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Dynamic risk assessment of power systems against wildfires

Rosa Serrano, Alessandra Parisio and Mathaios Panteli

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Motivation

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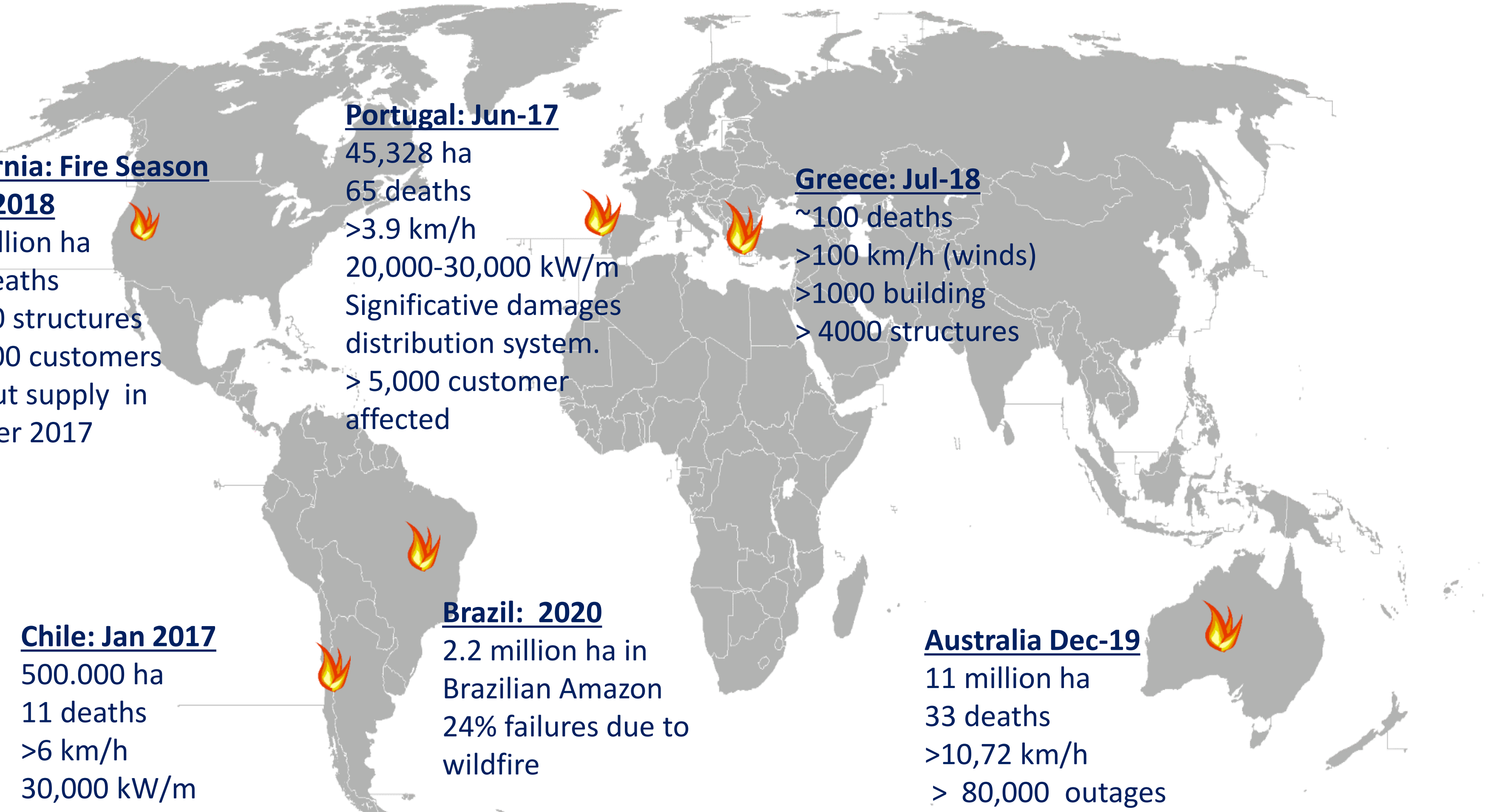


