Towards Resilient Power Systems: Experiences and Applications from International Projects

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16 February 2023

International Resilience Research Projects

2011-2016

Resilient Electricity Networks for Great Britain (RESNET)

2016-2018

Disaster management and resilience in electric power systems (UK-Chile)

2018-2022

TERSE: Techno-Economic framework for Resilient and Sustainable Electrification (UK-China-Malaysia)

2020-2021

Forward Resilience Measures (National Grid, UK)

2020-2023

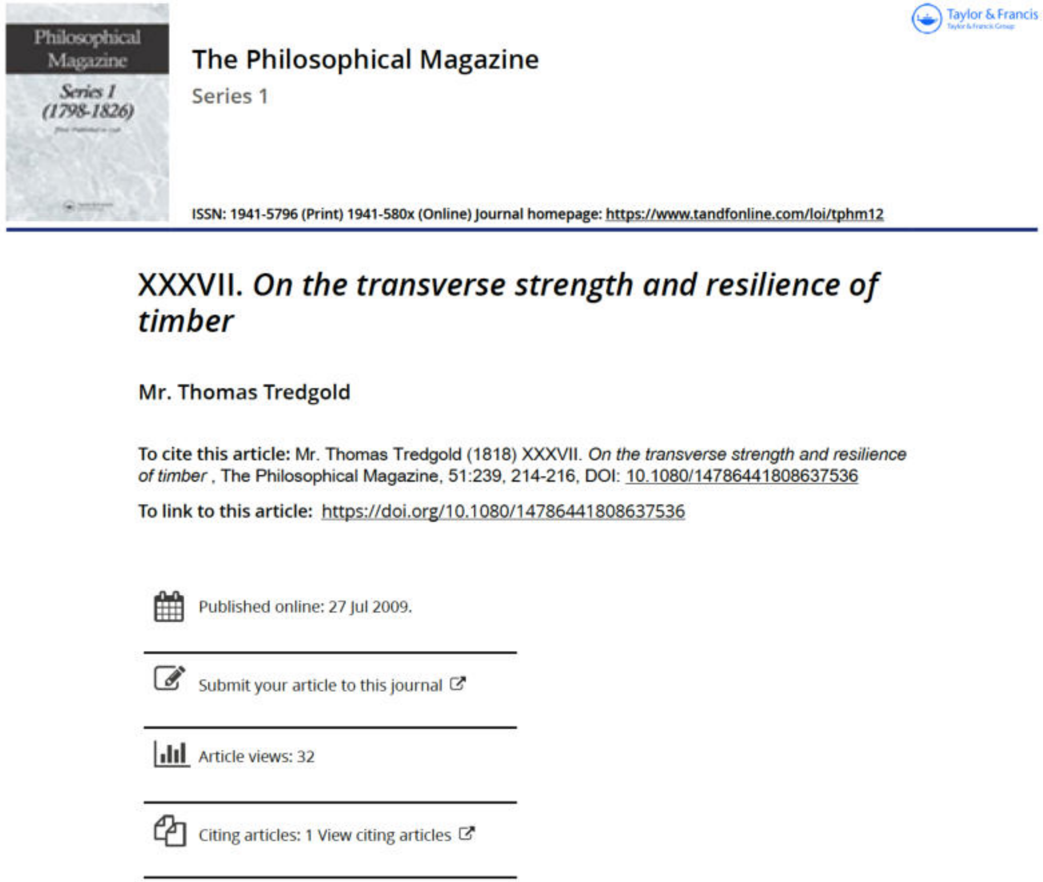
Severe Impact Resilience: Framework for Adaptive Compound Threats (US Department of Defence)

2022-2026

3 x newly awarded Horizon Europe projects (HVDC-WISE, R2D2 & ReCharged)

+ a number of consultancy projects with World Bank, CEATI, etc.

Resilience is not a recent concept…


Philosophical Magazine
Series 1
(1798-1826)

Taylor & Francis

The Philosophical Magazine
Series 1

ISSN: 1941-5796 (Print) 1941-580x (Online) Journal homepage: https://www.tandfonline.com/loi/tphm12

XXXVII. *On the transverse strength and resilience of timber*

Mr. Thomas Tredgold

To cite this article: Mr. Thomas Tredgold (1818) XXXVII. *On the transverse strength and resilience of timber* , The Philosophical Magazine, 51:239, 214-216, DOI: 10.1080/14786441808637536

To link to this article: https://doi.org/10.1080/14786441808637536

Published online: 27 Jul 2009.

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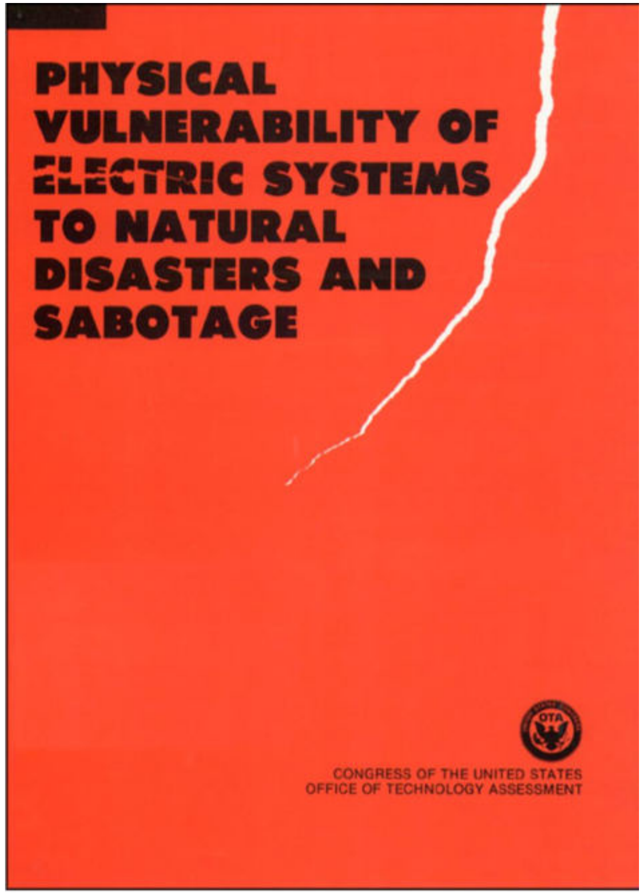
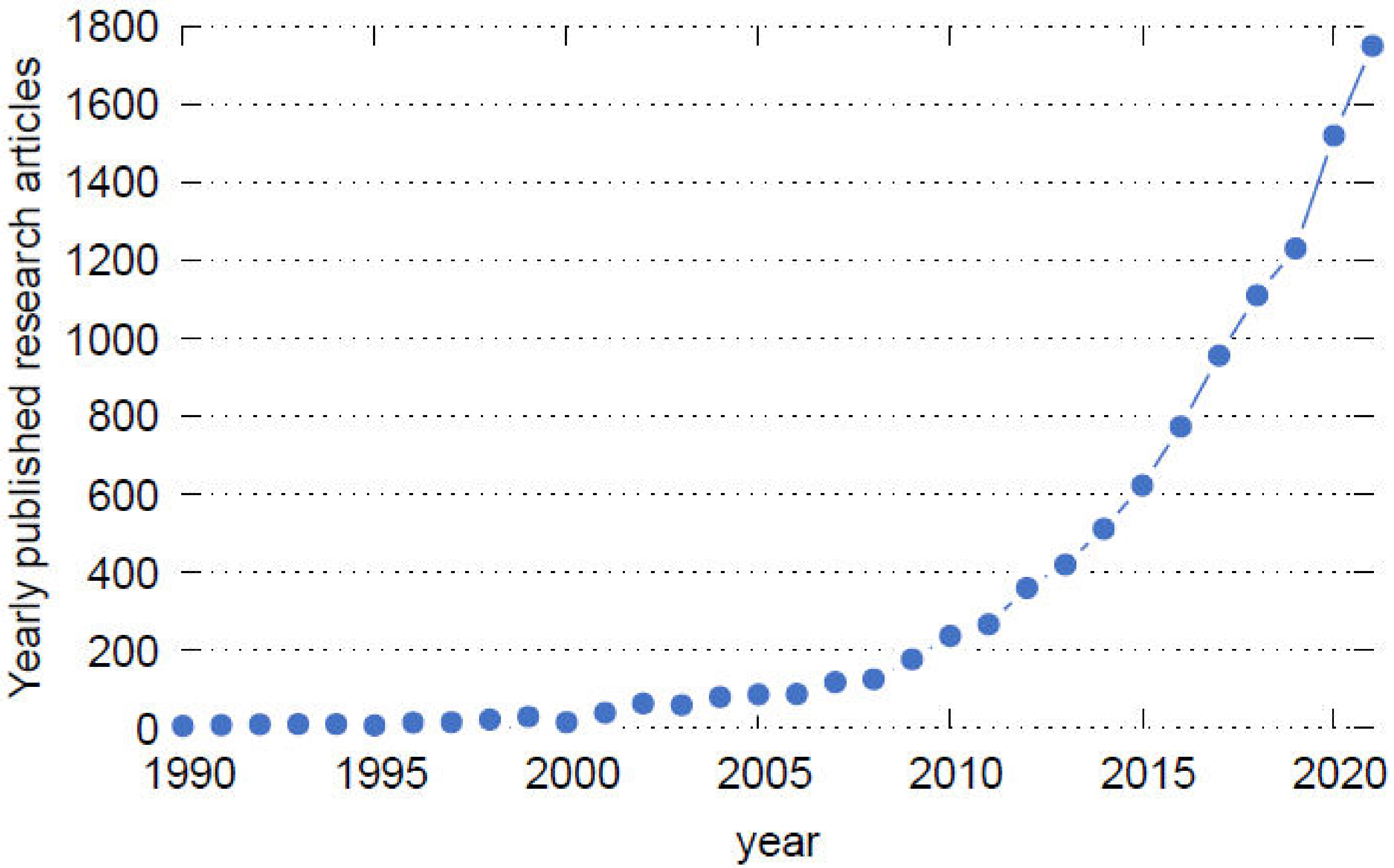
First reference to resilience in 1818!!



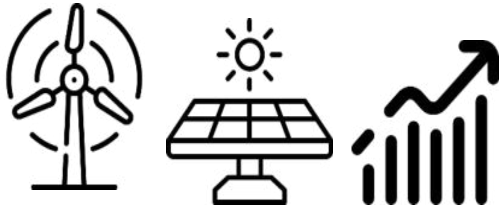
June 1990

Google Scholar Search – “Power Network/System Resilience”



Increasing Shocks and Stresses

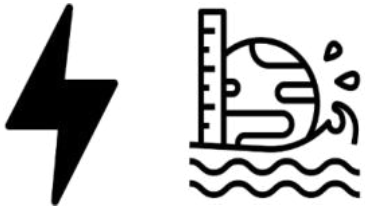
Rapid changes and stresses in energy landscape



Increasing Reliance on Reliable and Resilient Electricity

Increasing and Complex Interdependencies Between Critical Infrastructures

Threats and Shocks to Electricity Infrastructure



What is really a high-impact, low-probability (HILP) event?

“A bull with an itchy bottom knocked a transformer off an electricity pole as he tried to scratch his backside - and cut power to 800 homes.”

"We went up to feed our cows and it was my husband that noticed the transformer box had been knocked off the pole.

"We put two and two together and realised our bull had been scratching against the telegraph pole and he had knocked the box off the pole. All the wires were down in the field as well."

“Four-year-old Ron managed to avoid the box as it landed in his field, and escaped an 11,000 volt shock from the tumbling cables.”

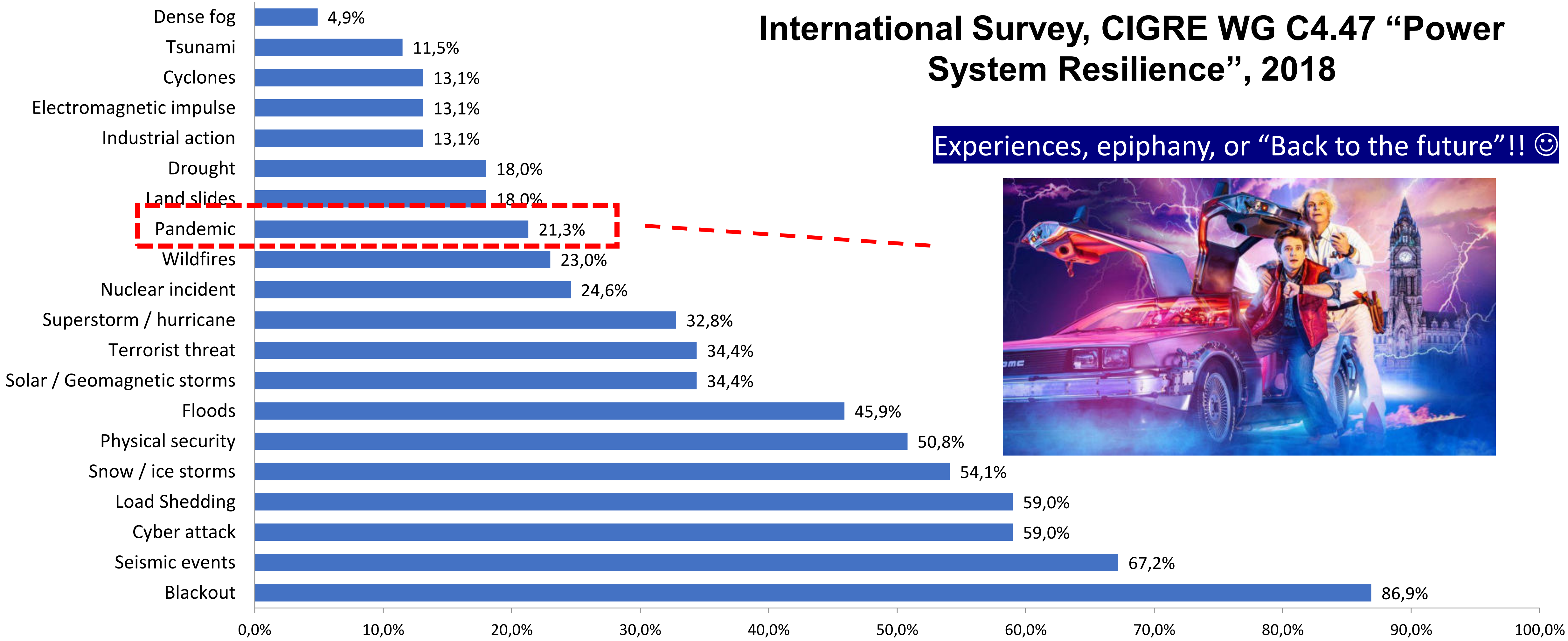
Bull's bid to scratch 'itchy bum' cuts off power to 800 homes

8 May 2020 Share

Ron has been relaxing in his field after his near-death experience

Source: https://www.bbc.co.uk/news/uk-scotland-glasgow-west-52591605

HILP Events in Power Systems



International Survey, CIGRE WG C4.47 "Power System Resilience", 2018

Experiences, epiphany, or "Back to the future"!! ☺

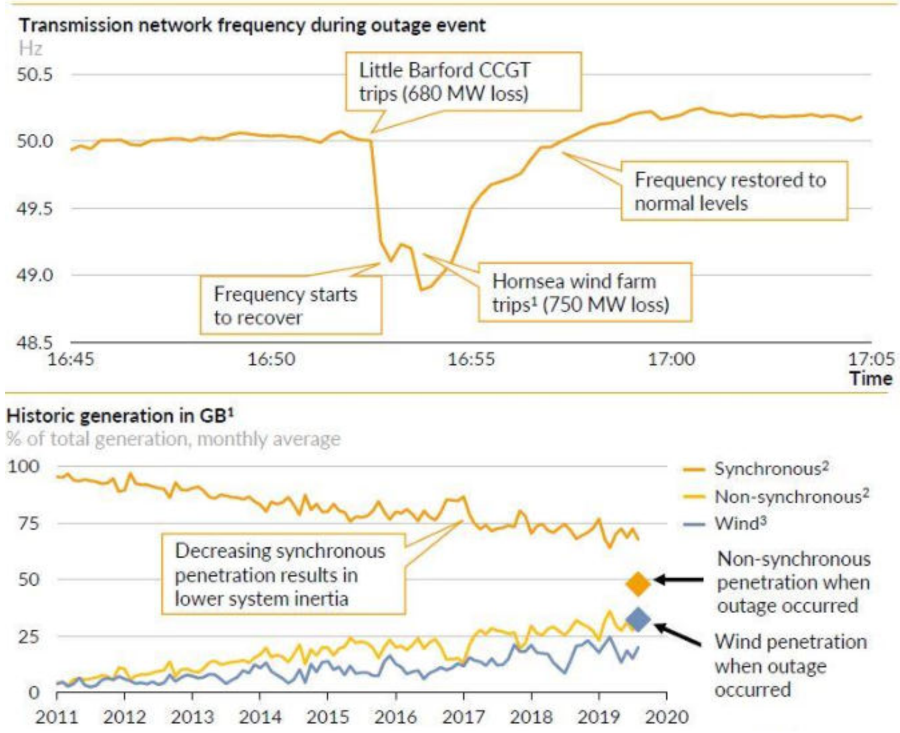
Recent Blackouts Around the World

South Australian Blackout, September 2016

"…highlights a number of challenges and valuable lessons relevant to improving power **system security** and customer supply reliability, particularly as the power system responds to **extreme circumstances**, as the NEM generation mix changes and Australia makes the transition to **high levels of renewable energy sources**"
"**Big batteries**, stabilisation urged for Australia's power system"

United Kingdom (UK) Blackout, August 2019

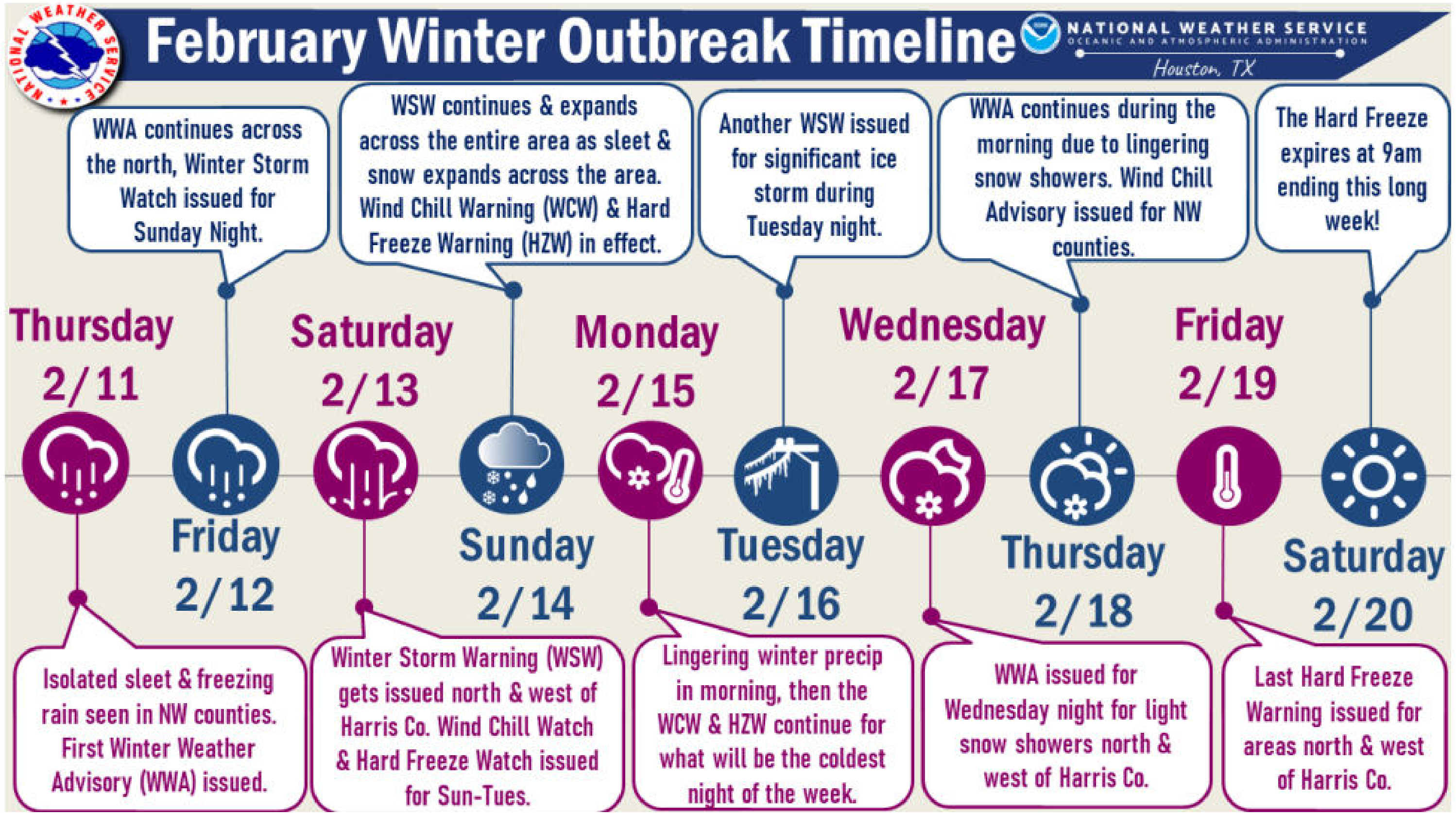
Around **30% of the generation was from wind**, 30% from gas and 20% from nuclear and 10% from interconnectors.
"As this generation would not be expected to trip off or de-load in response to a **weather event**, **this represents an extremely rare and unexpected event**."
"**Once-in-30-years event**", John Pettigrew, CEO National Grid



Source: https://www.energynetworks.com.au/news/energy-insider/blackout-uk-whos-to-blame/

Recent Blackouts Around the World

2021 Texas Blackout

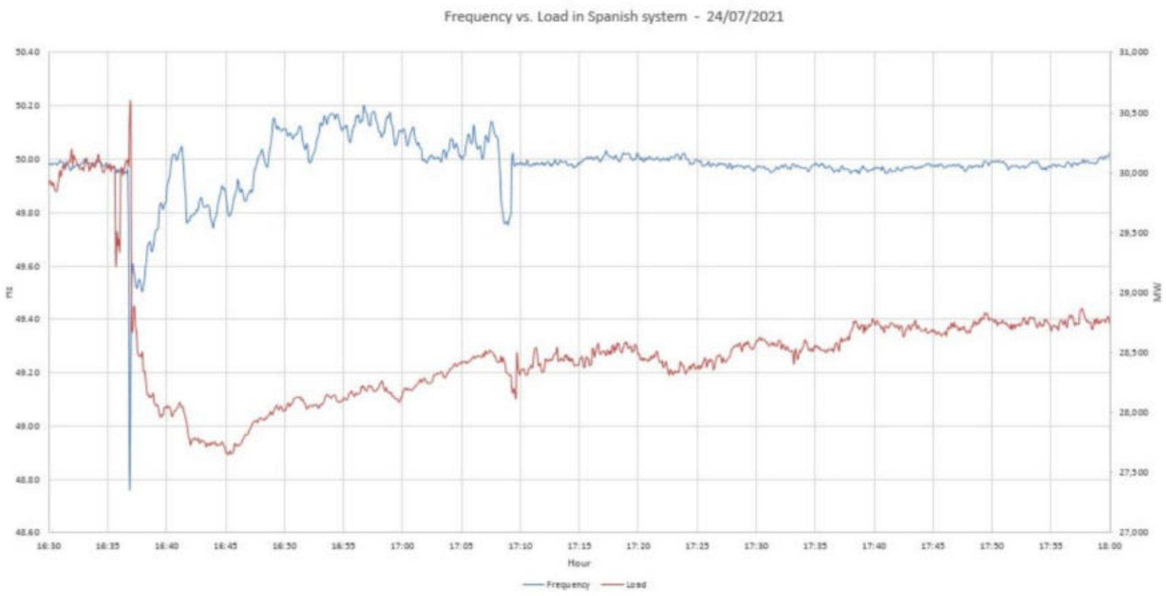


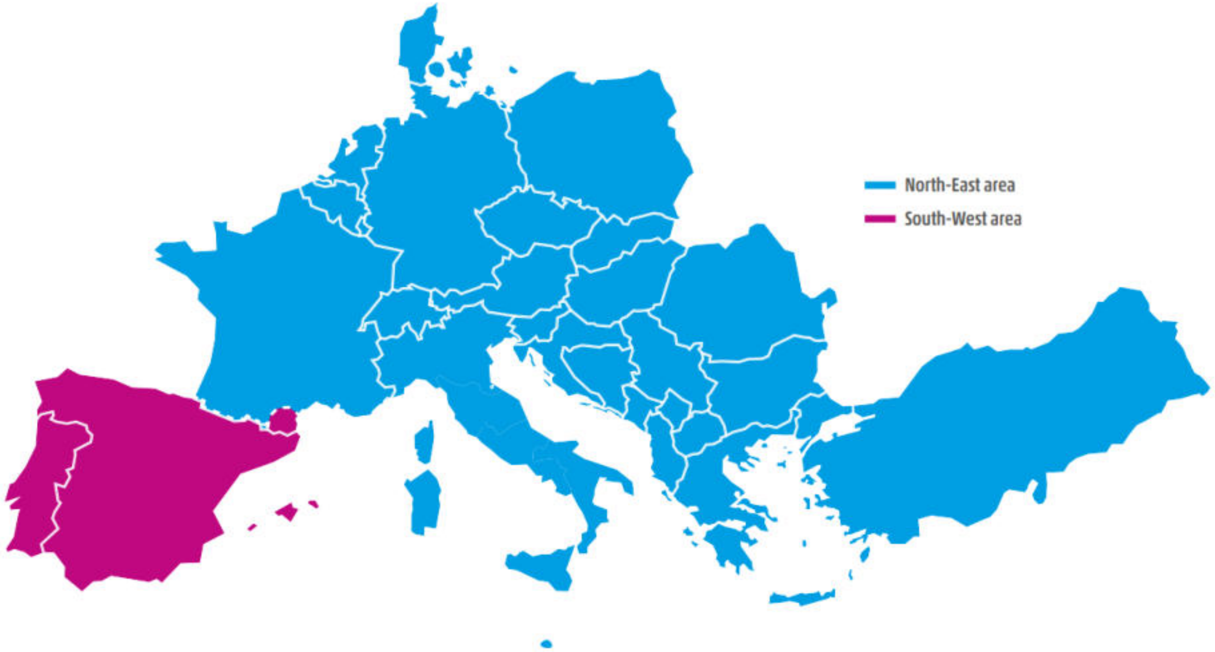
https://energy.utexas.edu/sites/default/files/UTAustin%20%282021%29%20EventsFebruary2021TexasBlackout%2020210714.pdf

What about near misses?

