Resilience through Distributed Energy Resources

How we can empower DSOs to mitigate extreme events

Speaker: Xavier Weiss (xavier.weiss@ri.se)

RI.SE

Distributed Energy Resources (DERs)

Definition: “Distributed generation, energy storage, and demand response resources connected to the distribution grid, either located behind-the-meter or in the form of small- to medium-scale installations.”

- 5.04 GW operational and 7.82 GW underway in Nordic-Baltic region
  → Will match up to ~8.8 % of (currently) installed generation capacity

RI.SE

Distributed Energy Resources (DERs)

Definition: "Distributed generation, energy storage, and demand response resources connected to the distribution grid, either located behind-the-meter or in the form of small- to medium-scale installations."

- 5.04 GW operational and 7.82 GW underway in Nordic-Baltic region
  → Will match up to ~8.8 % of (currently) installed generation capacity
- Over 2.93 million electric vehicles (EVs)
  → About 16 – 36% of all cars in the Nordics are now EVs

RI. SE

Distributed Energy Resources (DERs)

Definition: "Distributed generation, energy storage, and demand response resources connected to the distribution grid, either located behind-the-meter or in the form of small- to medium-scale installations."

- 5.04 GW operational and 7.82 GW underway in Nordic-Baltic region
  → Will match up to ~8.8 % of (currently) installed generation capacity
- Over 2.93 million electric vehicles (EVs)
  → About 16 – 36% of all cars in the Nordics are now EVs
- 12-23 GW of potential demand response

RI. SE

Distributed Energy Resources (DERs)

Definition: "Distributed generation, energy storage, and demand response resources connected to the distribution grid, either located behind-the-meter or in the form of small- to medium-scale installations."

- 5.04 GW operational and 7.82 GW underway in Nordic-Baltic region
  → Will match up to ~8.8 % of (currently) installed generation capacity
- Over 2.93 million electric vehicles (EVs)
  → About 16 – 36% of all cars in the Nordics are now EVs
- 12-23 GW of potential demand response
- 4147 GWh of solar capacity (in Sweden)

RI. SE

Distributed Energy Resources (DERs)

Definition: "Distributed generation, energy storage, and demand response resources connected to the distribution grid, either located behind-the-meter or in the form of small- to medium-scale installations."

- 5.04 GW operational and 7.82 GW underway in Nordic-Baltic region
  → Will match up to ~8.8 % of (currently) installed generation capacity
- Over 2.93 million electric vehicles (EVs)
  → About 16 – 36% of all cars in the Nordics are now EVs
- 12-23 GW of potential demand response
- 4147 GWh of solar capacity (in Sweden)
- 40,419 GWh of wind capacity (in Sweden)

RI. SE

Distributed Energy Resources (DERs)

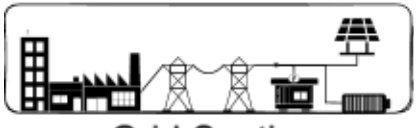
Definition: "Distributed generation, energy storage, and demand response resources connected to the distribution grid, either located behind-the-meter or in the form of small- to medium-scale installations."

- 5.04 GW operational and 7.82 GW underway in Nordic-Baltic region
  → Will match up to ~8.8 % of (currently) installed generation capacity
- Over 2.93 million electric vehicles (EVs)
  → About 16 – 36% of all cars in the Nordics are now EVs
- 12-23 GW of potential demand response
- 4147 GWh of solar capacity (in Sweden)
- 40,419 GWh of wind capacity (in Sweden)

Potential for Resilience?

