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U.S. DEPARTMENT OF
ENERGY

Risk-controlled Expansion Planning with Distributed Resources (REPAIR)

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Reliability and Resilience

Motivation

The electrification of important sectors of the economy and society (health, information, industry, etc.) makes power distribution vital for communities, which requires distribution grids to be **reliable**.

High Impact Low Probability Events (HILP) (such as storms, hurricanes, earthquakes, wildfires, etc.) are becoming more frequent, which requires distribution grids to be **resilient**.



Reliability and Resilience

A planning problem

How to make sure utilities have the necessary resources on the ground to respond to routine failures and mitigate the HILP events?

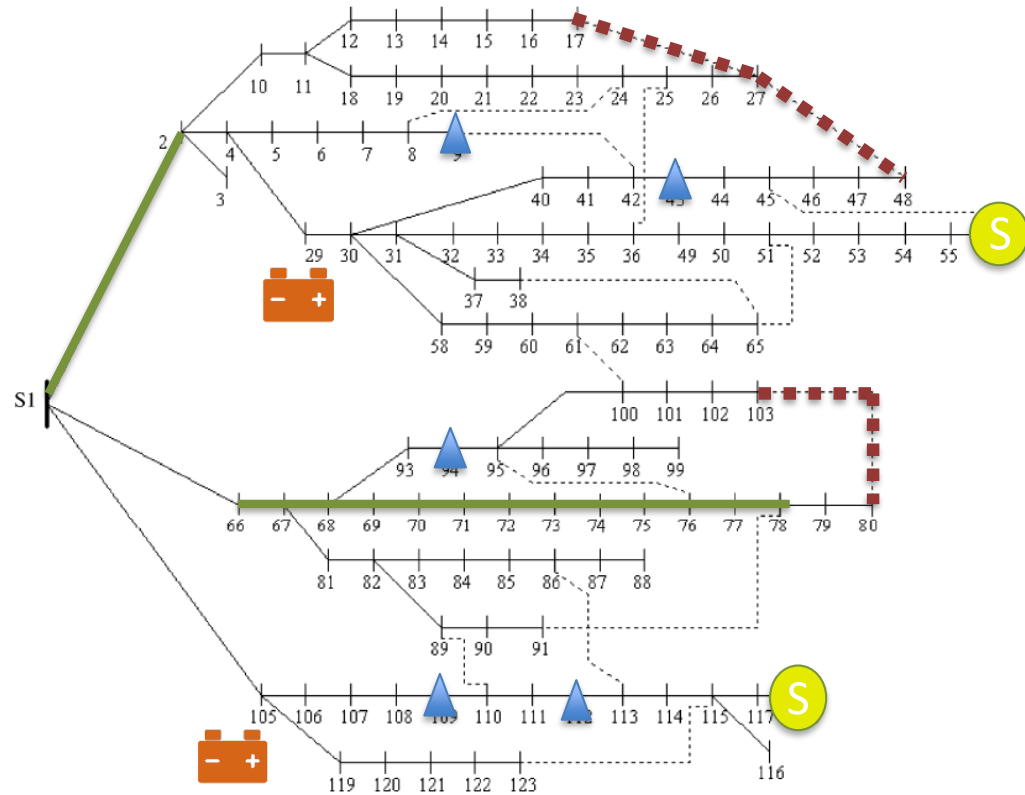
How can utilities make risk informed decisions when planning for investments?

What are the trade-offs between optimizing for Economic, Reliability and Resilience targets?



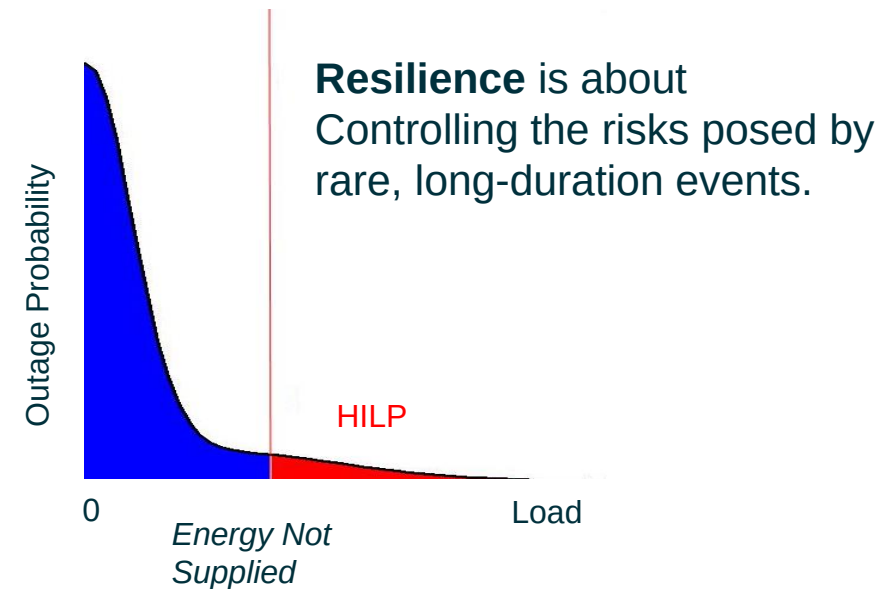
Distribution Grid Expansion Planning

Adding Reliability and Resilience



Reliability planning is about mitigating outages caused by routine events.

- Expected value of interruptions.



