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RISK Day
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Boosting Power Network Resilience to Extreme Weather Events by Preventive Islanding

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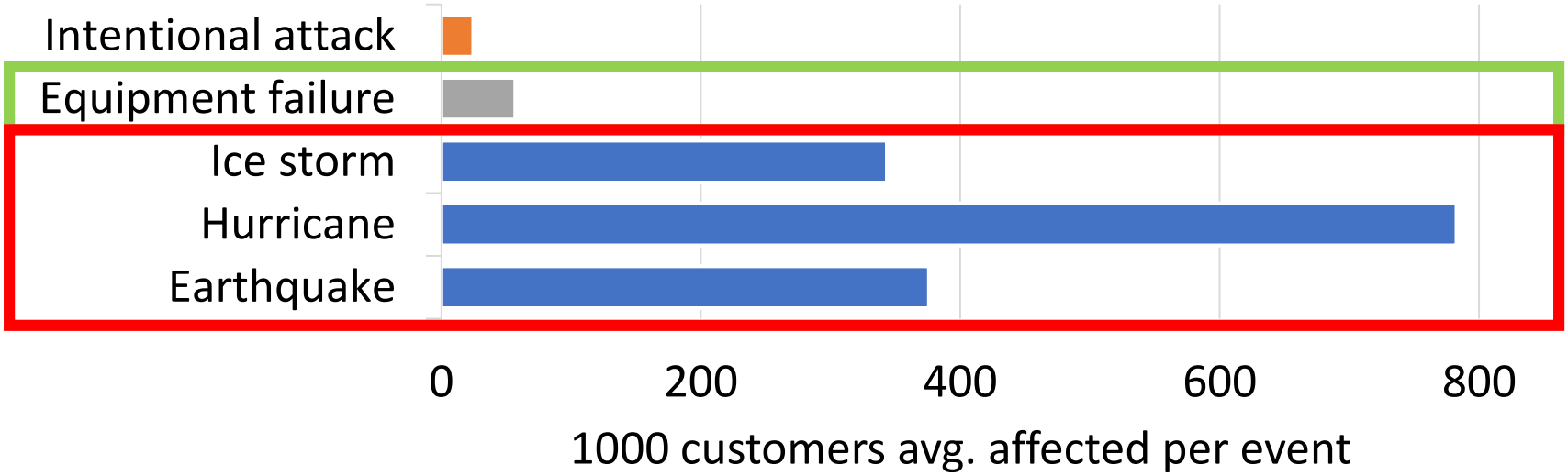
2020 Risk Day Glasgow

Overview

- Motivation
- Preventive Actions
  - Preventive Islanding
- Preventive Actions under Uncertainty
  - Location and Intensity
- Extensions and future work

Initial events of blackouts in the U.S. from 1984-2006



Reliability ↔ Resilience

Hines, P. et al. "Trends in the history of large blackouts in the United States." Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century. IEEE, 2008.

