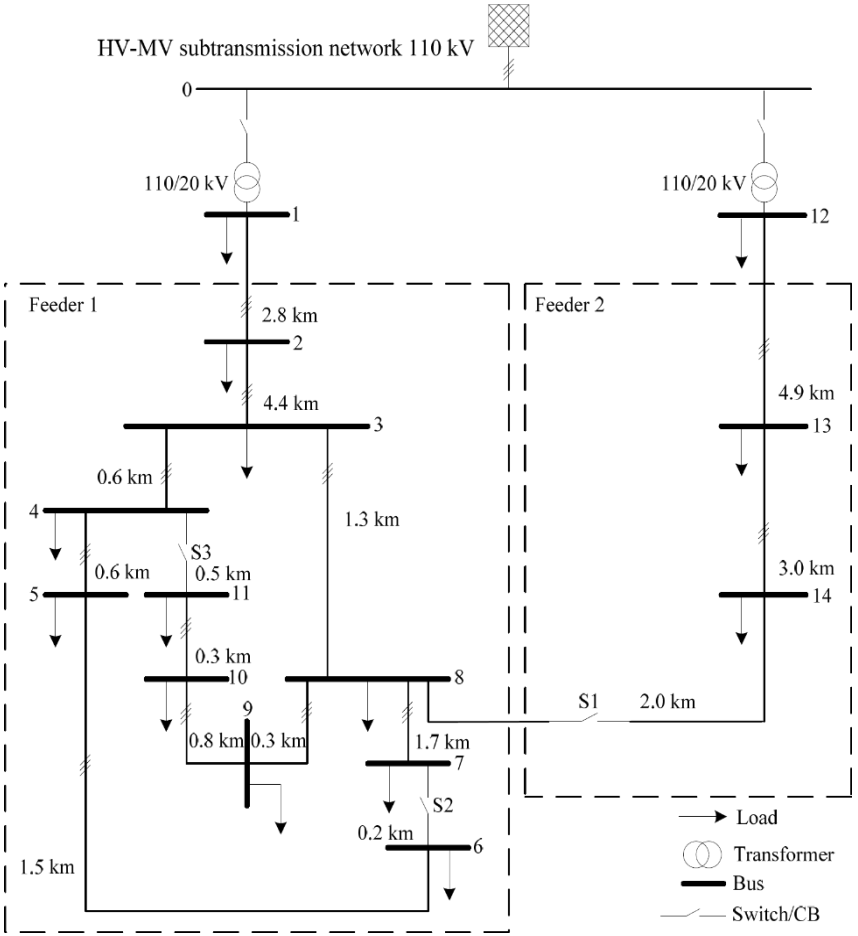
# Case study -- Substation configuration