Continental Europe Synchronous Area Separation on 24 July 2021

Severe fire in the vicinity of the city Moux, Southern France

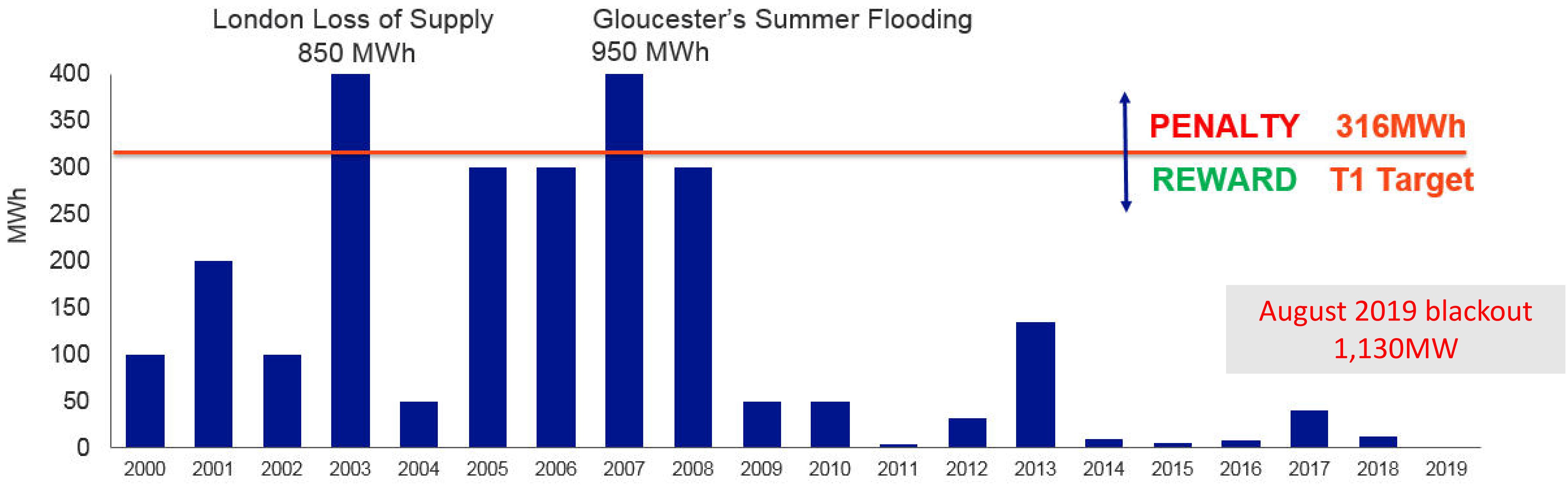




Limitations in Current Regulatory Standards

Ofgem – RIIO-2 Final Determination

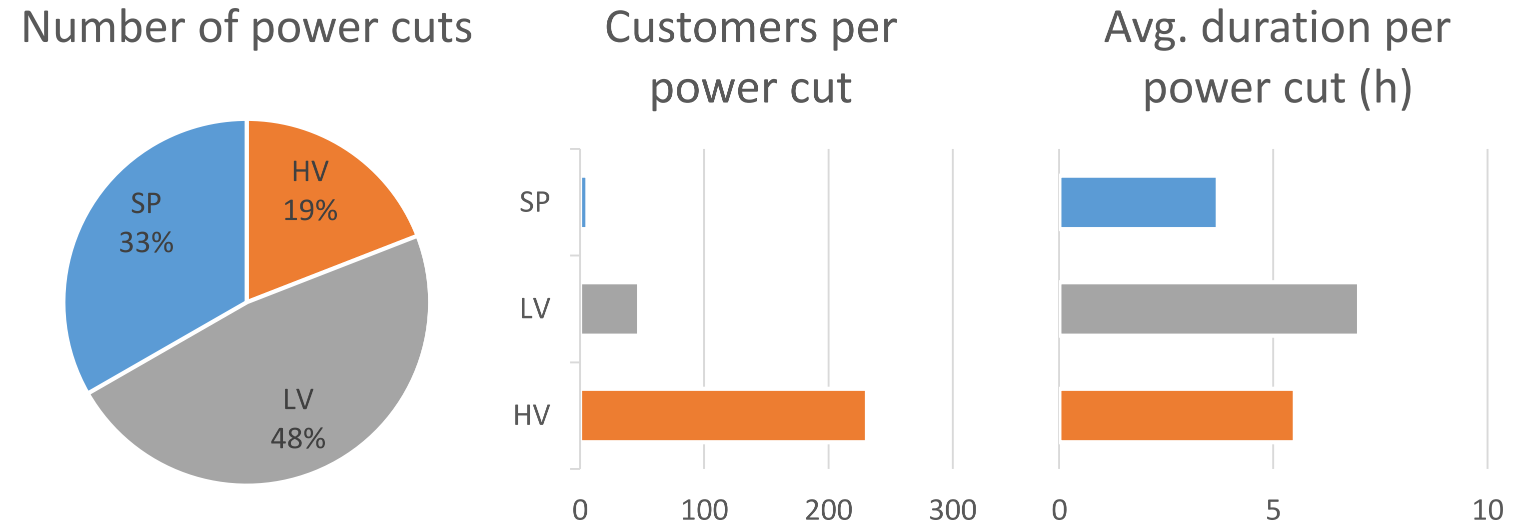
- The performance target for NGET is **147MWh** (average ENS).
- This is significantly lower than the RIIO-1 target of **316MWh**

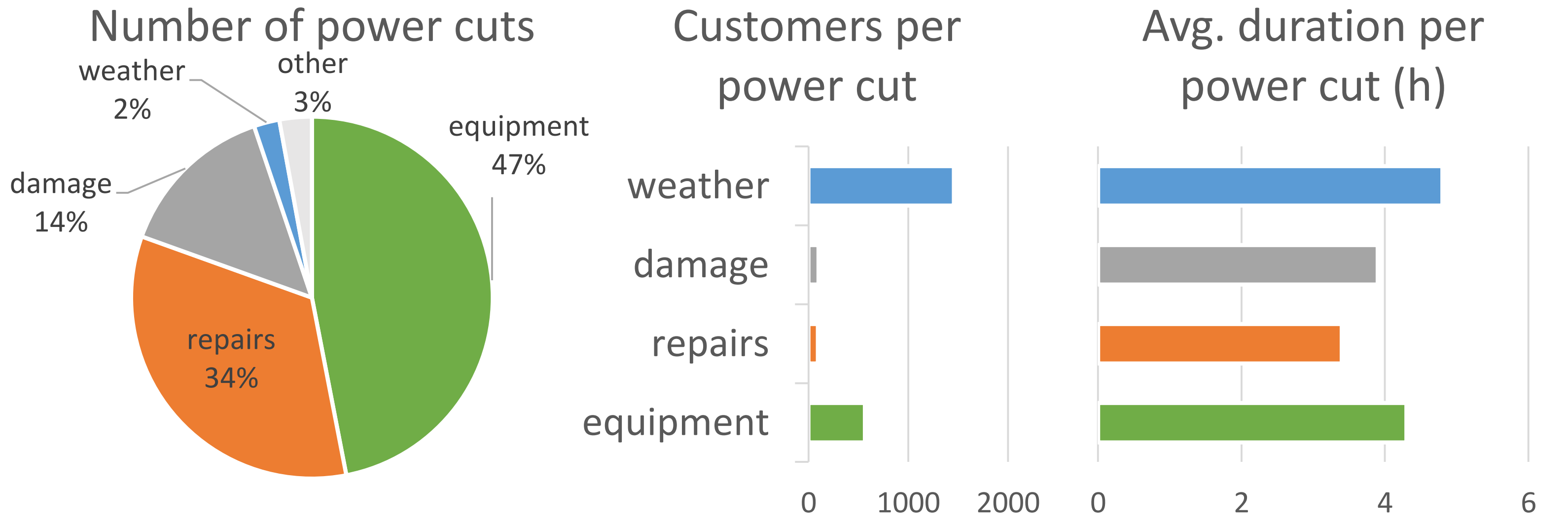


National Grid, "Annex NGET_A9.11 ENS Incentive", December 2019 (as part of the NGET Business Plan Submission) (Link)

Assessing resilience from UK outage data

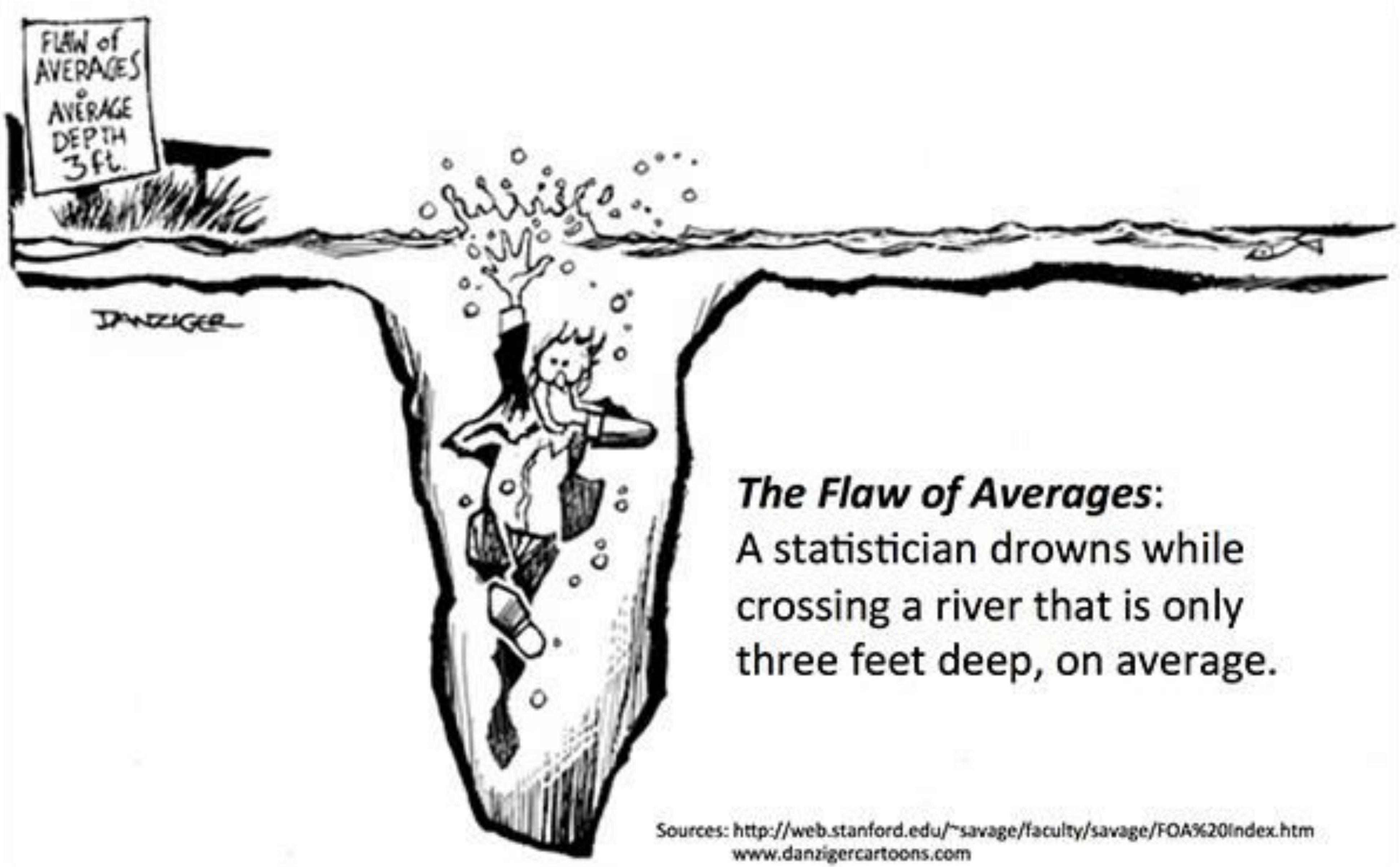
Real data analysis for performance and correlation analysis with shocks and stresses



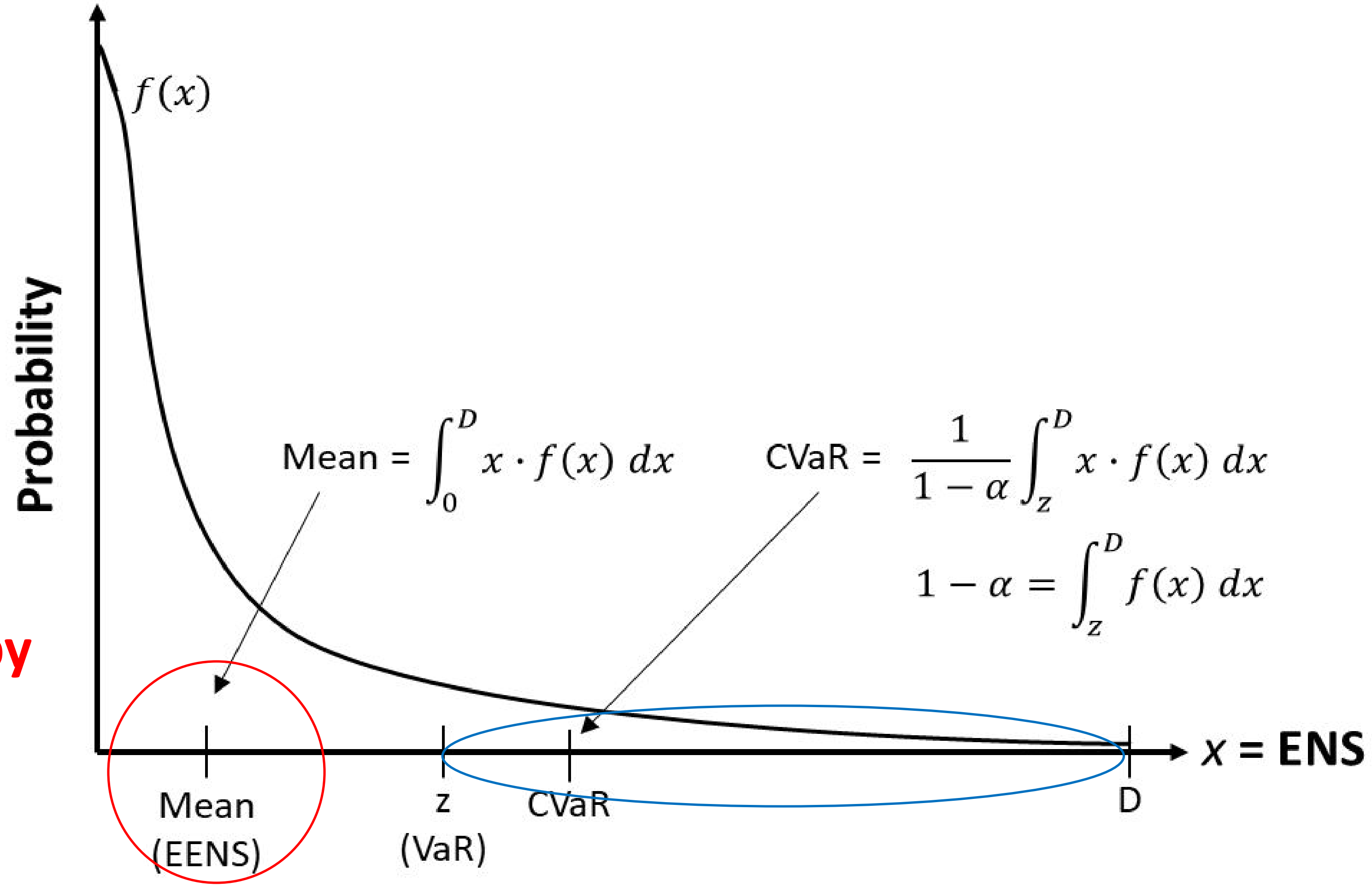


M. Noebels, M. Panteli, “Correlations of Shocks and Stresses with Distribution Network Outages”, IEEE PES GM (2021, accepted)

Limitations in Current Regulatory Standards



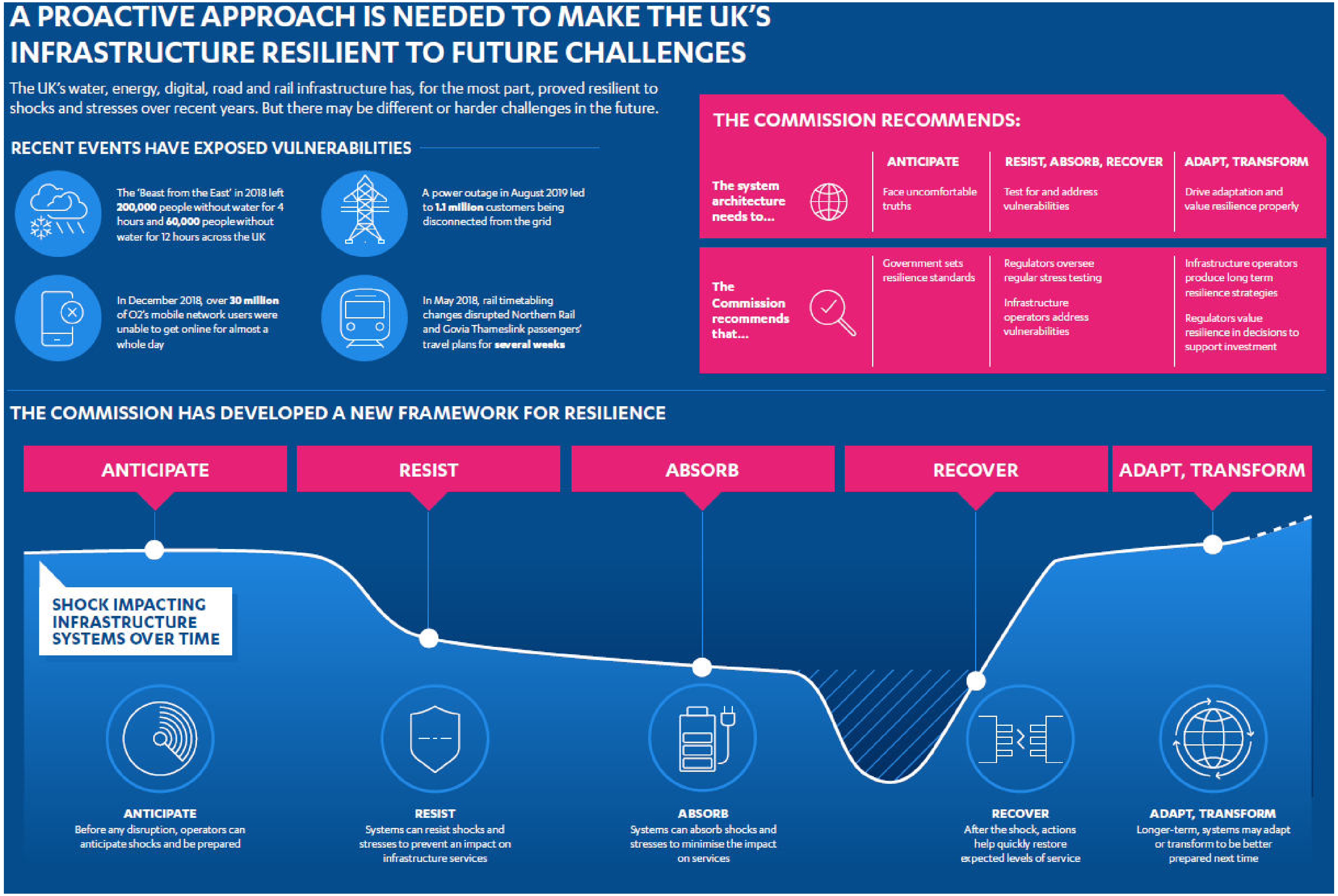
Moving from average to risk indicators: Risk-averse approach



Mainly affected by credible outages

-Natural hazards
-Catastrophic events
-Common mode failures

Reaction by National Infrastructure Commission (NIC), UK, May 2020



https://nic.org.uk/app/uploads/Anticipate-React-Recover-28-May-2020.pdf

UK Government Response to NIC Resilience Report, September 2021

"To deliver resilient infrastructure, a framework for resilience is required that:

- better anticipates future shocks and stresses by facing up to uncomfortable truths
- improves actions to resist, absorb and recover from shocks and stresses by testing for vulnerabilities and addressing them
- values resilience properly
- drives adaptation before it is too late

Much of what is needed is already in place, but improvements can still be made:

- government should publish a full set of resilience standards every five years, following advice from regulators, alongside an assessment of any changes needed to deliver them
- infrastructure operators should carry out regular and proportionate stress tests, overseen by regulators, to ensure their systems and services can meet government's resilience standards, and take actions to address any vulnerabilities
- infrastructure operators should develop and maintain long term resilience strategies, and regulators should ensure their determinations in future price reviews are consistent with meeting resilience standards in the short and long term"

The publication of the NIC resilience report occurred at a pivotal time in the nation's approach to resilience. The UK was in the early stages of the Covid-19 outbreak and the opportunities as well as challenges of this period were emphasised in the National Infrastructure Strategy and the Prime Minister's commitment in Autumn 2020 to build back better, greener and faster from the pandemic. In the National Infrastructure Strategy, the government also agreed with the primary findings of another NIC study on economic regulation, that the UK's system of economic regulation needed updating to rise to 21st century challenges such as floods, droughts and climate change.

