Risk-controlled Expansion Planning with Distributed Resources (REPAIR)

Miguel Heleno

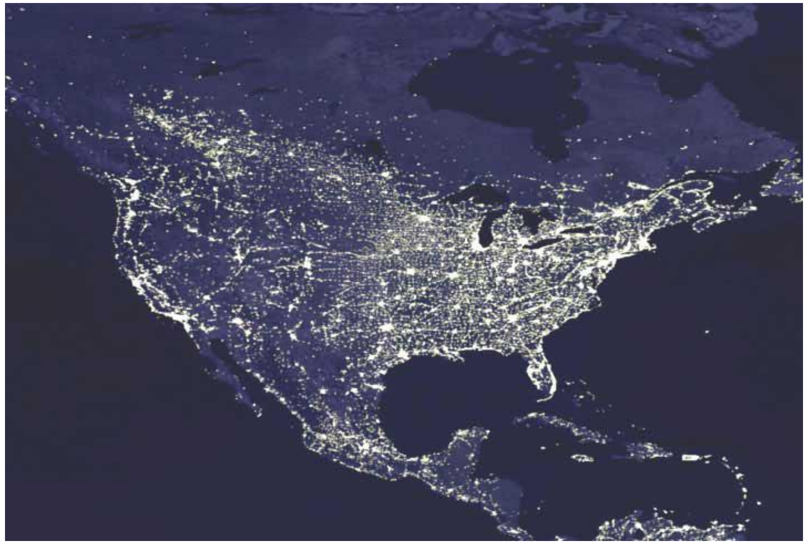
ESIG Fall Technical Workshop, October 12, 2021

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

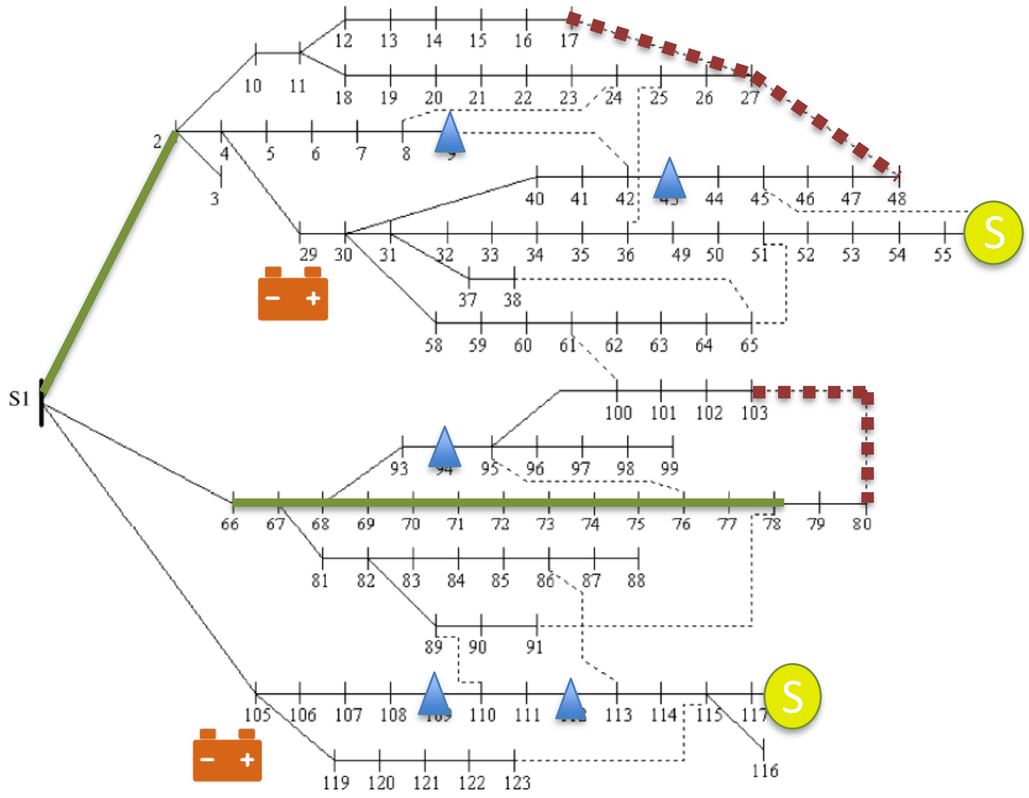
How to make sure utilities have the necessary resources on the ground to respond to routine failures and mitigate the HILP events?

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

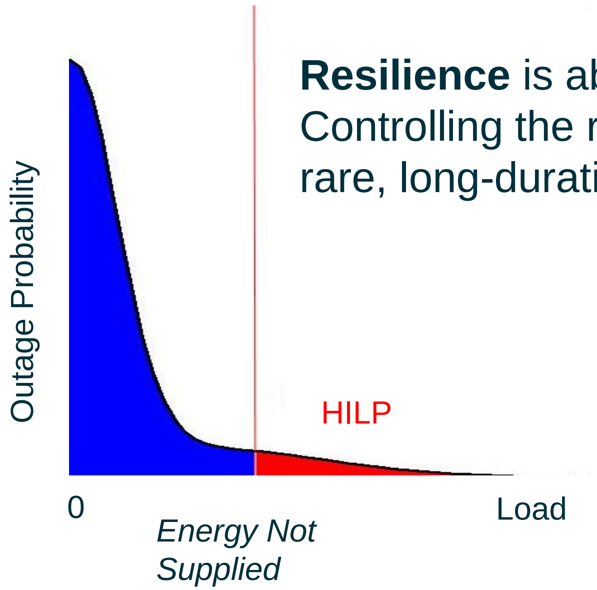
Adding Reliability and Resilience



Reliability planning is about mitigating outages caused by routine events.

- Expected value of interruptions.

Resilience is about Controlling the risks posed by rare, long-duration events.