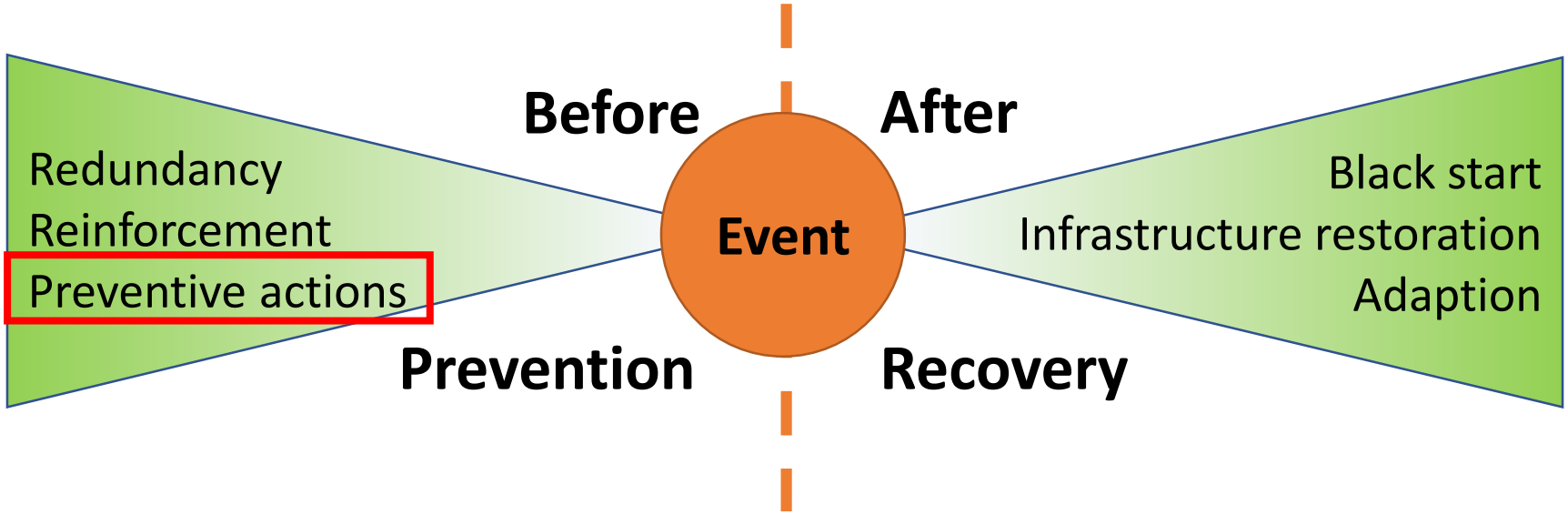
Implications on Infrastructure

- August 2019 blackout in the UK
  - Trains stopped and couldn‘t restart even after power was restored
  - Emergency generator in hospital failed
  - Traffic lights failed during evening rush hour

- Many parts of our society depend on electricity
- Dependency is likely to increase in the future

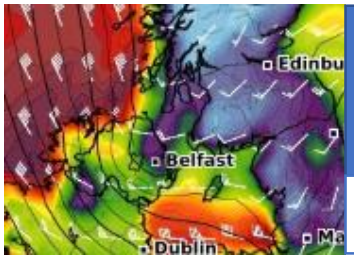
Increasing Power Network Resilience

Bowtie diagram



- Operational strategy that uses the functionality of a modern smart grid

Preventive Actions



Weather Forecast

Event type, intensity and trajectory

No action

Preventive action

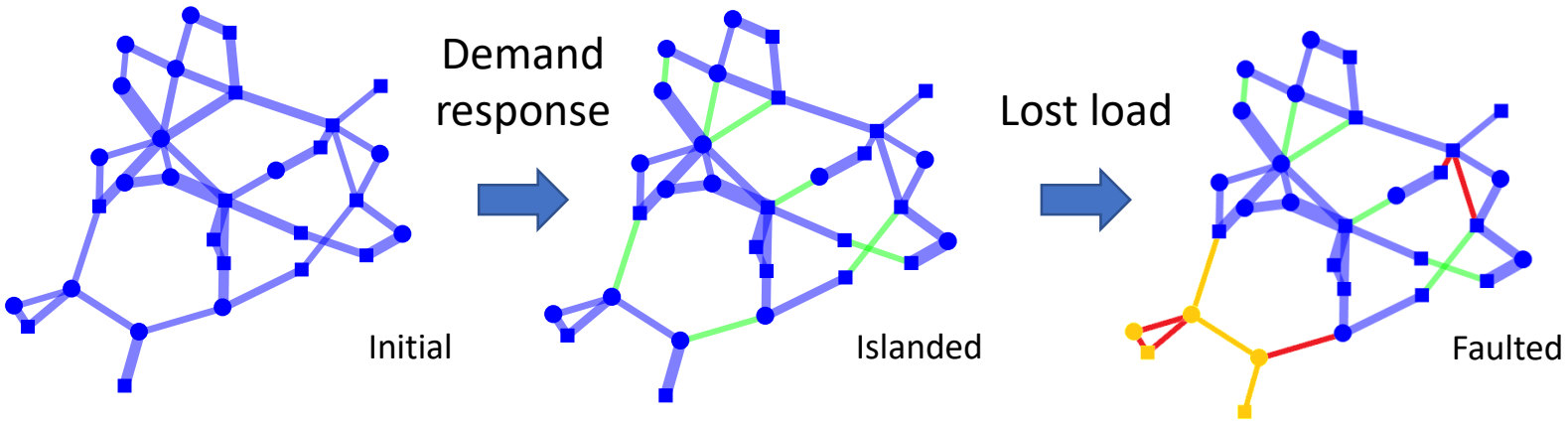
Small cost due to demand response (400 €/MWh)