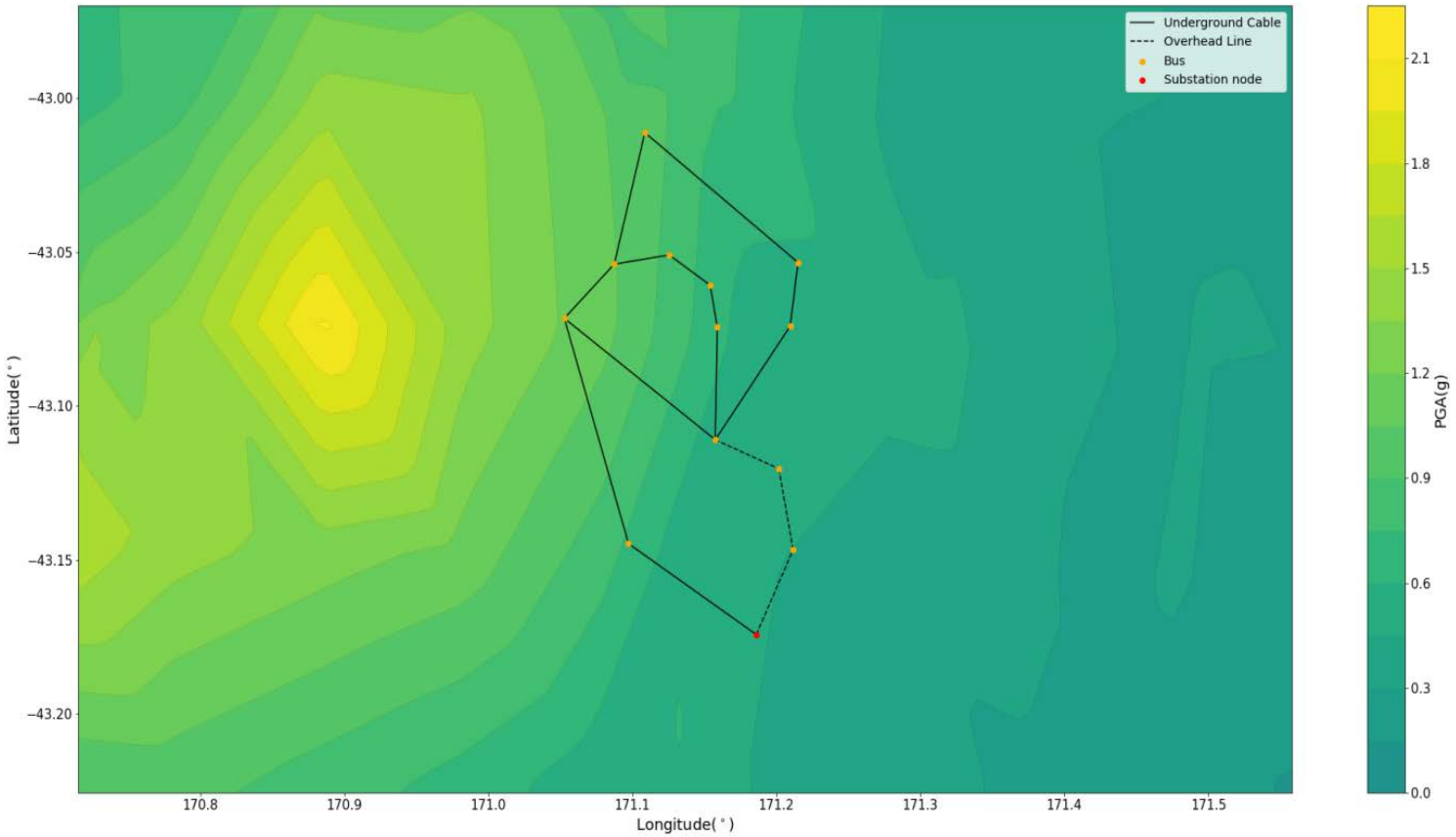

- Boolean logic
- Minimum cut set

# Case study -- Network configuration

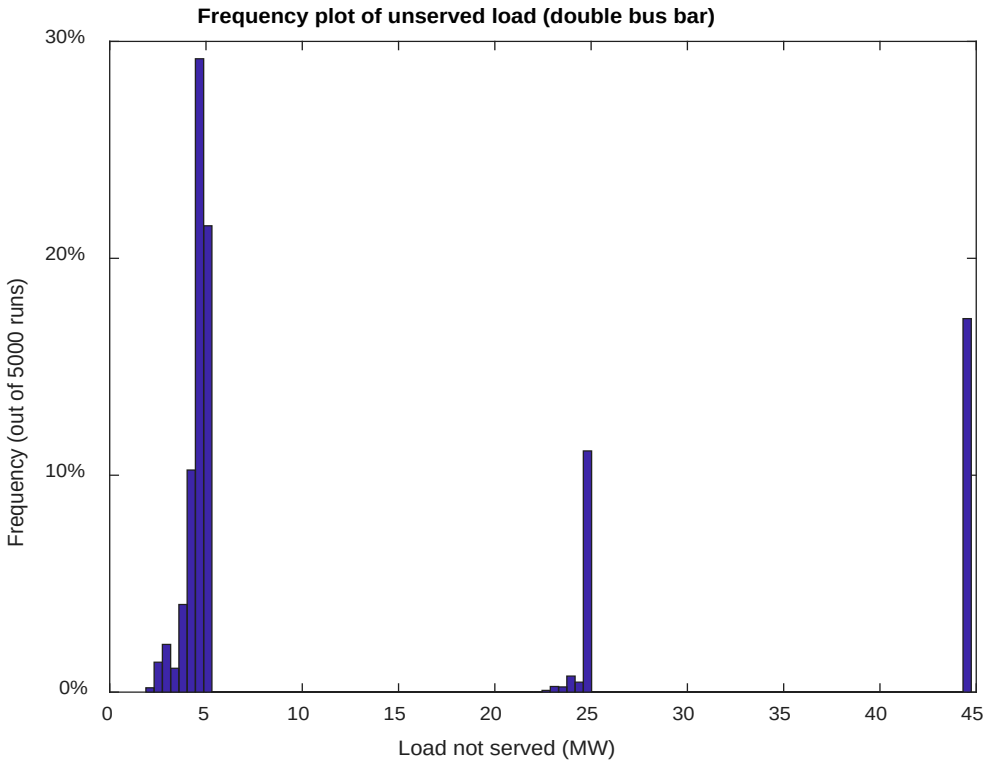



- Medium voltage distribution network supplying a small town and rural area
- Can be operated as either a radial or weakly meshed network by switching S1,S2,S3