In March 2021, HMG published the Integrated Review which sets the overarching vision and strategic framework for building the UK's security and resilience on a global scale. The Integrated Review incorporates a strong emphasis on the need for resilience and includes an increased commitment to resilience by defending the UK's CNI, including the economic infrastructure sectors, as well as the UK's people and way of life which directly depend on these sectors.

The Integrated Review also includes a government commitment to develop a comprehensive National Resilience Strategy that will establish a 'whole-of-society' approach to resilience, consider threats and hazards in the round, develop greater capabilities that can be used across a range of scenarios, review the approach to risk assessment, and strengthen HMG tools to better assess cross-cutting, complex risks. Development of this resilience strategy is now underway, with a final strategy to be published in the first half of 2022.

https://www.gov.uk/government/publications/government-response-to-the-national-infrastructure-commission-report-anticipate-react-recover-resilient-infrastructure-systems/government-response-to-the-national-infrastructure-commission-report-anticipate-react-recover-resilient-infrastructure-systems

CIGRE WG C4.47 Definition of Resilience

*the ability to limit the **extent, severity** and **duration** of **system degradation** following an **extreme event**.*

Anticipation	Preparation	Absorption	Adaptation	Rapid recovery	Sustainment of critical system operation
• the process by which newly incorporated knowledge gained is used to foresee possible crises and disasters	• the process through which grid operators establish a set of actions to be deployed in case the critical operating condition occurs	• the process through which a set of measures is deployed to limit the extent, the severity and the slope of the degradation of power system performance	• the process through which changes are carried out in the power system management procedures, on the basis of past disruptions, in order to adjust the system to undesirable situations	• the process through which the energy supply to the customers is restored and the damages to the grid infrastructure are repaired	• the process which deploys the measures allowing an impaired power system to supply a minimum system load level in order to maintain a reduced but acceptable functioning of everyday life

For more information on CIGRE WG C4.47 resilience definition

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Defining power system resilience

The definition of resilience has alluded utilities and standard authorities. Resilience is more than just "bouncing back". CIGRE Working Group SC C4.47 has researched and formulated a definition as well as key actionable measures as an integral part of the definition. This paper covers the process and derivation of the definition as well as the actionable measures. It compares reliability to resilience and discusses application of the definition in the electricity sector.

Despite several attempts by organisations worldwide in the power and energy engineering communities to define resilience, there is no universally accepted definition. Resilience is a multi-dimensional and dynamic concept. Resilience is more than simply "the ability to bounce back".

In 2017 CIGRE SC C4 formed a Working Group consisting of experts from 19 countries. The purpose was to formulate a standard definition and approach to resilience. An international survey was undertaken and the inputs consolidated into an internationally agreed definition. The group also discussed the difference between reliability and resilience as these terms are often confused.

https://www.cigre.org/article/GB/news/the_latest_news/defining-power-system-resilience

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Rethinking power grid resilience: experiences and lessons from the COVID-19 pandemic

02 June 2020, prepared by Mathaios Panteli and Malcolm Van Harte, CIGRE Working Group C4.47 "Power System Resilience"

In November 2019, the first cases of a new disease, later named COVID-19 by the World Health Organisation, were reported by health care workers in Wuhan, China. In December 2019, researchers from Wuhan reported a cluster of pneumonia cases caused by a novel coronavirus. The COVID-19 pandemic has resulted since then in severe stresses on essential services and operations of critical infrastructures around the world. The battle against this virus pandemic has placed and is placing tremendous pressure on countries' healthcare system, the economy, activities in general society, and especially on the ability of utilities to perform their operations and duties entrusted to them. Electricity utilities have swiftly mobilised across the world to implement measures to support, protect and empower their employees with reliable and accurate information about COVID-19, while keeping the lights on for critical essential service providers. Various measures have been taken in order to limit exposure or spread of the virus to their employees or public.

https://www.cigre.org/article/GB/rethinking-power-grid-resilience-experiences-and-lessons-from-the-covid-19-pandemic

PAPER
REFERENCE

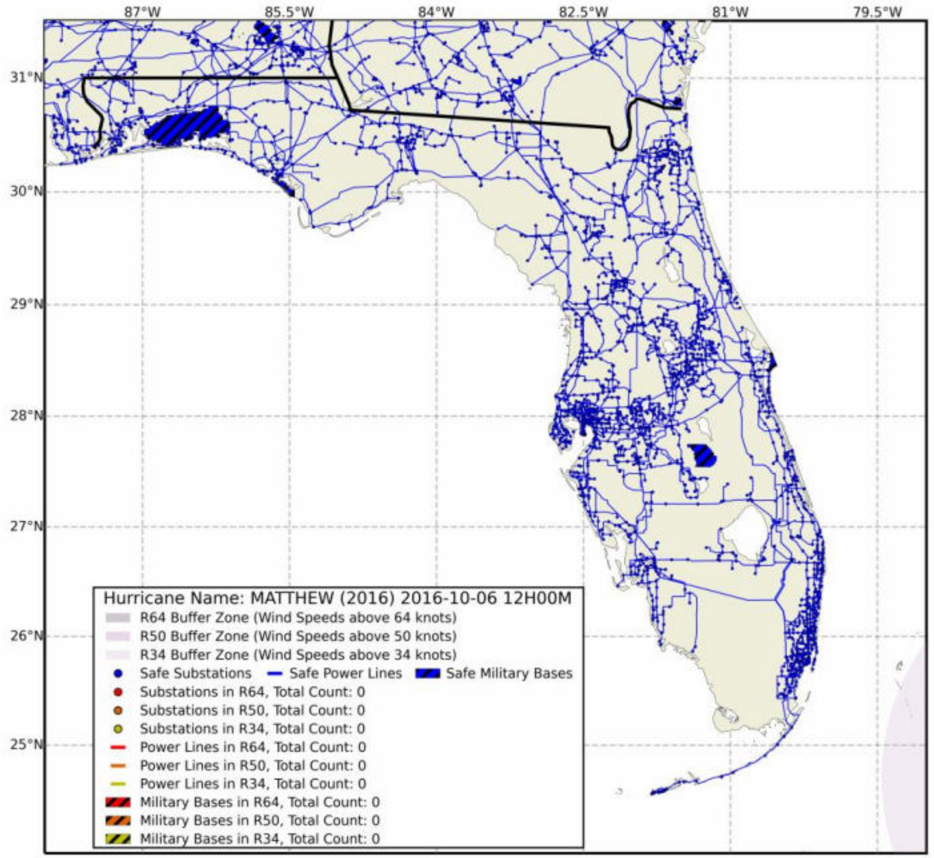
Defining power system resilience

By E. CIAPESSONI (IT), D. CIRIO (IT), A. PITTO (IT), M. PANTELI (UK), M. VAN HARTE (SA), C. MAK (CA) on behalf of C4.47 WG Members

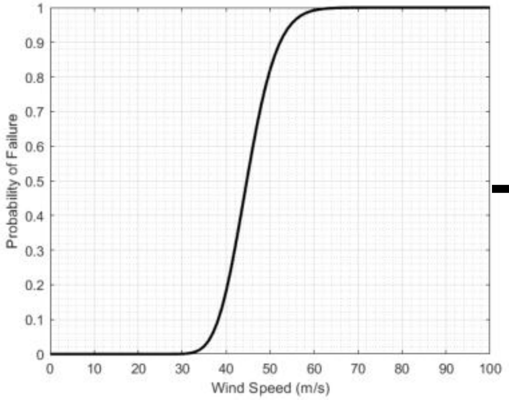
https://e-cigre.org/publication/RP_306_1-defining-power-system-resilience

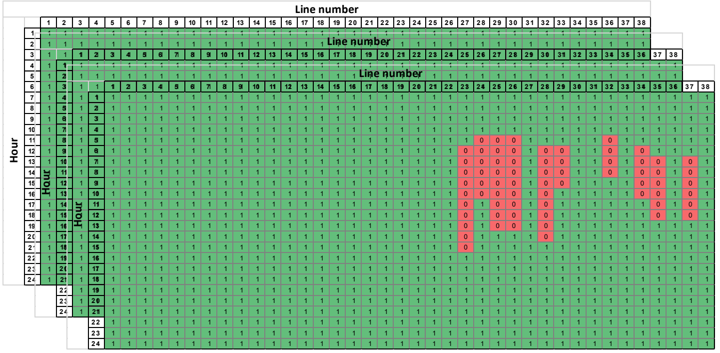
RESILIENT: Realistic Event Simulator for International Location-Independent Energy Network Testing

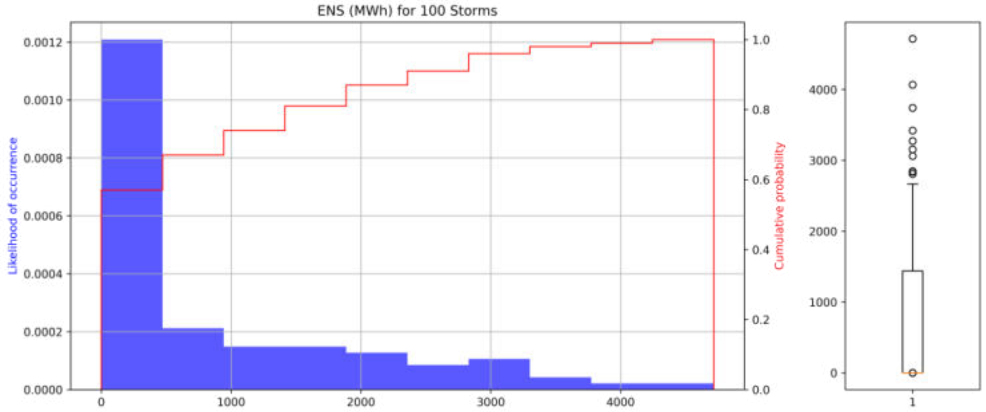
- Fully flexible and modular simulator of extreme weather events
- Enables the user to define several critical features, and simulate random events as well as historical ones, including:
  - Number of hazards per year
  - Temporal and spatial modelling
  - Hazard's intensity profile
  - Etc..



RESILIENT: Realistic Event Simulator for International Location-Independent Energy Network Testing







Forward Resilience Measures

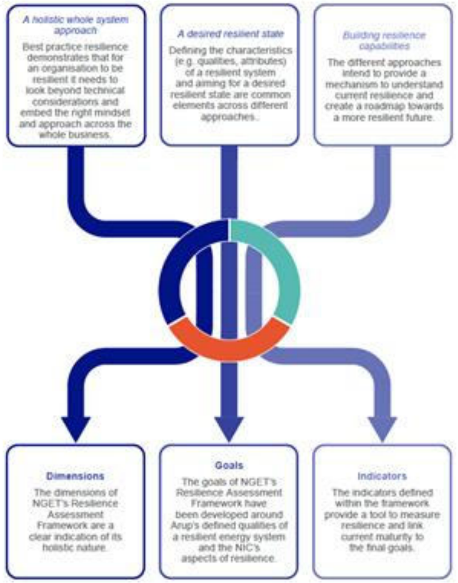
Resilience Tiered Approach

Tier 1 – Resilience Assessment Framework

A breakdown structure of the elements that matter for NGET's resilience allows for a holistic understanding of resilience maturity.

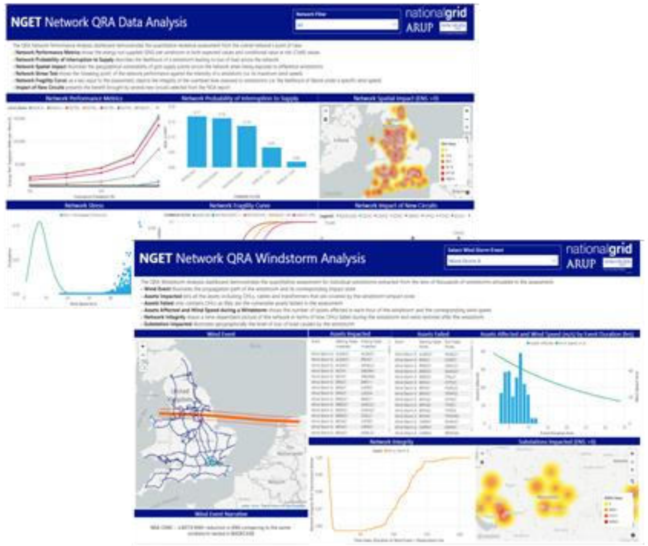
Tier 2 – Link to Existing and Planned Initiatives

The scoring of the different indicators is informed by existing and planned initiatives across the organisation.

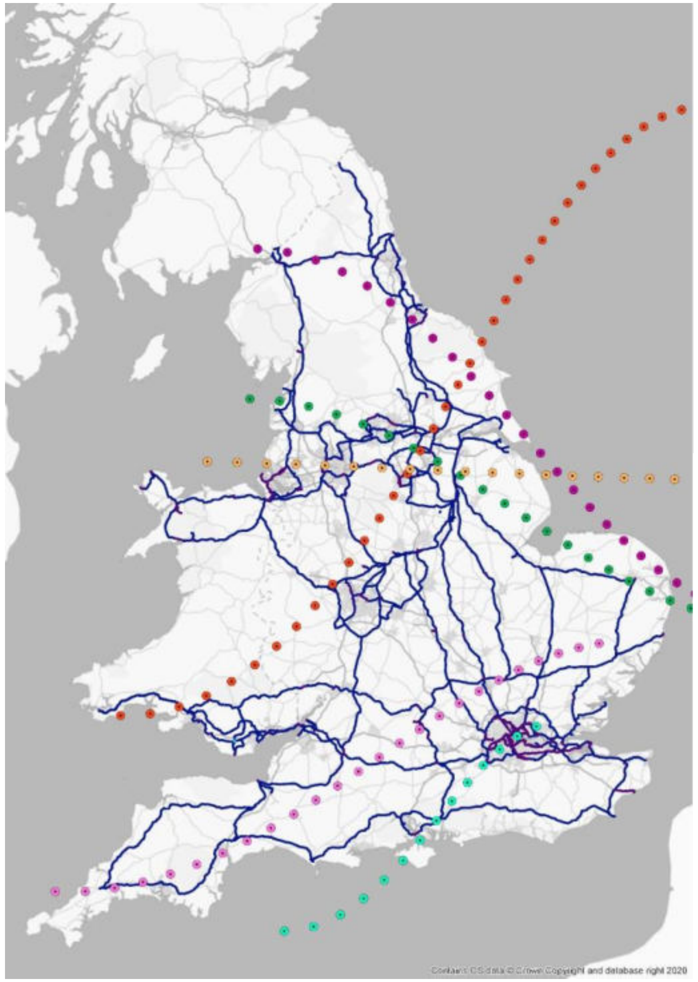


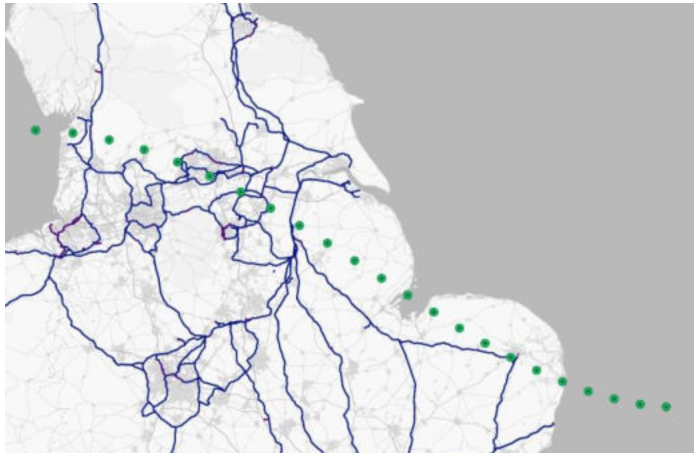
Tier 3 – Quantitative Resilience Assessment Tool

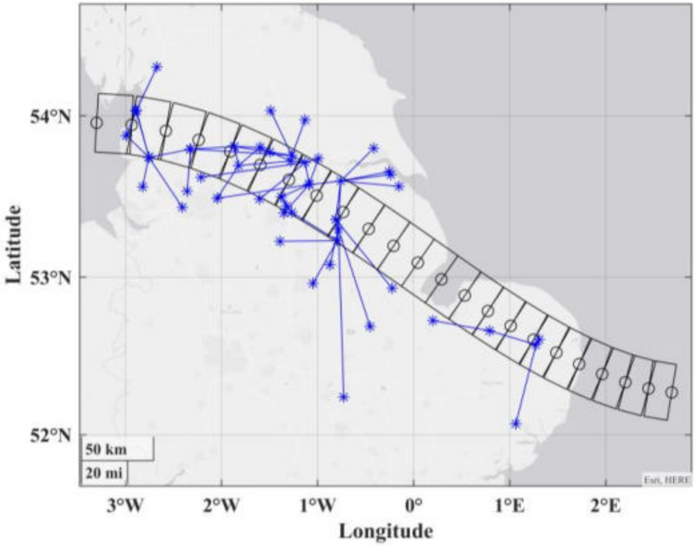
Quantify coupled effects of physical shocks and network stresses on NGET's resilience, using a wide range of metrics.