Event

£££££ (10,000 €/MWh)
High compensation due to lost load

£
Low compensation due to lost load

Preventive Islanding

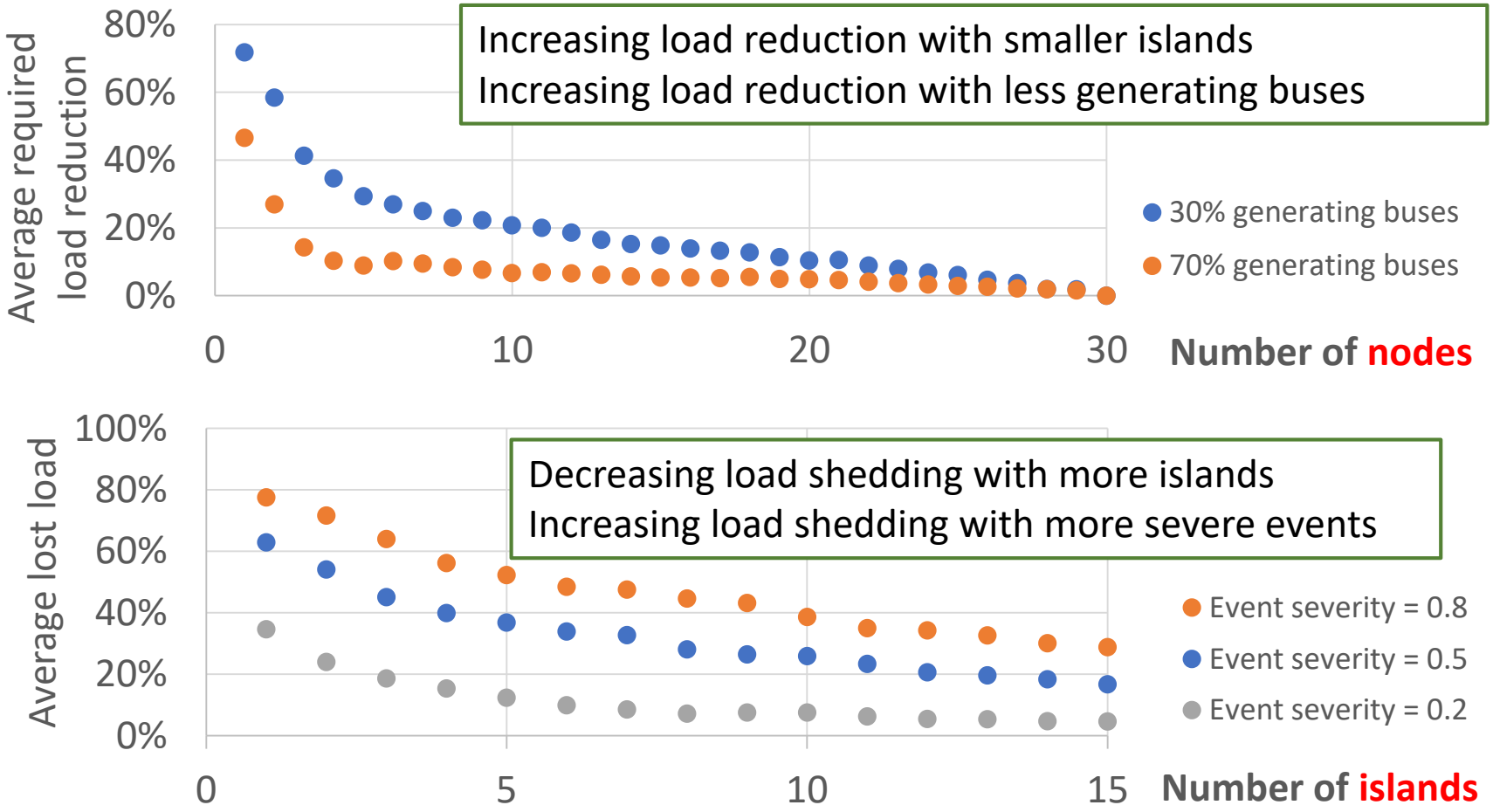


- Operational
- Intentionally opened
- Faulty due to extreme event
- Tripped due to overload

Advantages of Preventive Islanding

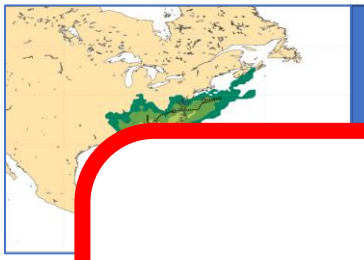
- Purely operational strategy
- Pre-planned and applied before the event hits
- Dynamic island boundaries
- Prevents the propagation of fault cascades

Demand response and lost load



Noebels, Matthias, et al. "Assessing the Effect of Preventive Islanding on Power Grid Resilience." 2019 IEEE Milan PowerTech. IEEE, 2019.