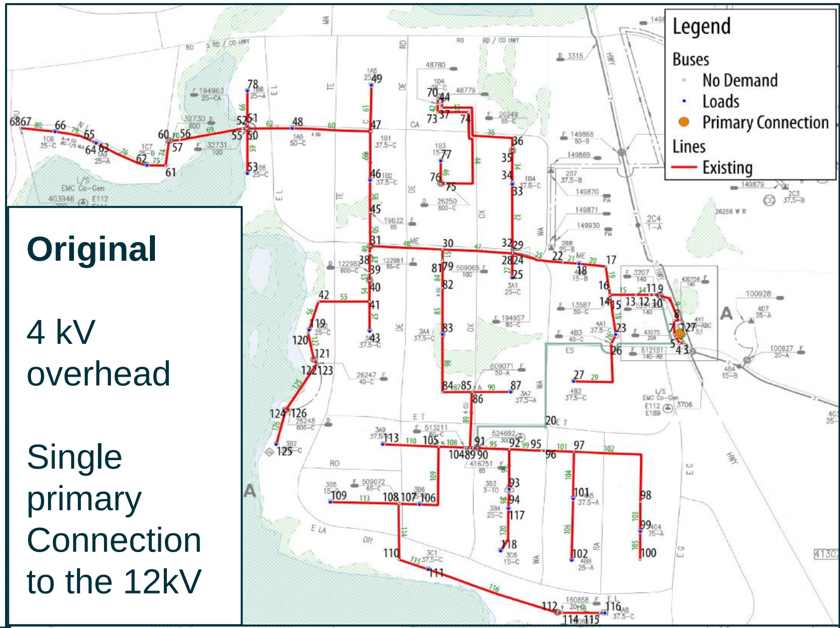
Case Study 1

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).

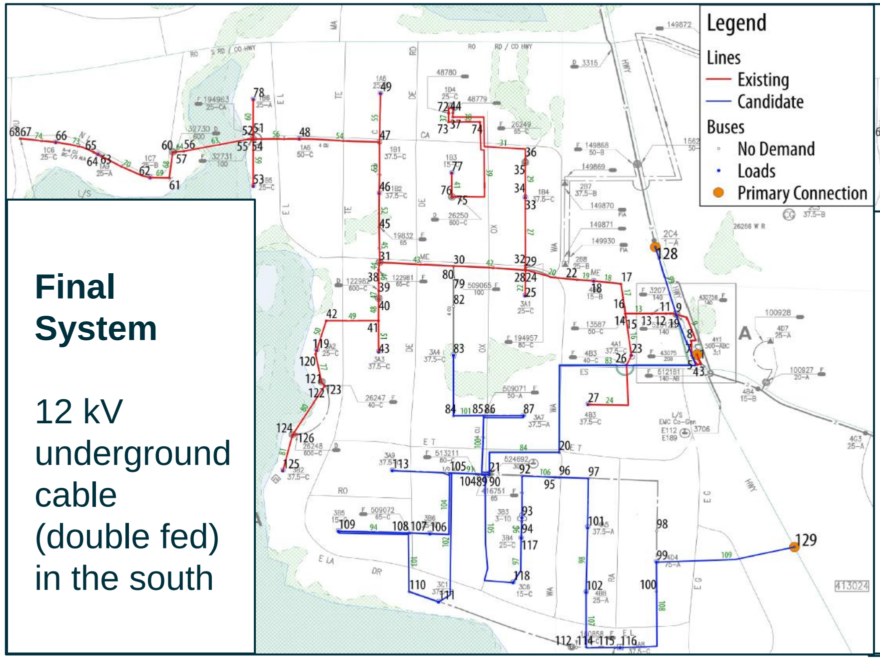
rate of failure	# lines
0.1	122
0.2	0
0.3	3
0.4	1
>=0.5	1
Total	127