California: Fire Season 2017-2018
1.2 million ha
151 deaths
28.000 structures
350,000 customers without supply in October 2017

Portugal: Jun-17
45,328 ha
65 deaths
>3.9 km/h
20,000-30,000 kW/m
Significative damages distribution system.
> 5,000 customer affected

Greece: Jul-18
~100 deaths
>100 km/h (winds)
>1000 building
> 4000 structures

Chile: Jan 2017
500.000 ha
11 deaths
>6 km/h
30,000 kW/m
More than 50 failures of transmission lines

Brazil: 2020
2.2 million ha in Brazilian Amazon
24% failures due to wildfire

Australia Dec-19
11 million ha
33 deaths
>10,72 km/h
> 80,000 outages
> 5,000 power poles

Risk assessment

- The risk assessment performs real-time monitoring of wildfire events and evaluates the risk exposure through a Severity Risk Index (SRI).

$$SRI=\sum_{sce=1}^{K} Prob_{sce} \cdot Impact_{sce}$$

- The $Prob_{sce}$ are calculated considering the combinatory of vulnerable components' states.

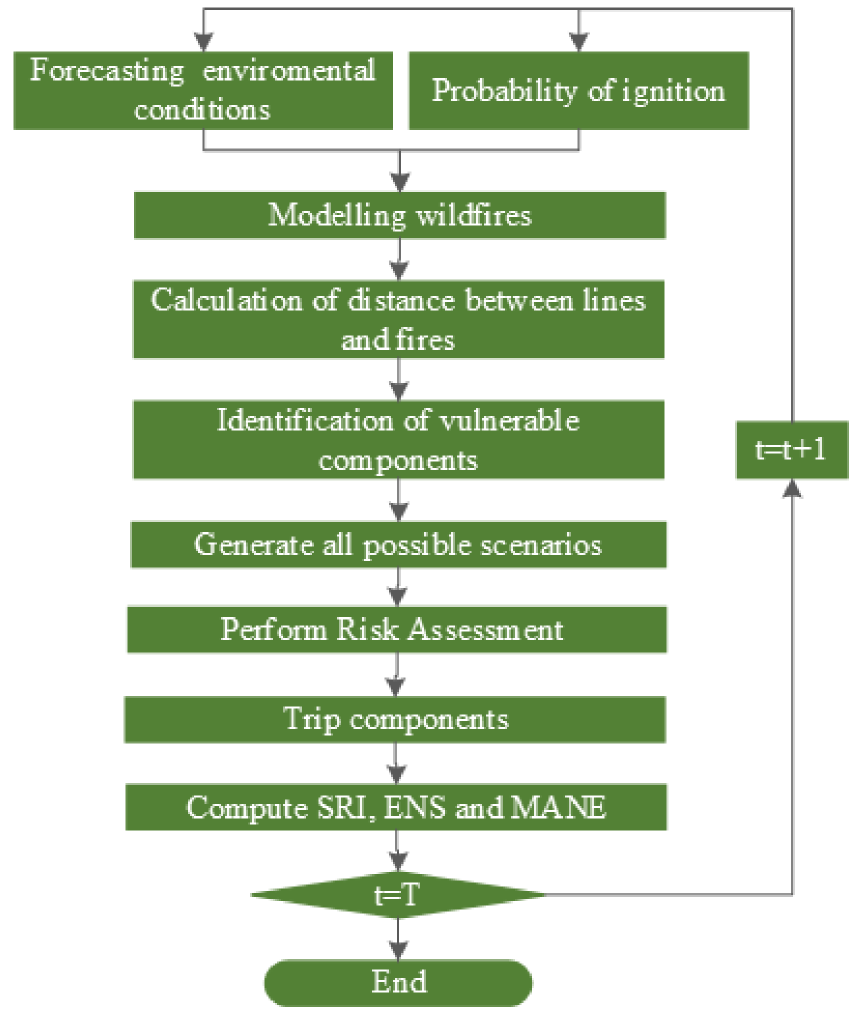
$$Prob_{sce}=\prod_{i=1}^{N_U} Prob_{,i} \prod_{j=1}^{N_A} (1-Probi_j)$$