# Case study


Underground Cable
Overhead Line
Bus
Substation node
−43.00
−43.05
−43.10
−43.15
−43.20
Latitude(°)
170.8
170.9
171.0
171.1
171.2
171.3
171.4
171.5
Longitude(°)
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0.0
PGA(g)

# Case study


Frequency plot of unserved load (double bus bar)
30%
20%
10%
0%
Frequency (out of 5000 runs)
0
5
10
15
20
25
30
35
40
45
Load not served (MW)

# Case study

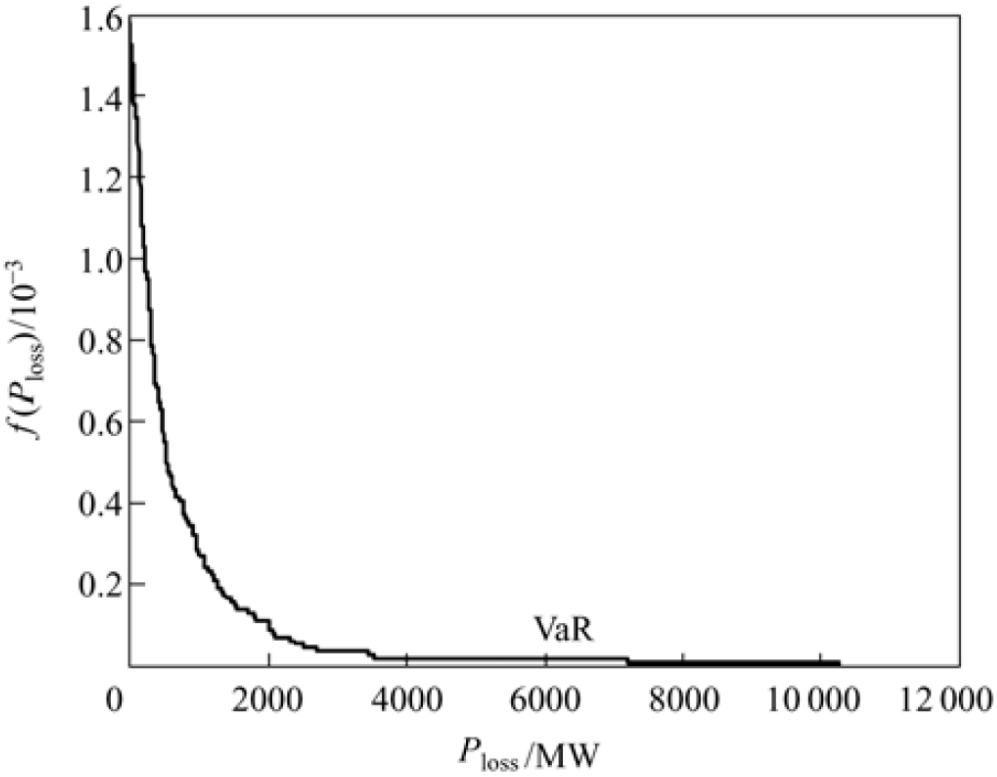
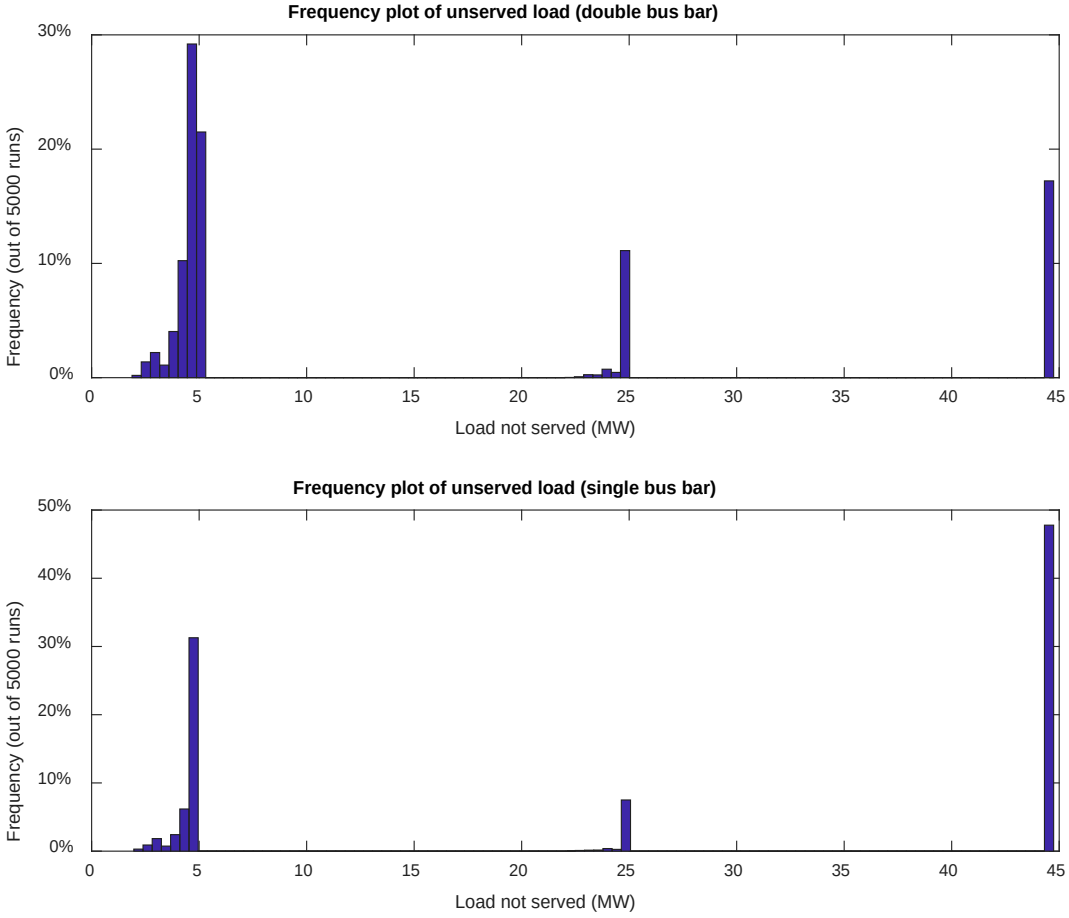