Original

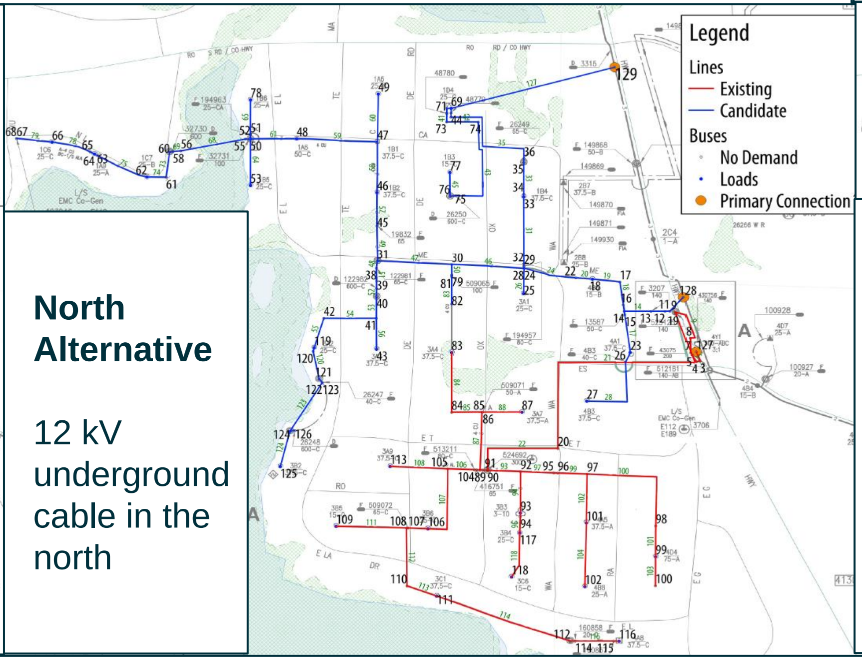
4 kV overhead

Single primary Connection to the 12kV



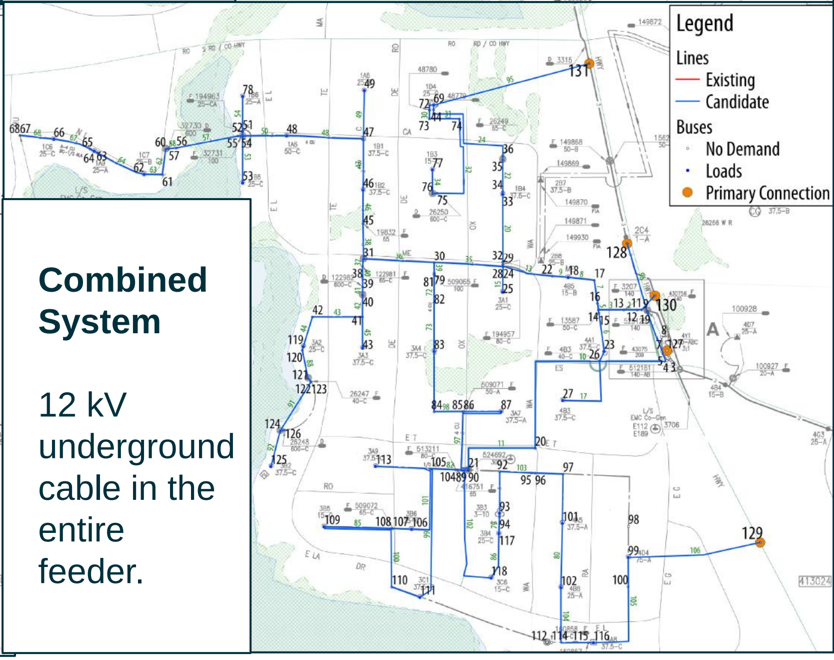
Final System

12 kV underground cable (double fed) in the south



North Alternative

12 kV underground cable in the north



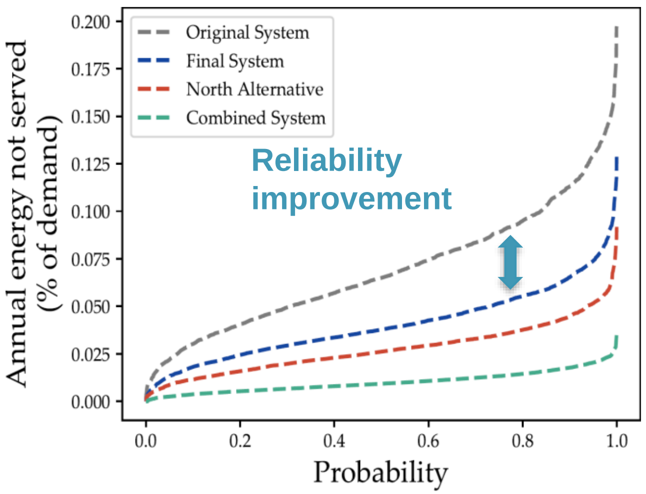
Combined System

12 kV underground cable in the entire feeder.