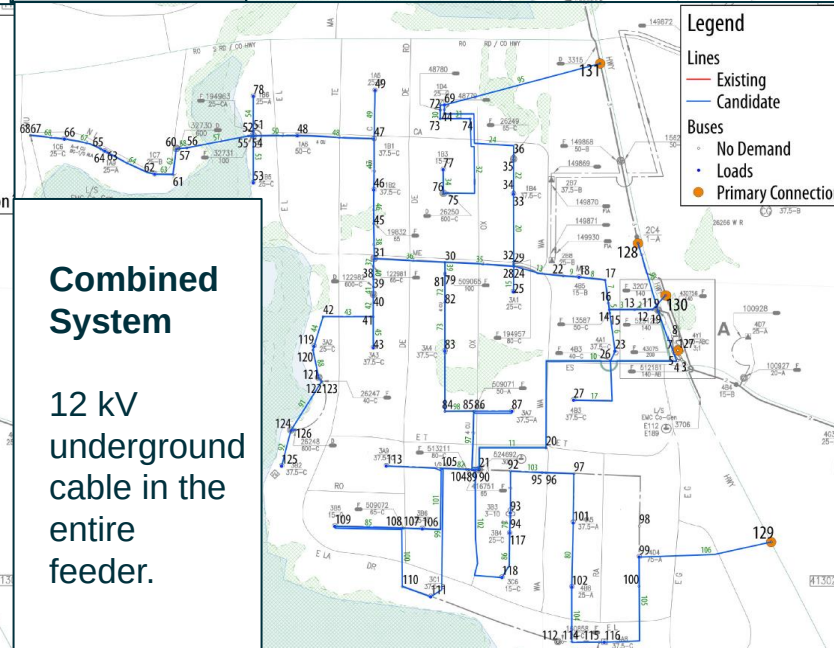
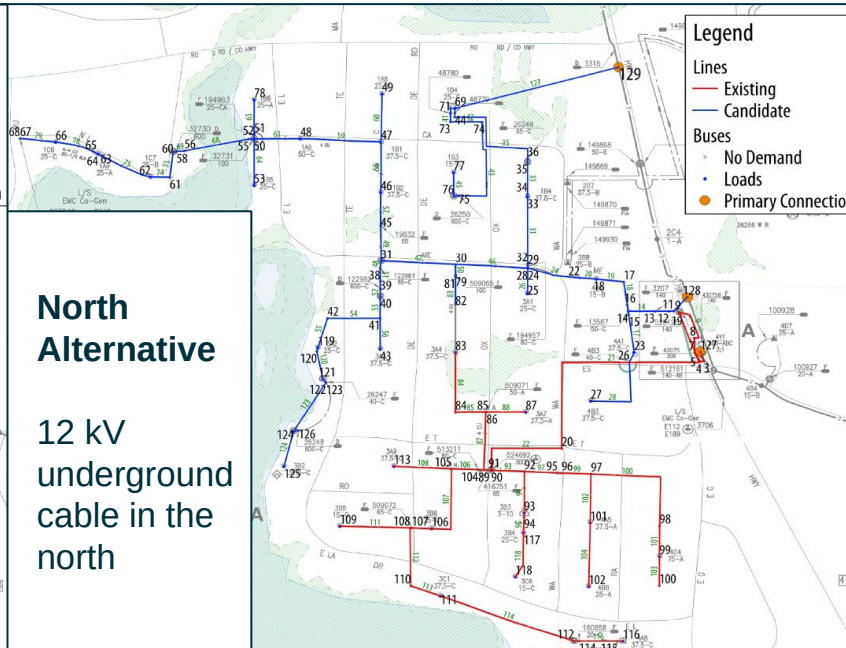
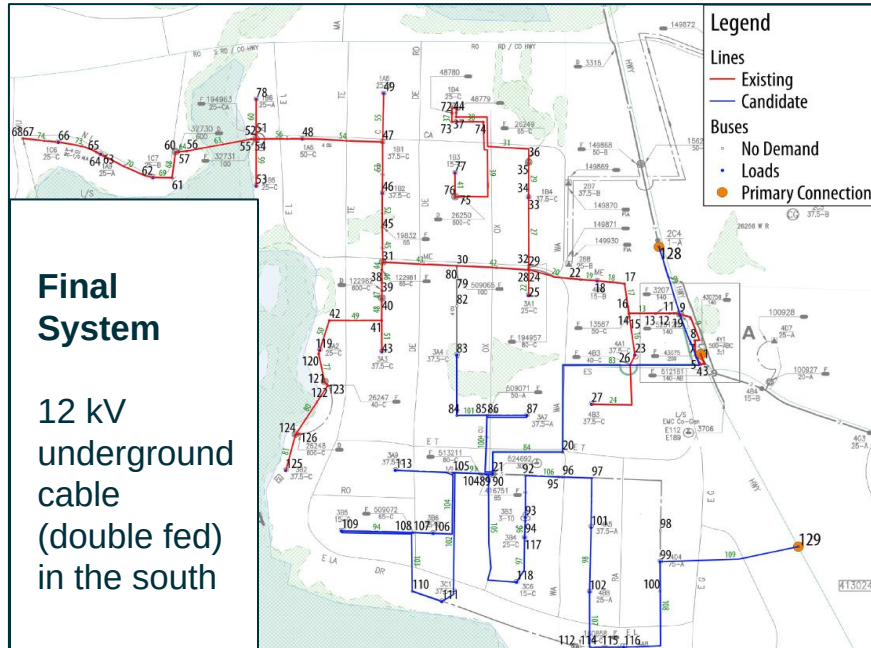
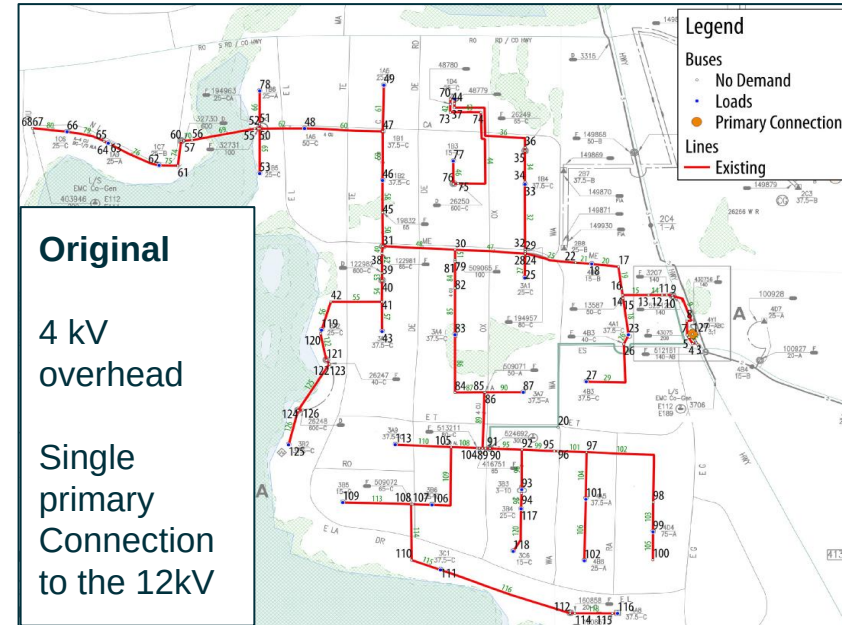
Case Study 1

Commonwealth Edison (ComEd) Feeder in Chicago area

10 years of historical outages modeled.

6 types of HILP events (4 storms 2 floods) very rate (take place 1/70 years).

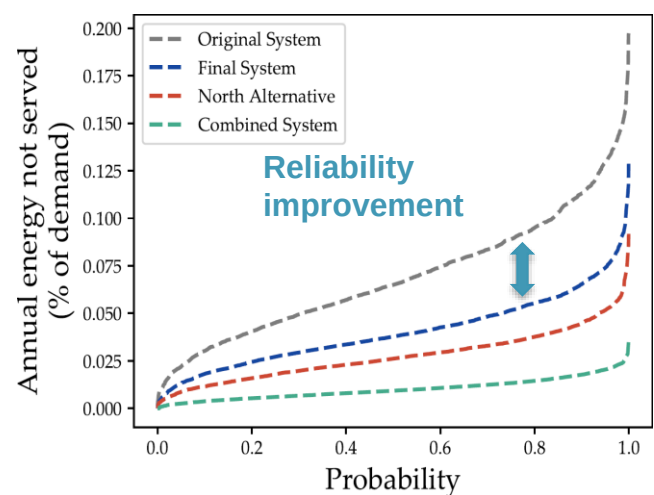
rate of failure	# lines
0.1	122
0.2	0
0.3	3
0.4	1
≥ 0.5	1
Total	127