**Figure 3.18** Probability density curve of North America blackout from 1996 to 2002

Mei, S., Zhang, X., & Cao, M. (2011). *Power grid complexity*. Springer Science & Business Media.

# Case study – Comparison of substation configuration



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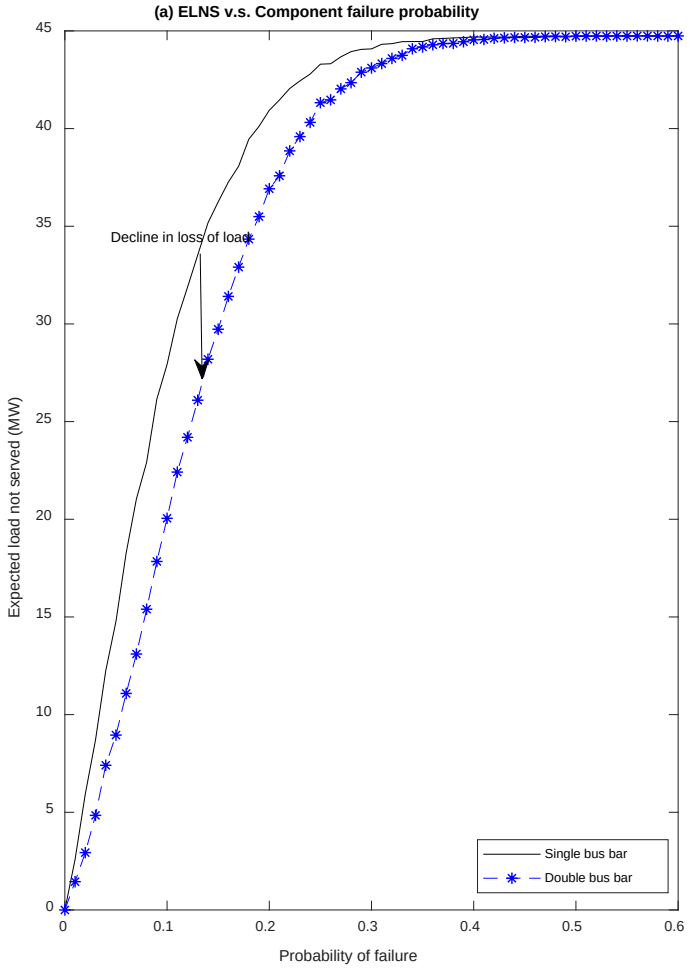