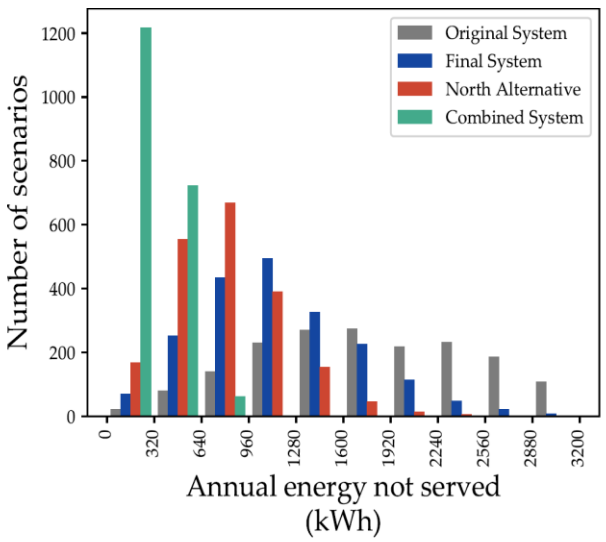
Case Study 1

Reliability Results

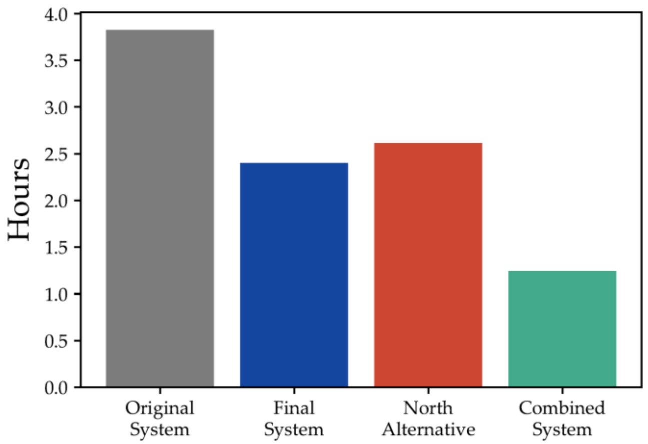
AENS – cumulative distribution



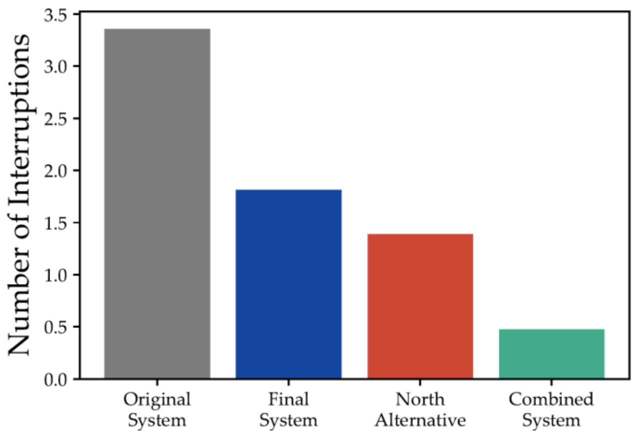
AENS – distribution



SAIDI



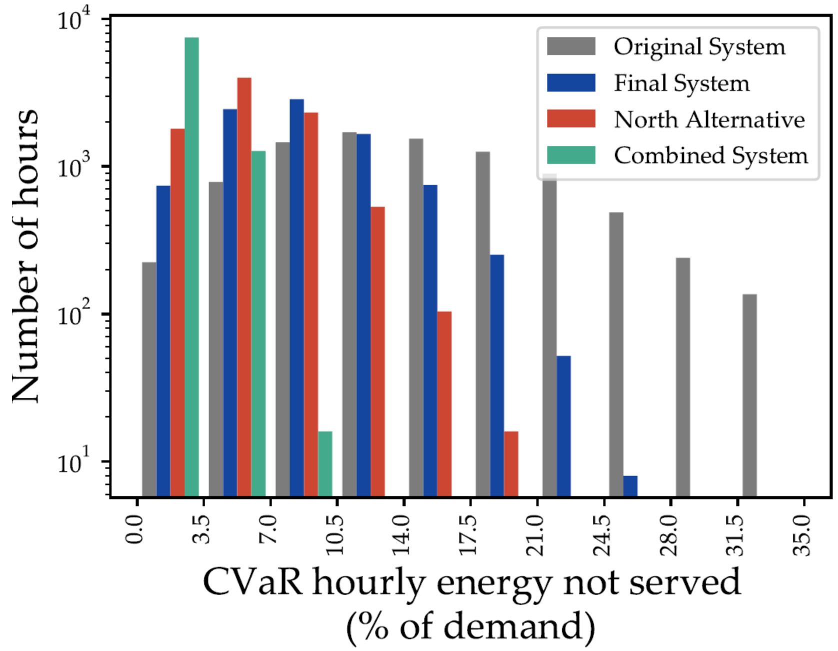
SAIFI



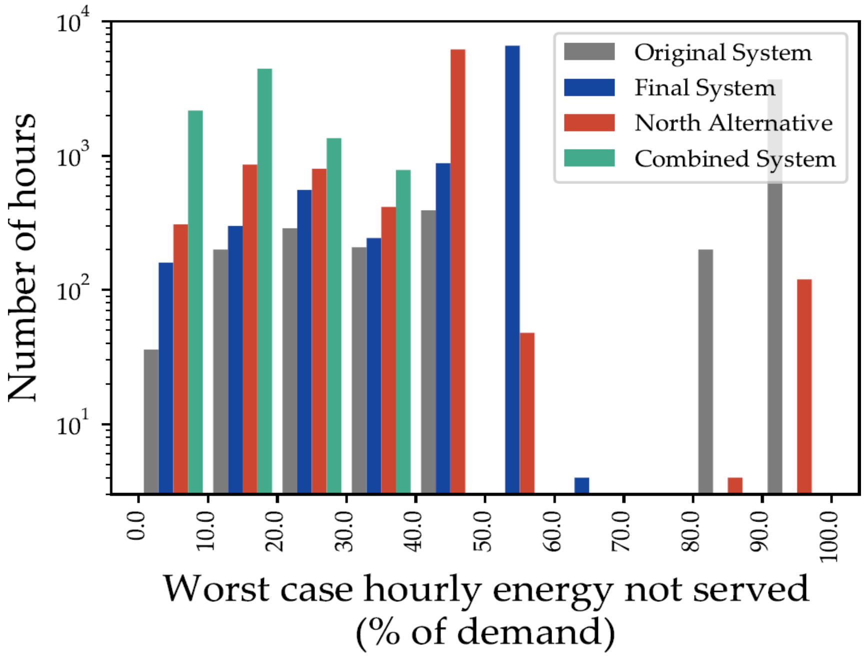
Case Study 1 (simulation)

Resilience Results

CVaR - Risk of not serving demand

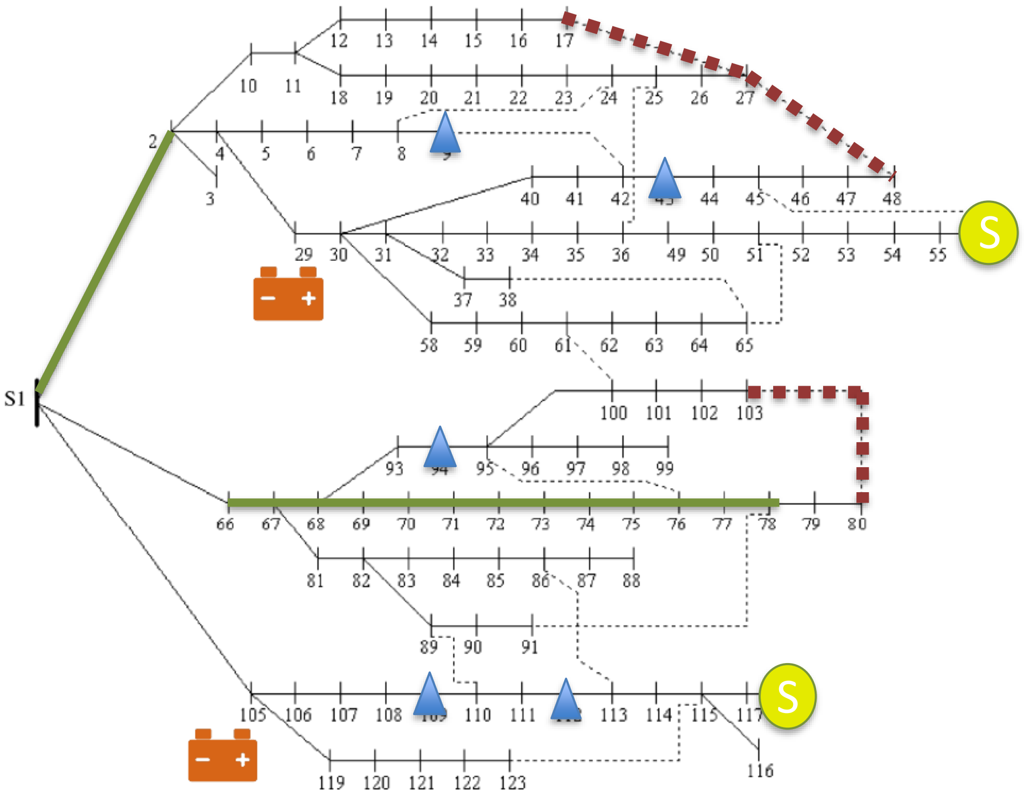


Worst case evaluation

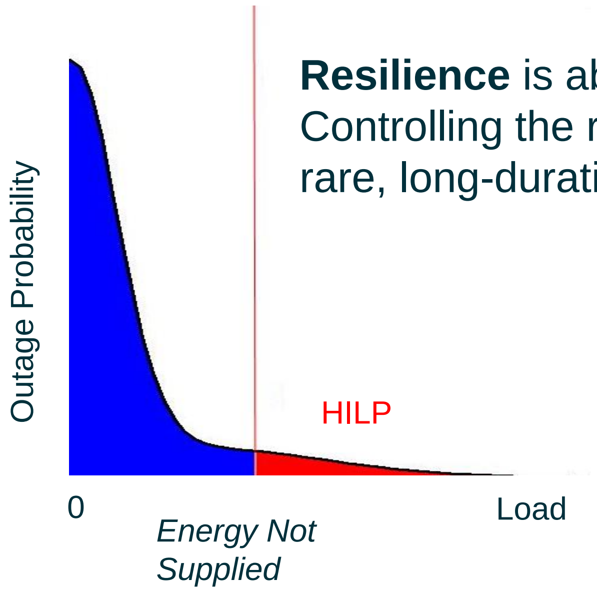


Distribution Grid Expansion Planning

Adding Reliability and Resilience



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



Resilience is about Controlling the risks posed by rare, long-duration events.