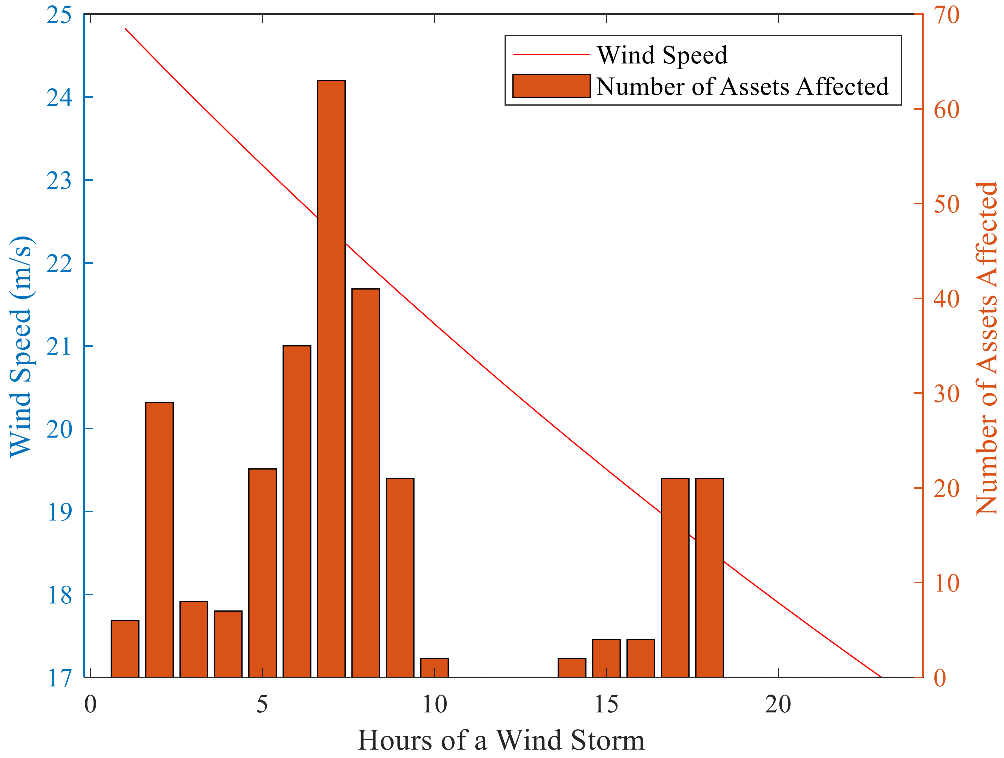


Spatial and Temporal Hazard Simulator: UK Transmission Network

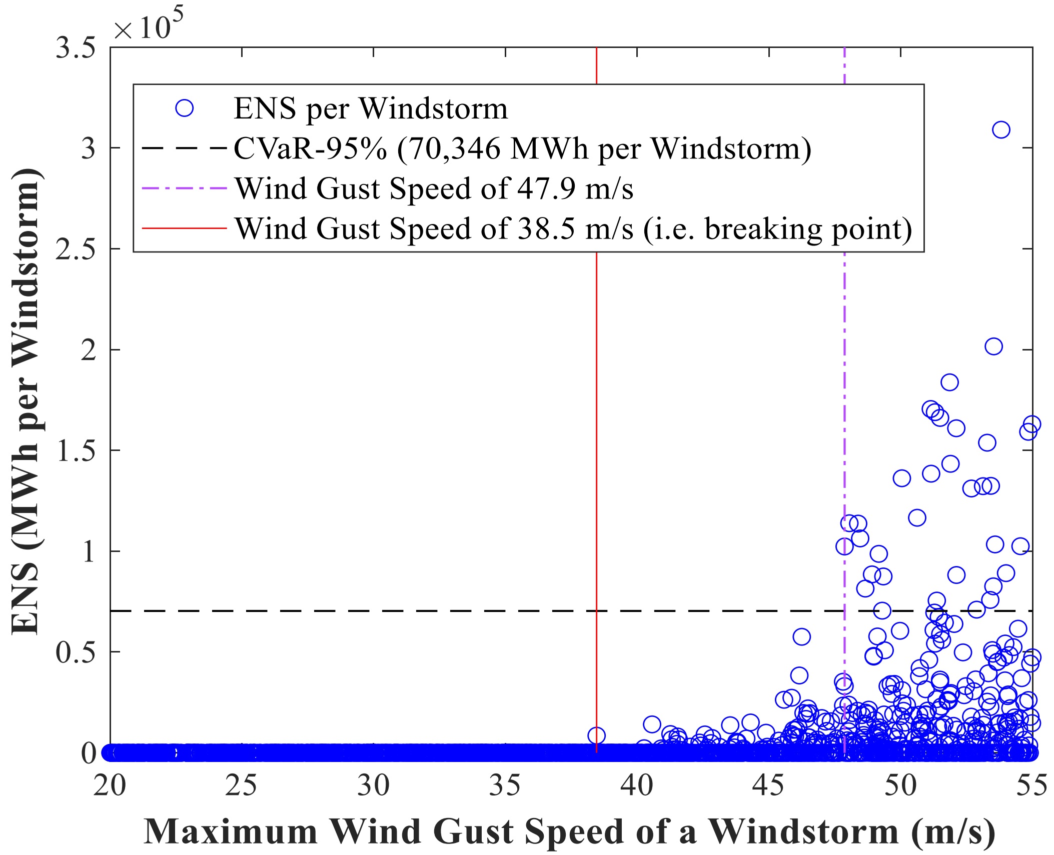


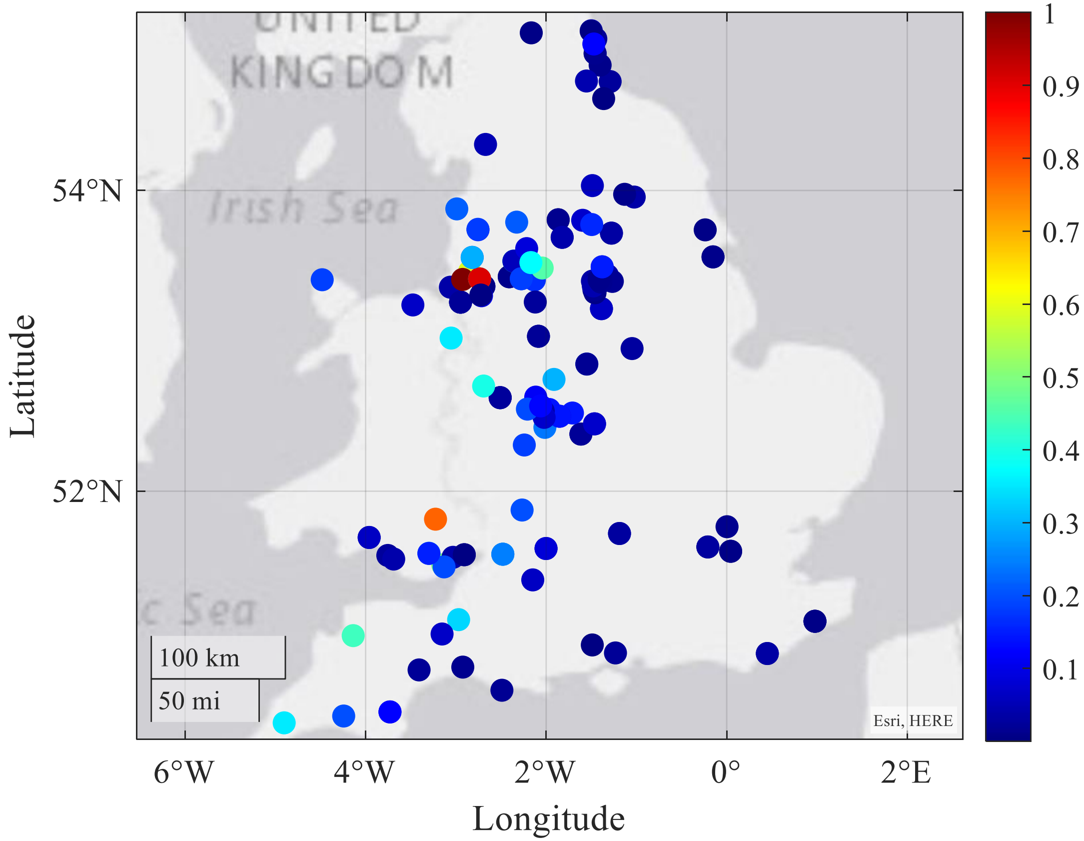






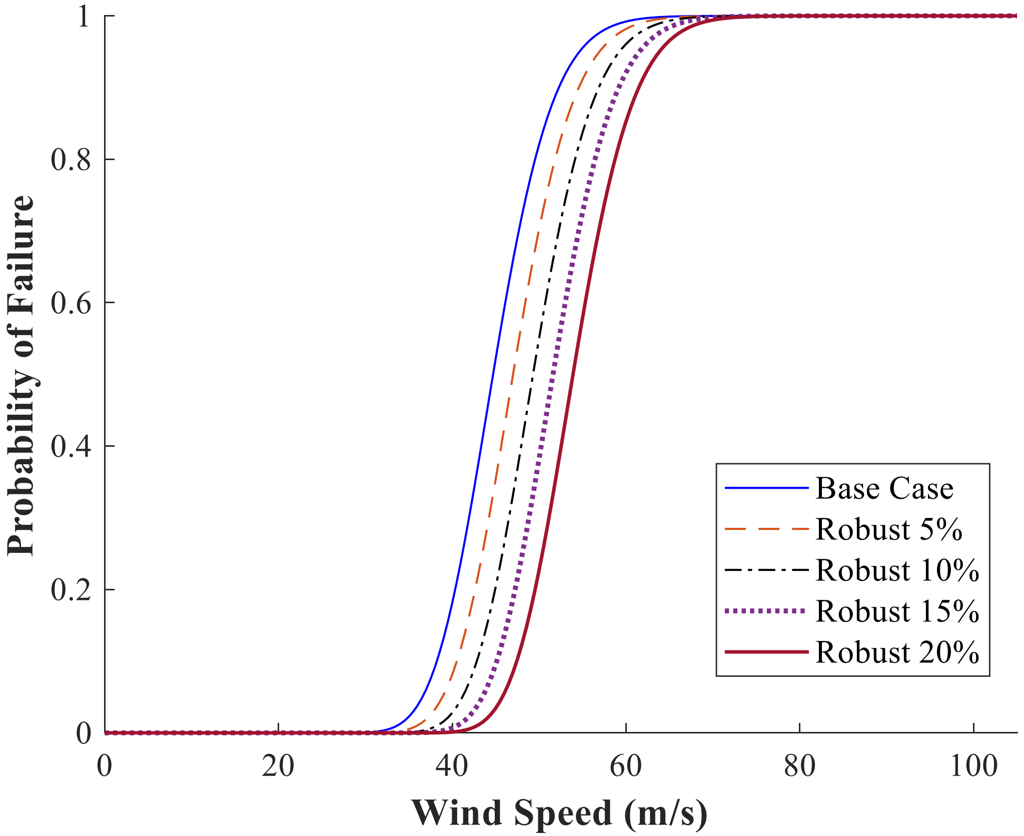
Network Stress-testing, Breaking Point and Spatial Energy Not Supplied

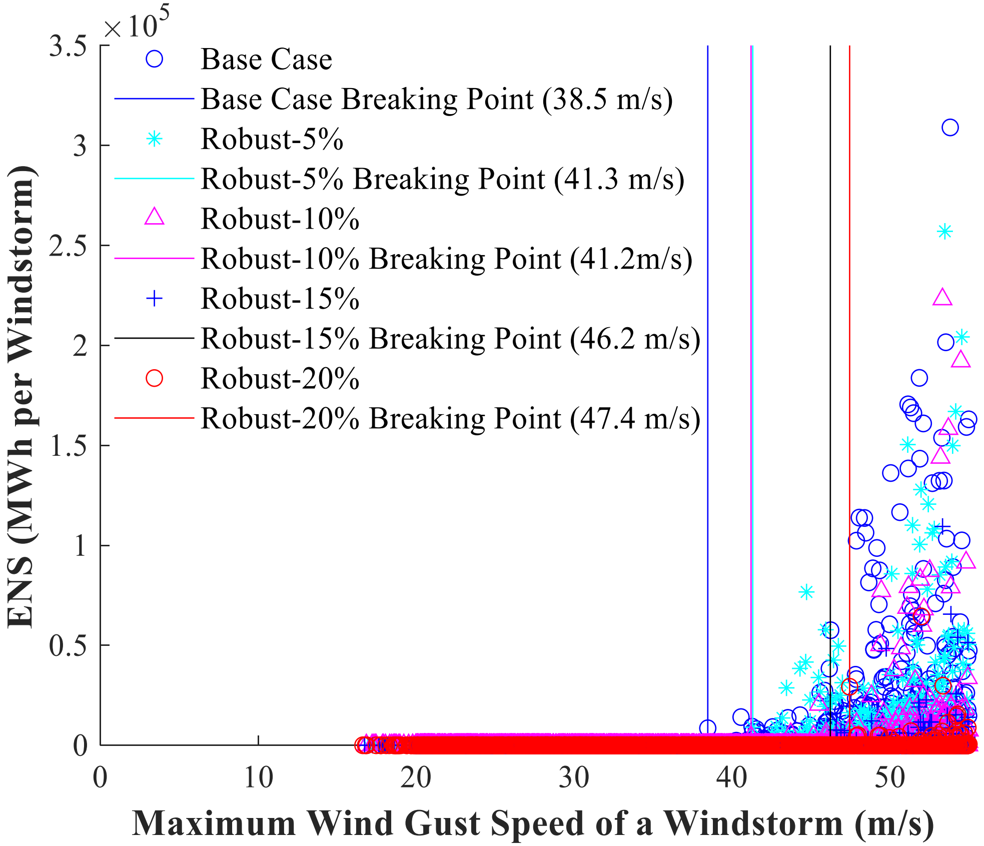




For Demonstration Only

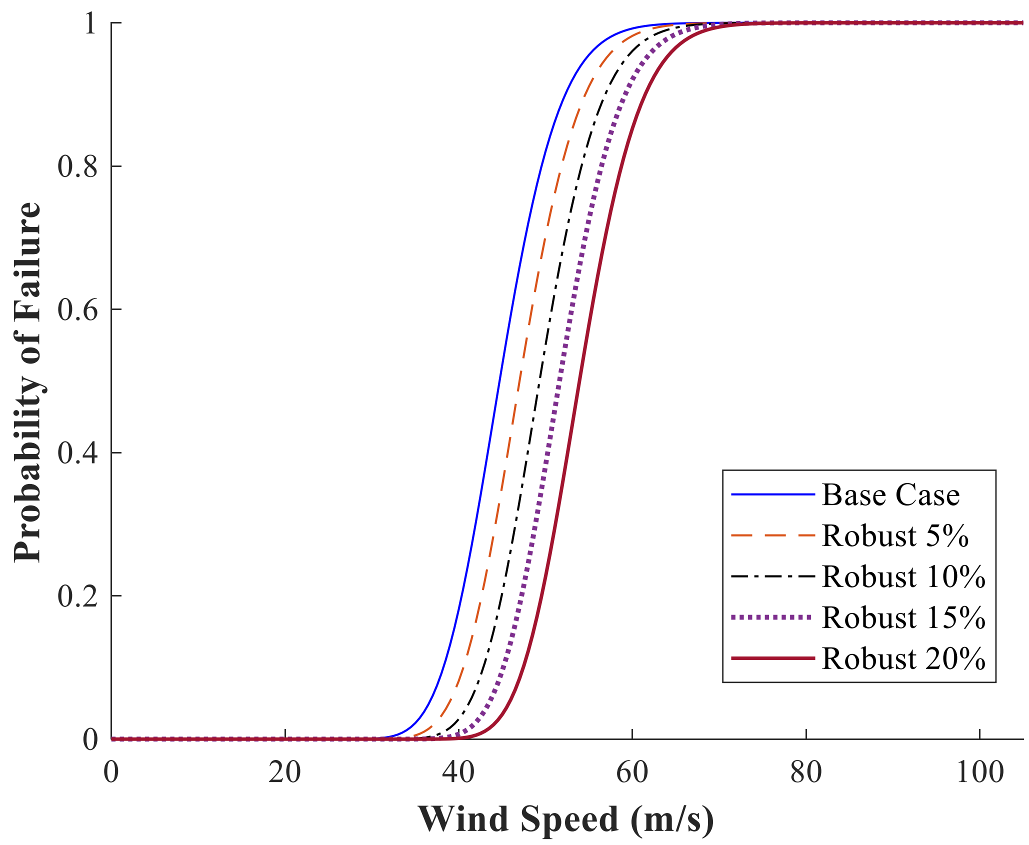
Breaking Point: Sensitivity to Network Robustness

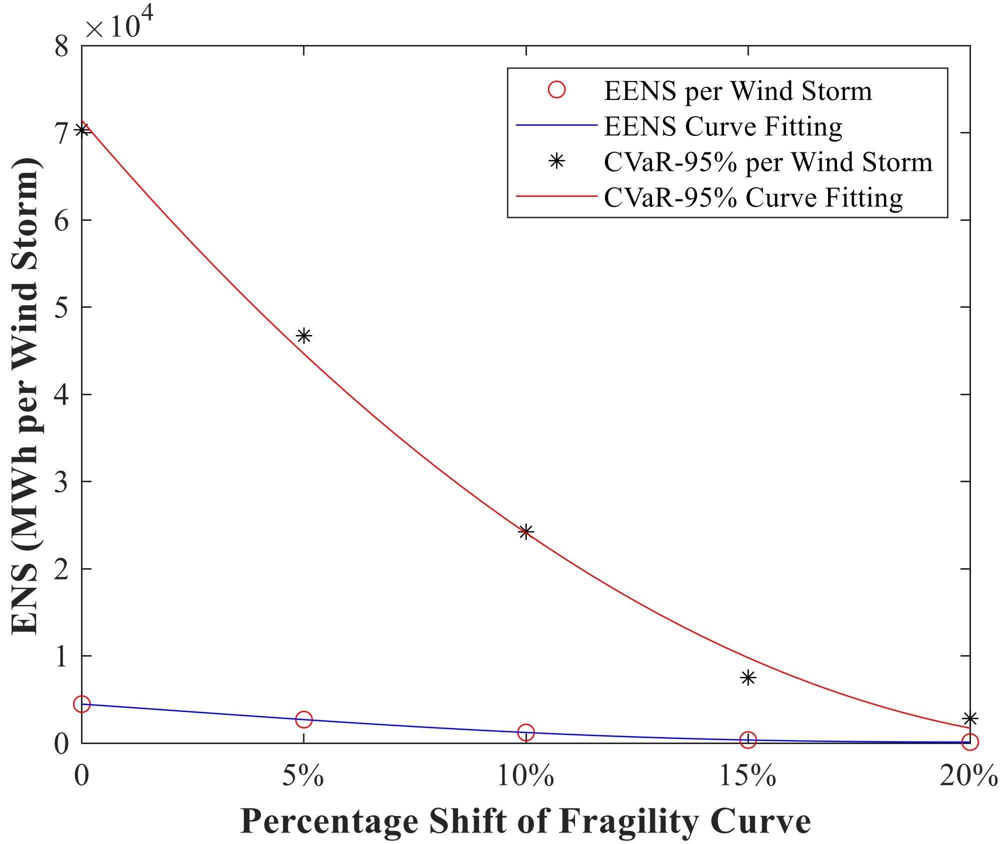




For Demonstration Only

Expected and Conditional Values of Energy Not Supplied: Sensitivity to Network Robustness





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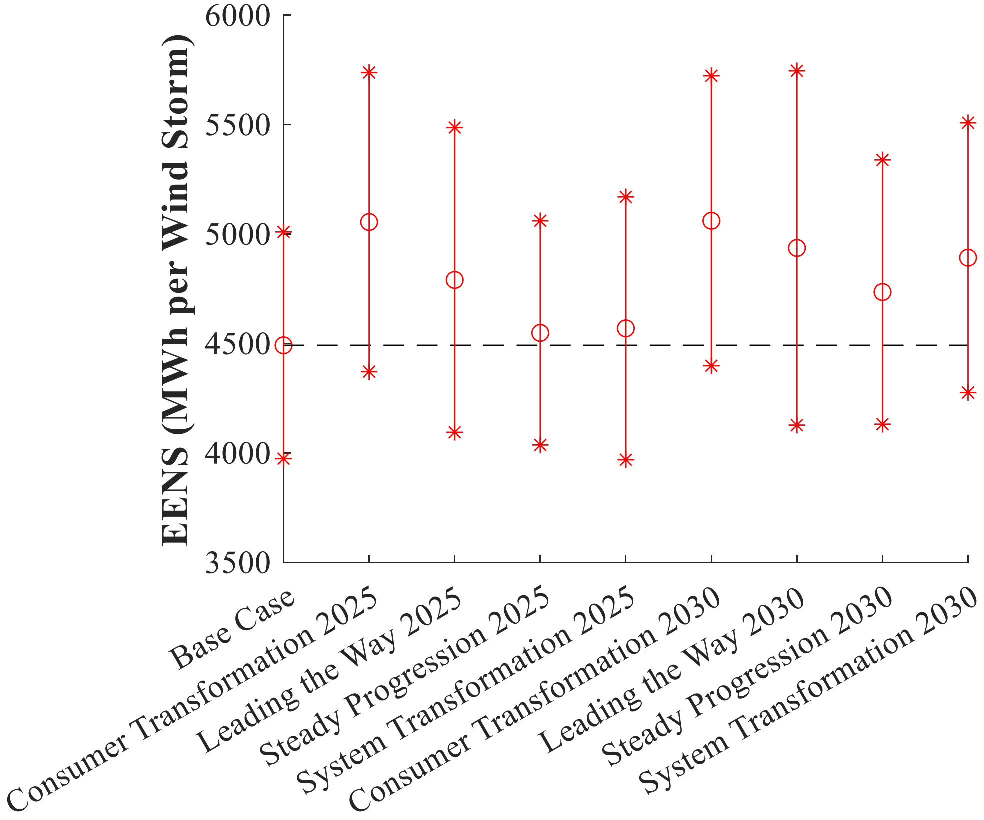
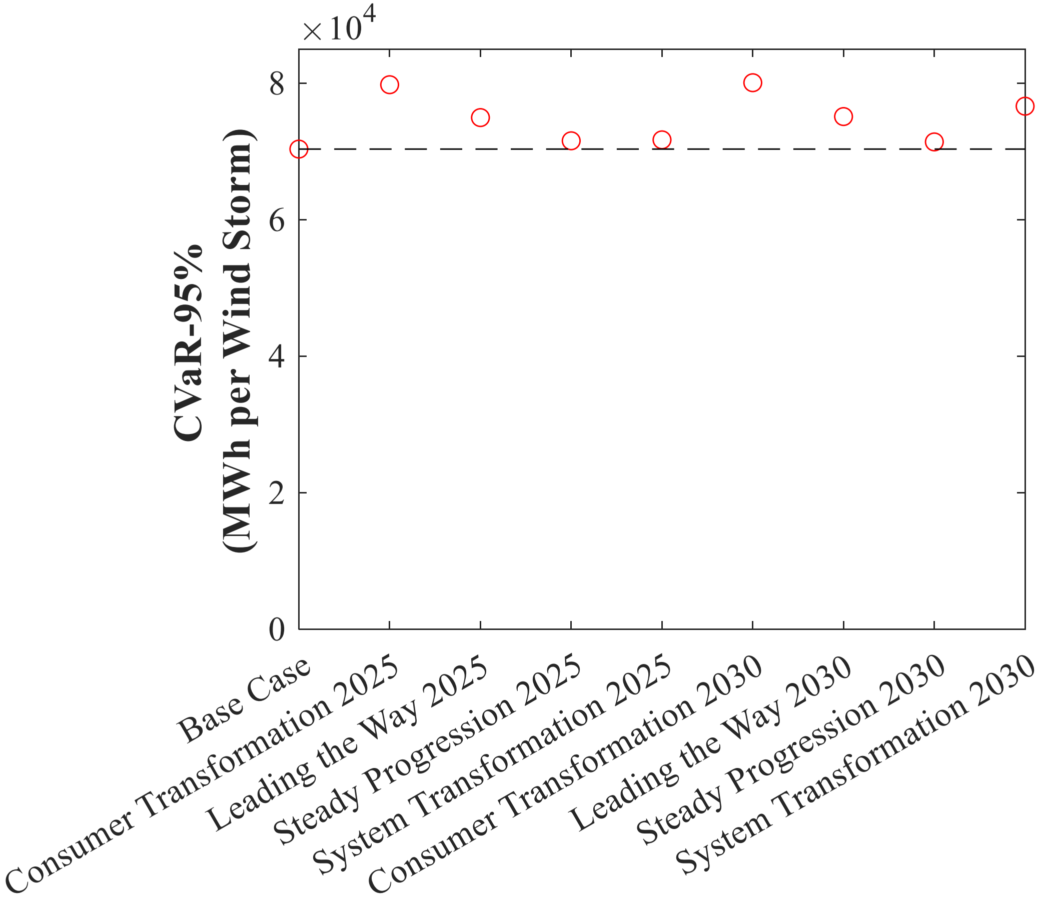
Future Energy Scenarios





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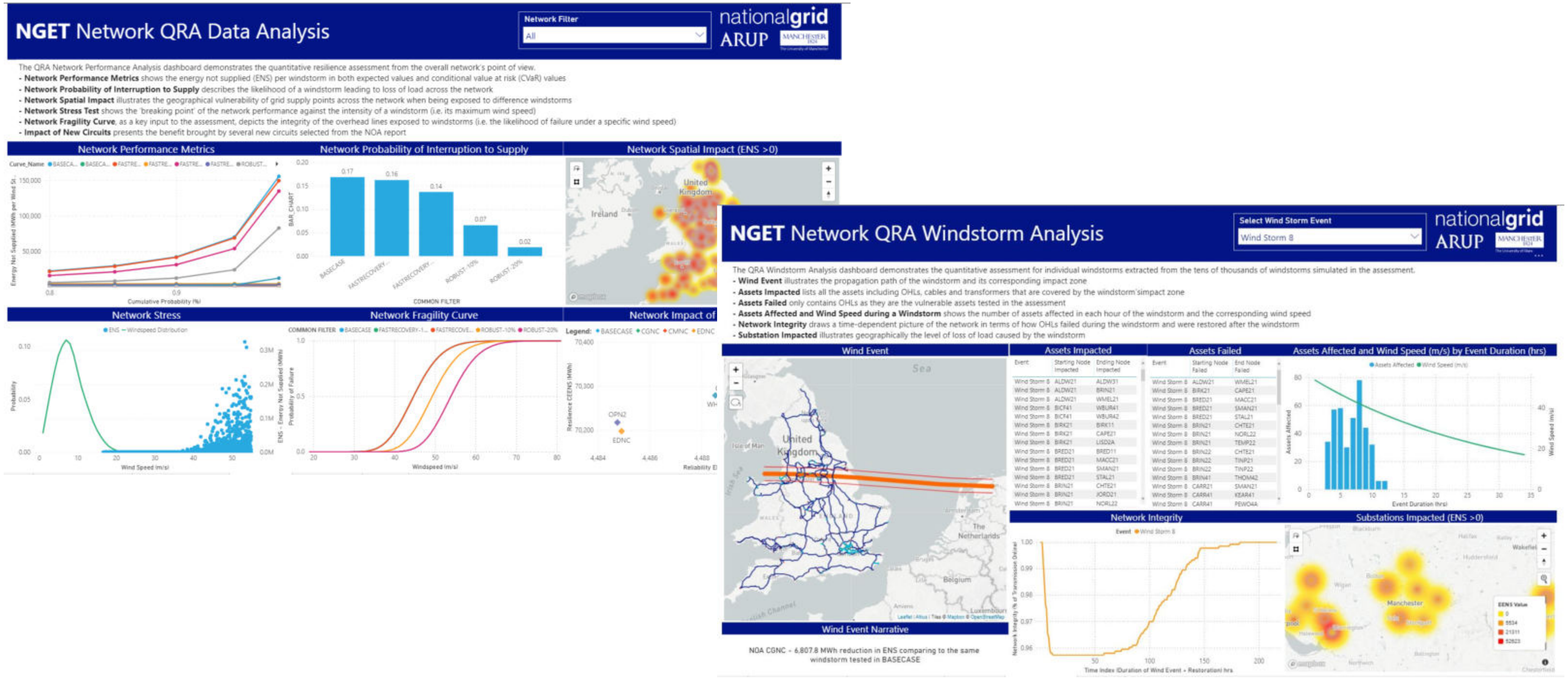
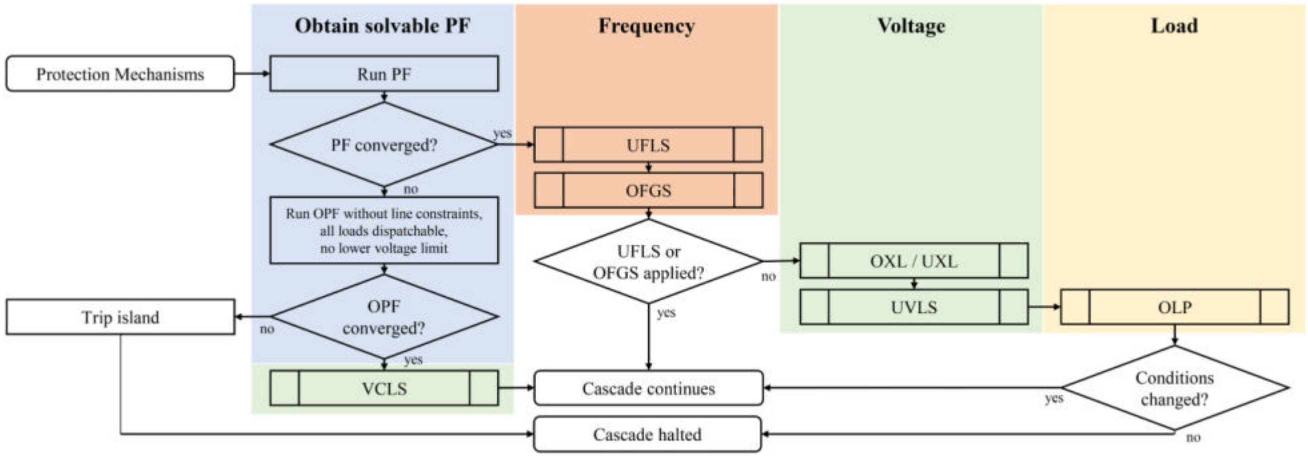
User Web-Interface



