



# Resilience and Reliability tradeoff

Distribution Grid Resilience: Metrics and  
Integration into Planning/Operation

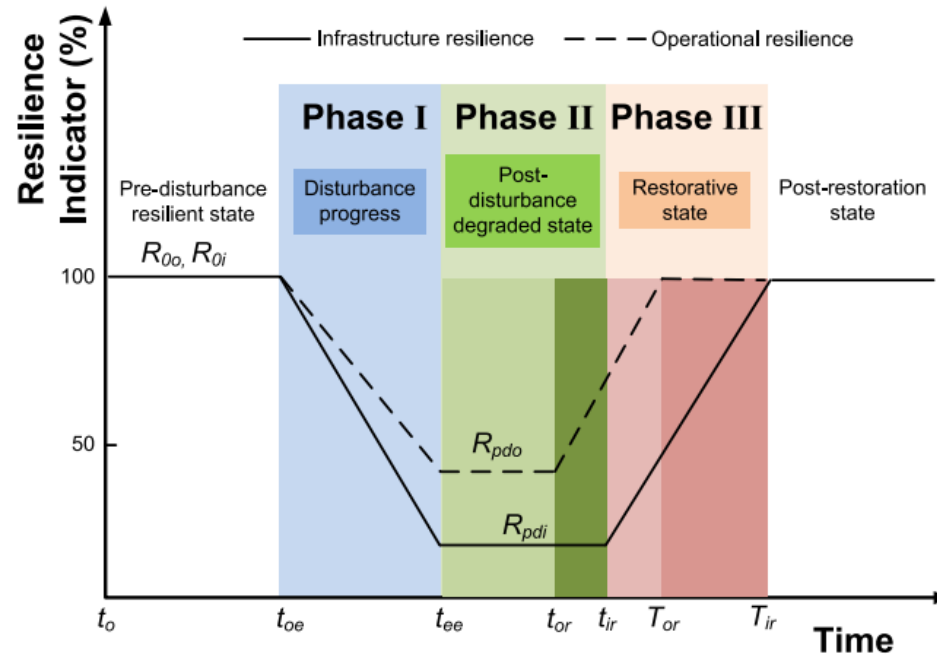
PES GM 2023

# Outline

- Resilience trapezoid
- Difference in nature and concept
- Tradeoff example
- Measuring the differences
- Winning both games: examples

# Resilience trapezoid

## Infrastructure vs. operational resilience



- Operational health improvements vs. infrastructure resilience
- Grid hardening vs. capacity improvements
- Preventive maintenance vs. outage repairs

Fig. 2. The multi-phase resilience trapezoid.

M. Panteli, P. Mancarella, D. N. Trakas, E. Kyriakides and N. D. Hatzargyriou, "Metrics and Quantification of Operational and Infrastructure Resilience in Power Systems," in *IEEE Transactions on Power Systems*, vol. 32, no. 6, pp. 4732-4742, Nov. 2017, doi: 10.1109/TPWRS.2017.2664141.



# Difference in nature and concept

## and how it builds the foundation of tradeoff

### Resilience:

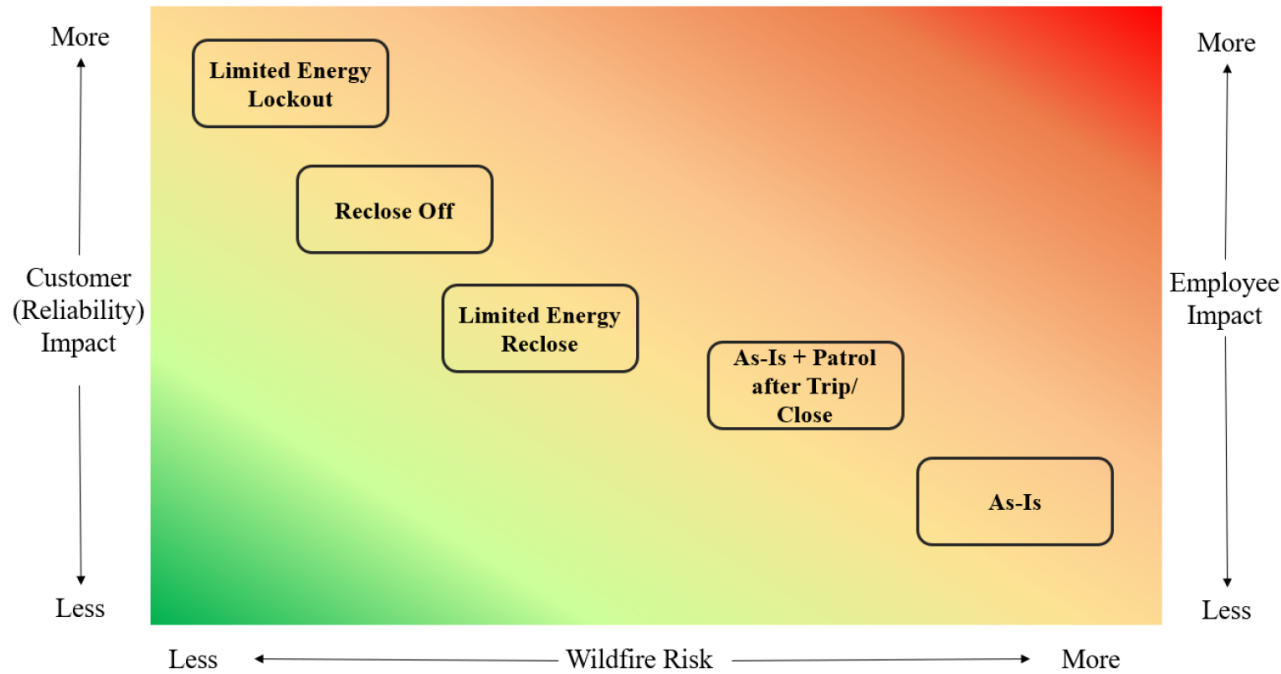
- “The capability of electric power distribution systems to deliver electric energy to end-use customers and recover this capability following exposure to high impact low frequency events.”