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

REPAIR - Methodology

Cost vs Risk Model – Stochastic Optimization Model

cost
- Investment cost
- Operation cost
- Loss of load cost

St
- nodal balance constraints
- power flow constraints
- substations constraints

time coupling constraints for battery operation

DG model and technical limits

For each hour “t” of a typical day “d”

Reliability
Expected value of the outages
(Routine events)

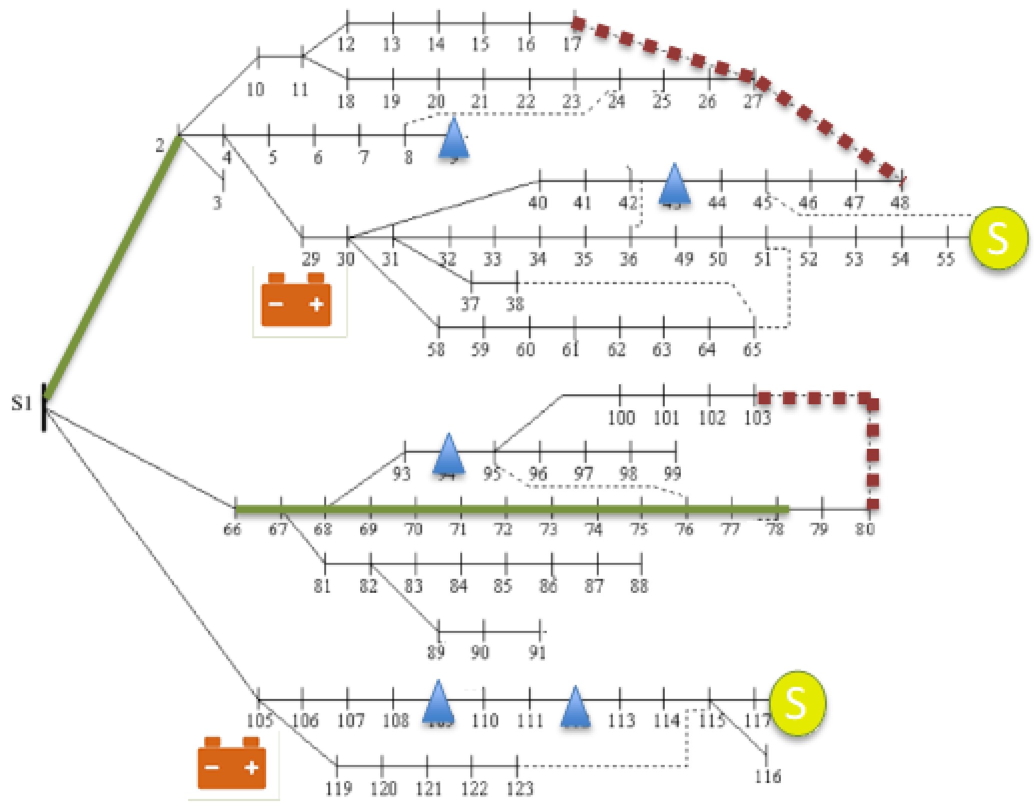
Resilience
Conditional value at Risk of outages
(HILP events)

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

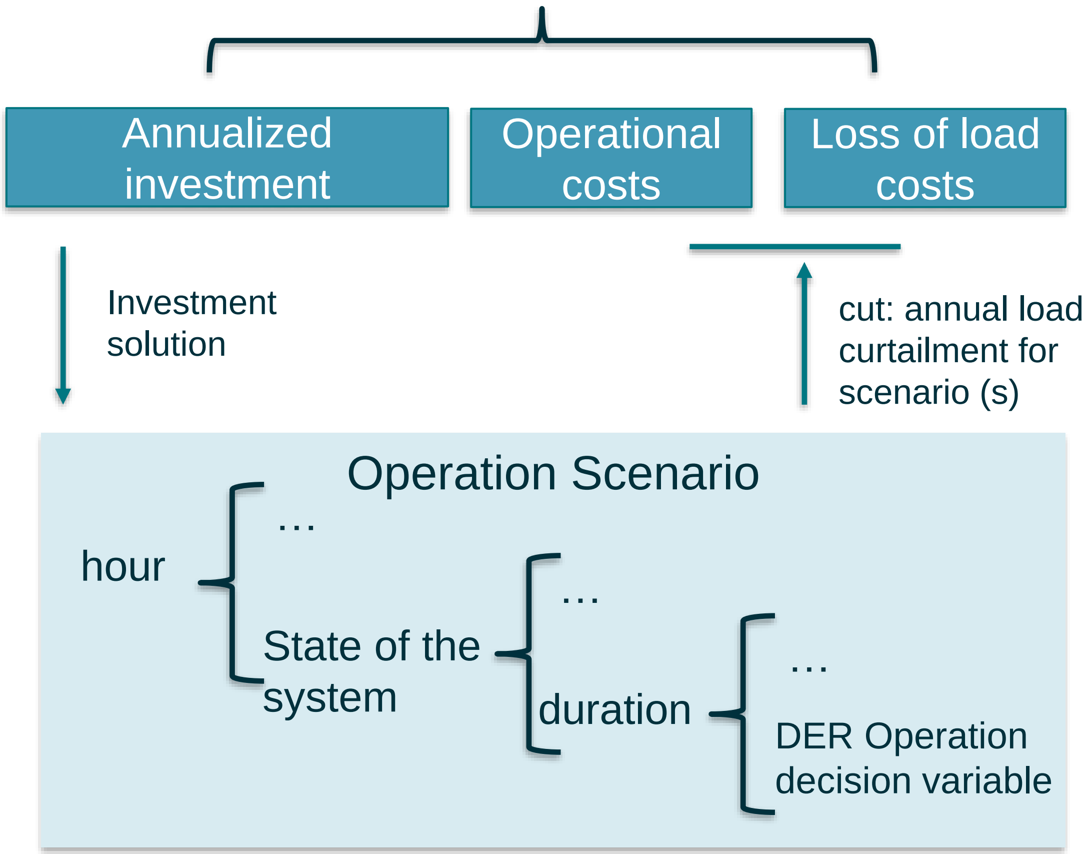
Level of Risk Aversion considered in the **reliability vs resilience** planning exercise