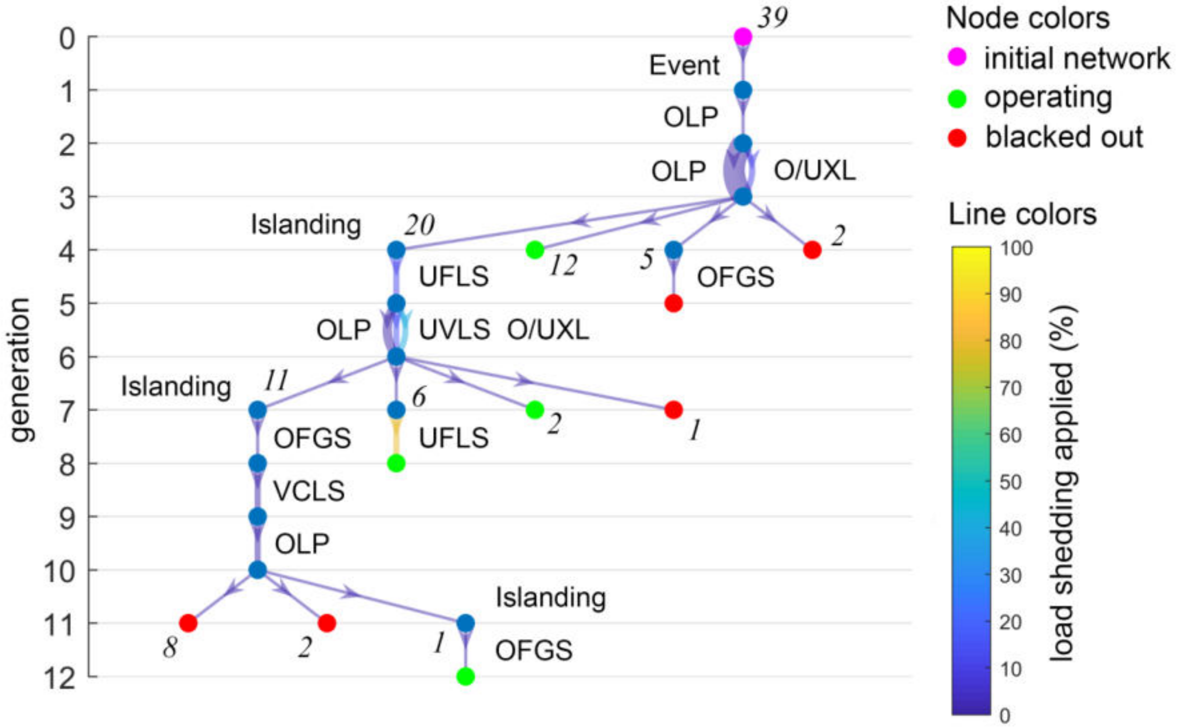
For Demonstration Only

AC Cascading Modelling for Resilience Applications

Modelling of Protection Mechanisms



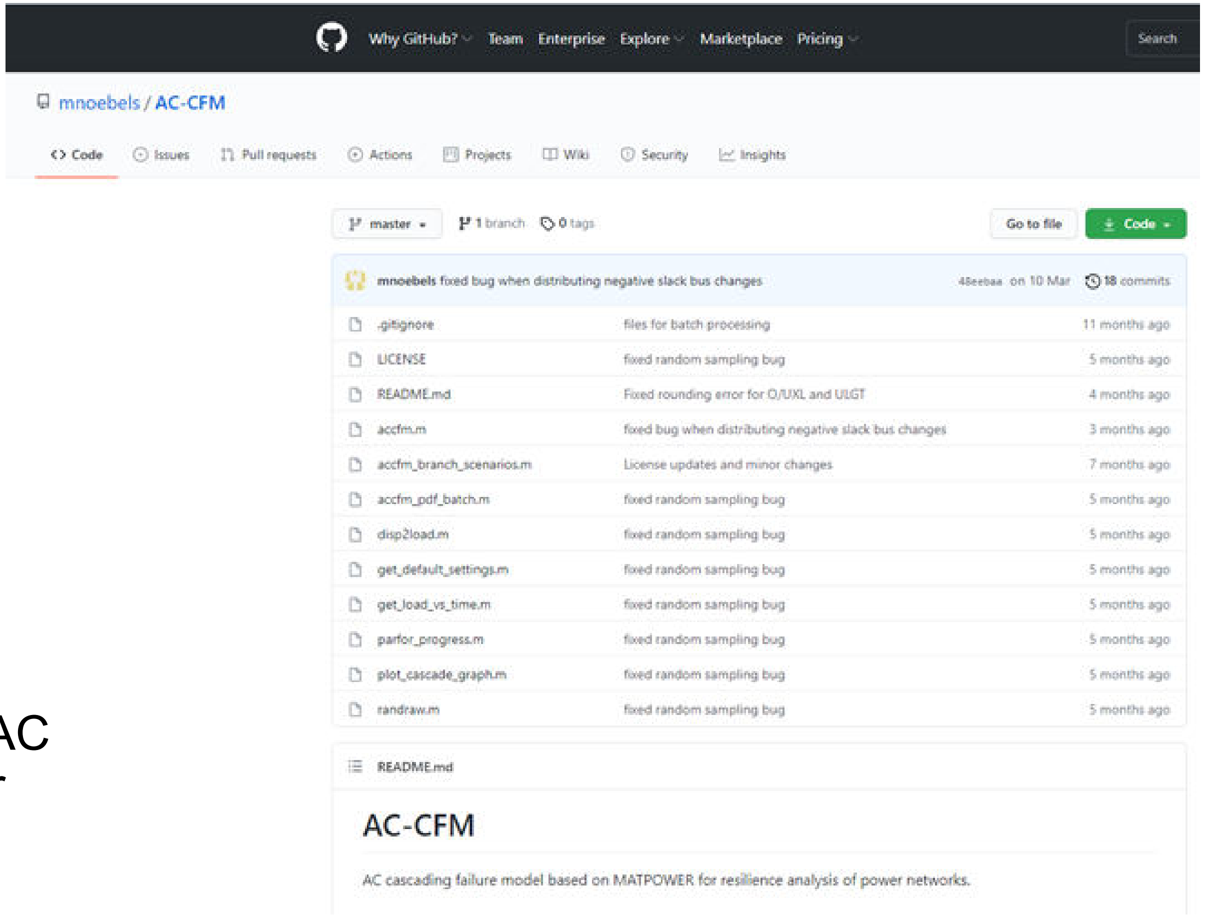
Cascading Propagation



M. Noebels, R. Preece, M. Panteli, "AC Cascading Failure Model for Resilience Analysis in Power Networks", IEEE Systems Journal (2020)

Code available via Github:
https://github.com/mnoebels/AC-CFM

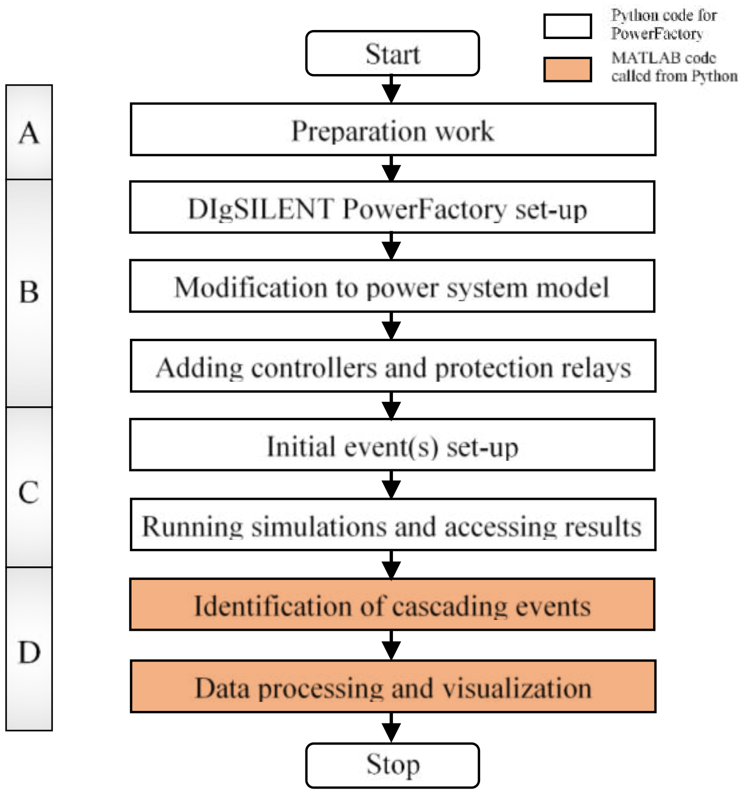
- Full, documented source code
- Getting started
- Installation prerequisites
- Usage example
- Troubleshooting



Further reading: M. Noebels, R. Preece and M. Panteli, "AC Cascading Failure Model for Resilience Analysis in Power Networks," in IEEE Systems Journal (open access)

https://ieeexplore.ieee.org/document/9282067

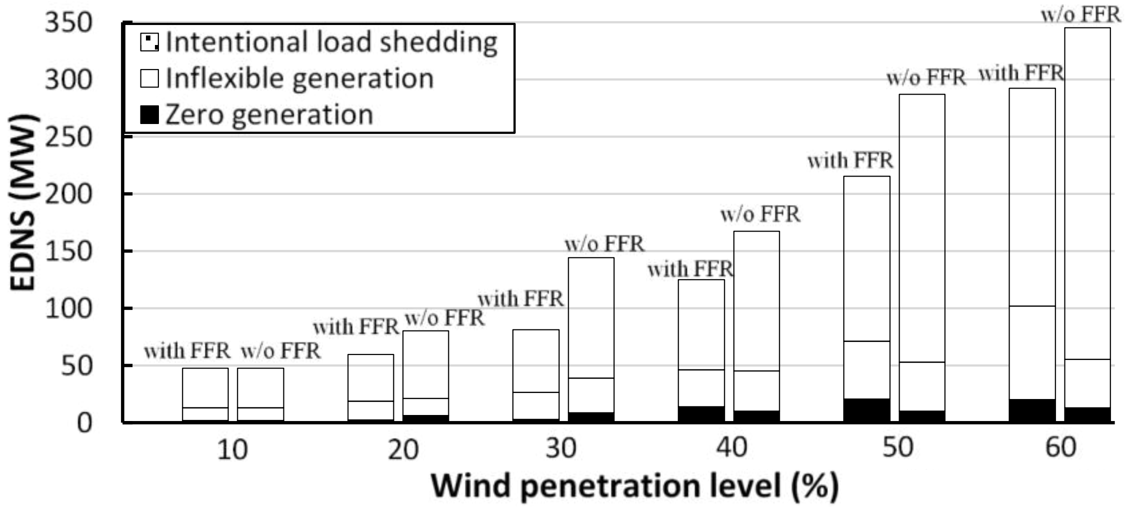
Dynamic Cascading Failure Simulator for Renewable-Rich Systems



https://github.com/YitianDai/Dynamic-cascading-failure-simulator

Application on (synthetic) Texas Power System

RES Penetration level (%)		10	20	30	40	50	60
Inertia level (GVA·s)		17.01	16.33	14.38	13.57	12.88	9.05
COI frequency nadir without FFR (p.u.)		0.991	0.987	0.985	0.981	0.977	0.976
Required BESS capacity (MW)	Near RES	0	12	36	60	132	192
	Near demand	0	12	30	66	132	186



Code available via Github:

https://github.com/YitianDai/Dynamic-cascading-failure-simulator

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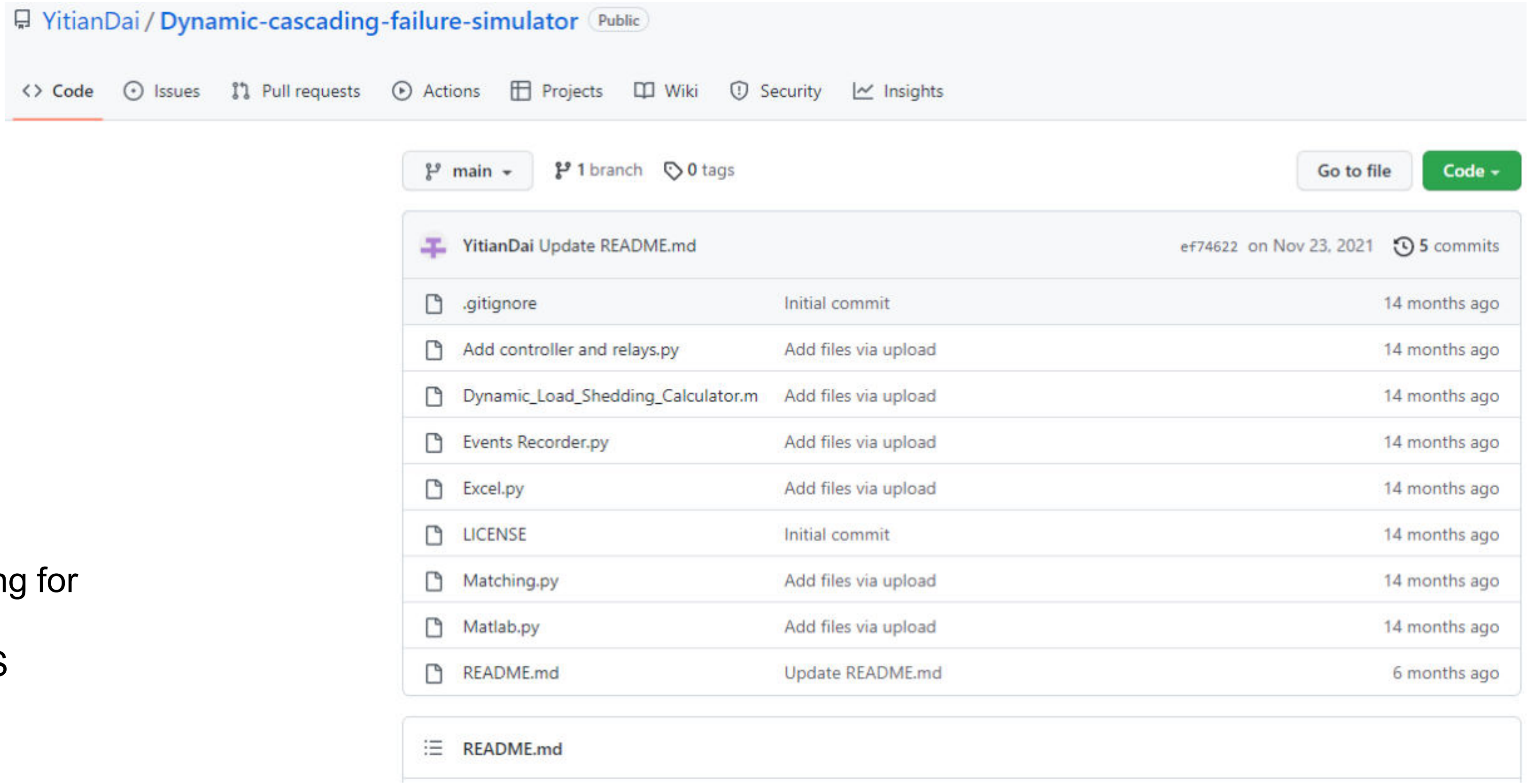
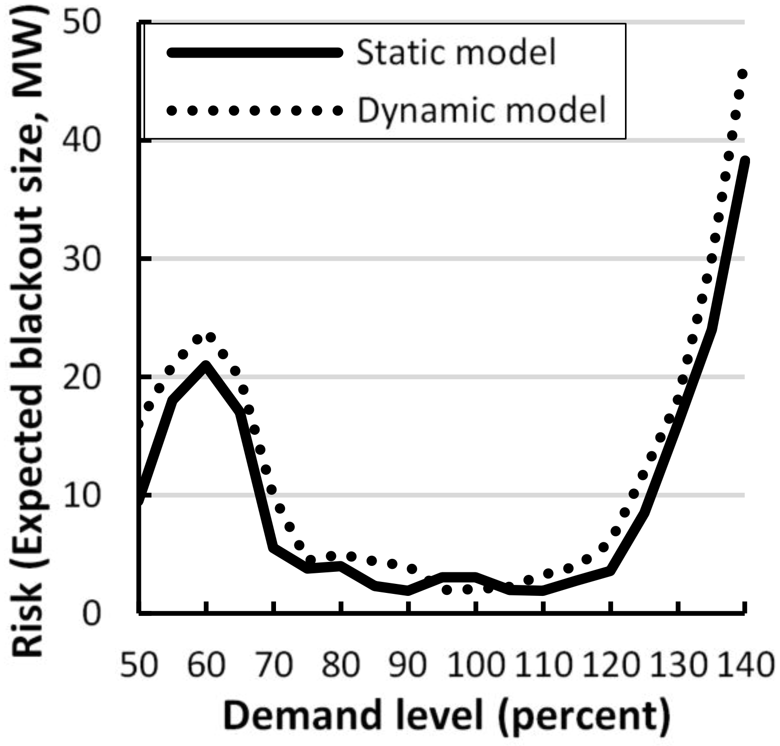
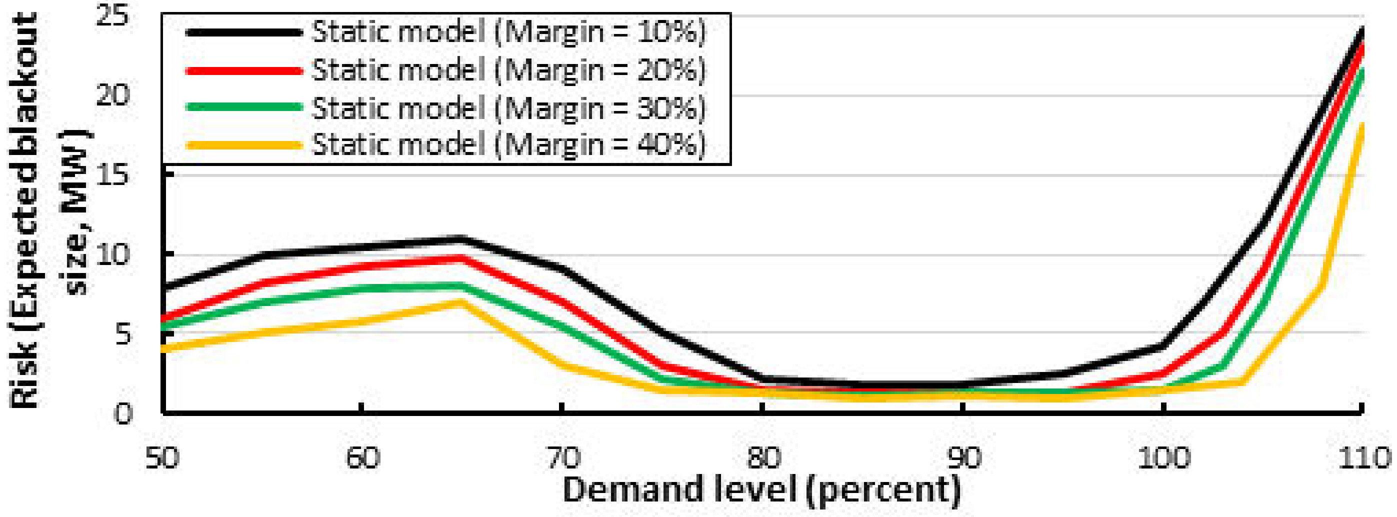


Y. Dai, M. Panteli, and R. Preece, "Python Scripting for DIgSILENT PowerFactory: Enhancing Dynamic Modelling of Cascading Failures", 2021 IEEE PES PowerTech Conference, June 2021

Blackout Risk in Lower Demand Levels?





Yitian Dai, Matthias Noebels, Robin Preece, Mathaios Panteli, and Ian Dobson, "Risk Assessment and Mitigation of Cascading Failures Considering Security-Constrained Generation Dispatch", Under Review, IEEE Transactions on Power Systems

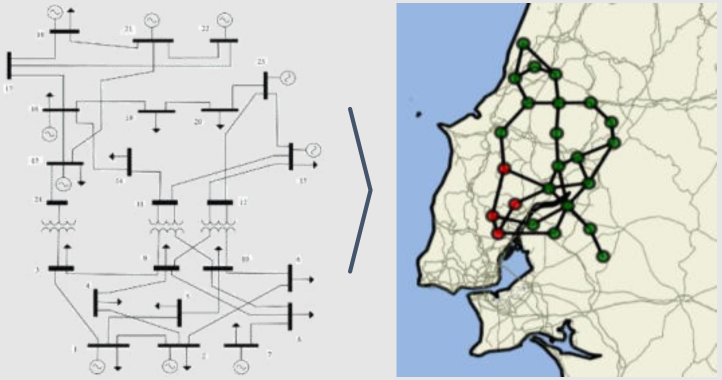
CIPROS: Capital Investment Planning for Resilience Optimization of Smart Grids

INNOVATION RADAR PRIZE

Advanced weather event simulator and situational awareness	Geospatial and temporal modelling of historical and random extreme weather events
Optimal coordination of low-carbon, flexible mobile energy resources	GIS modelling of energy, transportation and communication systems
Decision-making platform on resilience-driven investment portfolios according to user preferences	Trade-offs between profit maximization and risk mitigation
User-friendliness and ease of deployment	Graphical user interface to enhance usability and minimal technical knowledge prerequisites

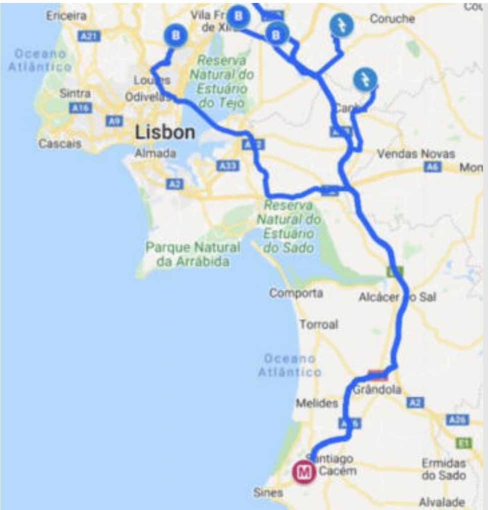
CIPROS: An all-in-one resilience planning software!

Geographic projection and modeling of power grids.

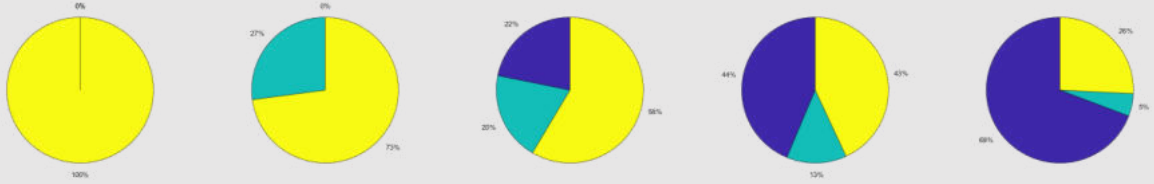


Advanced event simulator and situational awareness.

Optimal dispatch and pre-positioning of mobile energy resources.



Customized optimal investment portfolios.