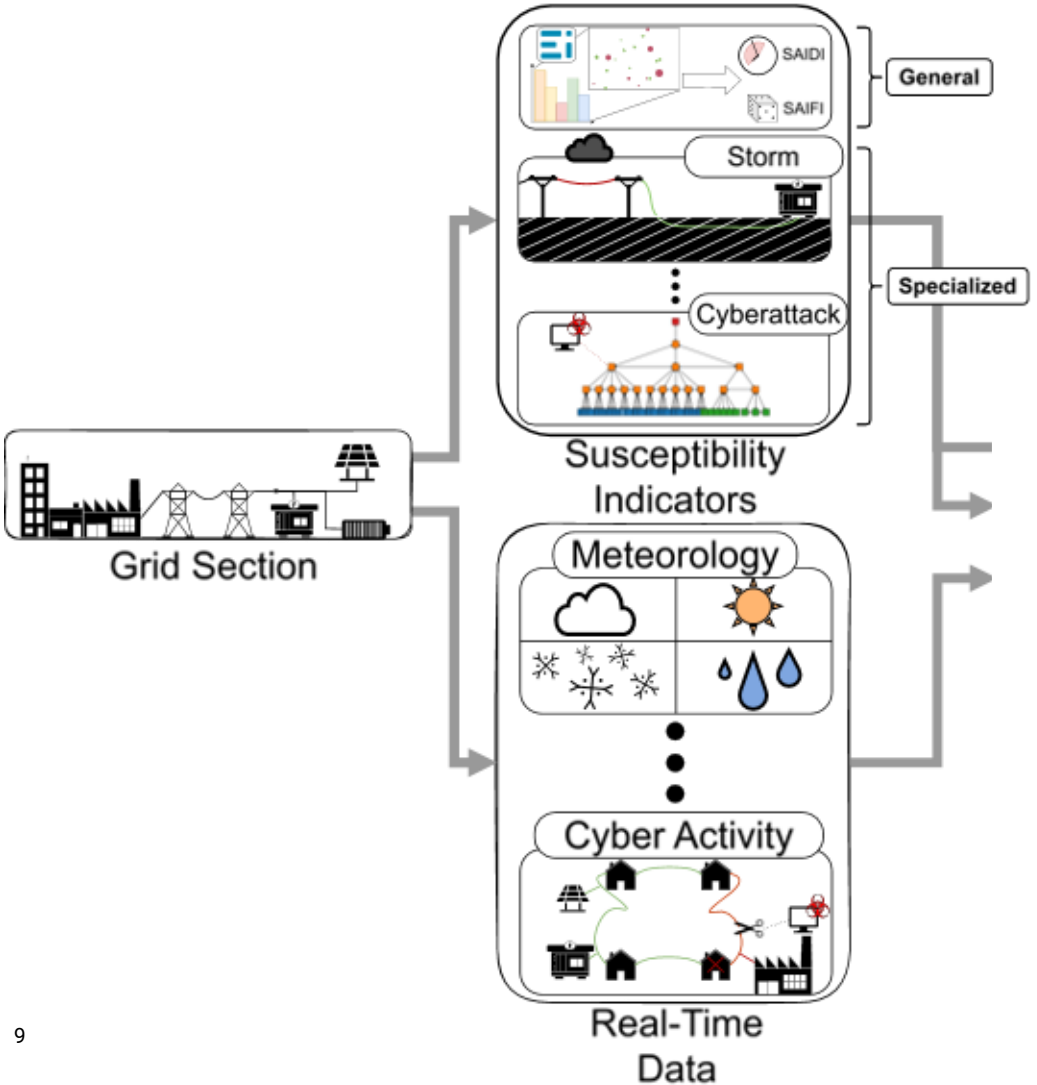
RI. SE

A Resilience-Enhancing Process

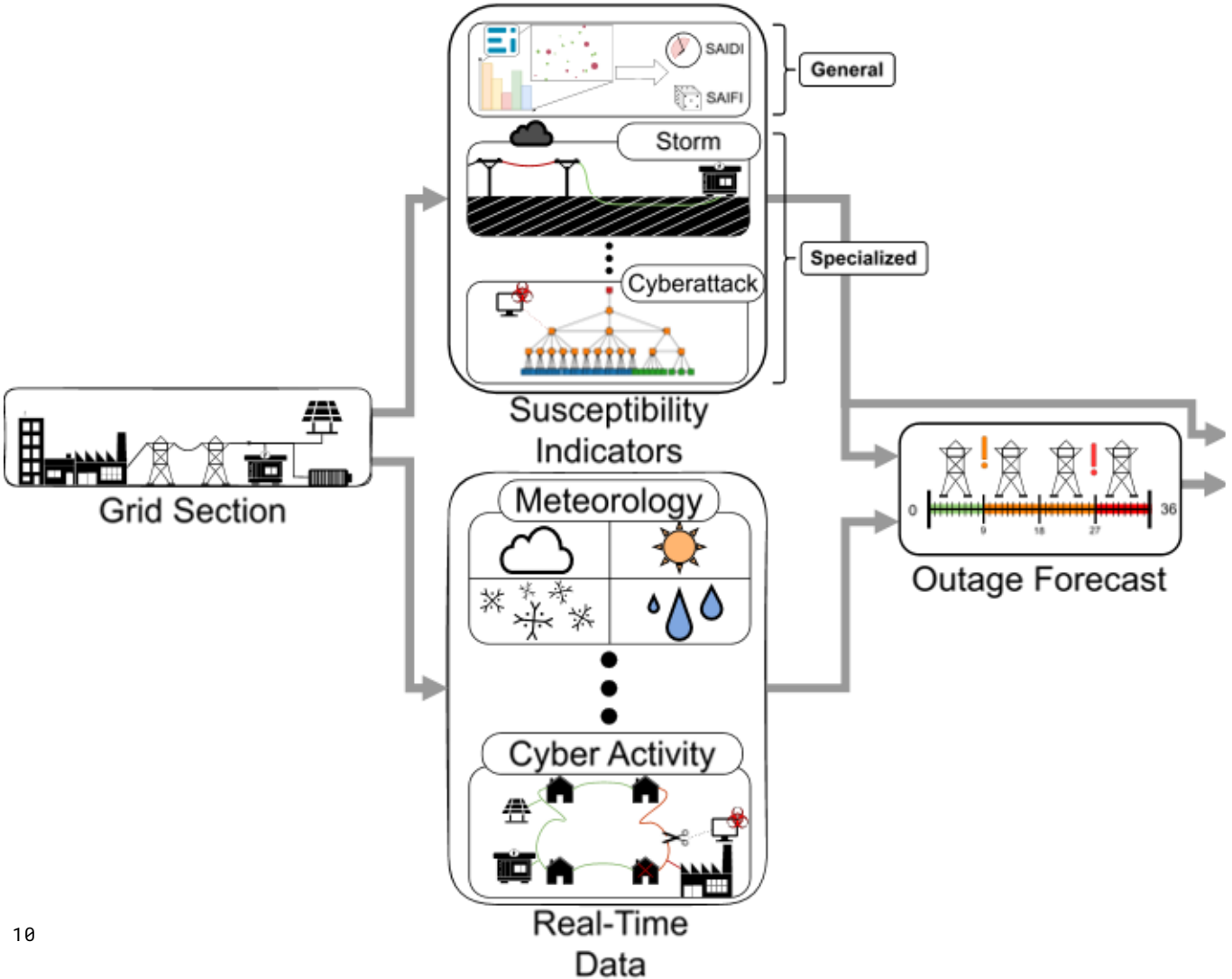


Grid Section