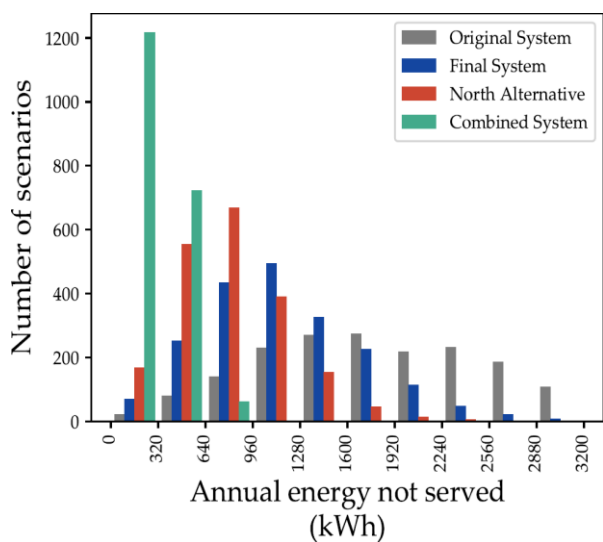
Case Study 1

Reliability Results

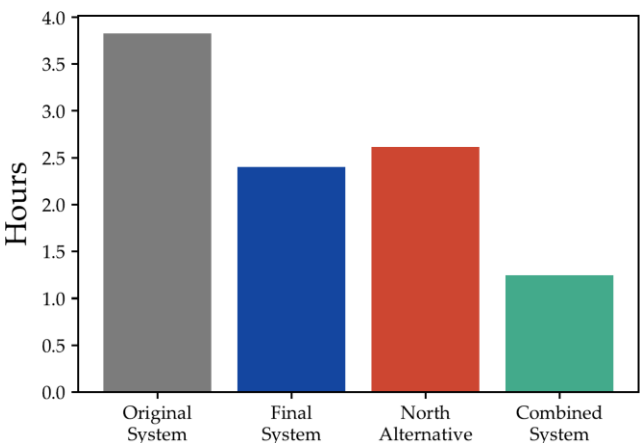
AENS – cumulative distribution



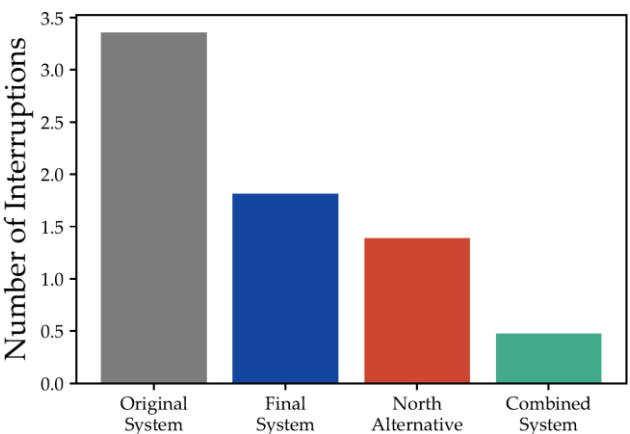
AENS – distribution



SAIDI



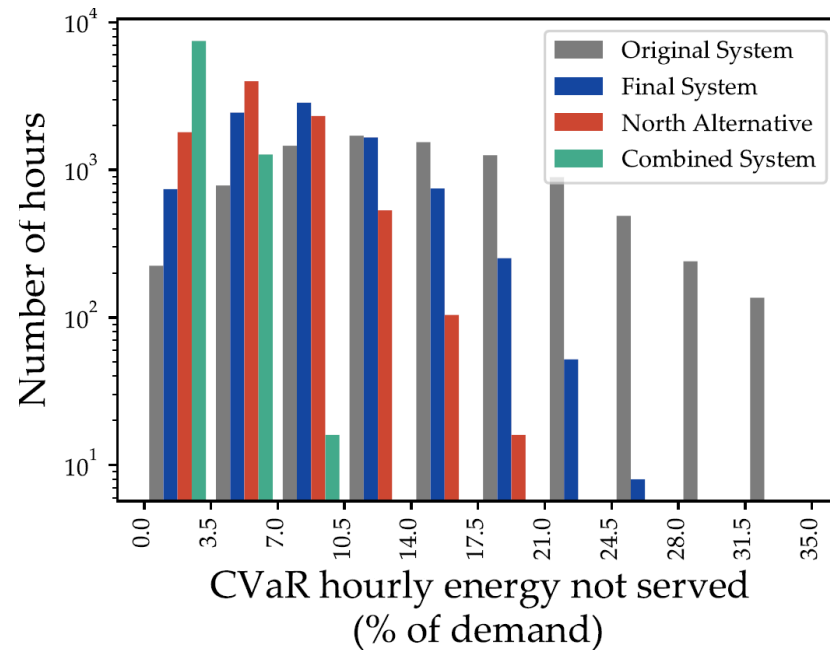
SAIFI



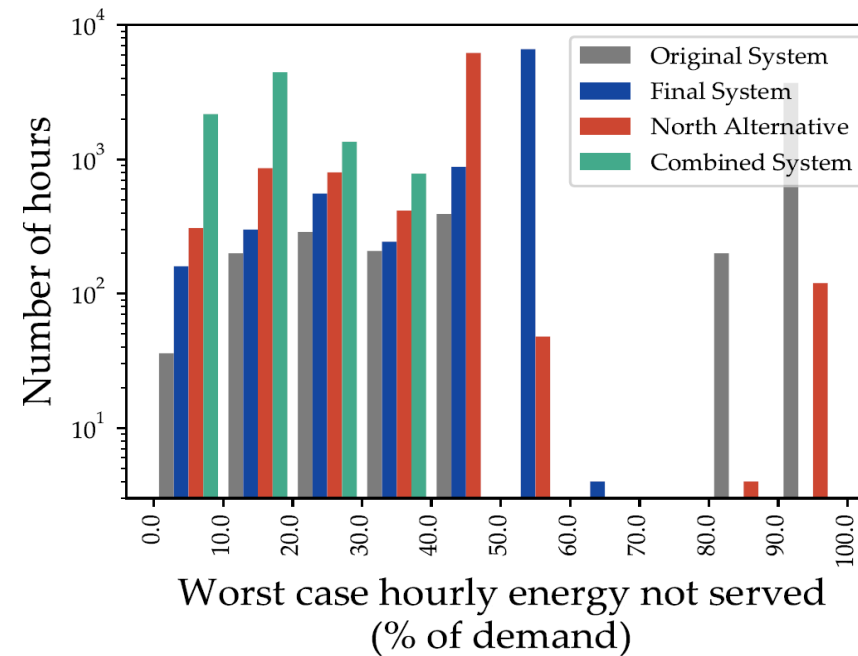
Case Study 1 (simulation)