12.5 MIL | 25 MIL | 50 MIL | 75 MIL | 100 MIL

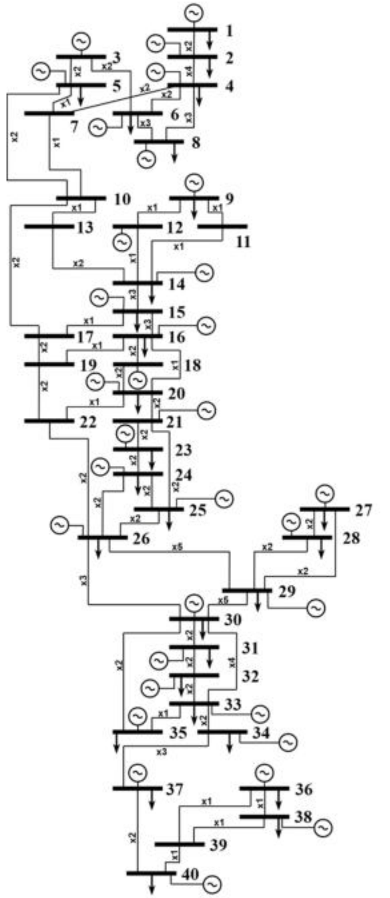
Resilience-Driven Investment Planning and Decision-Making: Application to Chilean Transmission System - Earthquakes

First stage
Propositions of new system enhancement options through optimization of resilience metric

Enhancement option →

← Resilience metric

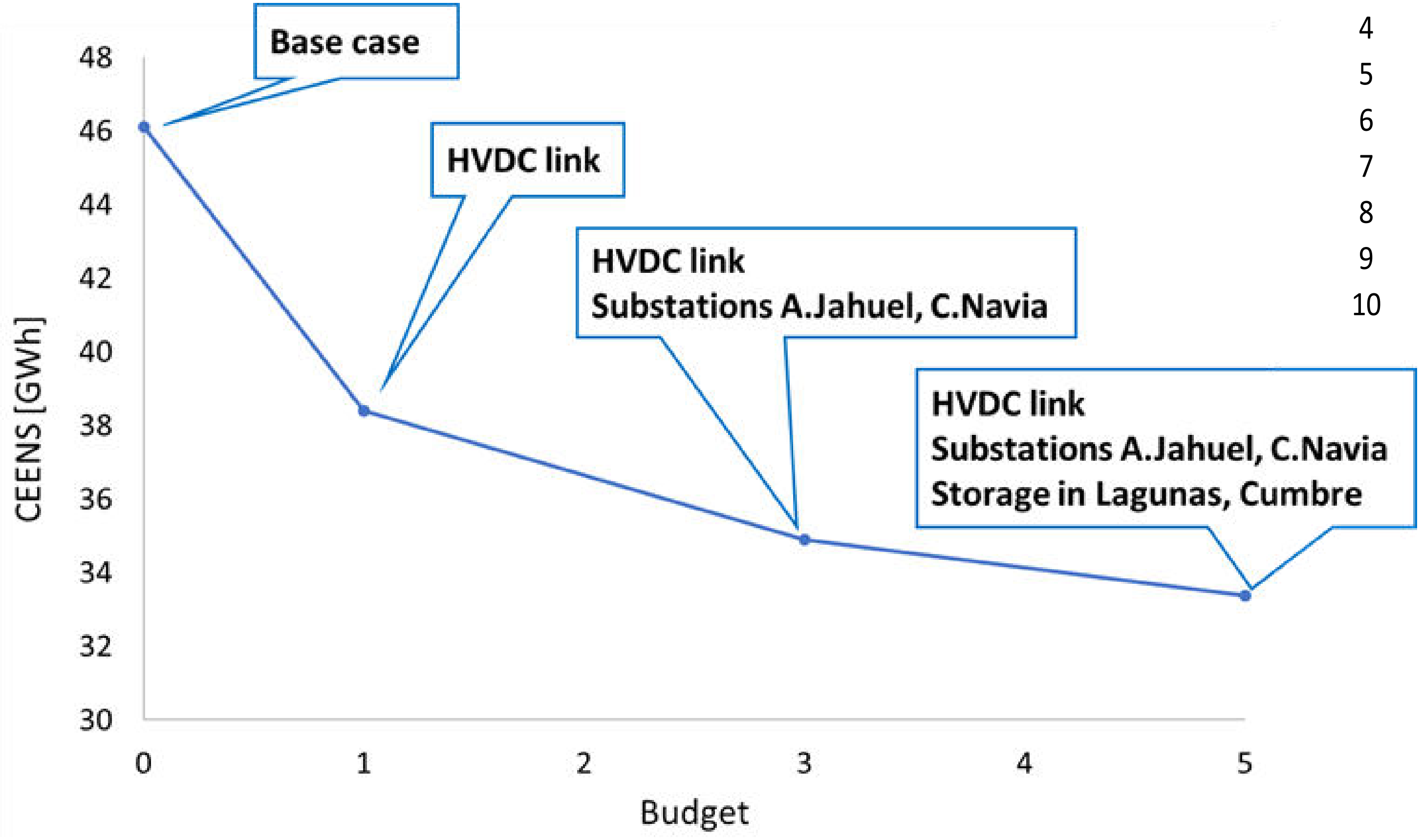
Second stage
Simulations of system impact and response and restoration after random natural hazards occur



1 Tarapaca
2 Lagunas
3 Kapatur
4 Crucero & Encuentro
5 Los Changos 220
6 Laberinto & Domeyko
7 Los Changos 500
8 Atacama & Mejillones
9 Paposo
10 Cumbre 500
11 Lalackama
12 Etaltal
13 Cumbre 220
14 Diego de Almagro
15 Cardones 220
16 Maitencillo 220
17 Cardones 500
18 Punta Colorada
19 Maitencillo 500
20 Pan de Azucar 220
21 Las Palmas
22 Pan de Azucar 500
23 Los Vilos
24 Nogales
25 Quillota
26 Polpaico
27 Rapel
28 Melipilla
29 Cerro Navia & Lo Aguirre
30 Alto Jahuel
31 Tinguiririca
32 Itahue
33 Ancoa
34 Charrua
35 Colbun
36 Puerto Montt
37 Cautin & Temuco
38 Rahue
39 Pichirropulli
40 Ciruelos & Valdivia

R. Moreno et al., "From Reliability to Resilience: Planning the Grid Against the Extremes," IEEE Power and Energy Magazine, vol. 18, no. 4, pp. 41-53, July-Aug. 2020

Optimal resilience portfolio solutions for resilience enhancement for different budgets



Reliability			Resilience		
Rank	Enhancement	EENS [MWh]	Rank	Enhancement	CEENS [GWh]
1	L: HVDC link	348	1	L: HVDC link	38
2	L: Laberinto - Cumbre	392	2	Ss: C. Navia	43
3	L: Ciruelos - Pichirropulli	523	3	Ss: A. Jahuel	43
4	L: Cautin - Charrua	580	4	Ss: Charrua	44
5	L: Ciruelos - Cautin	617	5	Ss: Crucero	45
6	Ss: Crucero	696	6	L: Laberinto - Cumbre	46
7	Ss: C. Navia	696	7	L: Ciruelos - Cautin	46
8	Ss: A. Jahuel	696	8	L: Cautin - Charrua	46
9	Ss: Charrua	696	9	L: Ciruelos - Pichirropulli	46
10	Base case	696	10	Base case	46

2018 Newton Prize!

Example on wildfire in Chile

figure 7. A representation of wildfires in Chile on 26 January 2017.

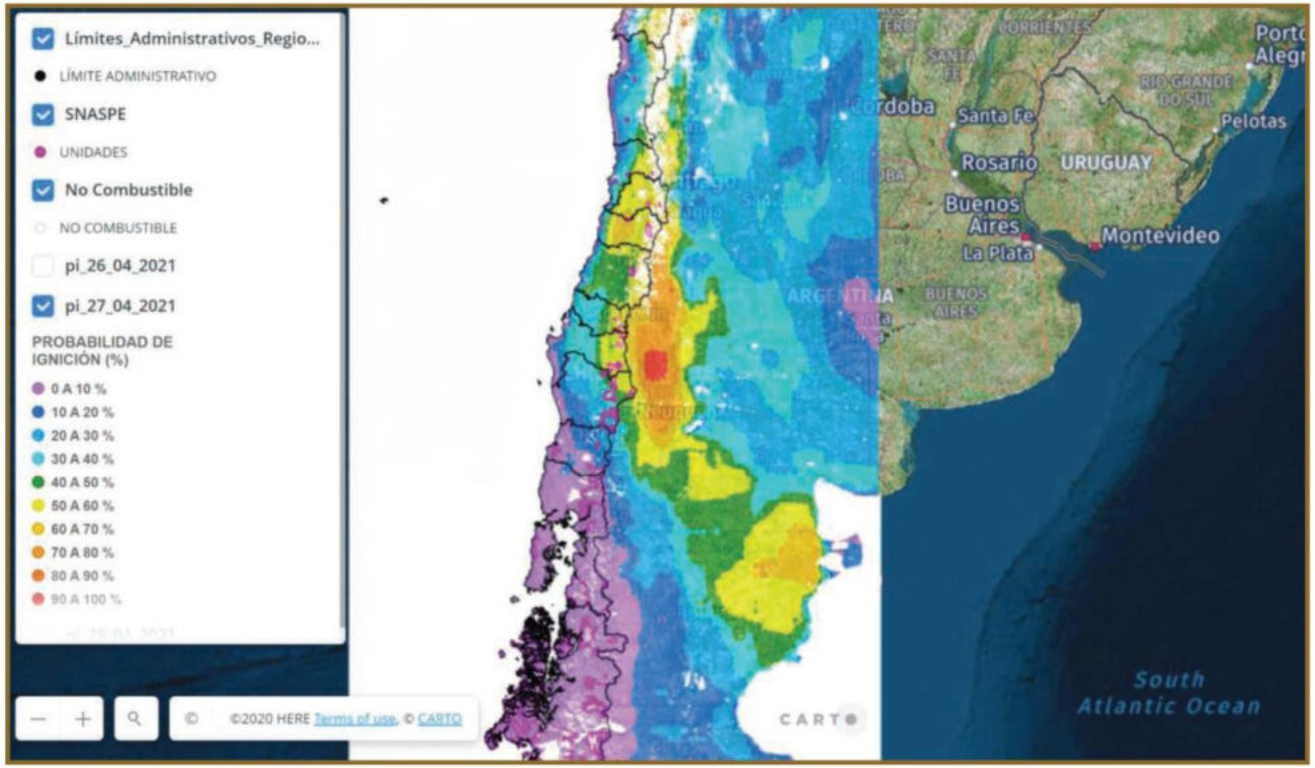
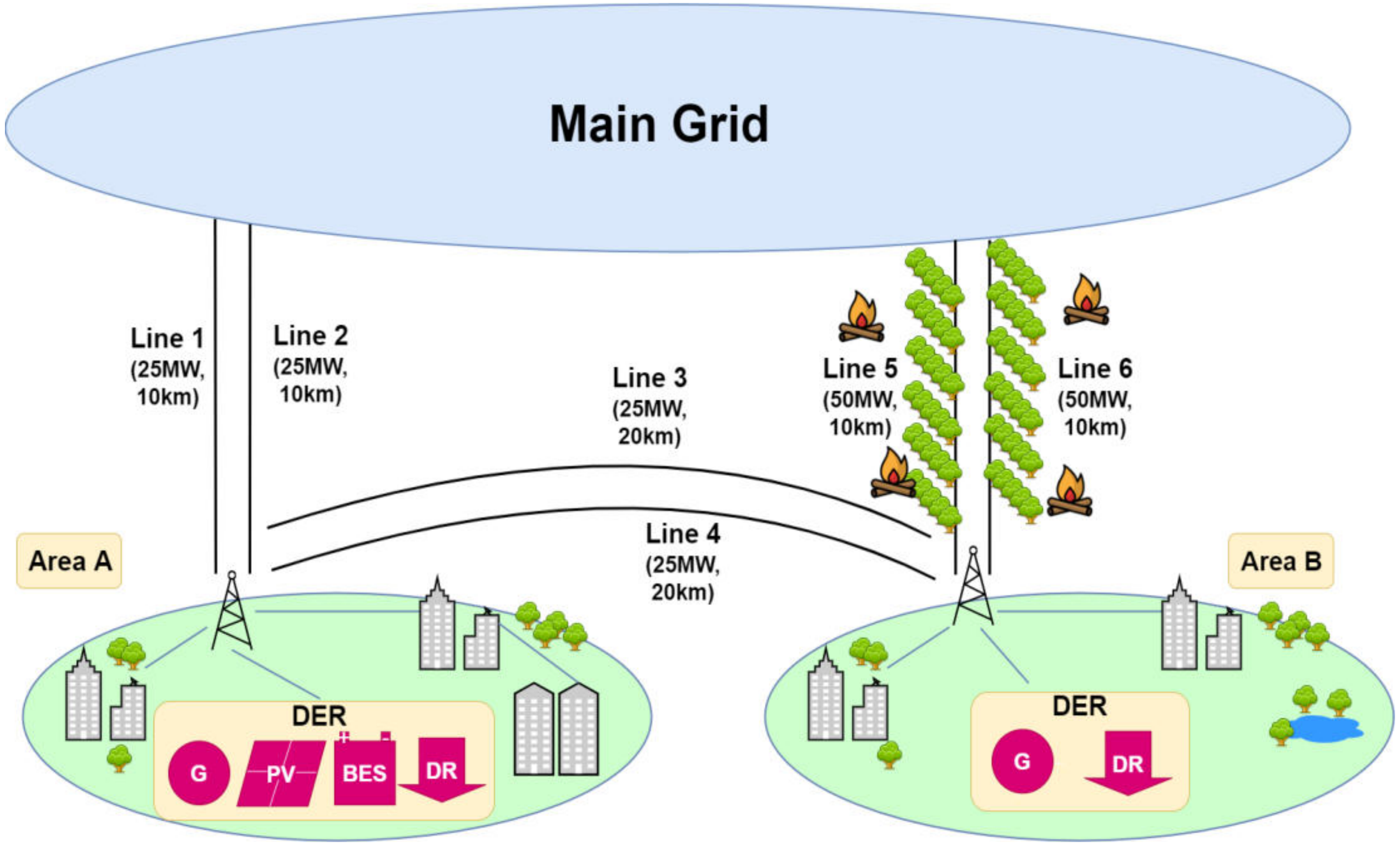


figure 6. The Forest Fire Ignition Probability Map, 27 April 2021. (Source: https://geprif.carto.com/.)

Moreno, R., Trakas, D. N., Jamieson, M., Panteli, M., Mancarella, P., Strbac, G., ... & Hatziargyriou, N. (2022). Microgrids Against Wildfires: Distributed Energy Resources Enhance System Resilience. IEEE Power and Energy Magazine, 20(1), 78-89.

Resilience from Distributed Generation: Case of Wildfires



R. Moreno, D. N. Trakas, M. Jamieson, M. Panteli, P. Mancarella, G. Strbac, C. Marnay, and N. Hatziargyriou, “Microgrids against Wildfires: Distributed Energy Resources Enhancing System Resilience”, IEEE Power and Energy Magazine, 2022 January/February issue

Illustrative example – Results

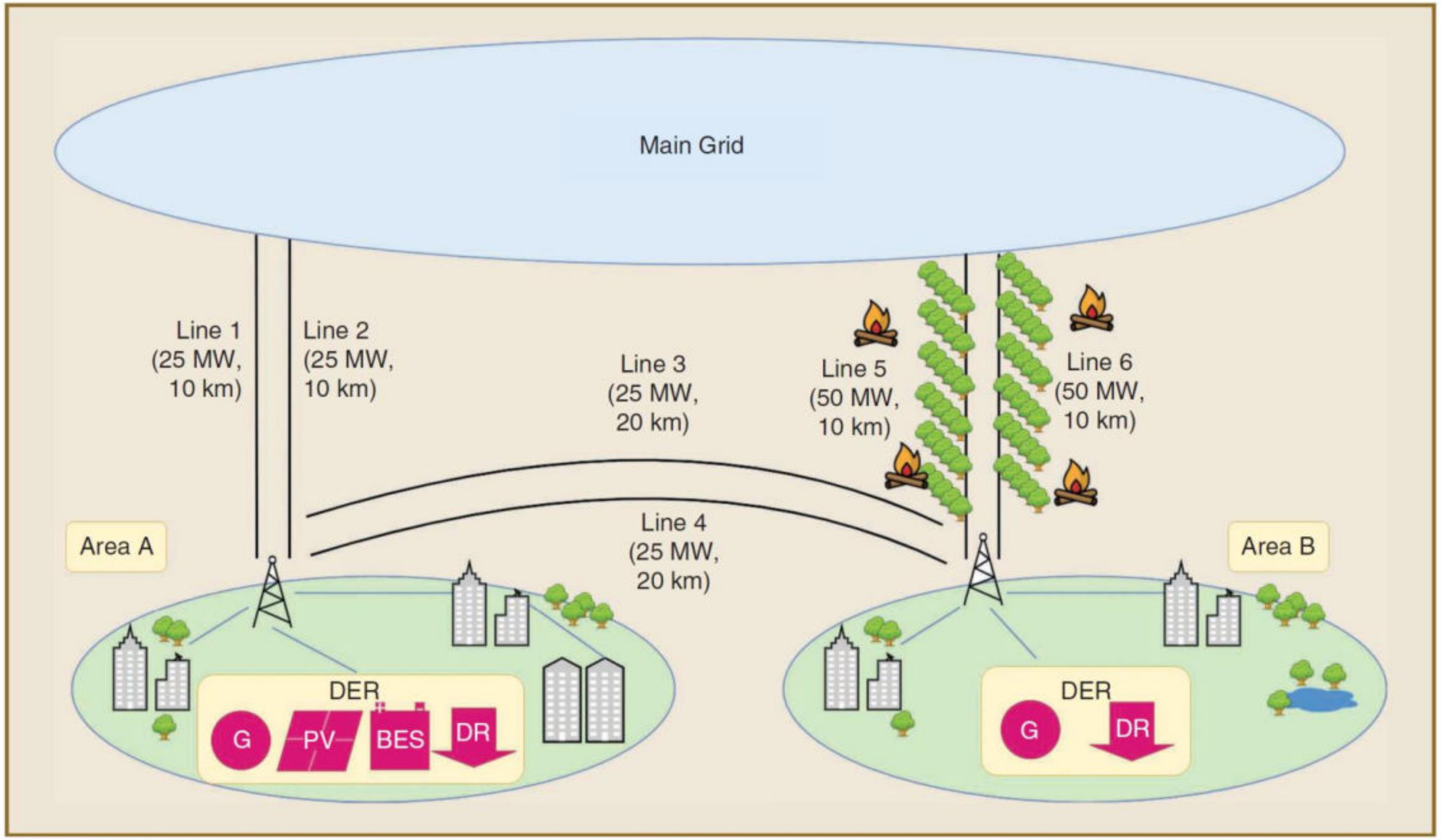


figure 8. The electricity network and DER candidates along with areas exposed to wildfires. BES: battery energy storage.

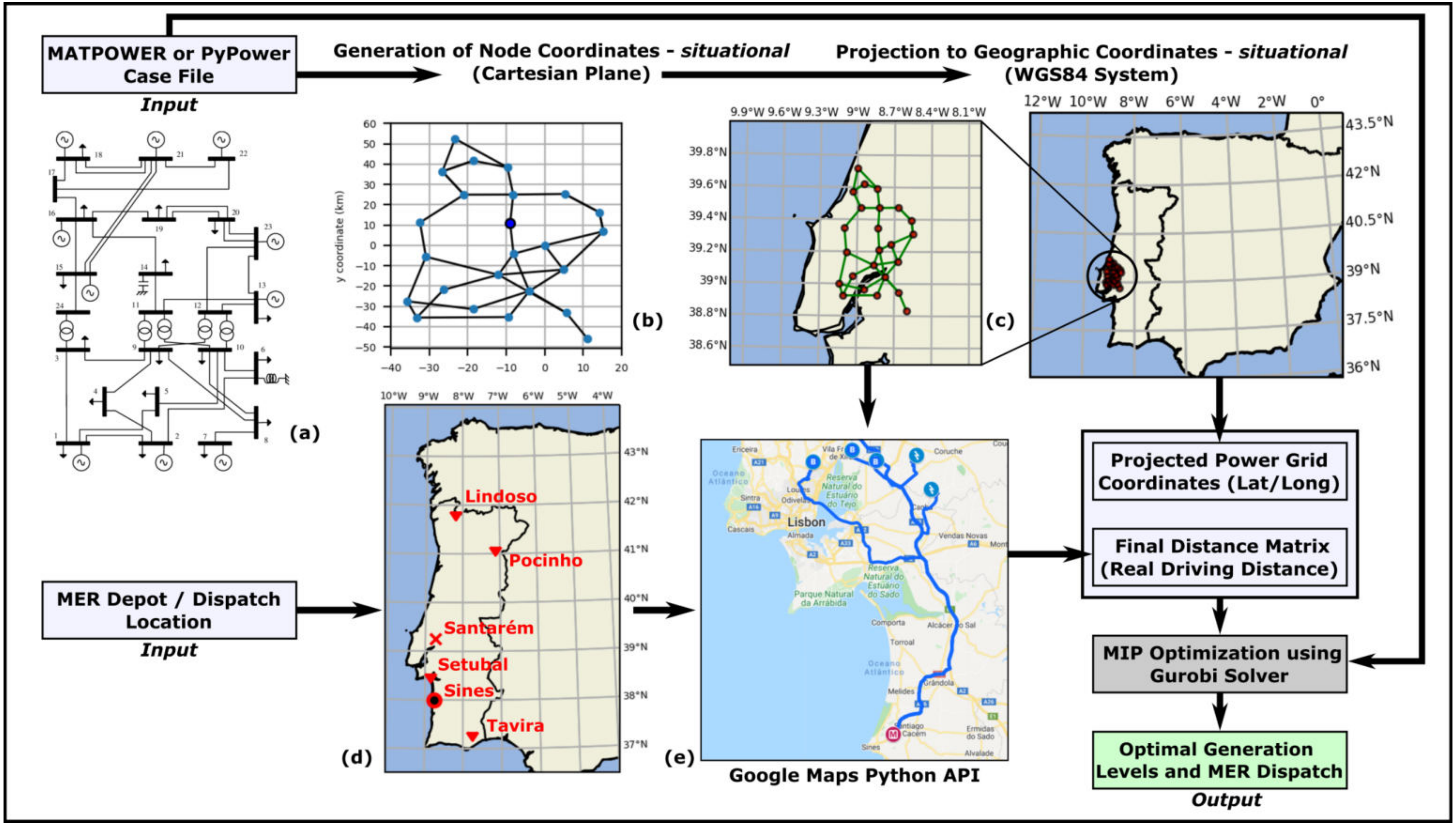
table 2. Results with costs in thousand U.S. dollars (kUS$) per year.

	N-1 Case A	Case A (Reevaluated)	Case B
Assets and measures	L1, L2, L5, L6, MG, DR	L1, L2, L5, L6, MG, DR	L1, L2, L3, L4, L5, PV, BES, MG, DR
PV + BES investment cost	—	—	11,500
Line investment cost	113	113	150
Operational cost	32,850	33,115	21,901
Lost-load cost	27	19,665	6
Total cost	32,990	52,893	33,558

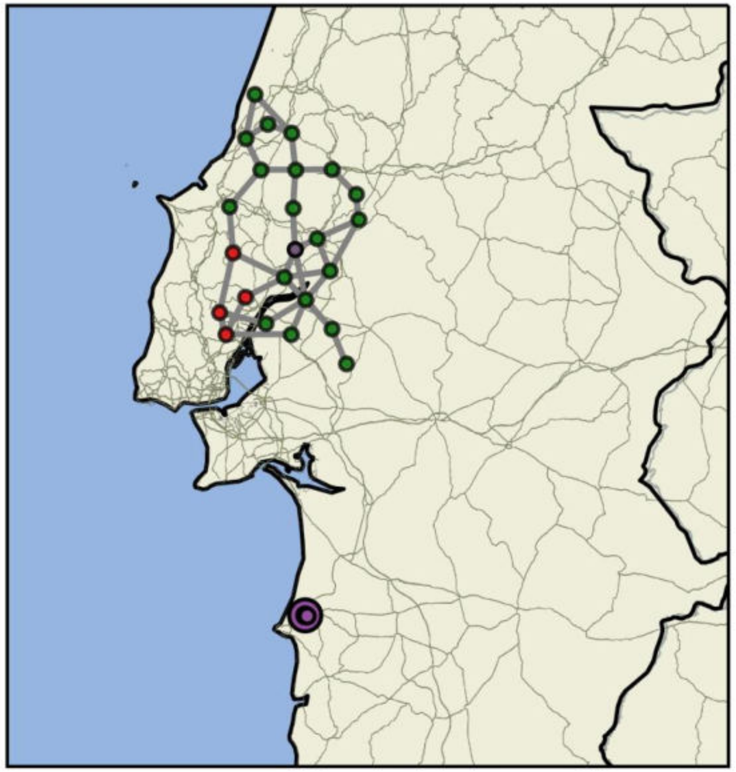
L: line; MG: mobile generator.