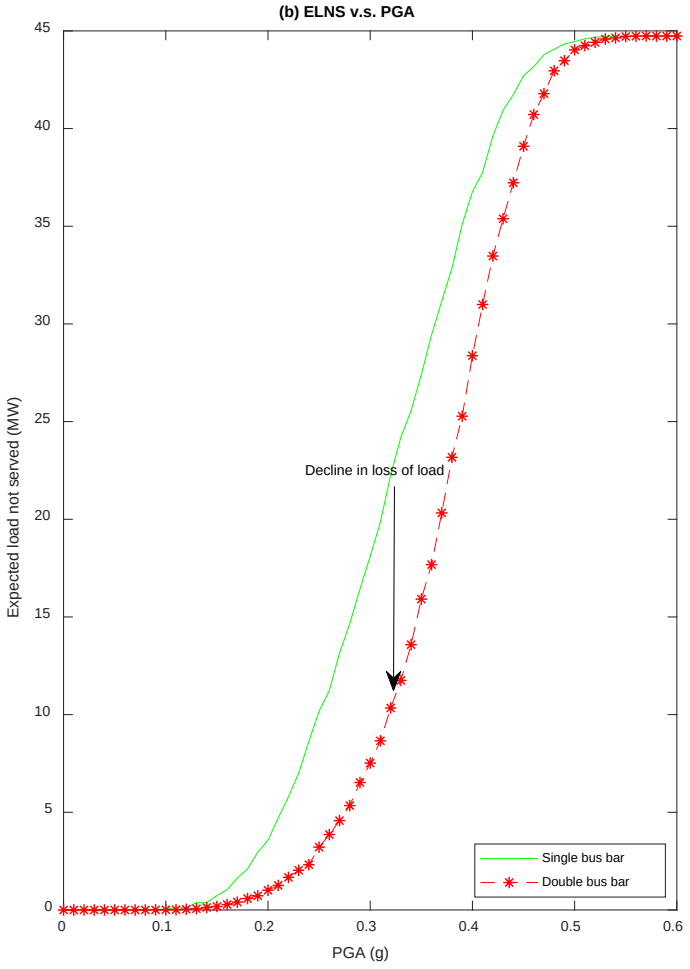

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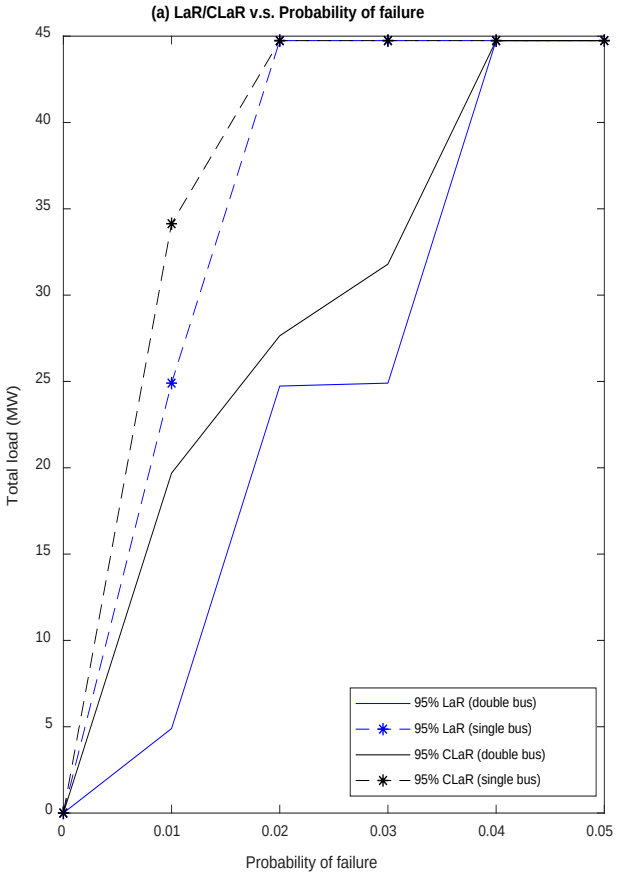