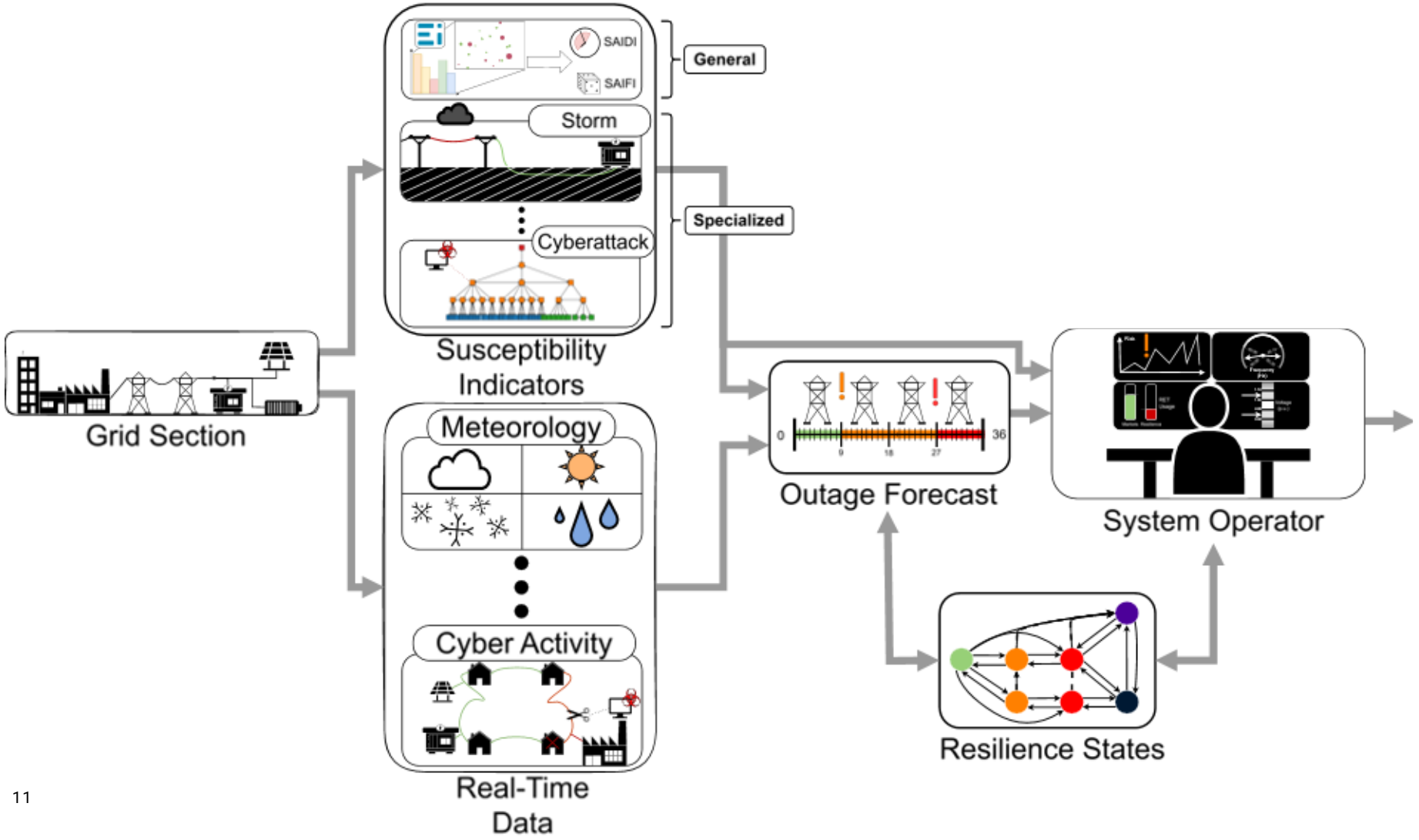
A Resilience-Enhancing Process



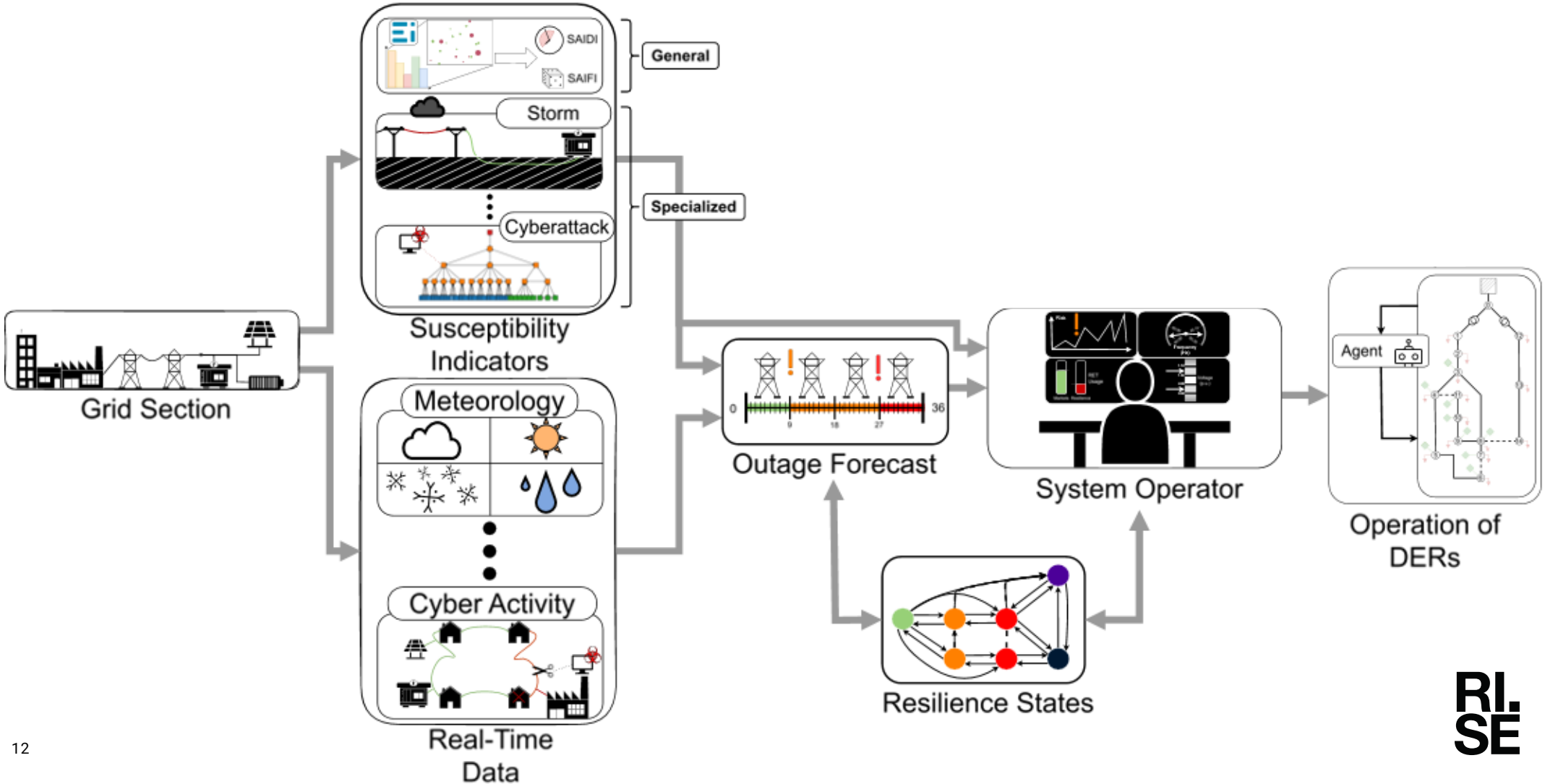
A Resilience-Enhancing Process



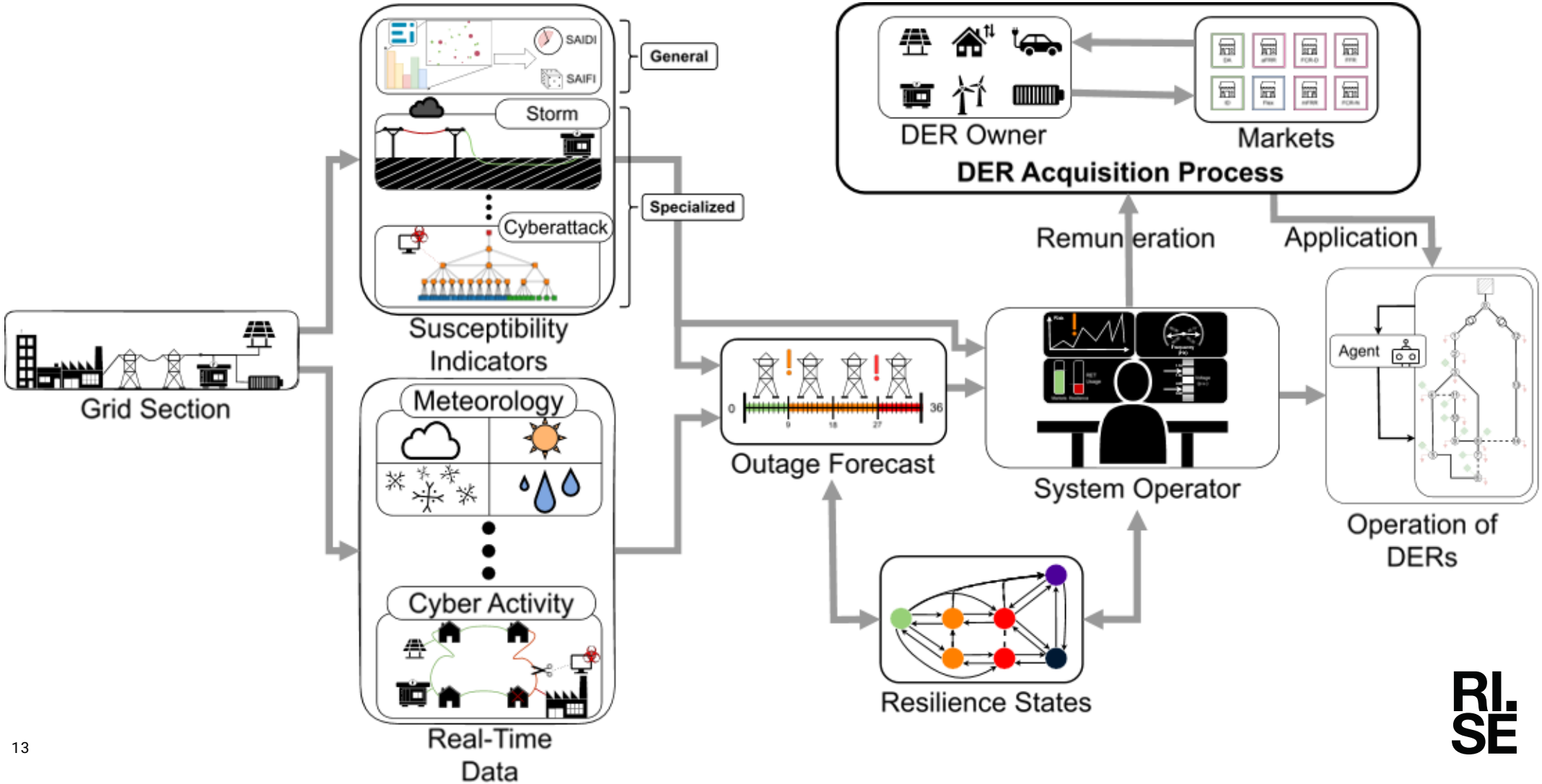