Resilience Results

CVaR - Risk of not serving demand

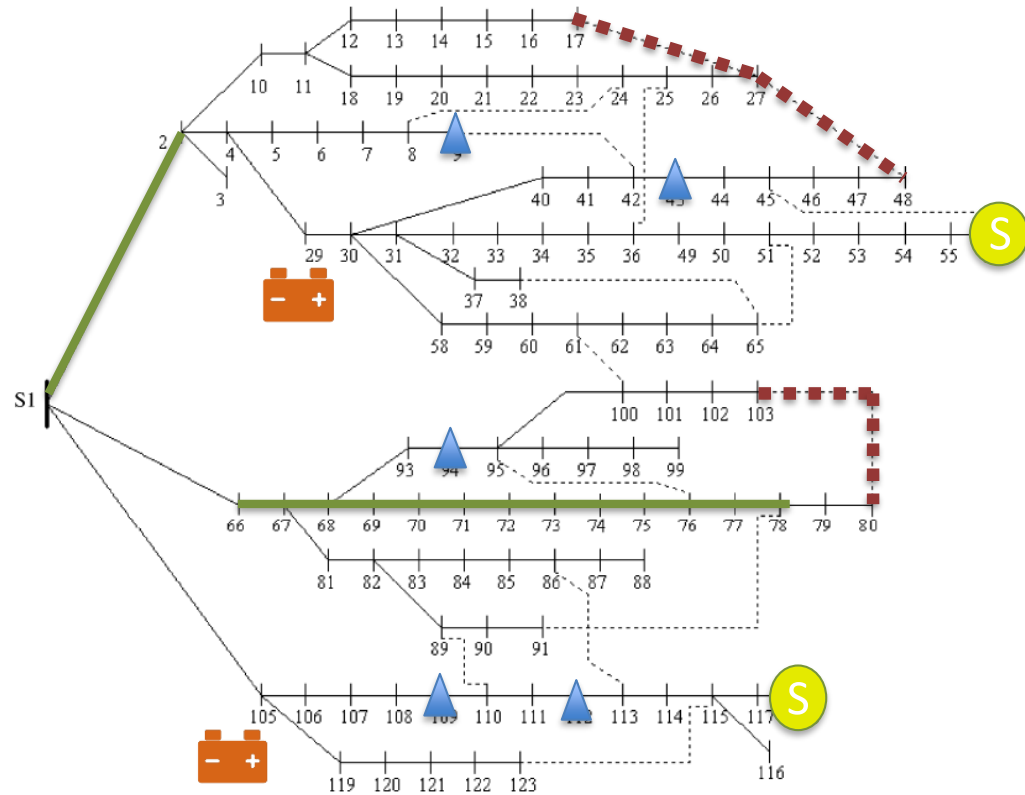


Worst case evaluation

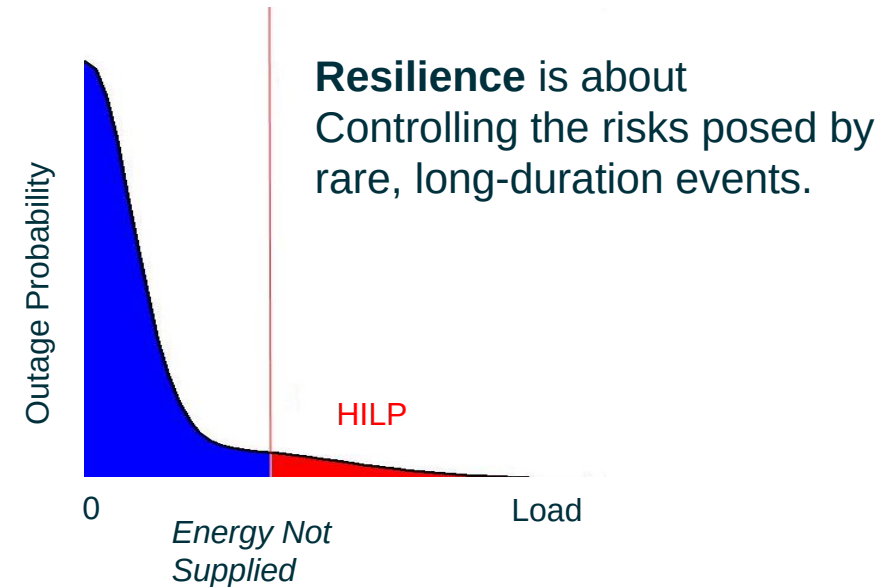


Distribution Grid Expansion Planning

Adding Reliability and Resilience



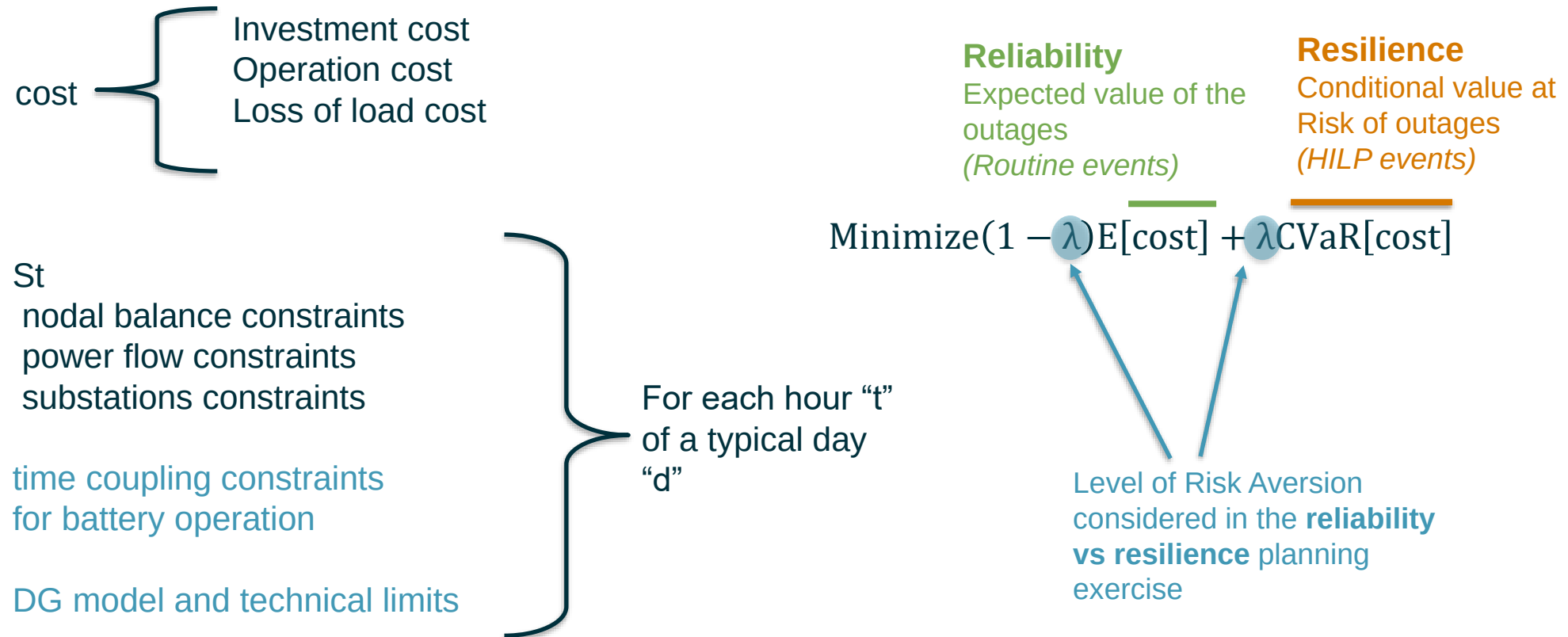
Reliability planning is about mitigating outages caused by routine events, i.e. the expected value of interruptions.



Reliability, resilience, costs: what are the trade-offs?