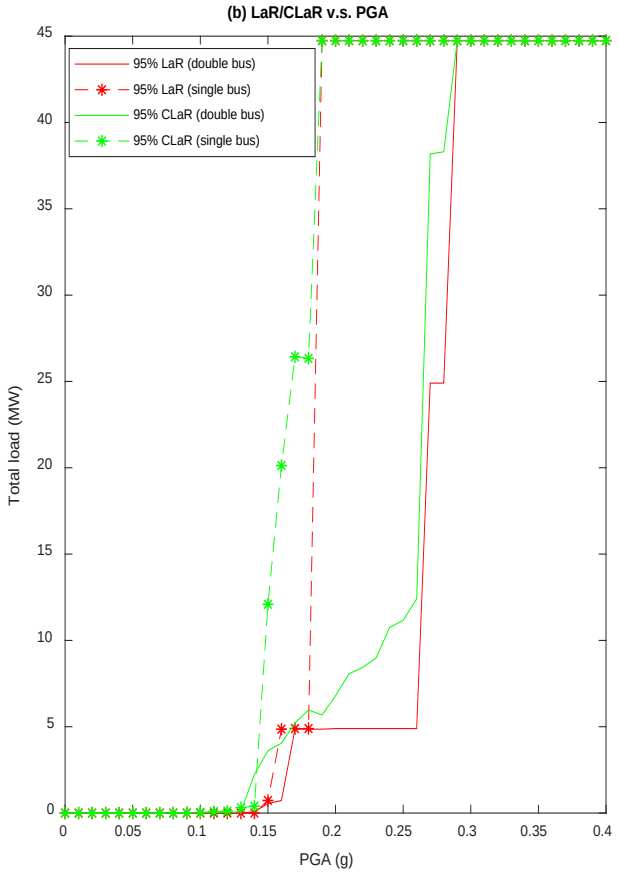
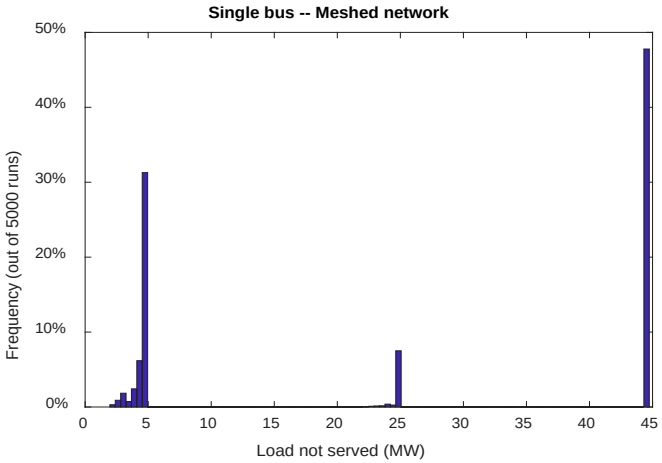
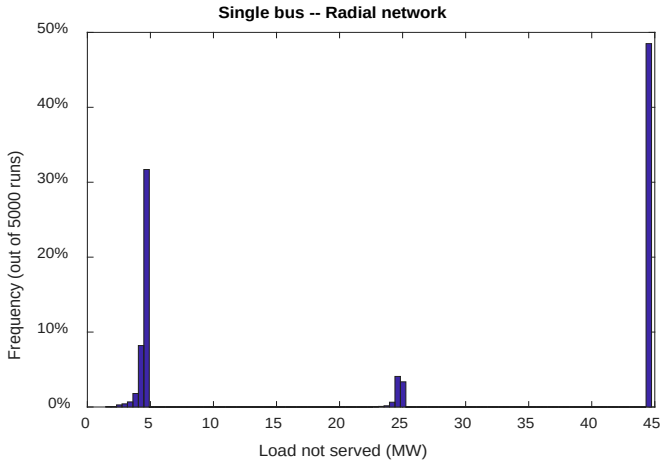
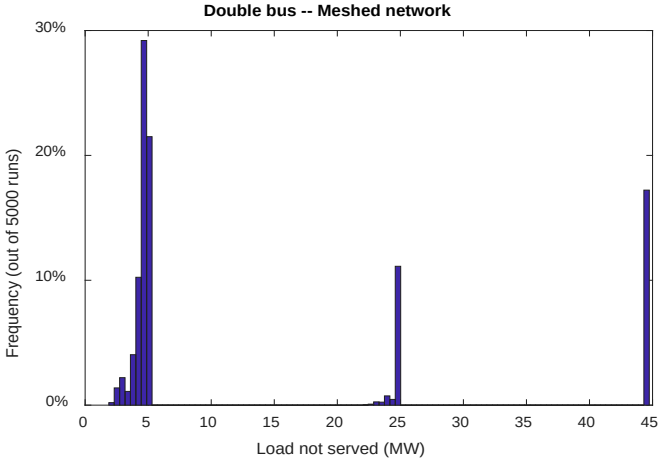