Moreno, R., Trakas, D. N., Jamieson, M., Panteli, M., Mancarella, P., Strbac, G., … & Hatziargyriou, N. (2022). Microgrids Against Wildfires: Distributed Energy Resources Enhance System Resilience. IEEE Power and Energy Magazine, 20(1), 78-89.

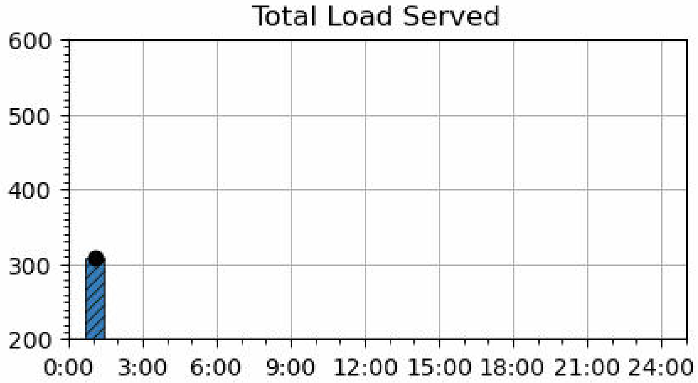
MERS-DIP: Mobile Energy Resource Scheduling and Dispatch Incorporated in Optimal Power Flow

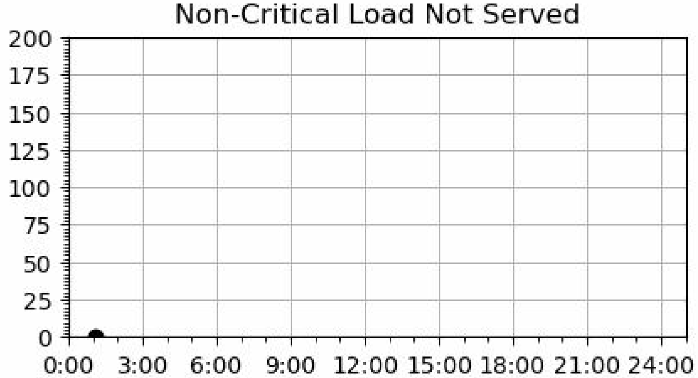


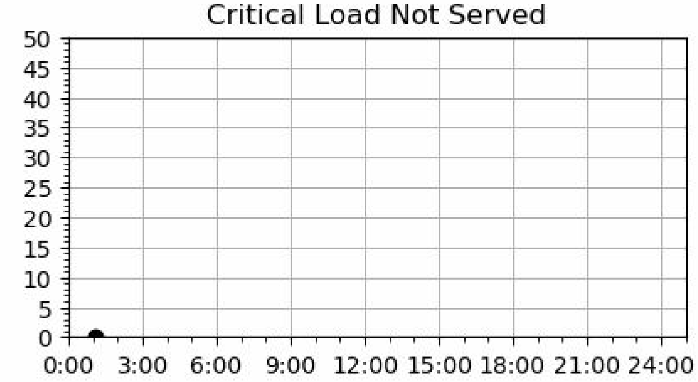
TIME:
00:00
MER LOCATION:
-8.759, 38.002



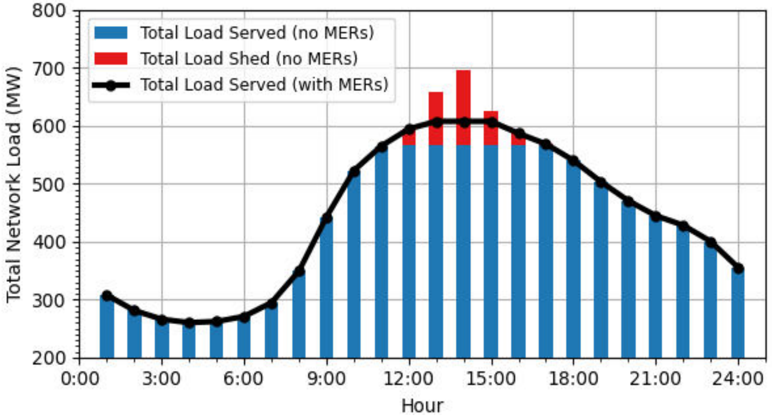
Load Shed with MERs





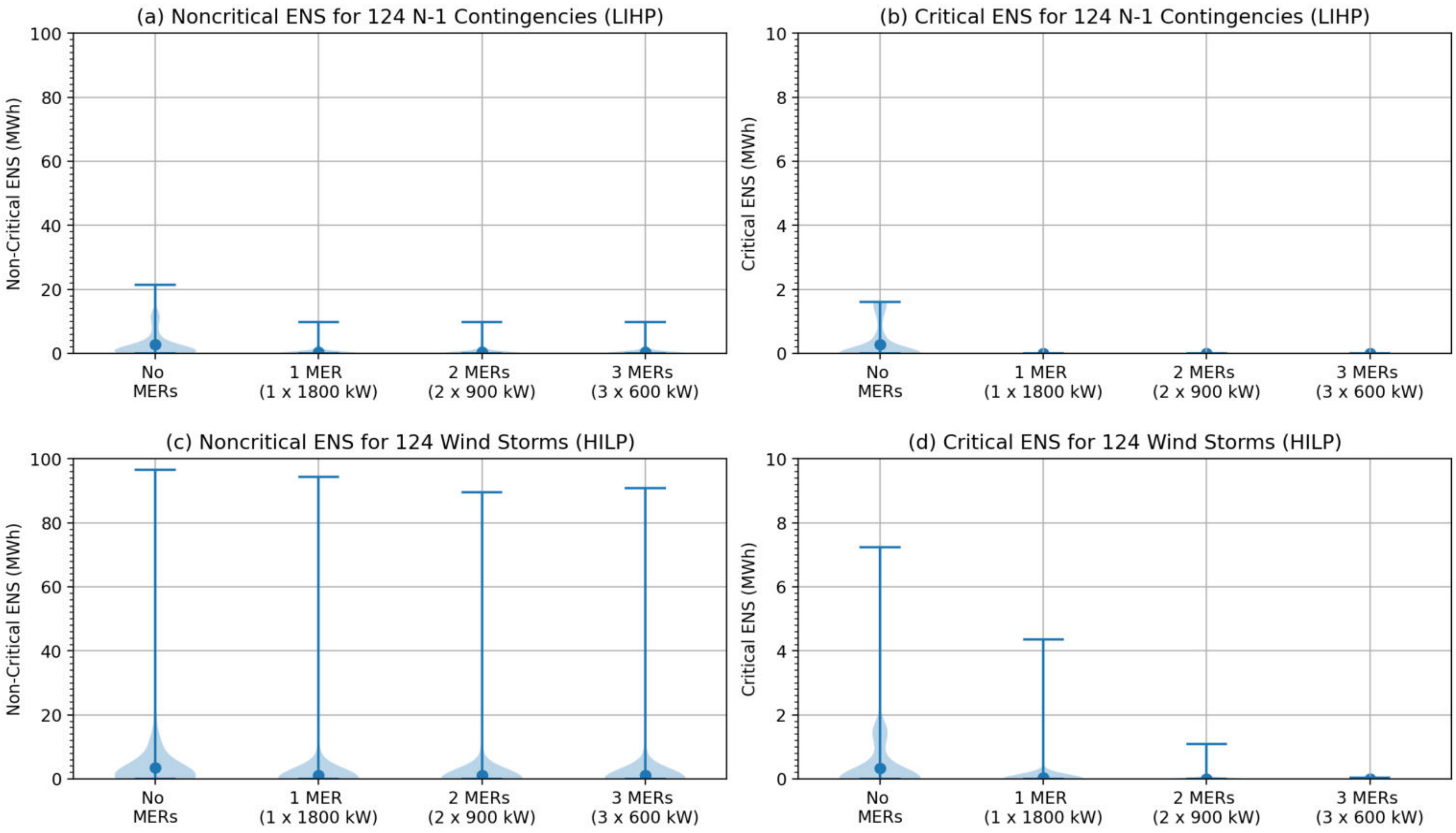


Load Shed without MERs

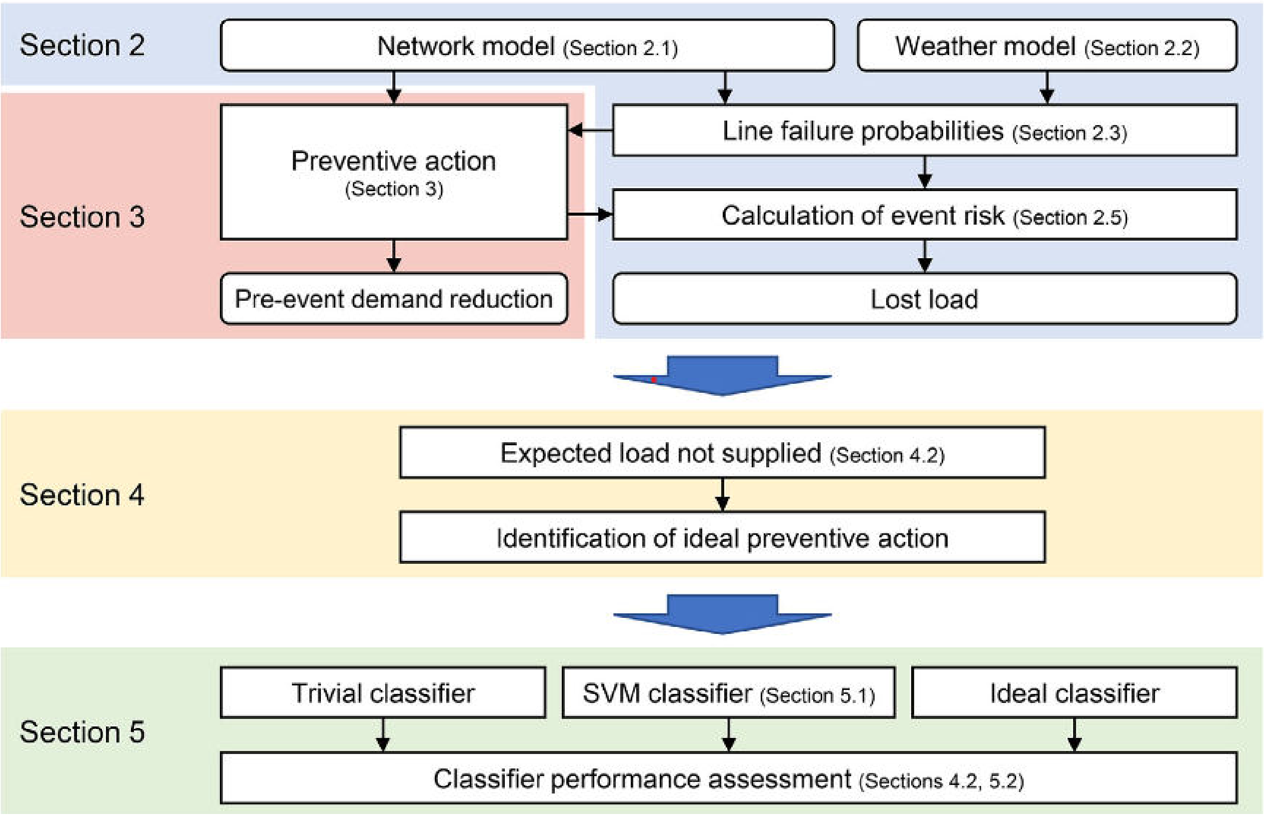


Reliability-Centric Analysis: An N-1 contingency study for LIHP was performed

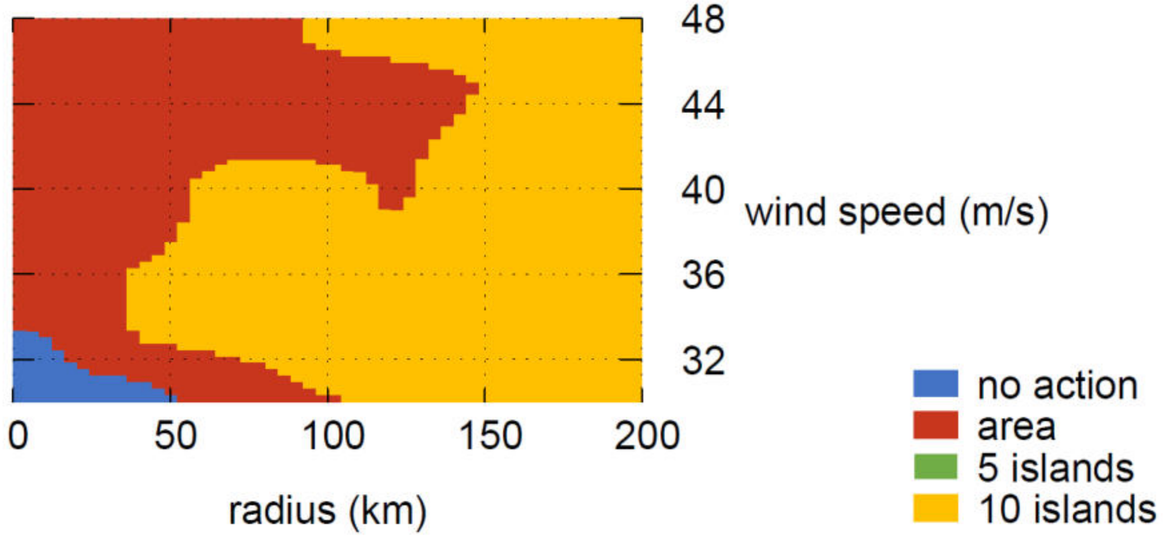
Resilience-Centric Analysis: A study of HILP events was performed by simulating 124 random wind storms

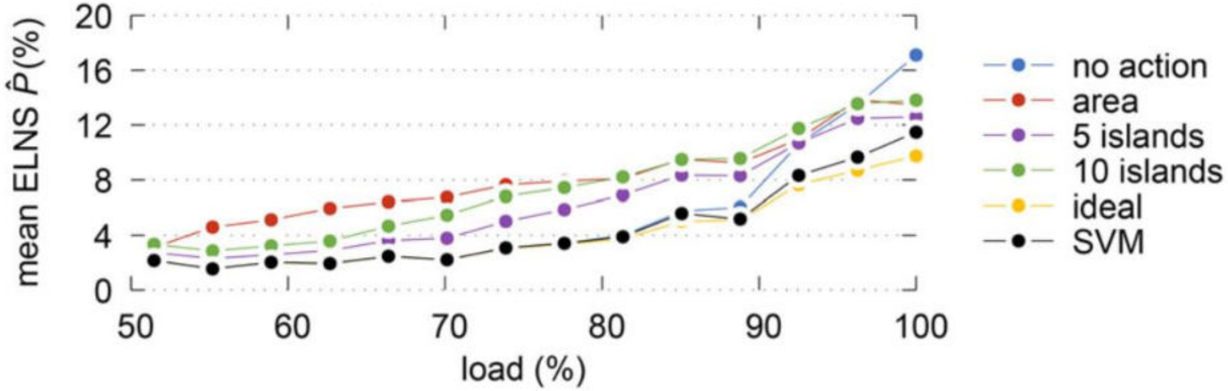


Machine-Learning Driven Operational Decision-Making Under Uncertainty

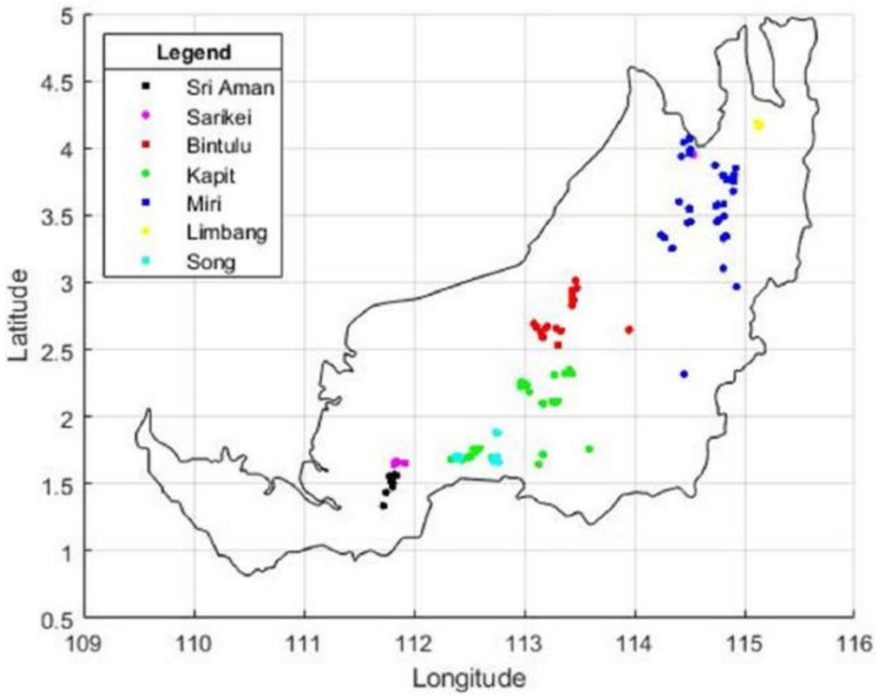


M. Noebels, R. Preece, and M. Panteli, "A Machine Learning Approach for Real-time Selection of Preventive Actions Improving Power Network Resilience", Early Access, IET Generation, Transmission and Distribution, October 2021



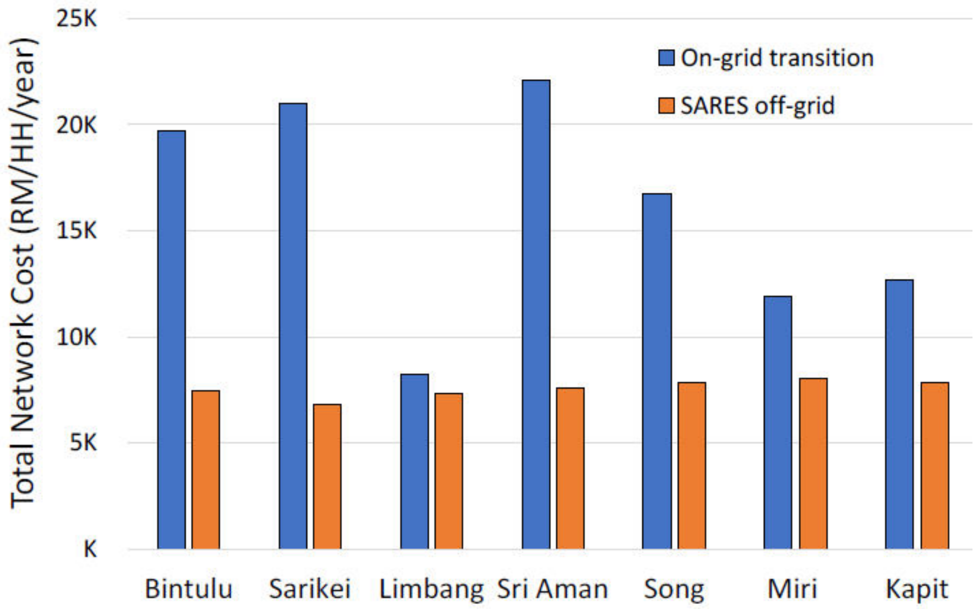


Resilient Rural Electrification: Case Study of Borneo Island, Malaysia



Location of SARES villages

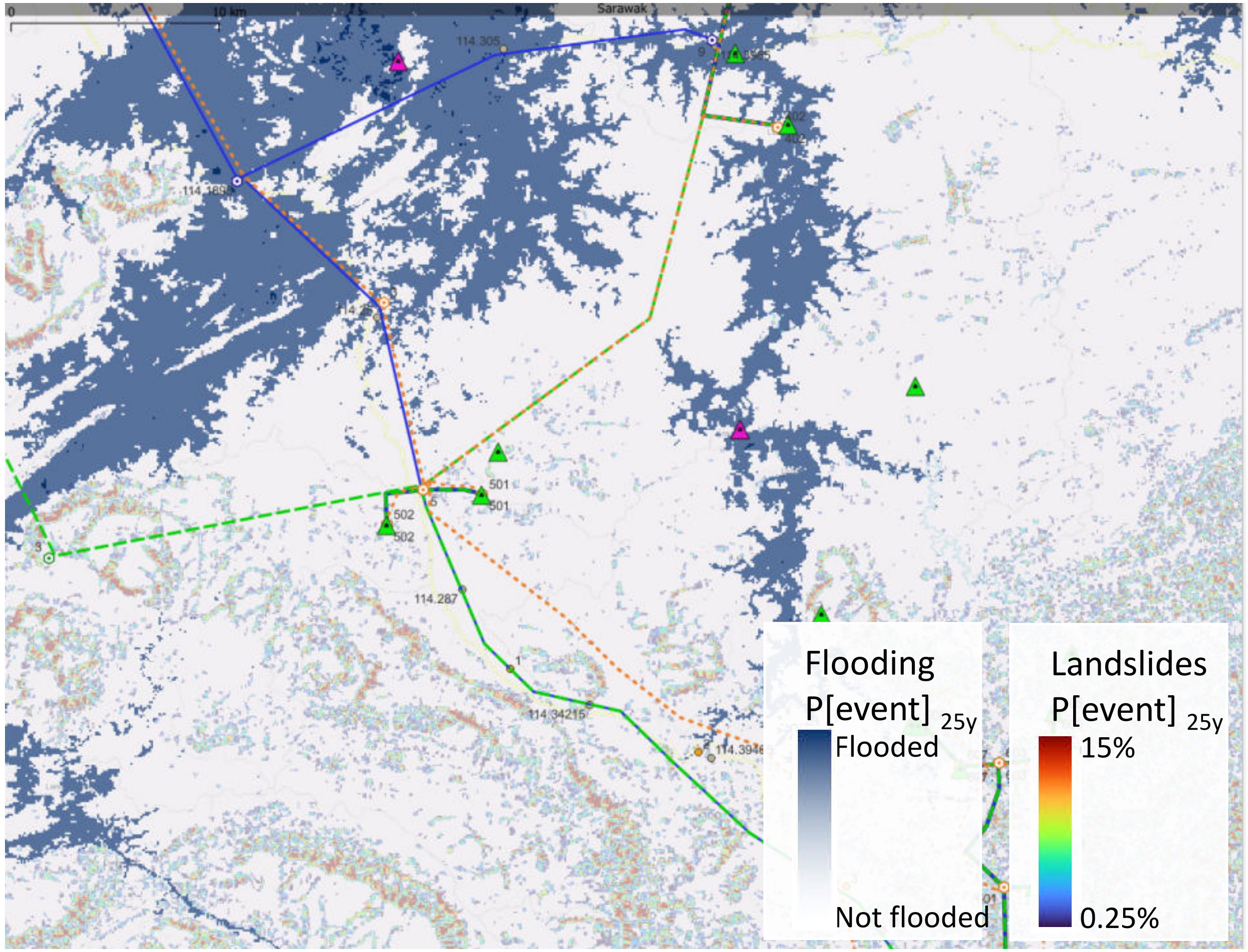
Sarawak Alternative Rural Electrification Scheme (SARES)



Total costs comparison between on-grid electrification and SARES

C. K. Gan, S. E. Chong, M. Panteli, and P. Mancarella, “Techno-Economic Analysis of On-Grid Transition: A Case Study of Remote Villages in Sarawak”, 2021 IEEE PES ISGT Conference, December 2021