- The impact is measured considering the ENS

- The SRI provides an expectation of the risk, considering the topology system, environmental conditions and the progression of the wildfire.

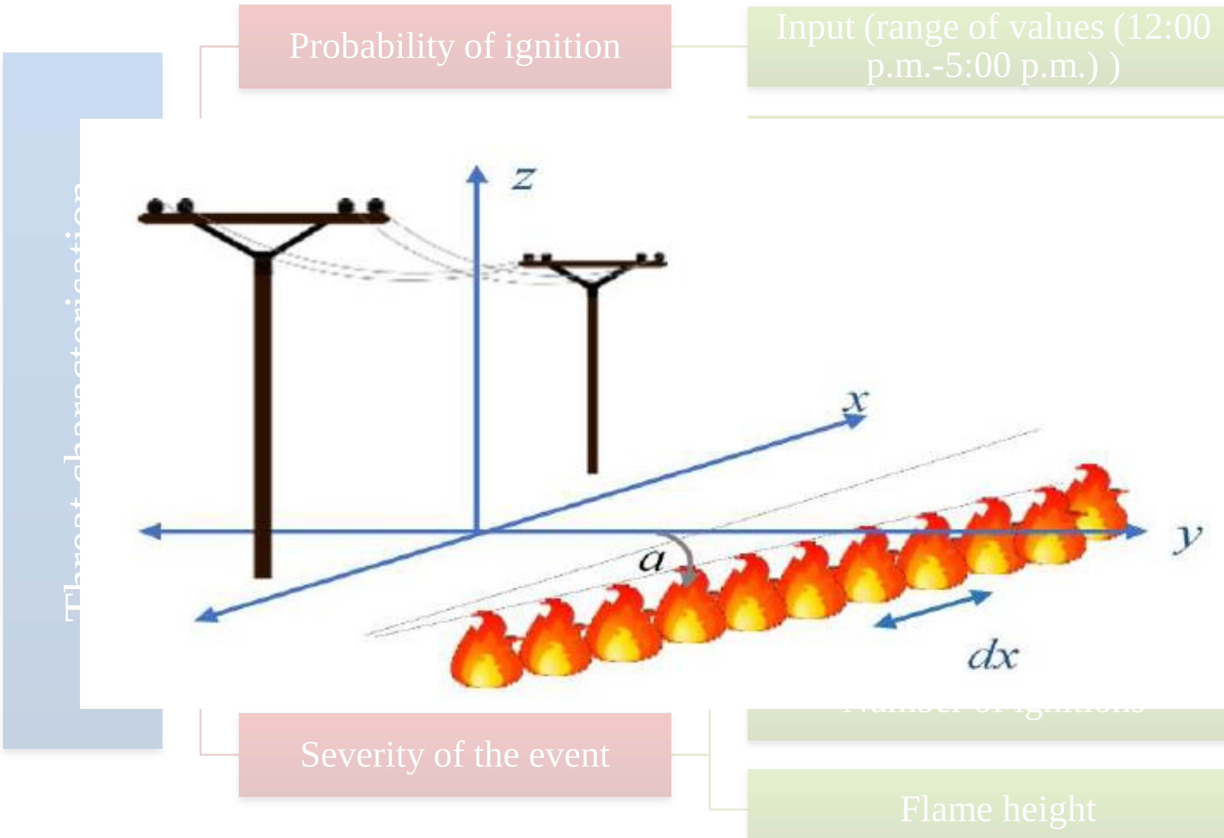
- Assesses spatiotemporal risk exposure due to local or massive wildfire events.