A Resilience-Enhancing Process



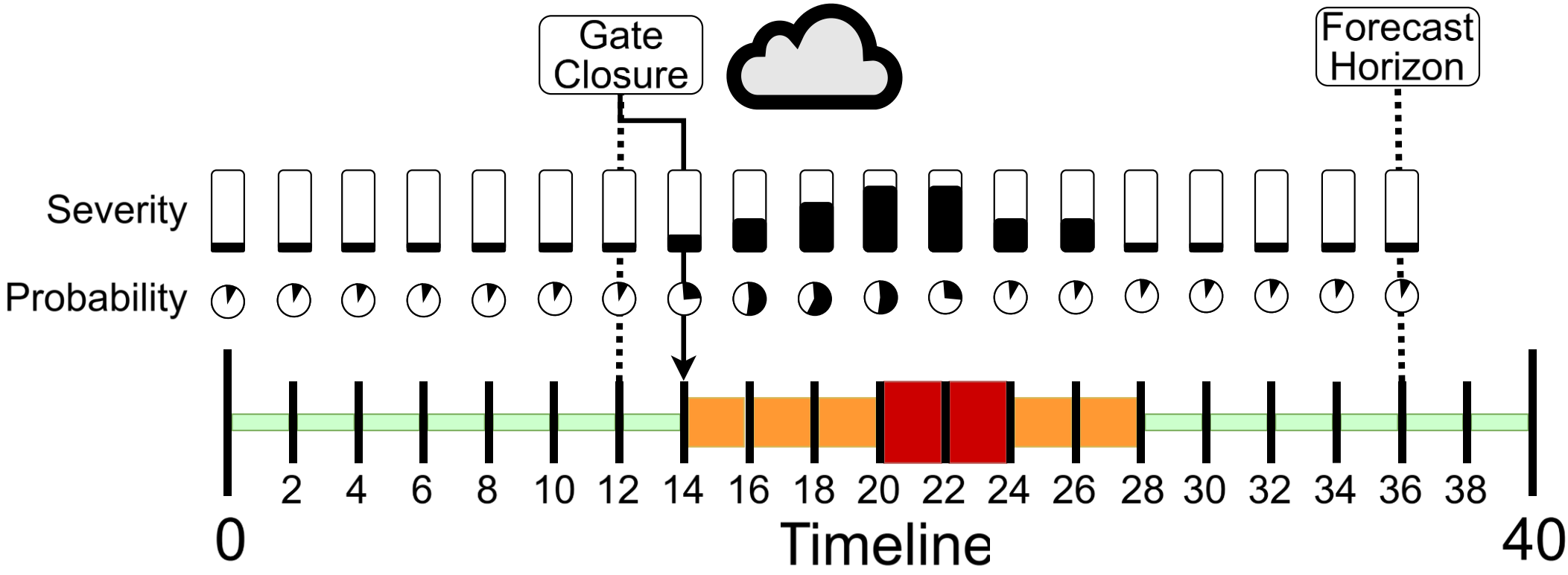
A Resilience-Enhancing Process



A Resilience-Enhancing Process