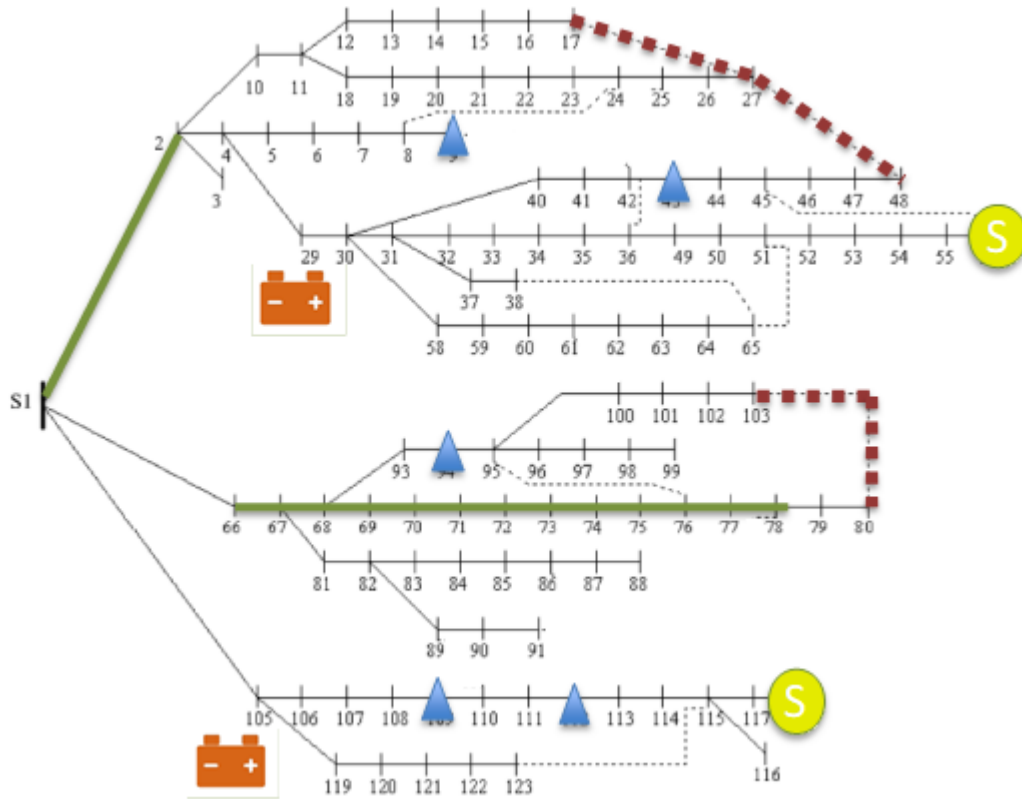
REPAIR - Methodology

Cost vs Risk Model – Stochastic Optimization Model

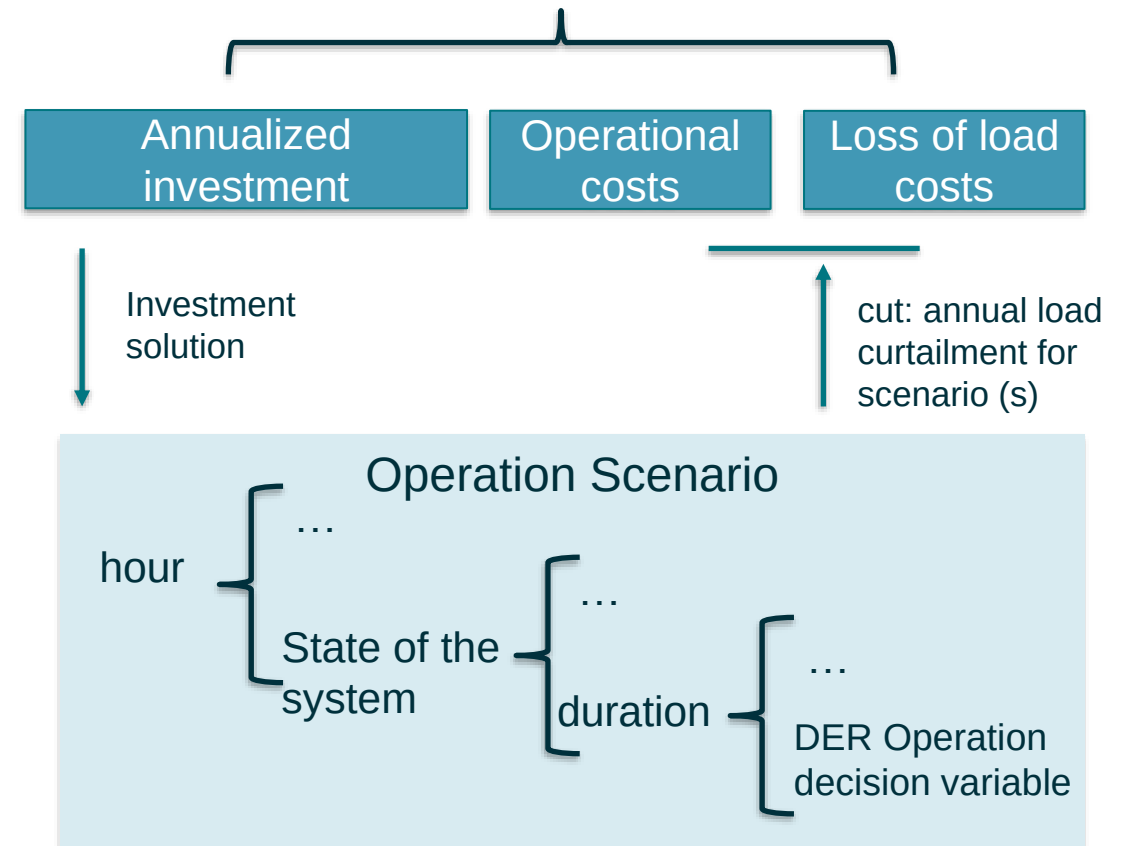


Optimization Model

A large problem

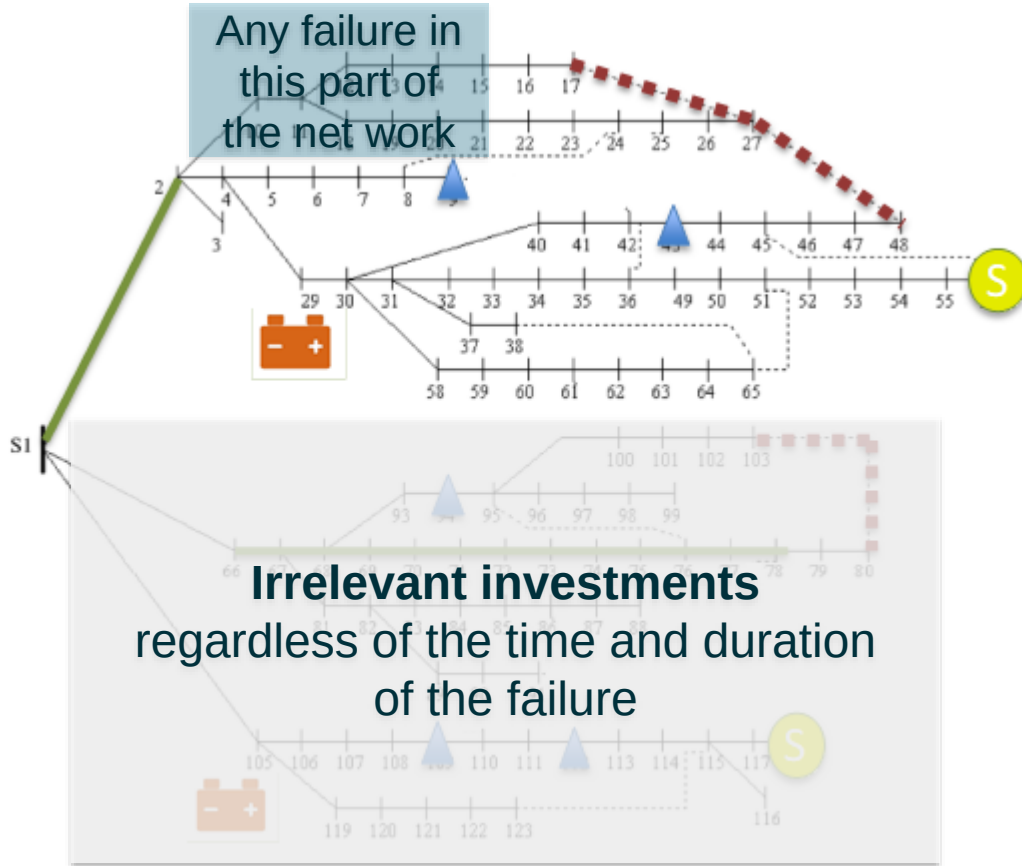


$$\text{Minimize}(1 - \lambda)E[\text{cost}] + \lambda\text{CVaR}[\text{cost}]$$

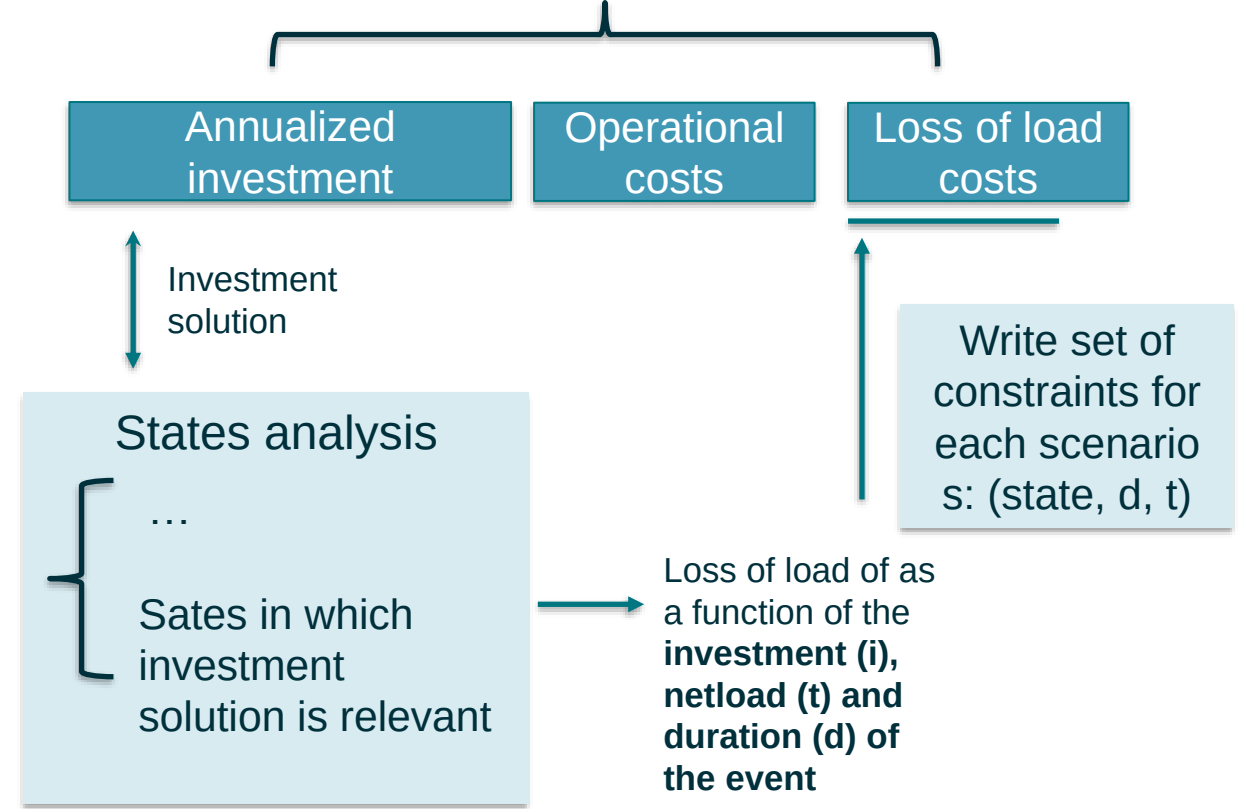


Optimization Model

Reducing complexity



$$\text{Minimize}(1 - \lambda)E[\text{cost}] + \lambda\text{CVaR}[\text{cost}]$$