Preventive Actions



Weather Forecast

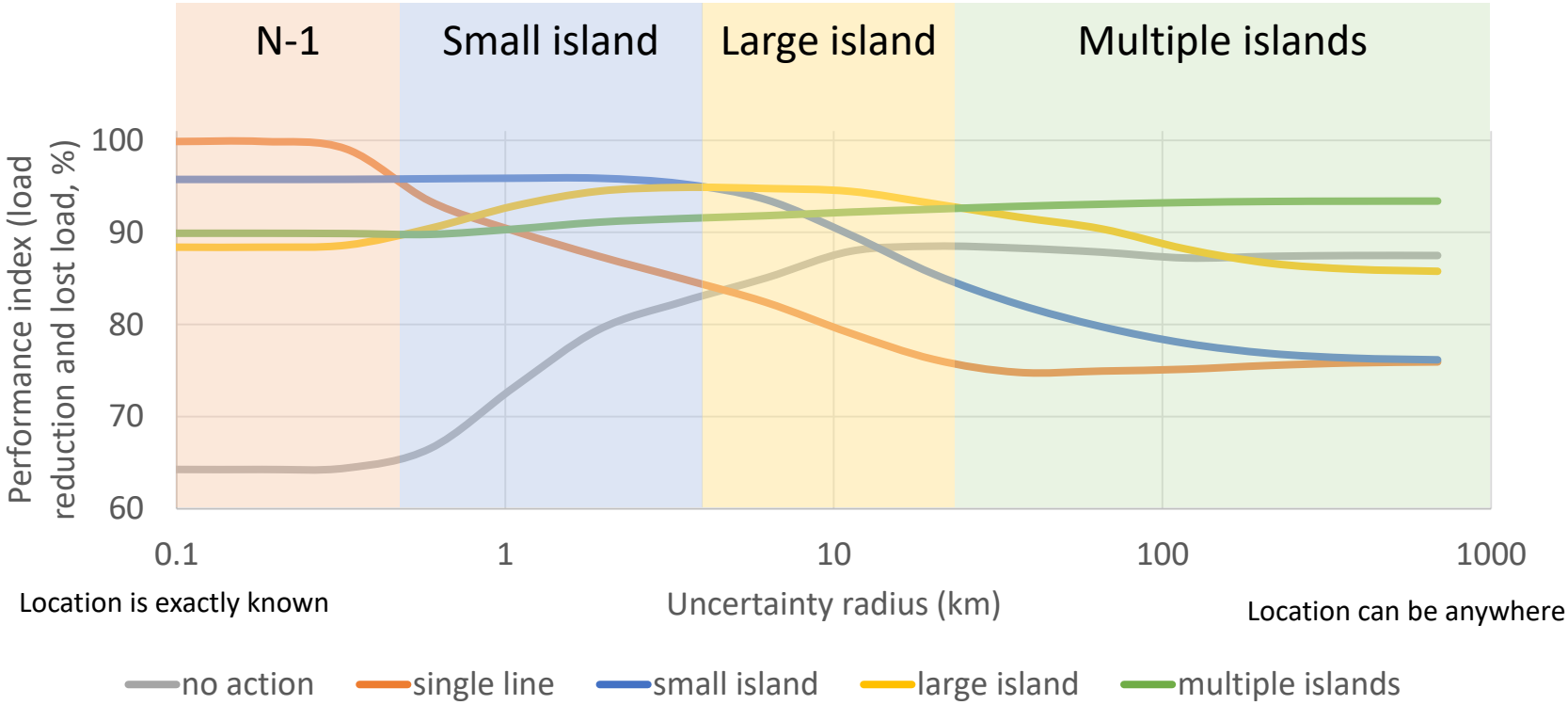
How certain do we have to be to justify a preventive action?

action

Event	**High compensation due to lost load**	**Low compensation due to lost load**
No event	**No cost at all**	**Cost due to Demand Response**