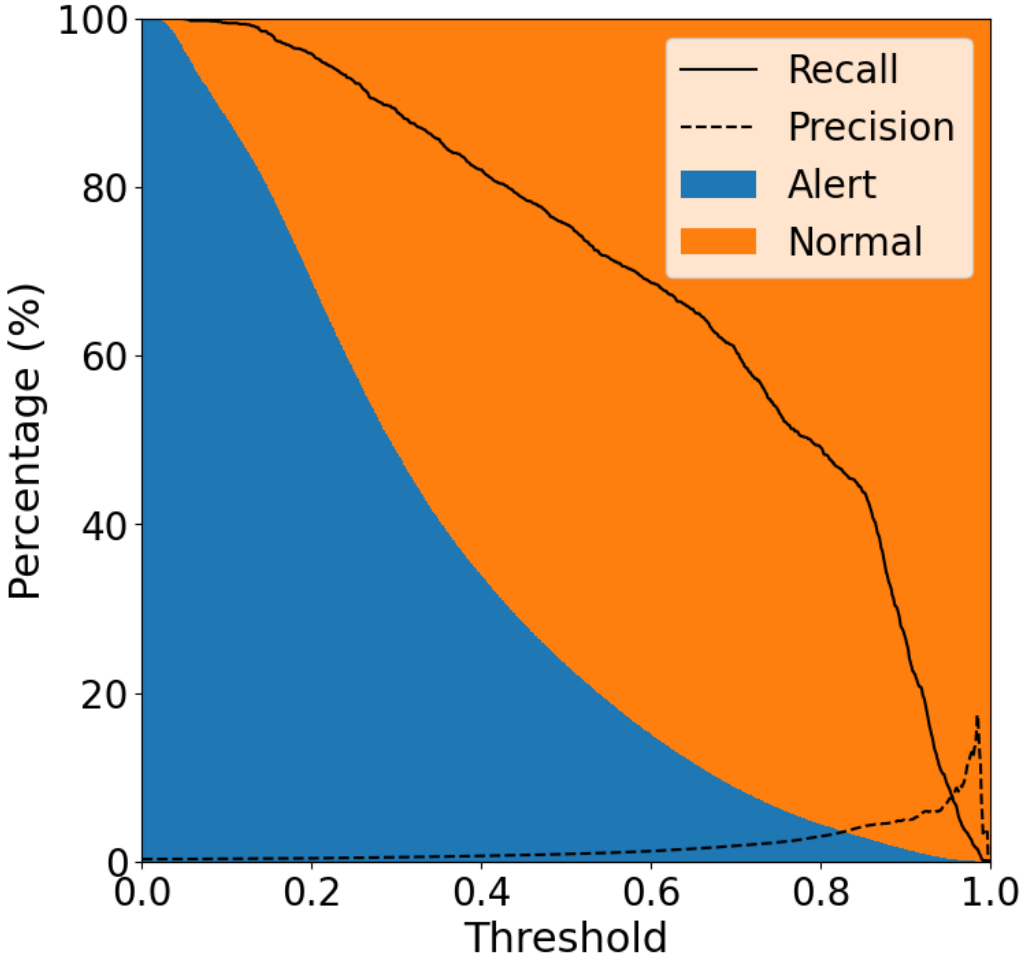


Outage Forecasting: Timeline



RI. SE

Outage Forecasting: Tuneable Model



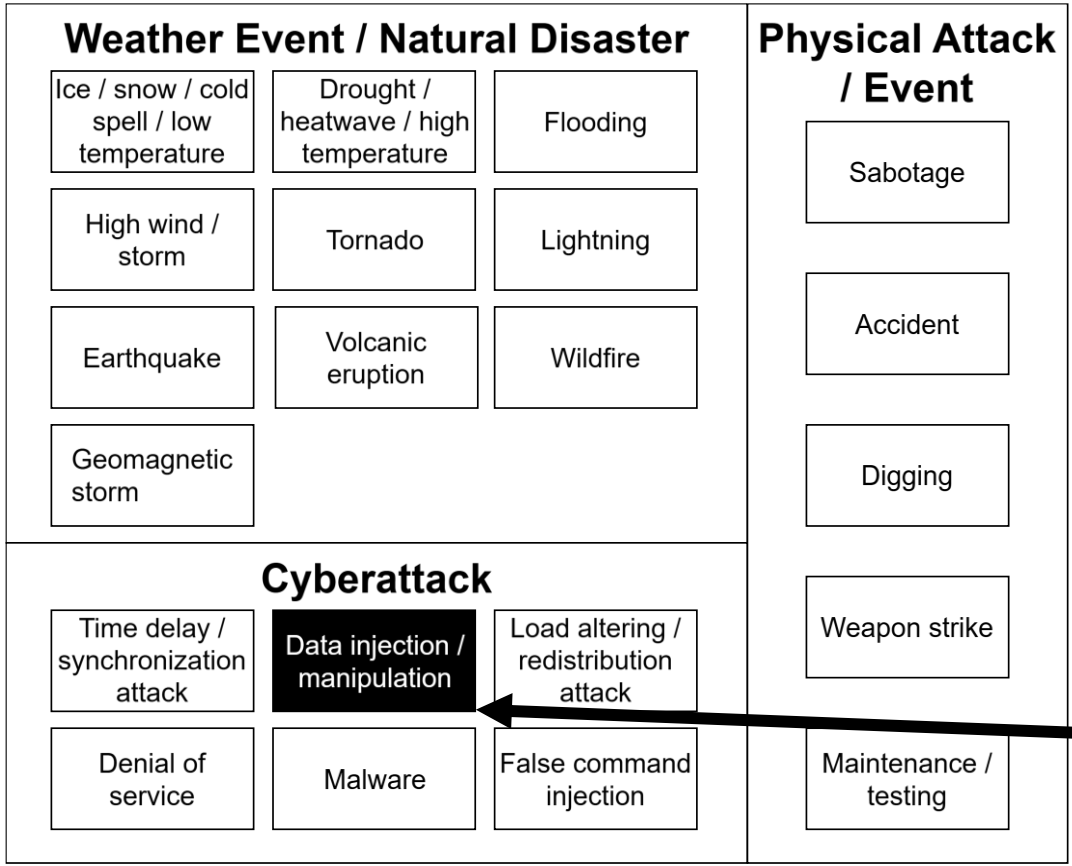
Classification (Outage or Non-Outage) depends on chosen threshold

Risk Averse (0.3) = 96%, 0.37% precision
Default (0.5) = 76% recall, 0.87% precision
Risk Tolerant (0.8) = 49% recall, 3% precision

Can use classification to decide whether or not to acquire DERs.

RI.
SE

Susceptibility Indicator (Example)