This is effective in realistic conditions:

- The number investments is small in comparison with the number of outage scenarios.
- Time coupling operation decisions are not influenced by the probability of outages.

Case Study 2

Test Feeder

13.5 kV

54 Nodes – 50 Lines

7 MW Peak

Scenarios

1263 scenarios of **routine** failures (1 every 2.5 years)

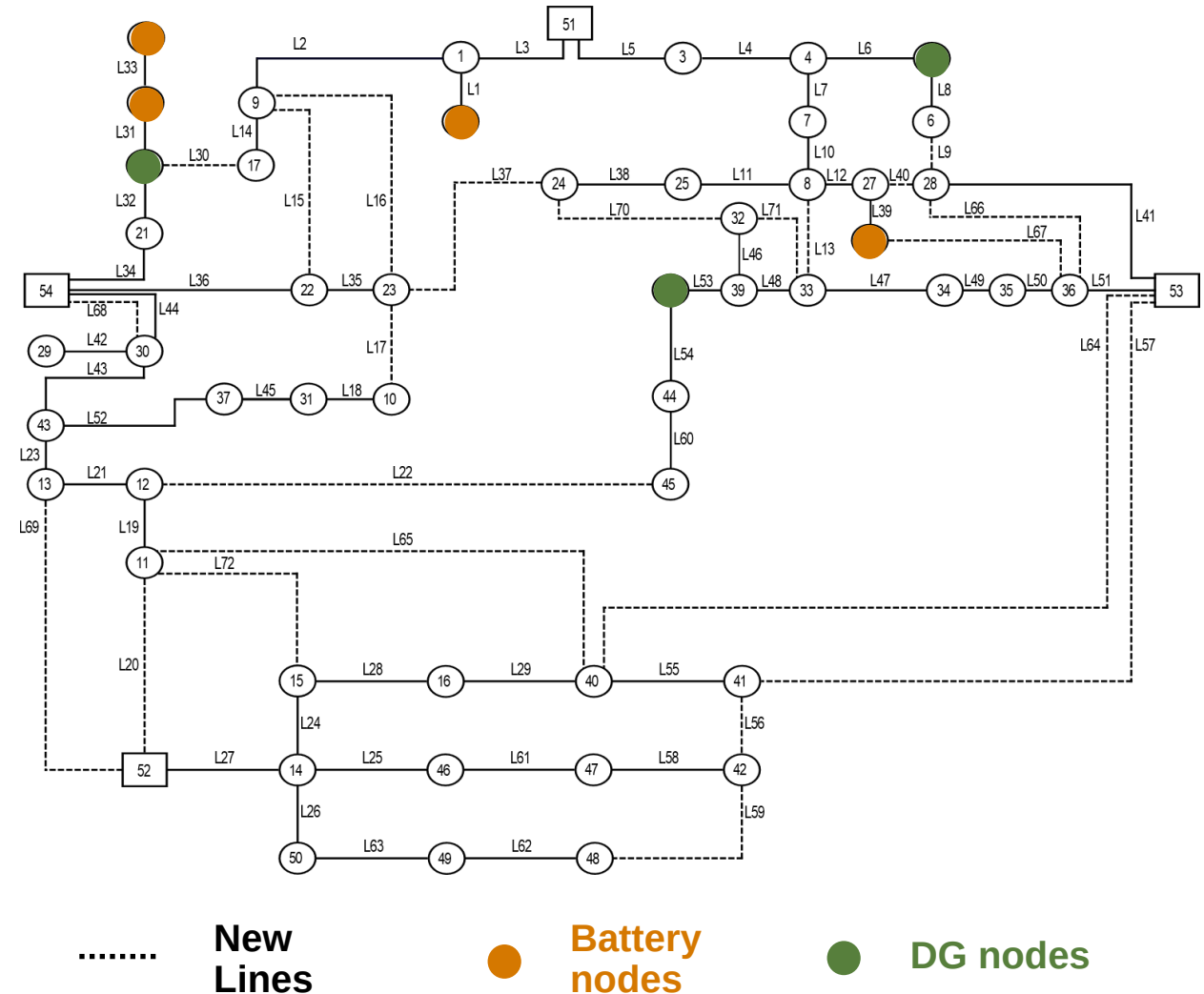
100 scenarios of **HILP events** (1 every 70 years)