Uncertainty in Location

- N-1 contingency in stressed German transmission network



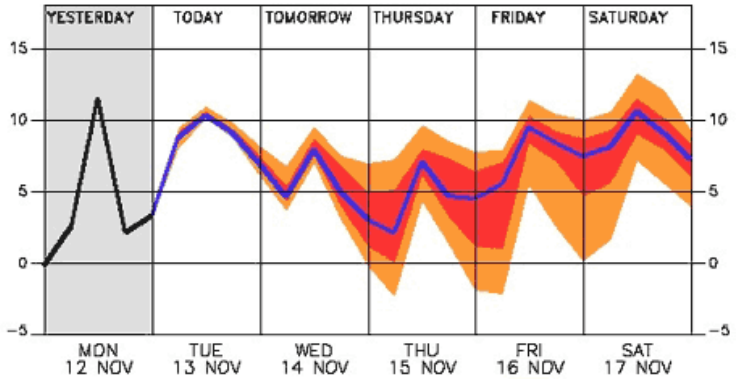
Noebels, Matthias, et al. "Performance-driven Decision-Making on Preventive Actions under Uncertainty for Power Grid Resilience." IEEE Transactions on Power Systems (under review), 2020.

Uncertainty in Intensity

Ensemble forecast gives range of possible outcomes and their probability

Expected cost $= P_{\mathrm{DR}} \cdot \mathrm{VoDR} + \sum p_\omega \cdot P_{\mathrm{lost}}^{\omega} \cdot \mathrm{VoLL}$

P_{DR}	pre-event load reduction
VoDR	Value of Demand Response
p_ω	probability of outcome ω
$P_{\mathrm{lost}}^{\omega}$	lost load during event
VoLL	Value of Lost Load