Resilient Rural Electrification: Case Study of Borneo Island, Malaysia



Scenarios:

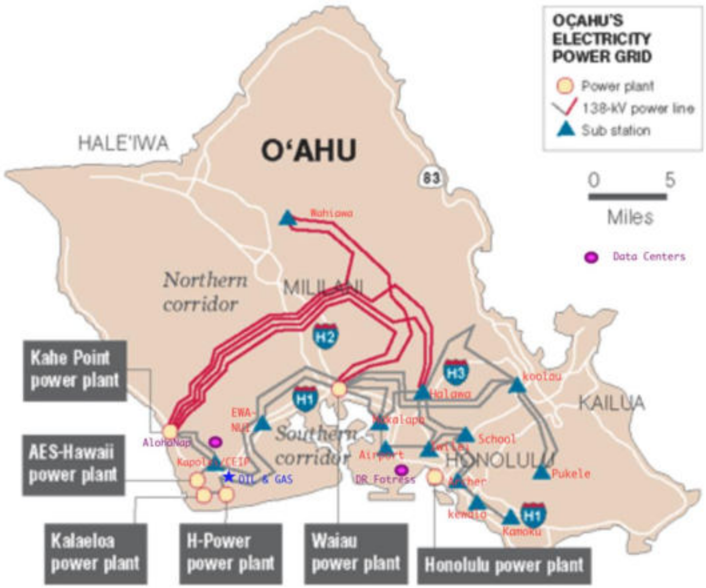
1. Access – following existing roads
2. Avoiding areas with moderate/high risk of landslides
3. Avoiding areas with moderate/high risk of flooding

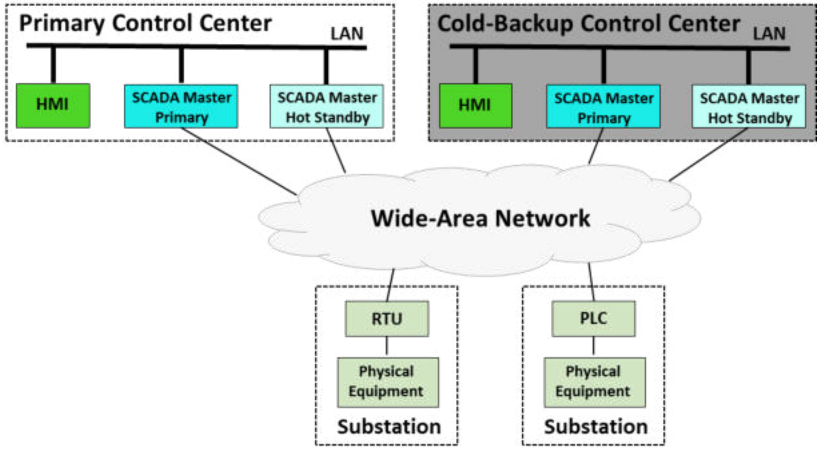
$$Risk = P[event] \cdot Consequence$$

Consequence → Likelihood ↓	Extremely high	Very high
Probable (>10%)	High	Moderate
Likely (> 1%)	Moderate	Moderate
Unlikely (< 1%)	Low	Low

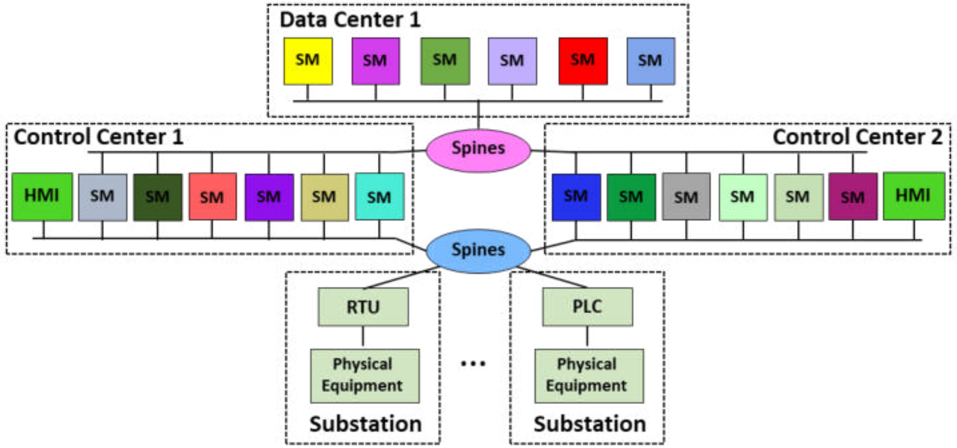
Cyber-Physical Risk Assessment of Power Systems

Case Study: Oahu, Hawaii





Modern primary backup architecture

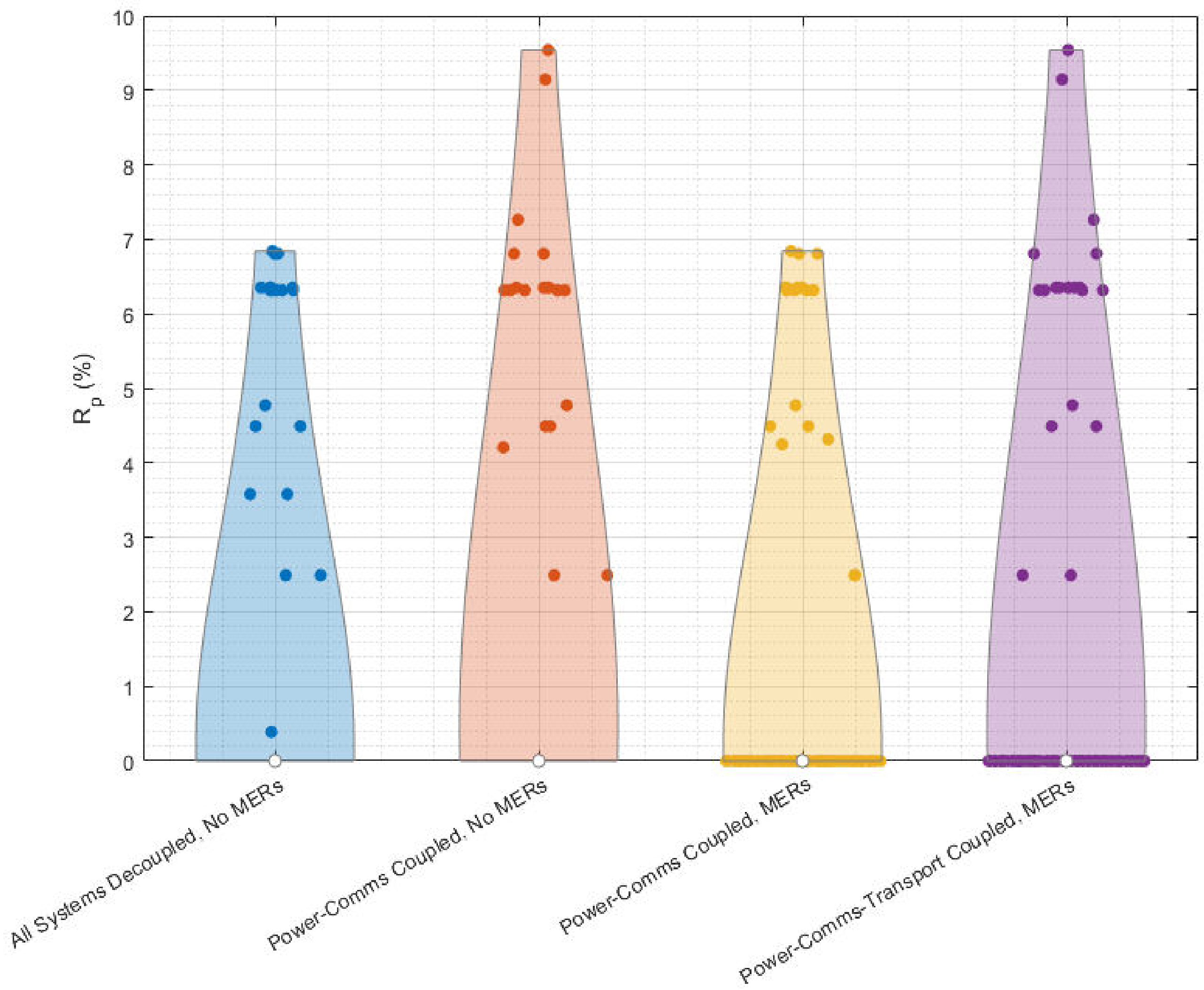


Intrusion-tolerant architecture [BTAPA18]

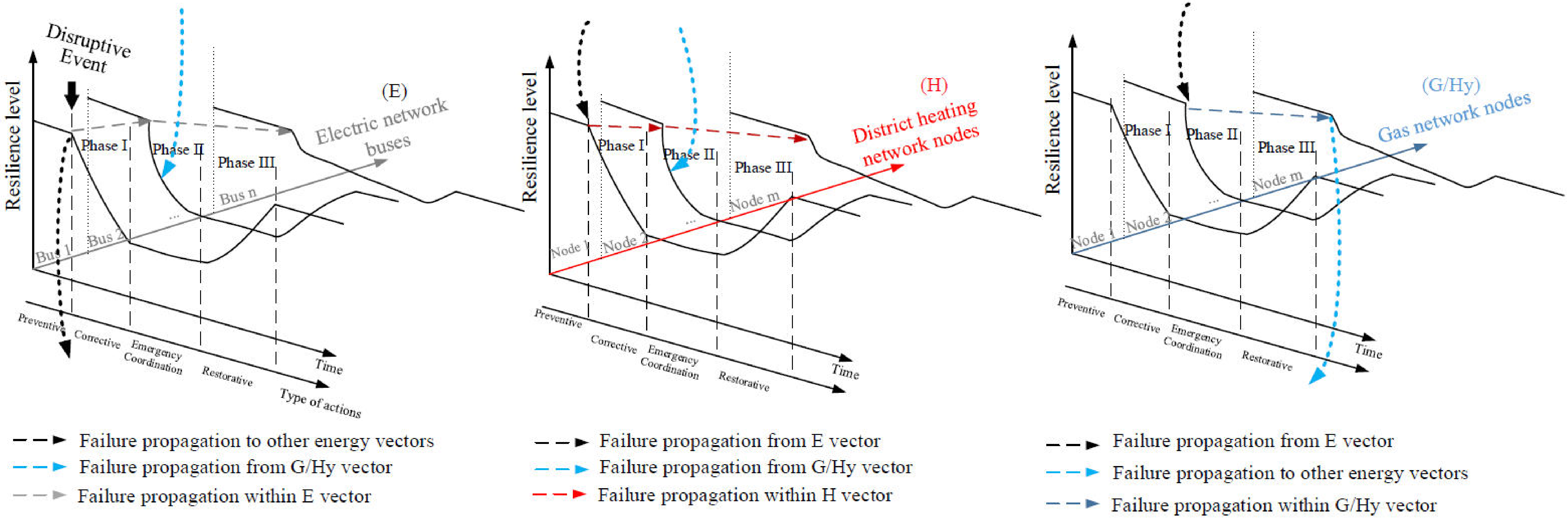
Cyber-Physical Risk Assessment of Power Systems

Scenarios:
- All systems decoupled, no mobile energy resources (MERs)
- Power-comms coupled, no MERs
- Power-Comms coupled, with MERs
- Power-Comms-Transport coupled, with MERs

The more interdependencies we consider, the higher the risk of cascading impacts and power disruptions



Multi-Energy Resilience

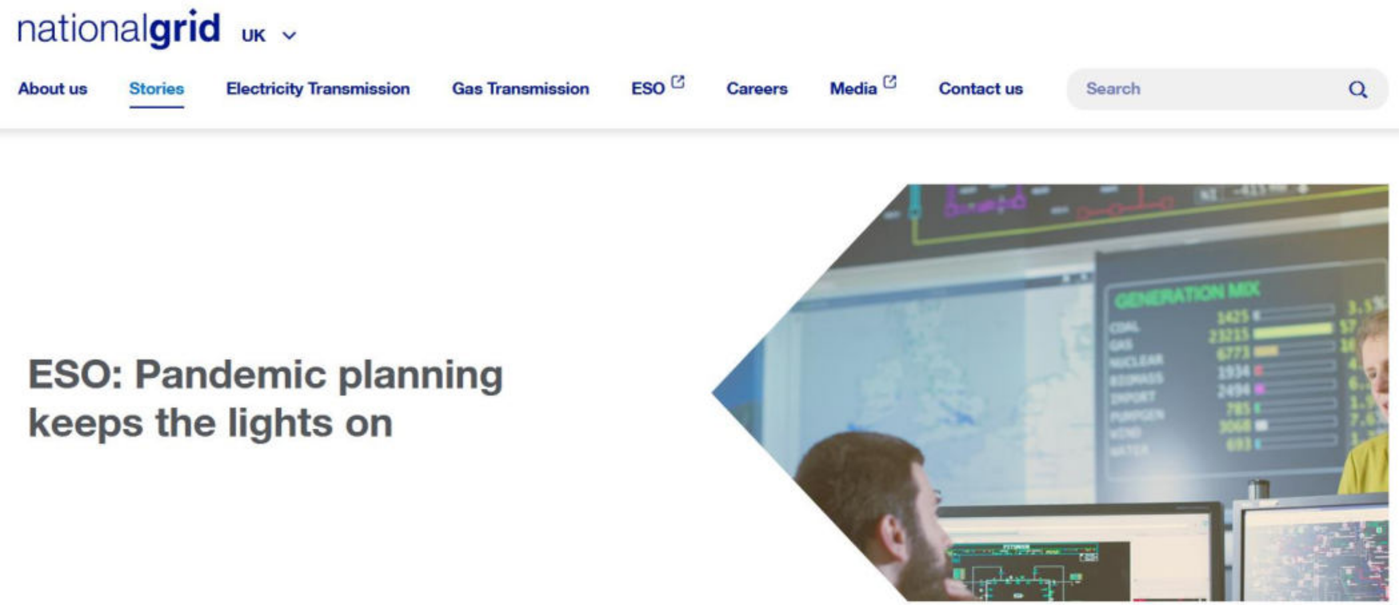


Jiawei Wang, Pierre Pinson, Spyros Chatzivasileiadis, Mathaios Panteli, Goran Strbac, and Vladimir Terzija, “On Machine Learning-Based Techniques for Future Sustainable and Resilient Energy Systems”, IEEE Transactions on Sustainable Energy

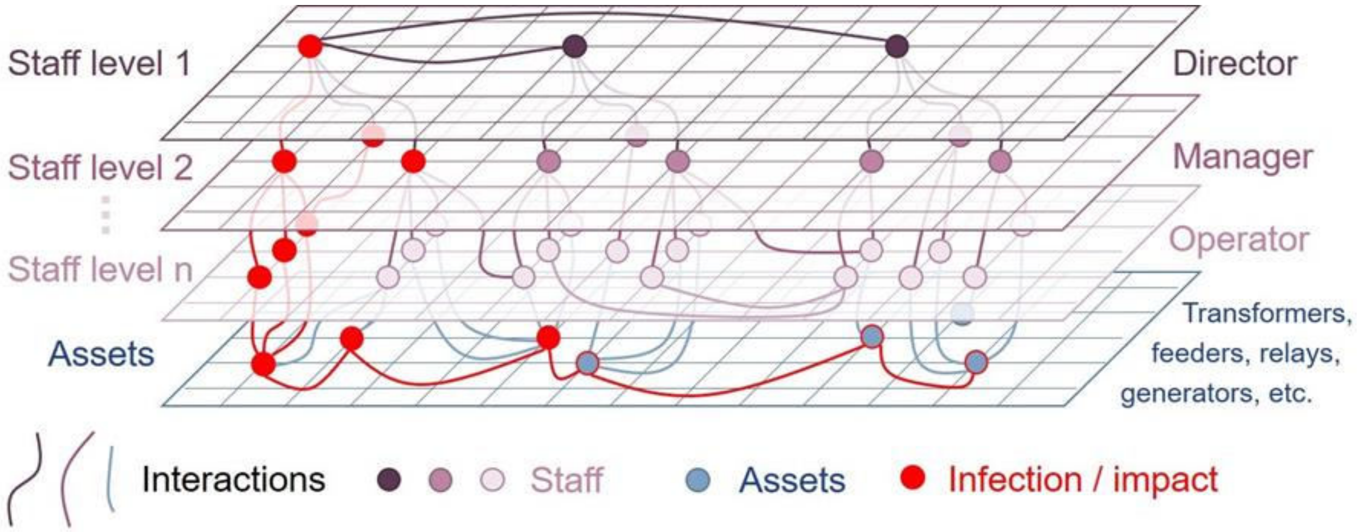
Organizational Resilience

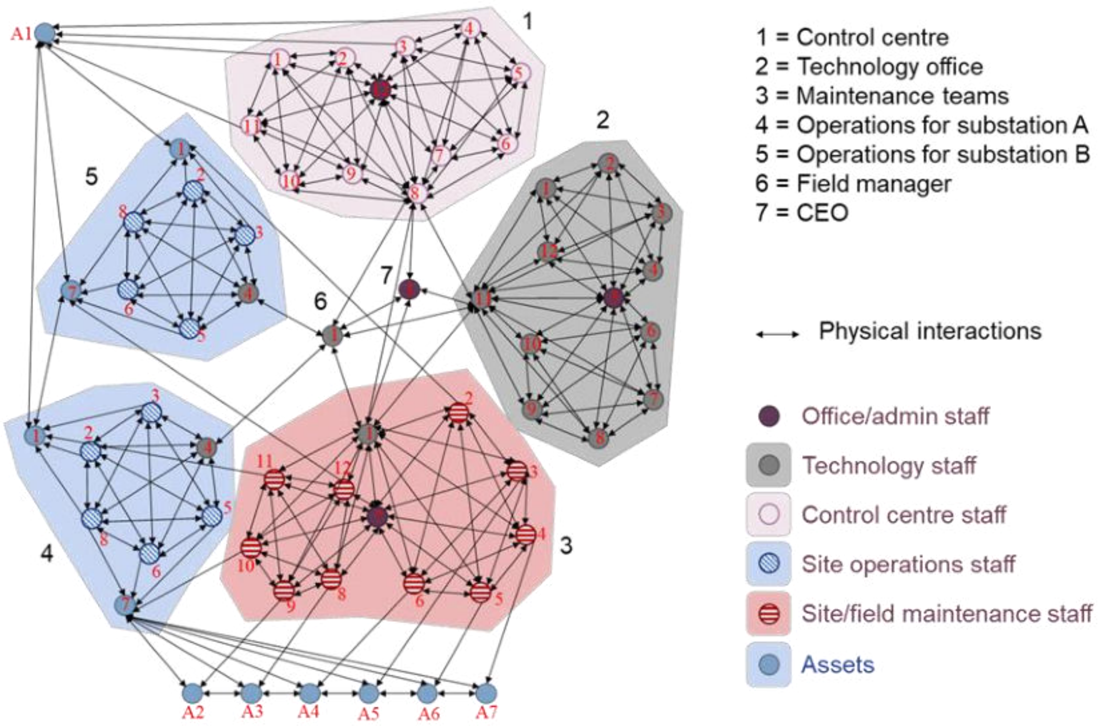
- **Organizational resilience**: refers to the underlying mechanisms and strategies keeping the infrastructure together, is a fundamental step towards achieving the three essential capabilities of a resilient system, namely *absorptive, adaptive and restorative capacities.*

- Essential in having key staff available, and in swiftly mobilising measures to support, protect and empower this staff to sustain rapid response and recovery and limit exposure to the virus.
- Such provision is imperative to ensure the smooth, safe and secure execution of operations, maintenance and construction activities to ensure electricity provision.



Organizational Structure and Interlinkages





S. Skarvelis-Kazakos, M. Van Harte, M. Panteli, E. Ciapessoni, D. Cirio, A. Pitto, R. Moreno, C. Kumar, C. Mak, I. Dobson, C. Challen, M. Papic, C. Rieger, “Resilience of electric utilities during the COVID-19 pandemic in the framework of the CIGRE definition of Power System Resilience”, International Journal of Electrical Power & Energy Systems, Volume 136, 2022

bridgeUkraine: Supporting Ukraine's Post War Recovery

Sustainable Cities and Society 91 (2023) 104405

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Conflict-resilience framework for critical infrastructure peacebuilding

Stergios-Aristoteles Mitoulis [a,b,c,*], Sotirios Argyroudis [b,c,d,*], Mathaios Panteli [b,e], Clemente Fuggini [b,f], Sotirios Valkaniotis [b,g], William Hynes [h], Igor Linkov [i,j]

[a] Department of Civil Engineering, School of Engineering, University of Birmingham, UK
[b] bridgeUkraine (www.bridgeUkraine.org), London, UK
[c] Infrastructuresilience (www.infrastructuResilience.com), London, UK
[d] Department of Civil and Environmental Engineering, Brunel University London, UK
[e] Department of Electrical and Computer Engineering, University of Cyprus, Cyprus
[f] Infrastructures Business Unit, Rina Consulting S.P.A., Italy
[g] Department of Civil Engineering, Democritus University of Thrace, Greece
[h] OECD (Organisation for Economic Co-operation and Development), France
[i] US Army Engineer Research and Development Center, USA
[j] University of Florida, Gainesville, USA

we are committed to building post-war resilience into Ukraine's critical infrastructure for a sustainable future

https://www.bridgeukraine.org/

Open-source tools coming soon!

RESILIENT – **R**ealistic **E**vent **S**imulator for **I**nternational **L**ocation-**I**ndependent **E**nergy **N**etwork **T**esting

CIPROS – Capital **I**nvestment **P**lanning for **R**esilience **O**ptimization of **S**mart Grids

MERS-DIP – **M**obile **E**nergy **R**esource **S**cheduling and **D**ispatch **I**ncorporated in Optimal **P**ower Flow

Stay tuned! ☺

New Horizon Europe Projects

- **Reliability, Resilience and Defense technology for the grid (R2D2)**
  - Duration: 2022-2025
  - Coordinator: ETRA INVESTIGACION Y DESARROLLO SA (Spain)
- **HVDC-based grid architectures for reliable and resilient WIdeSprEad hybrid AC/DC transmission systems (HVDC-WISE)**
  - Duration: 2022-2026
  - Coordinator: SuperGrid Institute, France
- **Climate-aware Resilience for Sustainable Critical and interdependent Infrastructure Systems enhanced by emerging Digital Technologies (ReCharged)**
  - Duration: 2023-2026
  - Coordinator: Grid Engineers, Greece

Stay tuned! ☺

Acknowledgments

- Resilient Electricity Networks for Great Britain (RESNET), Engineering and Physical Sciences Research Council (EPSRC), EP/I035781/1
- Disaster management and resilience in electric power systems, EPSRC UK – Conicyt Chile, EP/N034899/1
- TERSE: Techno-Economic framework for Resilient and Sustainable Electrification, EPSRC, EP/R030294/1
- Resilient Planning of Low Carbon Power Systems, Newton Fund (2018 Newton Prize)
- Market Enabling Interface to Unlock Flexibility Solutions for Cost-effective Management of Smarter Distribution Grids (EUniversal), H2020, EC, Grant agreement ID: 864334
- Forward Resilience Measures, ENA, NIA, NIA_NGT0049

Further Reading

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- C. K. Gan, S. E. Chong, M. Panteli, and P. Mancarella, “Techno-Economic Analysis of On-Grid Transition: A Case Study of Remote Villages in Sarawak”, 2021 IEEE PES ISGT Conference, December 2021
- M. Noebels, and M. Panteli, “A Probabilistic and Cost-based Decision Strategy for Power Grid Resilience using Ensemble Forecasting”, 2021 IEEE PES PowerTech Conference, June 2021
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Thank you for your attention!

We can prevent the hazard from becoming a disaster!

panteli.mathaios@ucy.ac.cy