- Assesses the operational impact of flame heights.



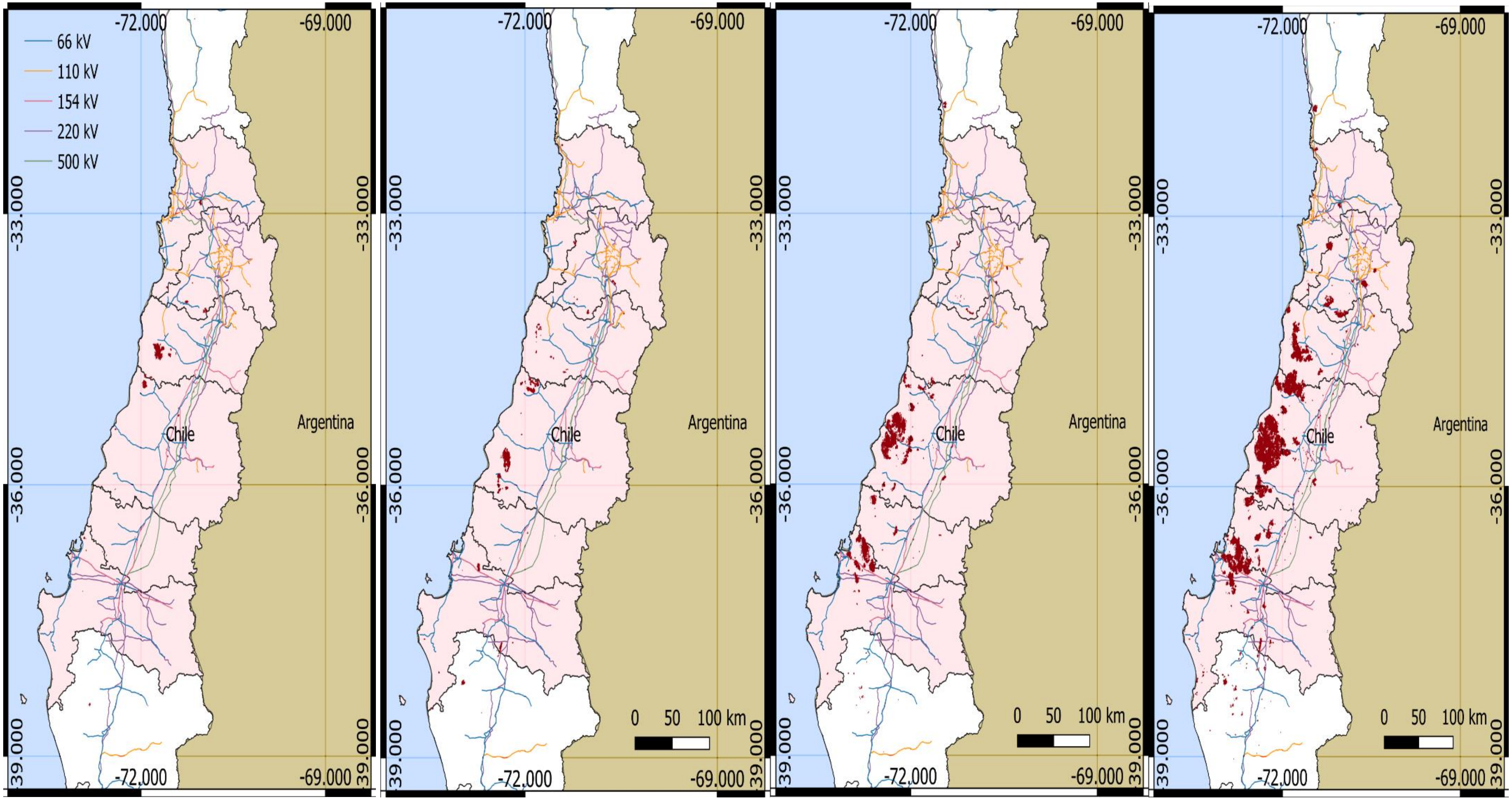
Threat characterisation

- Wildfire events are dynamic processes where multiple fires may ignite and extinguish throughout the simulation, according to the severity of the event and mitigation measures in place.