Optimization Model

A large problem

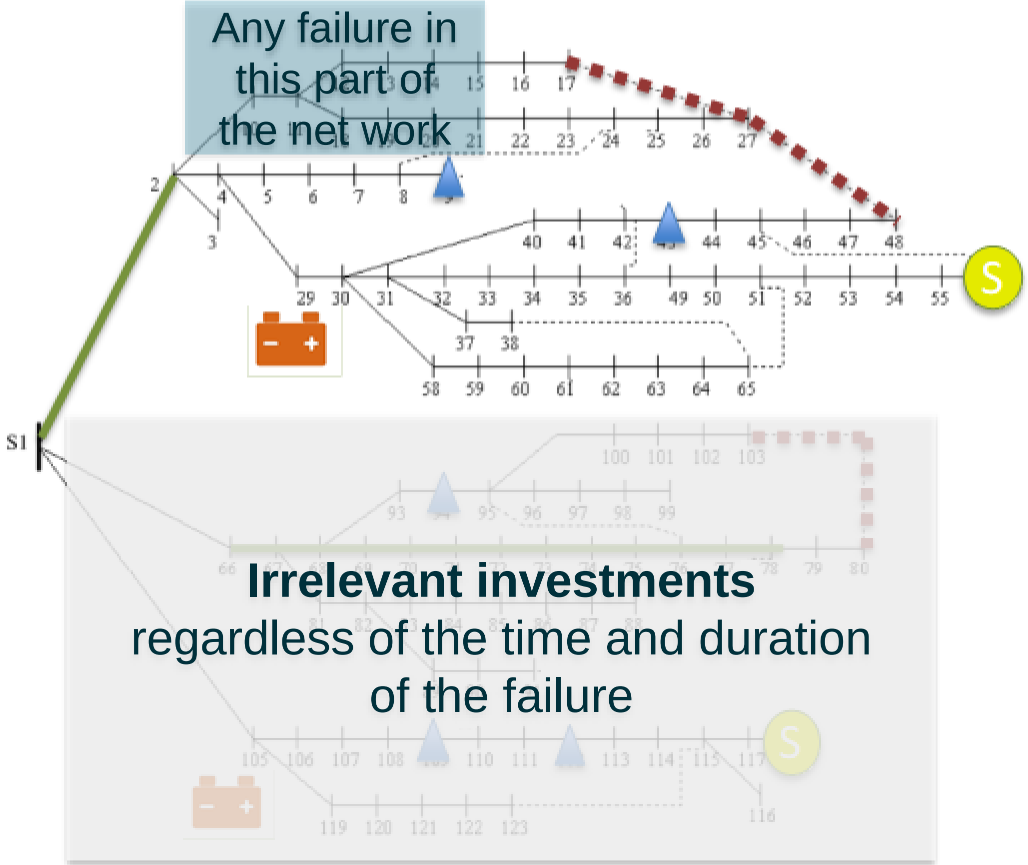


$$\text{Minimize}(1-\lambda)\text{E}[\text{cost}] + \lambda\text{CVaR}[\text{cost}]$$



Optimization Model

Reducing complexity



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

Annualized investment | Operational costs | Loss of load costs

Investment solution

Write set of constraints for each scenario s: (state, d, t)

States analysis

…

Sates in which investment solution is relevant

Loss of load of as a function of the **investment (i), netload (t) and duration (d) of the event**

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)

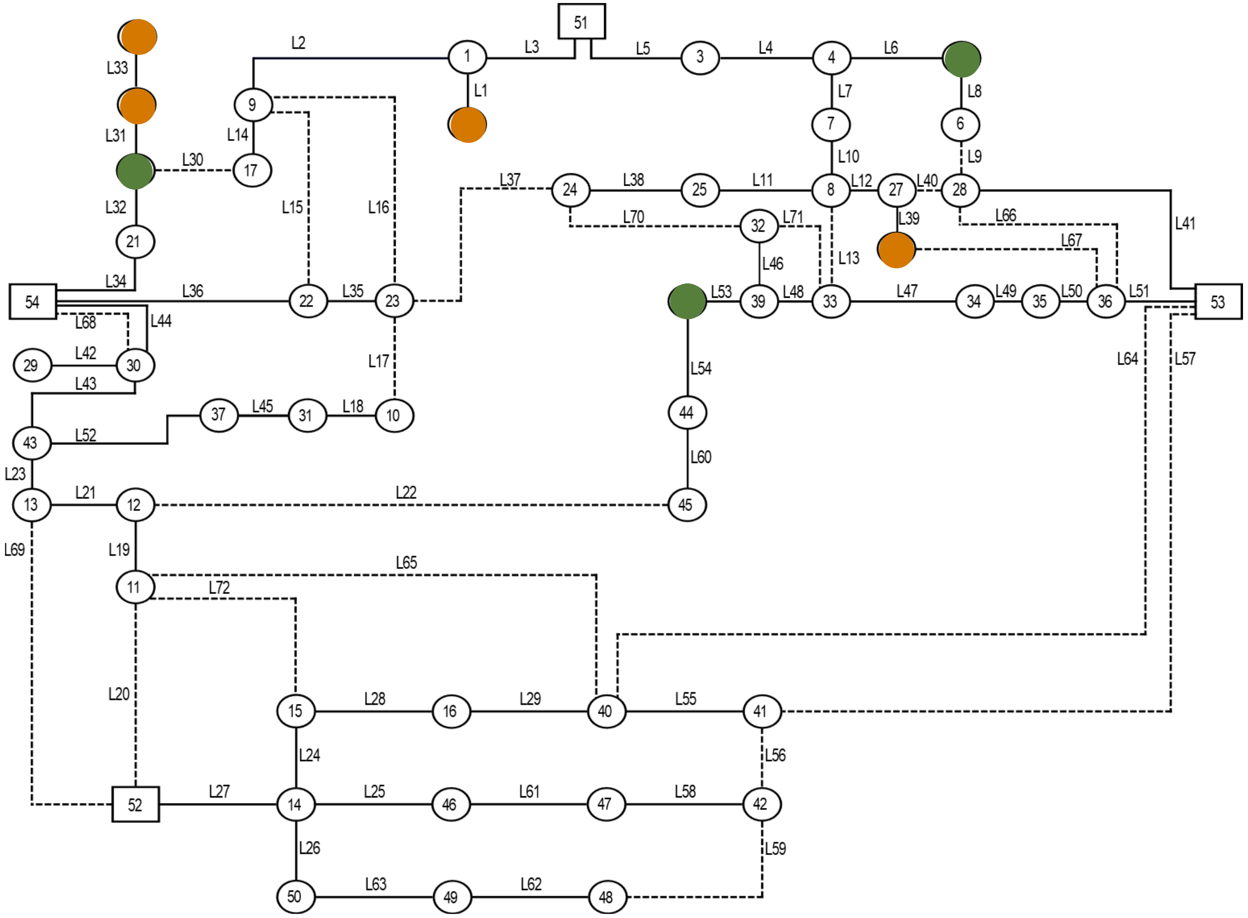
100 scenarios of **HILP events** (1 every 70 years)