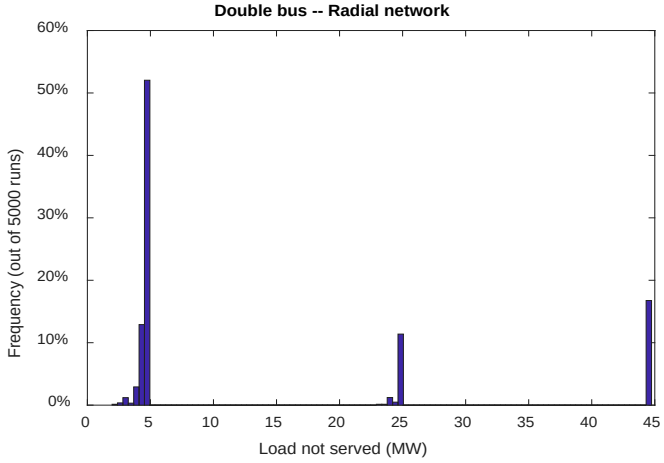



# Case study – Comparison of network configuration



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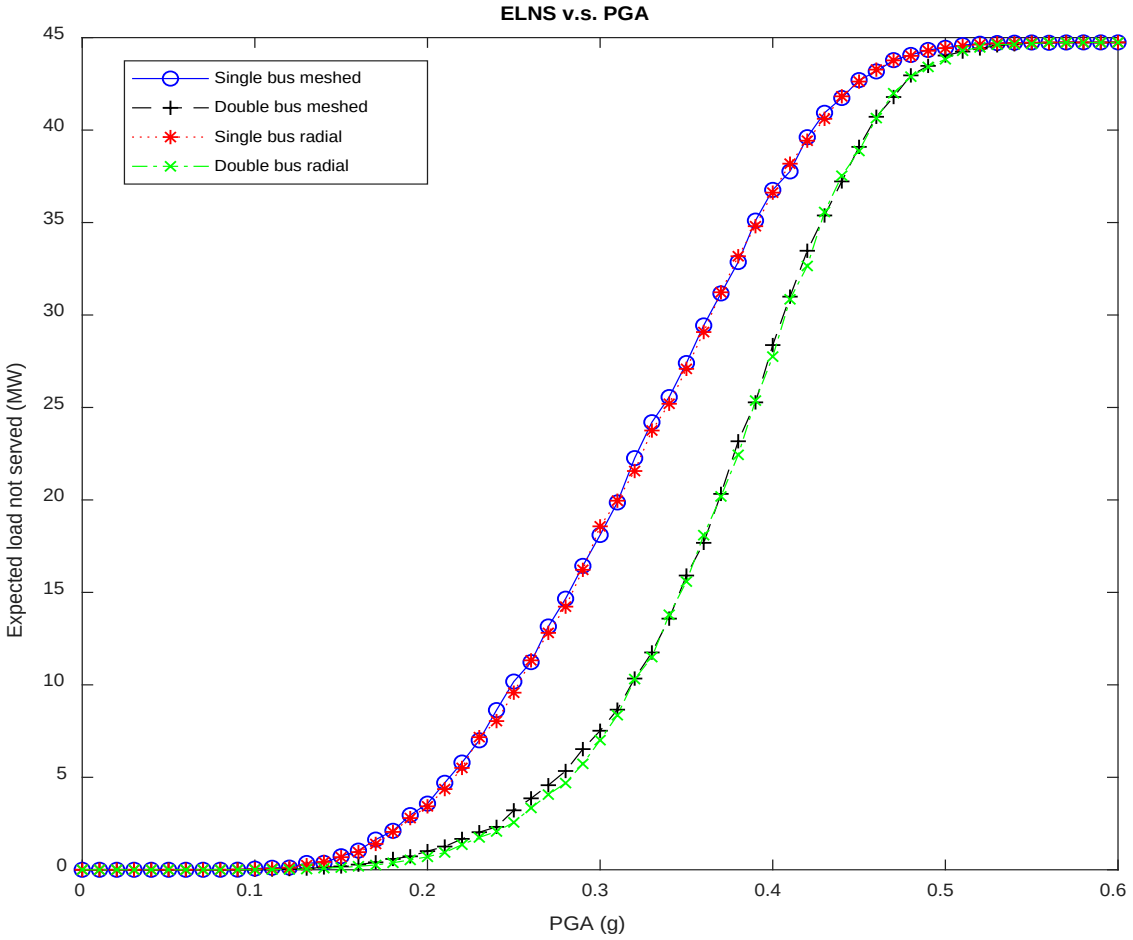