Goal: Compromise Specific asset

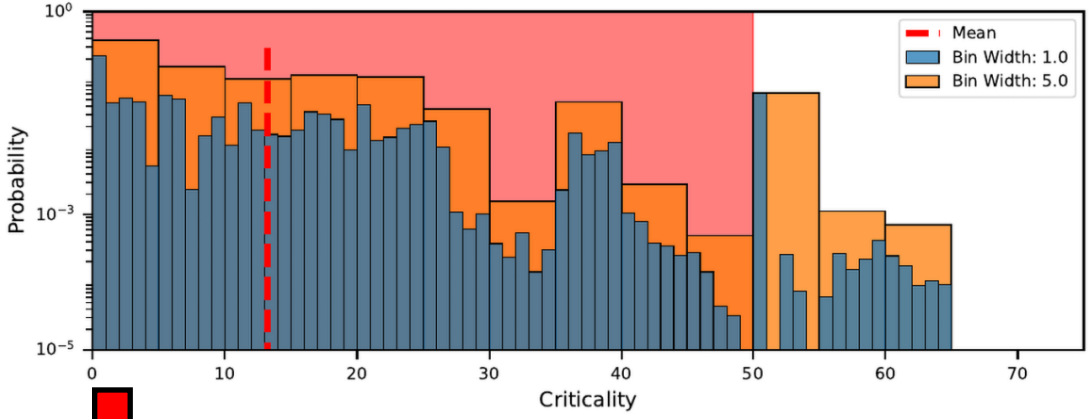
Inspires

Threats2Power

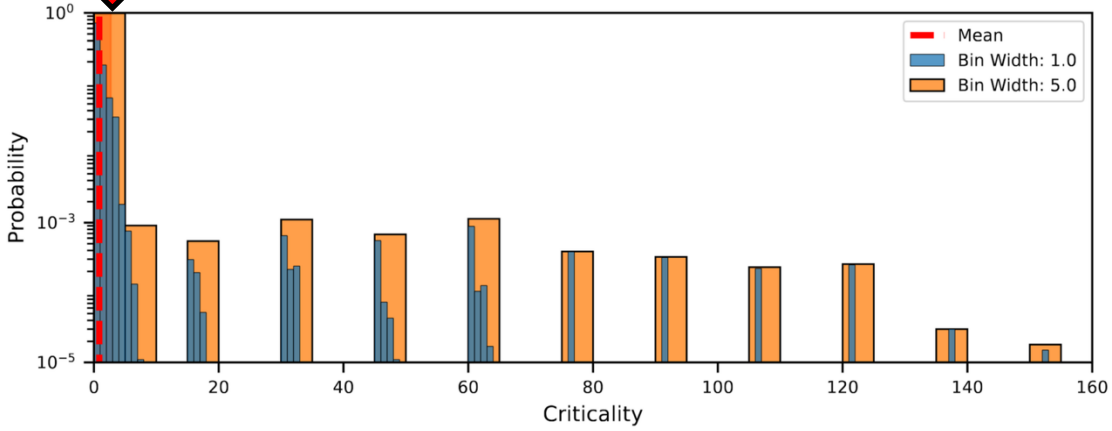
Goal: Try to compromise as many assets as possible

Susceptibility Indicator (Example)

13.21 MVA (out of 191.6 MVA)



0.86 MVA (out of 1511.05 MVA)



CIGRE MV Network:

- Took 31.06 minutes
- Effects of **asymmetry** in network are visible
- **Bottlenecks** results in higher-probability regions

Real LV network:

- Took 165.73 minutes
- High value assets (transformers) lead to gaps
- Larger networks resilient by virtue of their scale

Operation of RETs

Problem: Unplanned line outages cause line overloads

Goal: Minimize energy not supplied (ENS) while prioritising critical loads

Method: Reinforcement Learning (RL) / Markov Decision Process (MDP)

Chosen Grid: CIGRE MV Benchmark

Action Space:
- ❖ Demand response
- ❖ Energy storage



Application of DERs in Operation

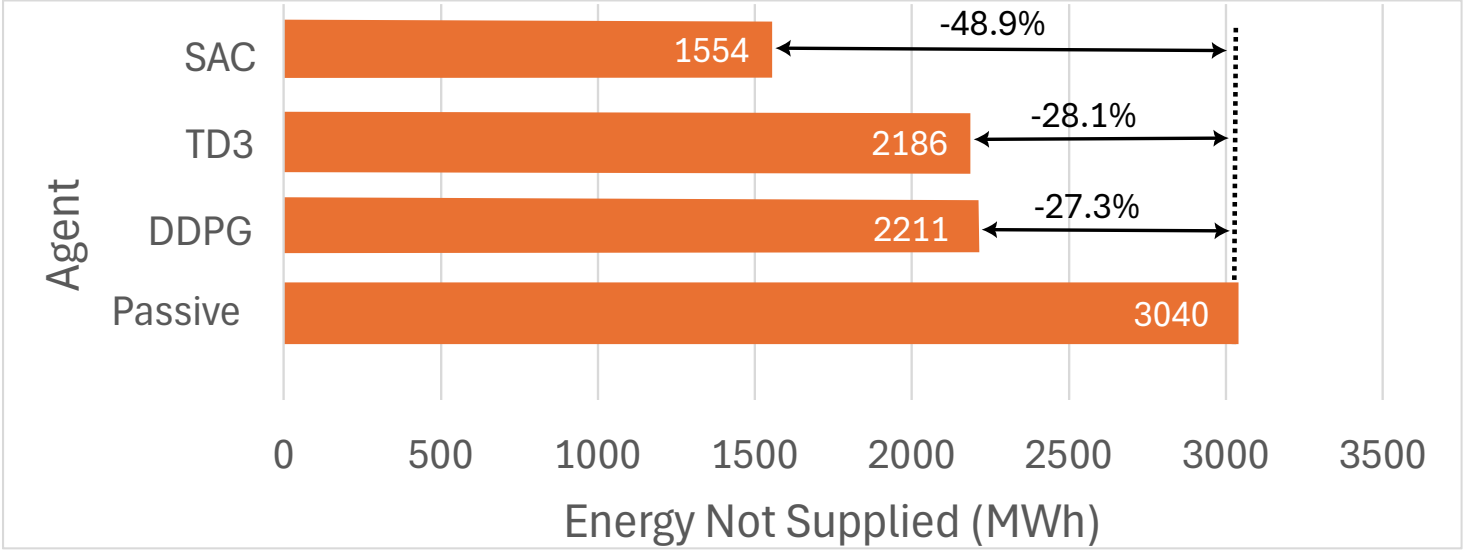


***Figure 2**: Performance of Soft Actor Critic (SAC), Deep Deterministic Policy Gradient (DDPG) and Twin-Delayed DDPG (TD3) agents on unseen extreme event scenarios*

Reinforcement Learning (RL) agents can reduce Energy Not Supplied (ENS) by an **average of 48.9%** on unseen test scenarios (in simulation) using Demand Response (DR) and Energy Storage Systems (ESS).

Could be used as **decision-support** in the control room.

Thank you for listening

Contact Details
xavier.weiss@ri.se