MEAN strategy

Choose preventive action based on most likely event outcome

MAX strategy

Choose preventive action based on most severe event outcome

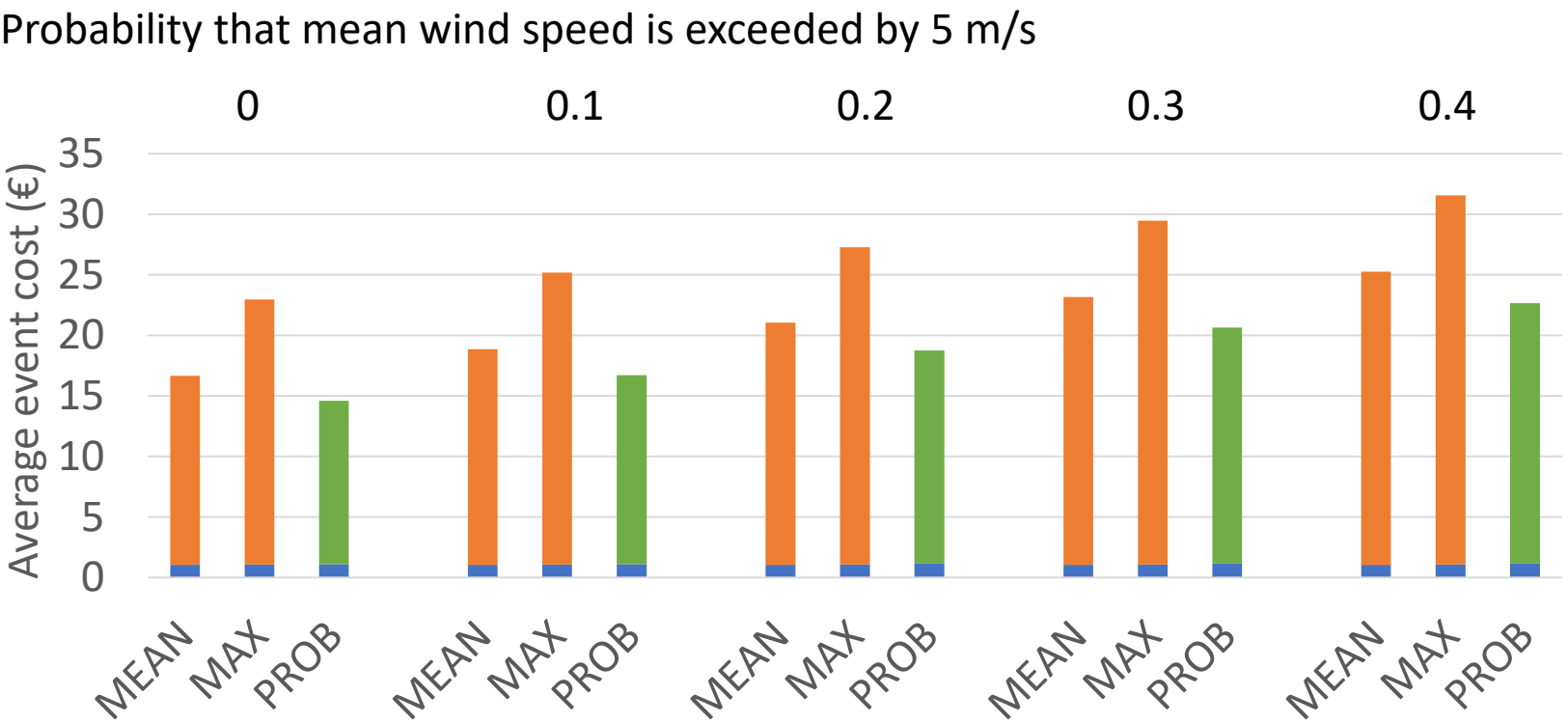
PROB strategy

Choose preventive action based on probability of each event outcome

Noebels, Matthias, et al. "A Probabilistic and Cost-based Decision Strategy for Power Grid Resilience using Ensemble Forecasting." PMAPS (under review), 2020.

Average cost per event

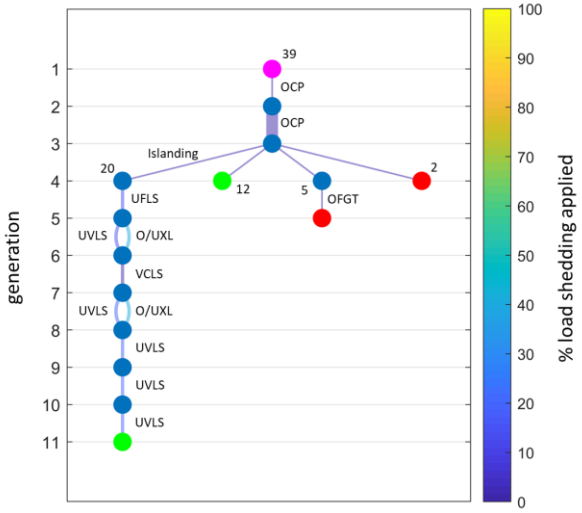
(mean wind 30 m/s)

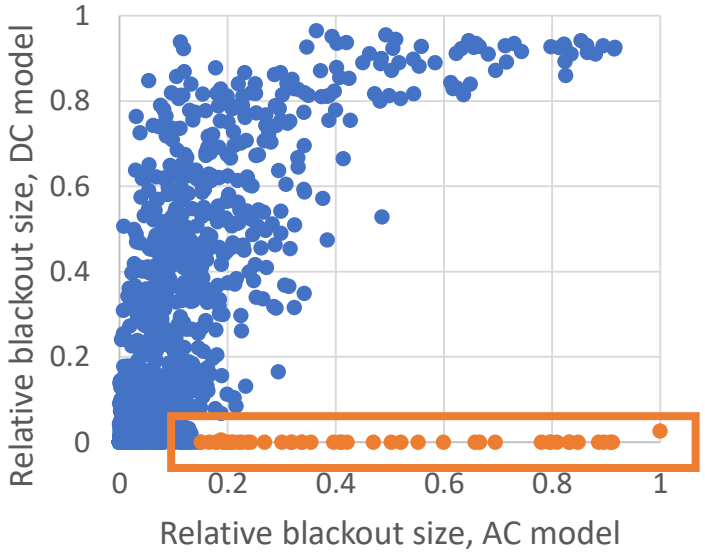


PROB strategy leads to cost reduction of around 10% compared to MEAN strategy

Extending the Cascading Fault Model

- DC cascading fault model ignores reactive power flows
- New AC model considers underfrequency and undervoltage load shedding, overexcitation





Noebels, Matthias, et al. "An AC Cascading Fault Model for Resilience Analysis in Power Networks." IEEE Transactions on Power Systems (under review), 2020.

Conclusion

- Climate change stresses the need for resilience
- Preventive islanding mitigates spreading of cascading faults
- Network operator must balance between
  - Cost due to pre-event load reduction
    (can be achieved using existing smart grid capabilities)
  - Less cascading faults and less compensation for lost load
- Uncertainty supports decision-making
- Extension to AC cascading fault model reveals additional outages and require further analysis

Literature

- M. Noebels and M. Panteli, “Assessing the Effect of Preventive Islanding on Power Grid Resilience“, in 2019 IEEE Milan PowerTech. IEEE, 2019, pp. 1-6.
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- M. Noebels, J. Quirós-Tortós and M. Panteli, “Performance-driven Decision Making on Preventive Actions under Uncertainty for Boosting Power Grid Resilience”, in IEEE Transactions on Power Systems (under review), 2019.
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Acknowledgments

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