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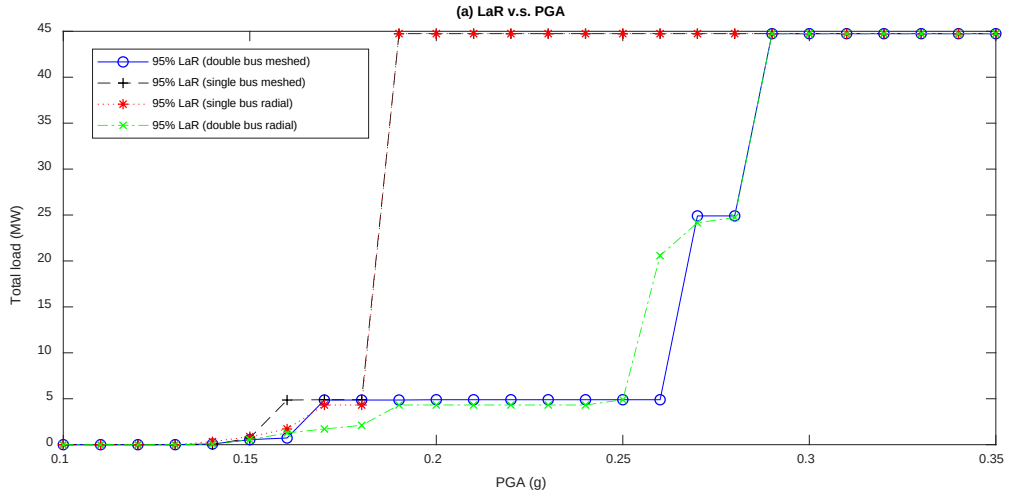


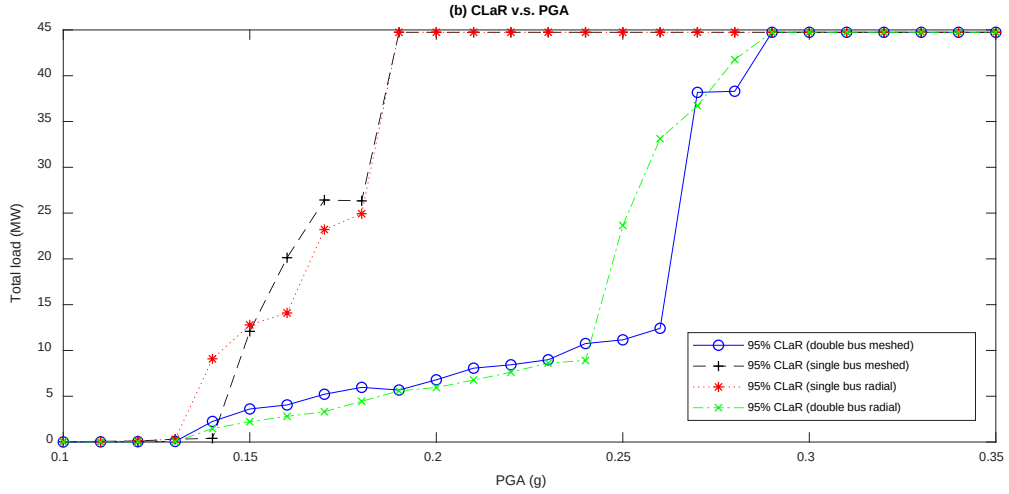

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# Conclusion and outlook

- Quantification of network level of functionality using network process modelling
- Assessment of the effect of component fragility, network topology and substation configuration

- Future work
  - Recovery process determined by operational decisions and network interdependencies
  - Addition of temporal characteristics will enable resilience quantification

# Thanks

# Q&A