Candidate Assets

22 new lines

4 batteries nodes

4 types of DG in 3 candidate nodes



.... **New Lines** **Battery nodes** **DG nodes**

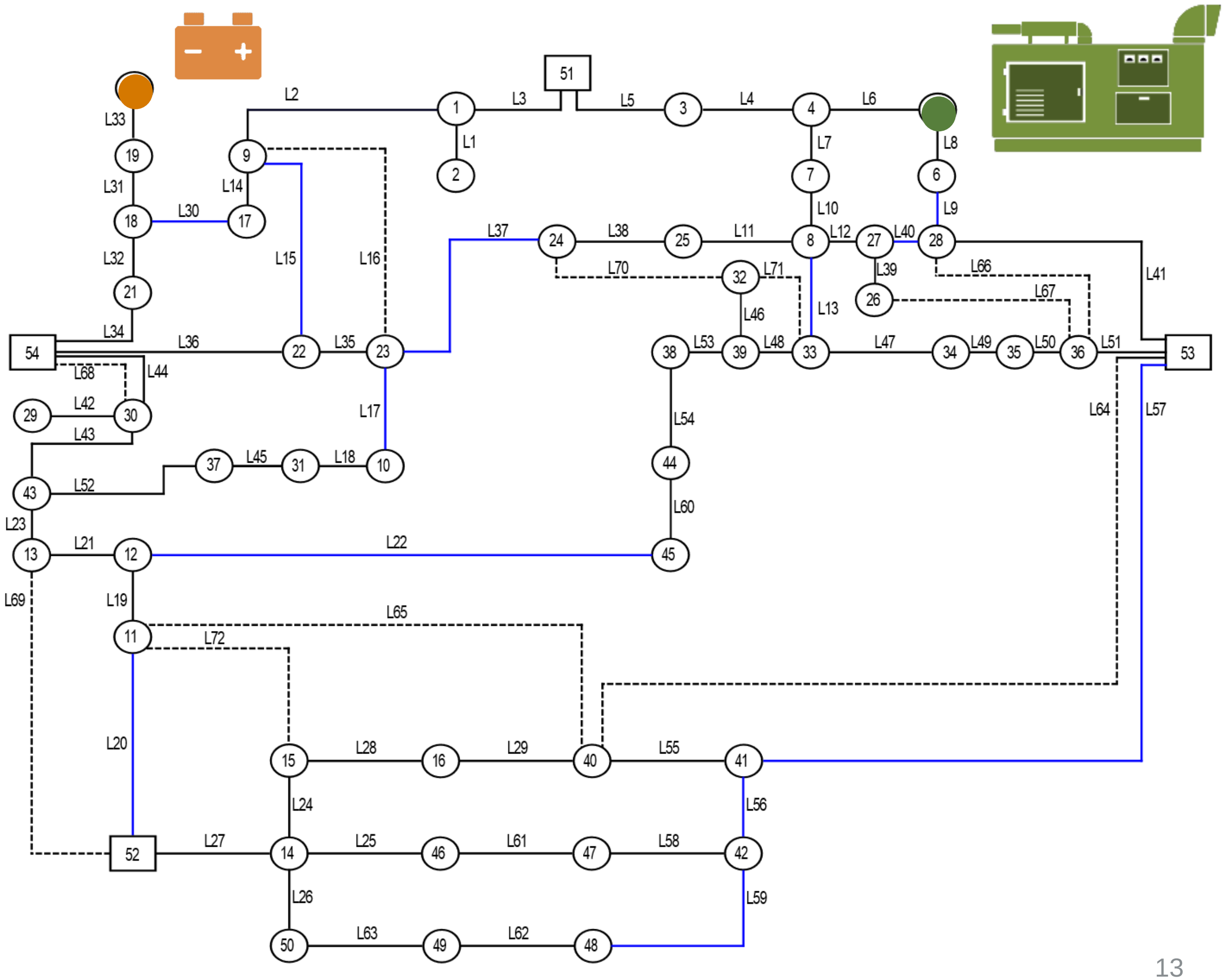
Case Study 2

Results: considering reliability only (λ=0)

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

● **Battery nodes: 1 x 280 kWh**

● **DG: 1 x 800 kW (NG)**



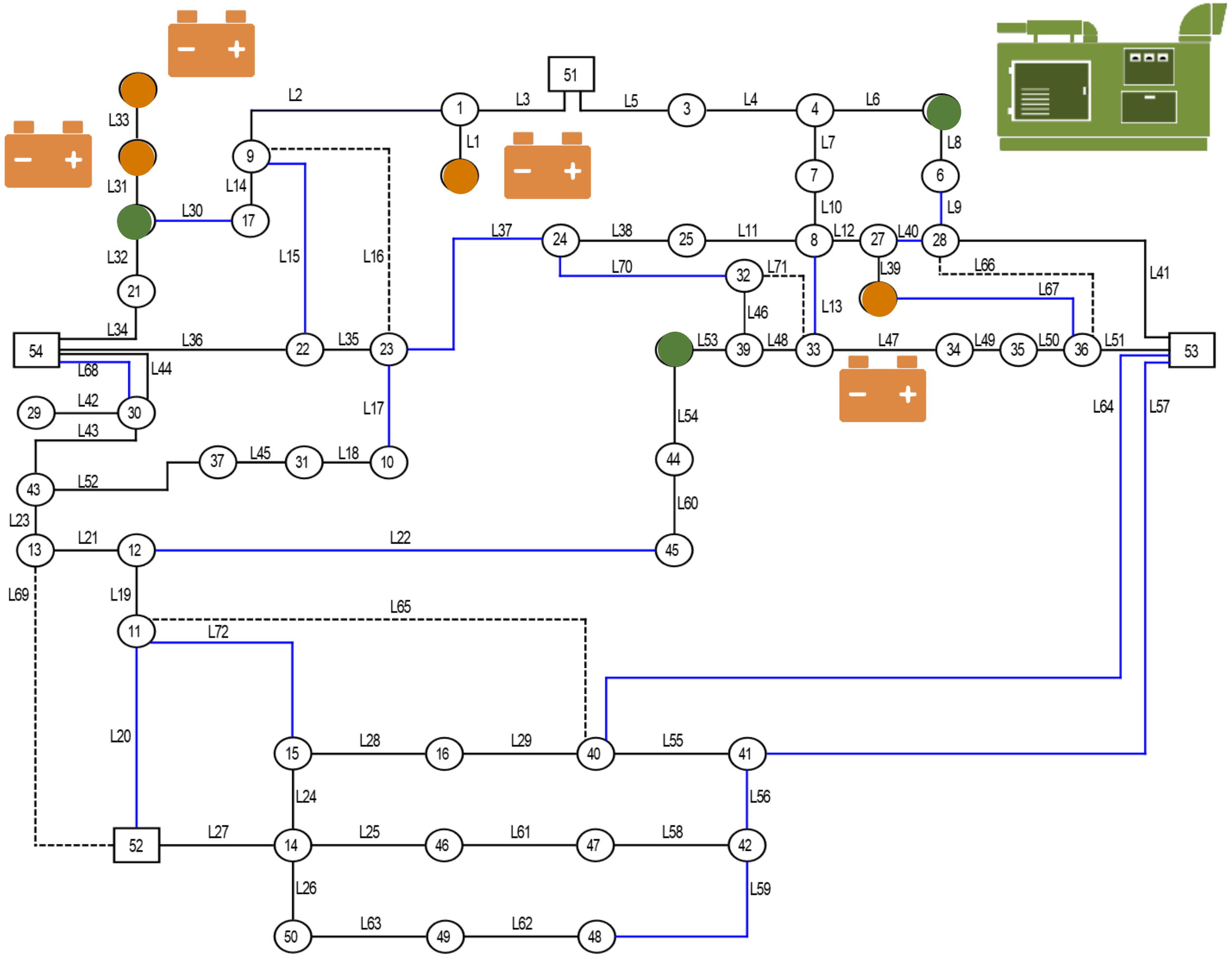
Case Study 2 (Optimization)