Candidate Assets

22 new lines

4 batteries nodes

4 types of DG in 3 candidate nodes



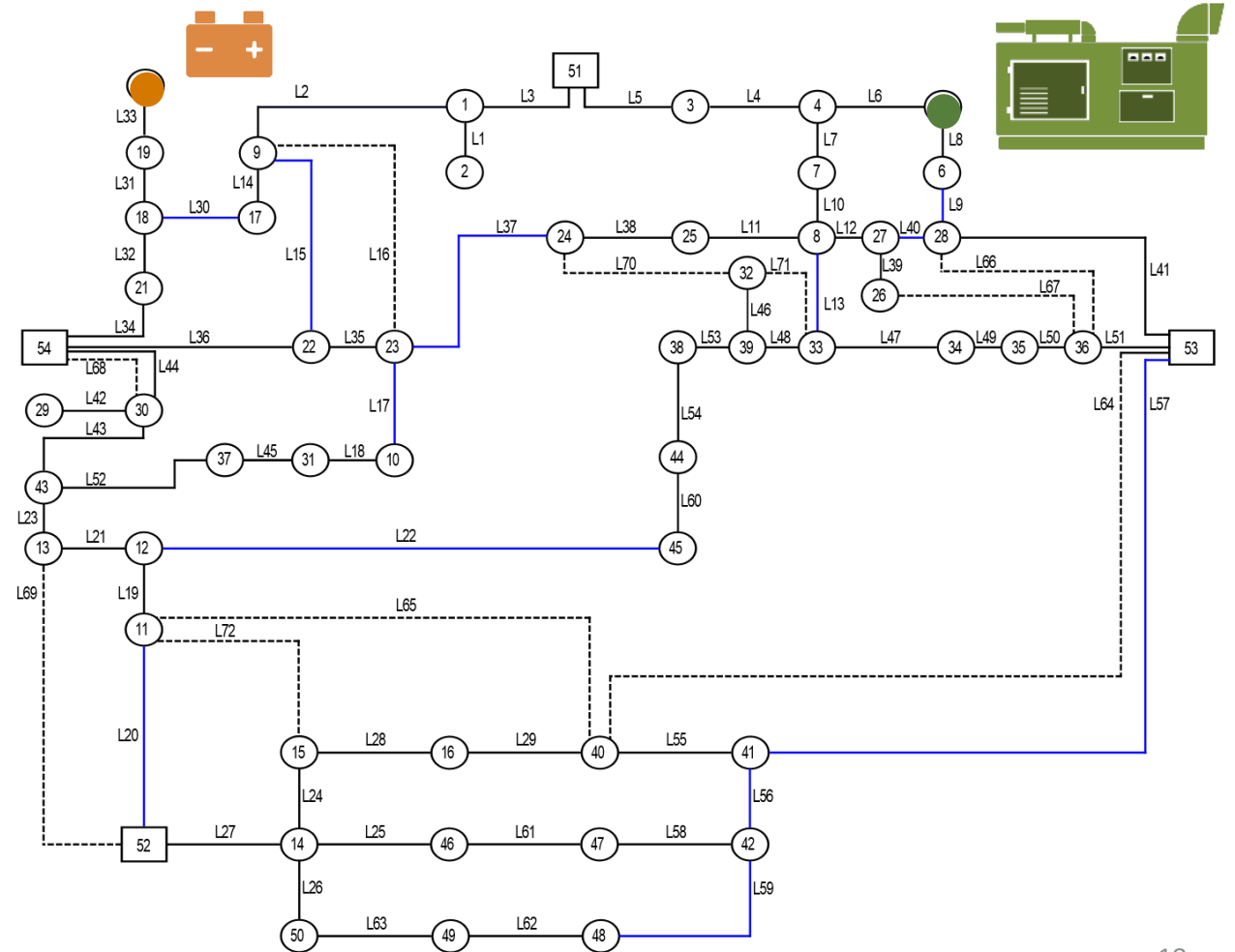
Case Study 2

Results: considering reliability only ($\lambda=0$)