Threat characterisation

- Why is important to consider the severity of the event?



18 January 2017 | 22 January 2017 | 26 January 2017 | Total event

- Power system are exposed to local and massive events

Vulnerability of system components

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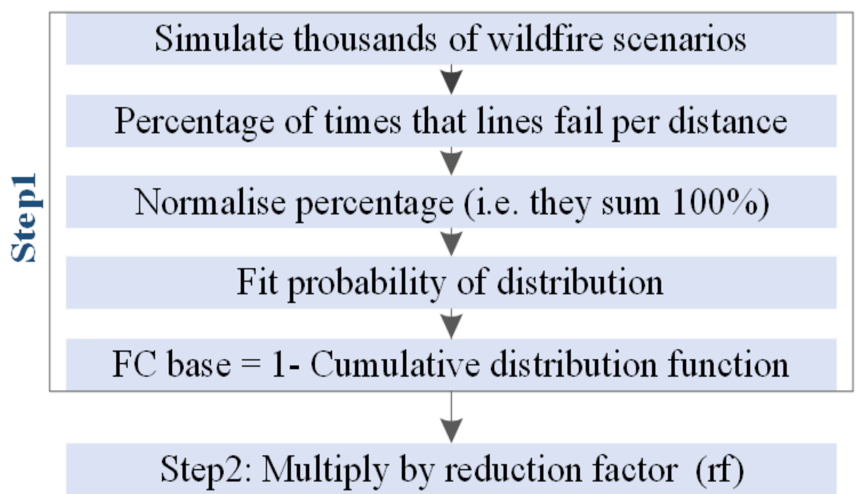
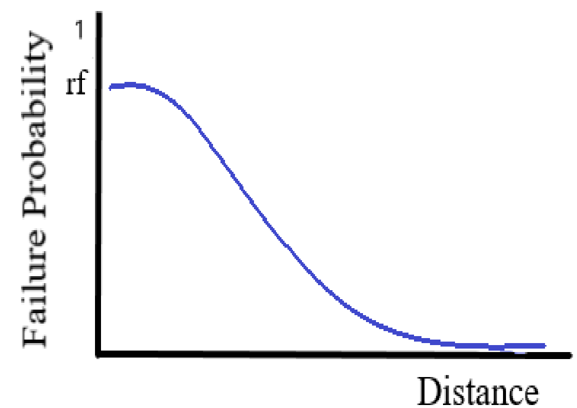
- Transmission lines are considered vulnerable components to excessive heat transfer (radiative and convective).
- Fragility-driven impact assessment of excessive heat transfer on transmission lines considering the effect of wildfires as a distance-type of conductor-dependent function.