Results: risk-aversion (λ=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

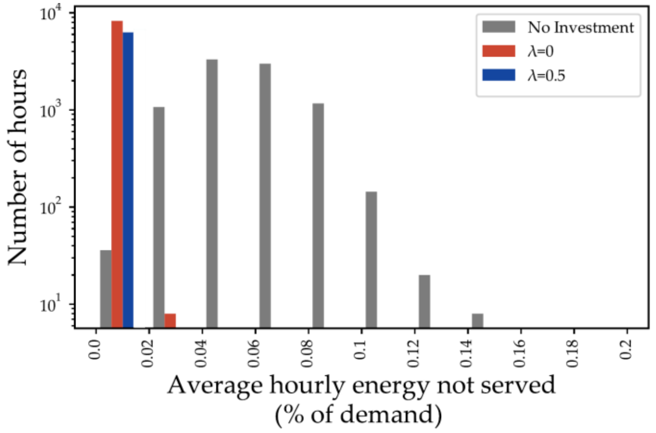
DG: 1 x 800 kW (NG)



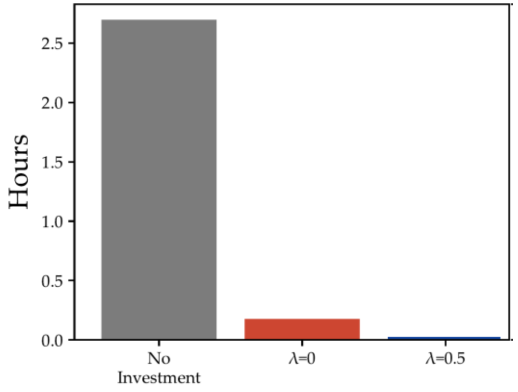
Case Study 2

Results comparison (simulation)

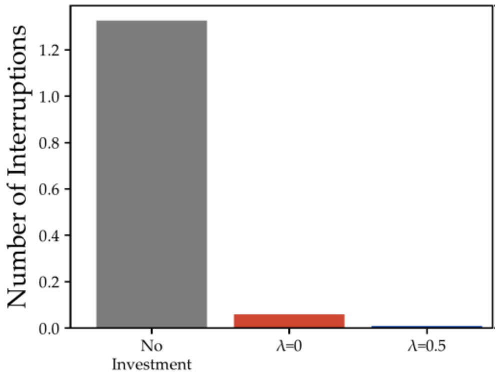
% AENS – distribution



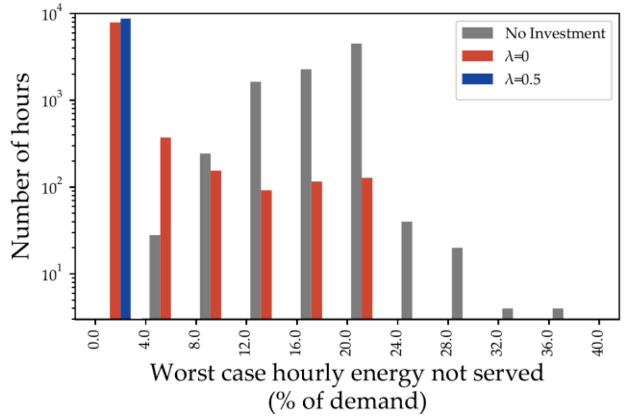
SAIDI



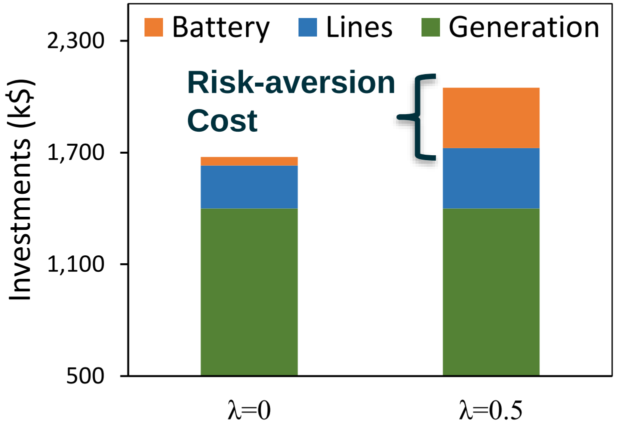
SAIFI



Worst case evaluation



Investments



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

Miguel Heleno
Research Scientist

Alex Moreira
Postdoc

Alan Valenzuela
Scientific Engineering Associate

Joe Eto
Staff Scientist

Contact:

miguelheleno@lbl.gov

Partner:

ComEd®