..... **New Lines: 12**

● **Battery nodes: 1 x 280 kWh**

● **DG: 1 x 800 kW (NG)**



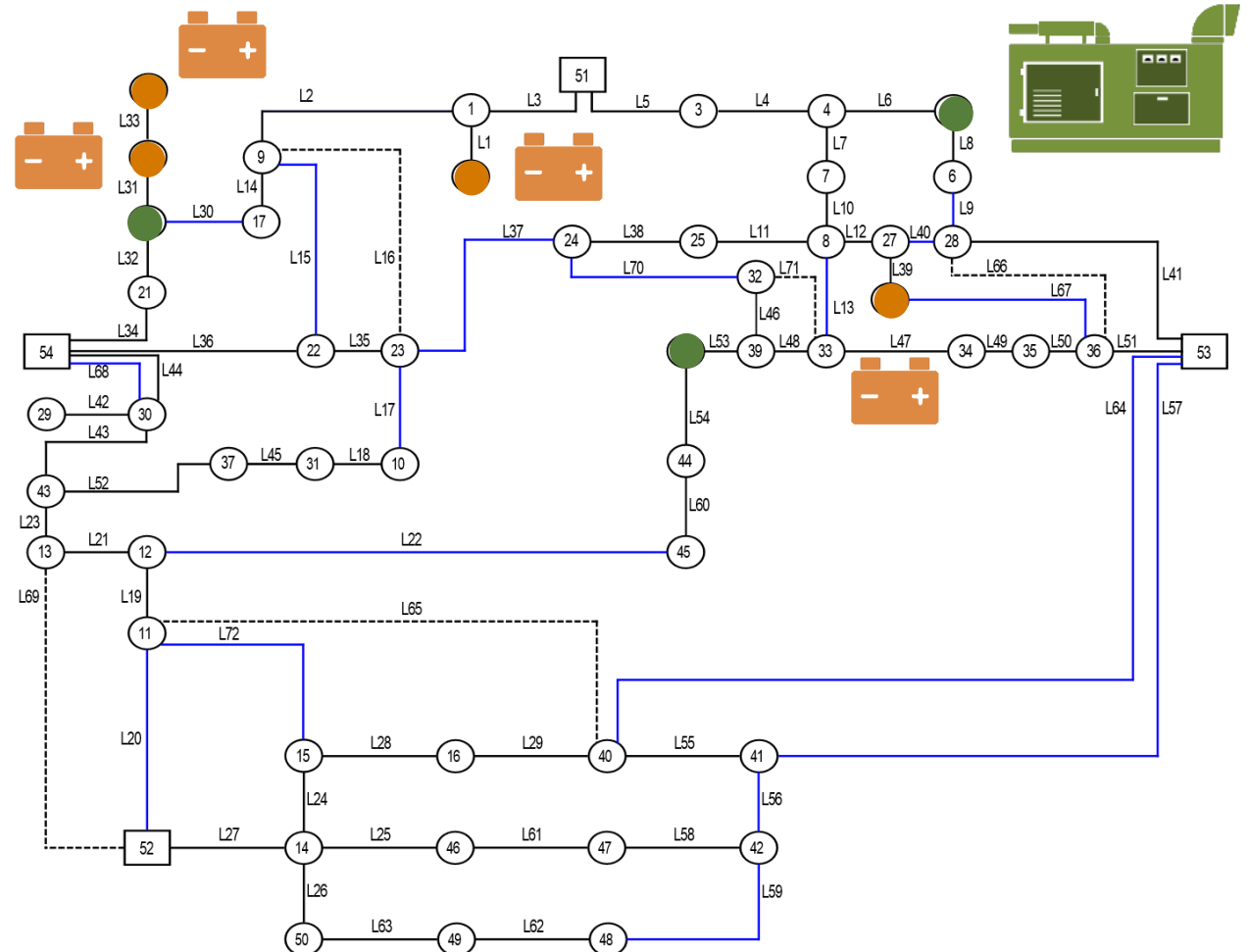
Case Study 2 (Optimization)

Results: risk-aversion ($\lambda=0.5$), considering reliability and resilience

..... **New Lines: 17**

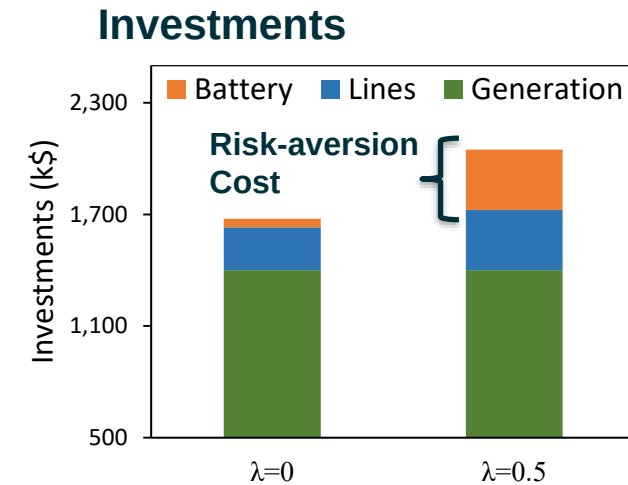
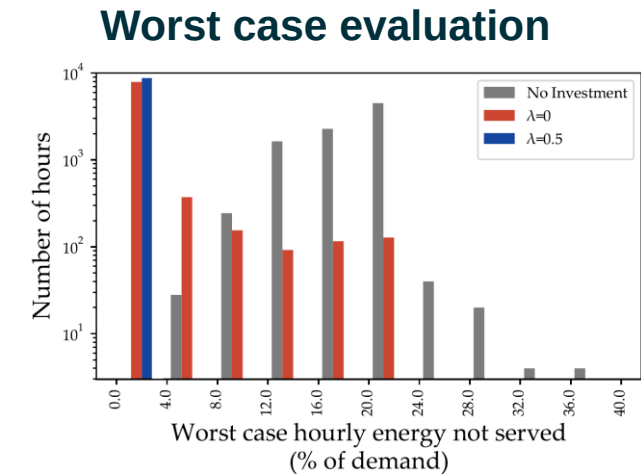
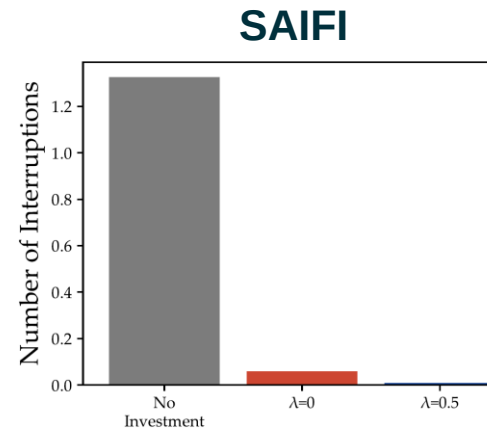
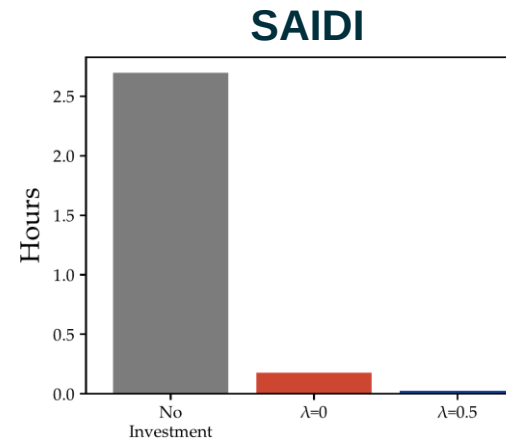
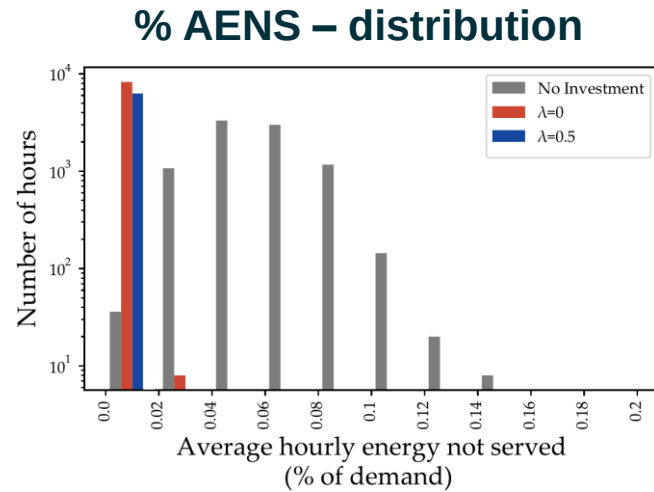
● **Battery nodes: 1 x 800 kWh**
1 x 500 kWh
1 x 360 kWh
1 x 360 kWh

● **DG: 1 x 800 kW (NG)**



Case Study 2

Results comparison (simulation)



Conclusions

Distribution grid investment solutions might improve reliability and resilience in different ways.

The trade-offs can be translated as a risk-aversion parameter input by the user.

This results in a stochastic “cost vs risk model”. Although this is a computationally intensive problem, the real-world planning conditions actually help scaling it.

This model can capture the additional costs of different risk-aversion planning policies.

Project Team



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