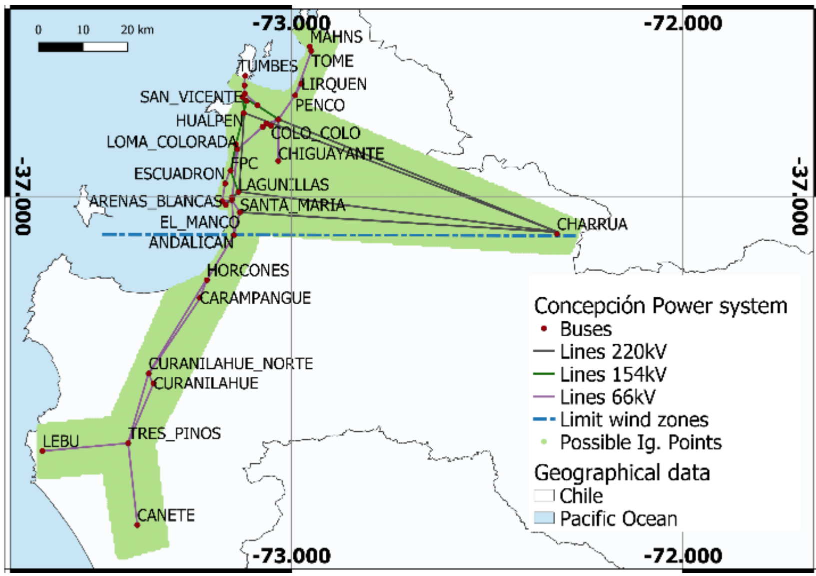
Fragility curve methodology

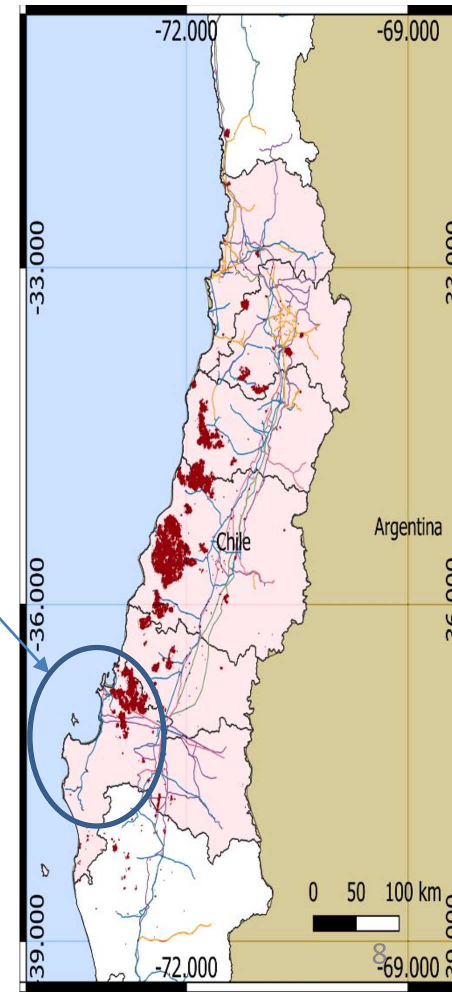


Generic fragility curve

Case study

- The methodology is tested on a 36-bus representation of the Concepción power system, one of the most affected zones during the firestorm that hit Chile in 2017





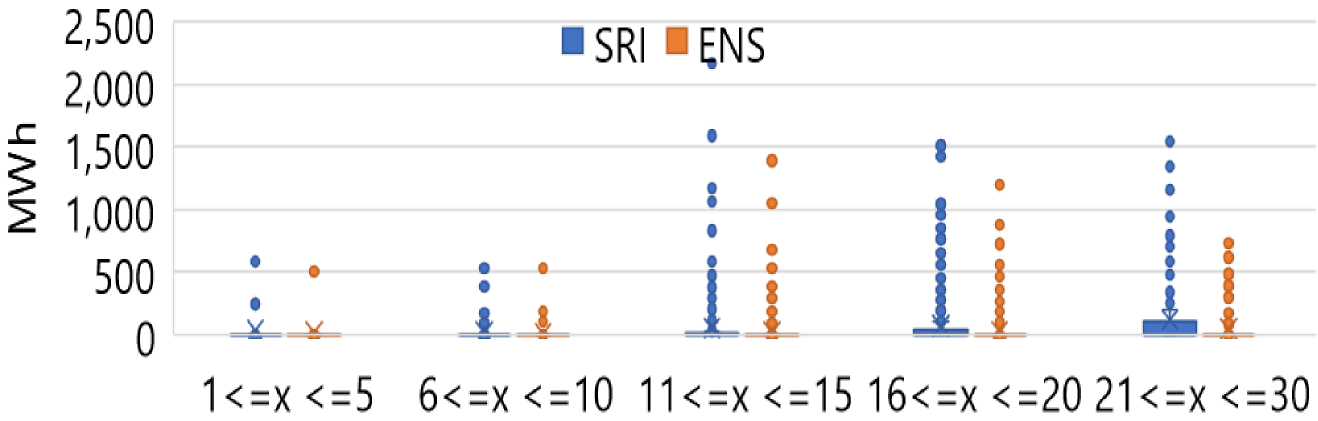
- Percentage of failures by maximum fire height

Conductor characteristics			Maximum fire height (m)			
Material	kV	Span height [m]	1	3	5	7
Al	66	15.5	0.2%	14.0%	19.1%	31.3%
Al	154	21 (*)	0.1%	11.0%	15.3%	26.9%
Al	220	25.5	0.0%	8.6%	12.2%	23.2%
Cu	66	15.5	0.5%	19.4%	24.9%	40.2%
Cu	154	21	0.1%	11.1%	14.5%	27.1%
Total			0.1%	11.4%	15.5%	27.7%

(*) Estimated values

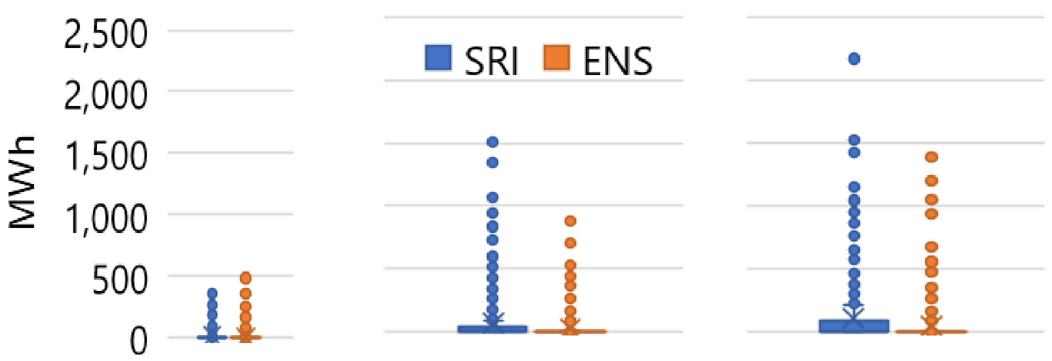
Case study- results

- ENS according to the number of fires



x = number of fires

- ENS for maximum flame height



(a) 3m (b) 5m (c) 7m

Case study- results

- Error calculation:

Calculated using the Mean Absolute Normalized Error (MANE), which represents the absolute difference between the actual ENS and SRI, calculated as a demand percentage

$$\text{MANE}(\%)=\frac{1}{M}\sum_{i}^{M}\frac{|SRI_i - ENS_i|}{Dem_i}$$

- MANE by number of active wildfires by step

Number of Fires	MANE (3m)	MANE (5m)	MANE (7m)
1<=x <=5	-	0.13	0.01
6<=x <=10	0.04	0.07	0.15
11<=x <=15	0.08	0.18	0.28
16<=x <=20	0.06	0.30	0.41
21<=x <=25	0.10	0.58	0.49

- The value of MANE increases when the number of fires and the flame height increase, which means the risk exposition also increases.

Conclusions

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- The impact of heat transfer from wildfires on transmission lines is relevant when fires are under the line, and it strongly depends on the conductor height and material, as well as the fire intensity.

- The flame intensity also depends on the vegetation type. The results show that although small vegetation reduces the operational risk, it is not eliminated.

- The vulnerability of the power system also increases when power systems are exposed to a higher number of fires. Thus, it is crucial to explore operational and investment strategies that help to deal with different severity levels.

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Many Thanks!

Contact:
Rosa serrano: rosa.serrano@postgrad.manchester.ac.uk