### Difference between Resilience and Reliability:

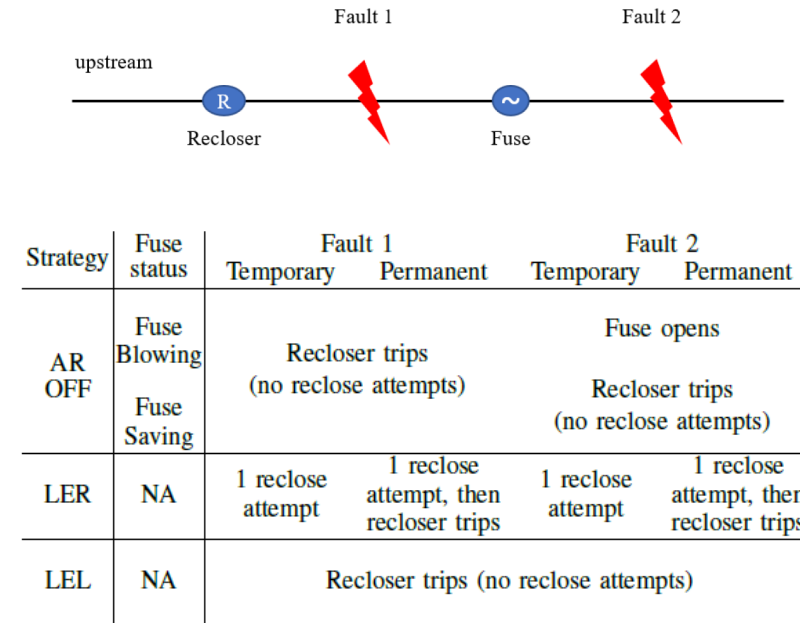
- Resilience covers unexpected, high-impact, low frequency events
- Resilience looks at a longer term
- Resilience also considers personnel and equipment, but with a possible greater impact and recovery needs
- Impacts on customer experience in each effort is different

# Tradeoff Example

## Resilience Orientated Reclosing



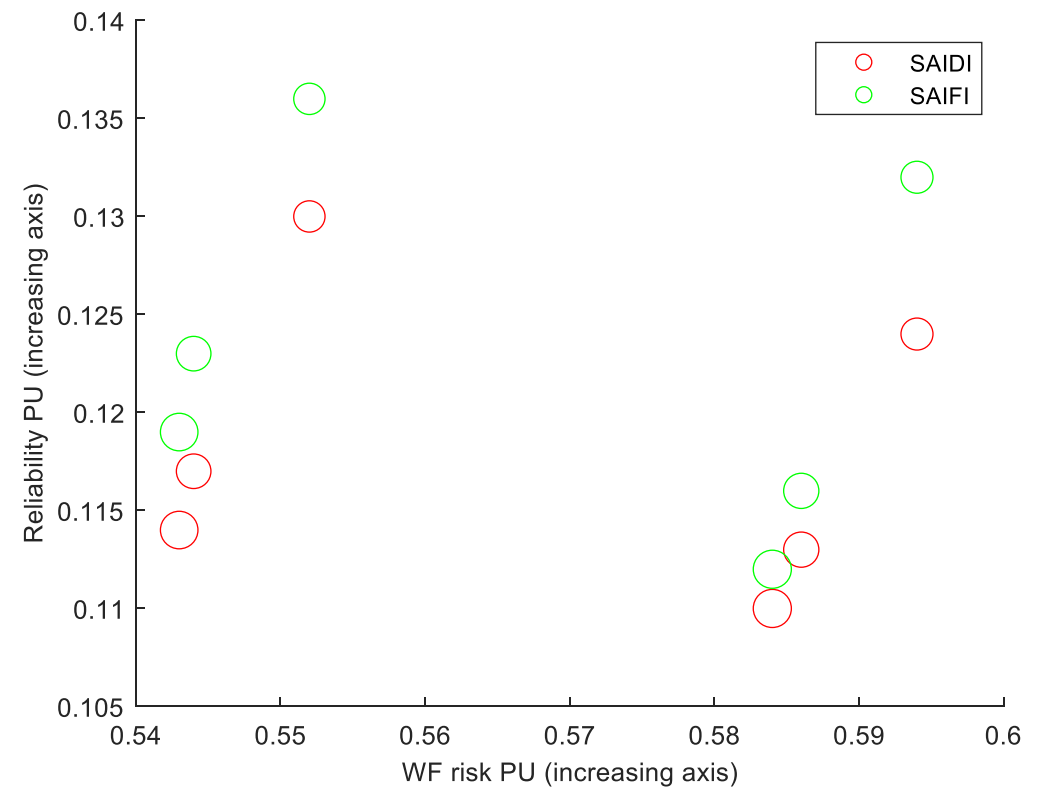
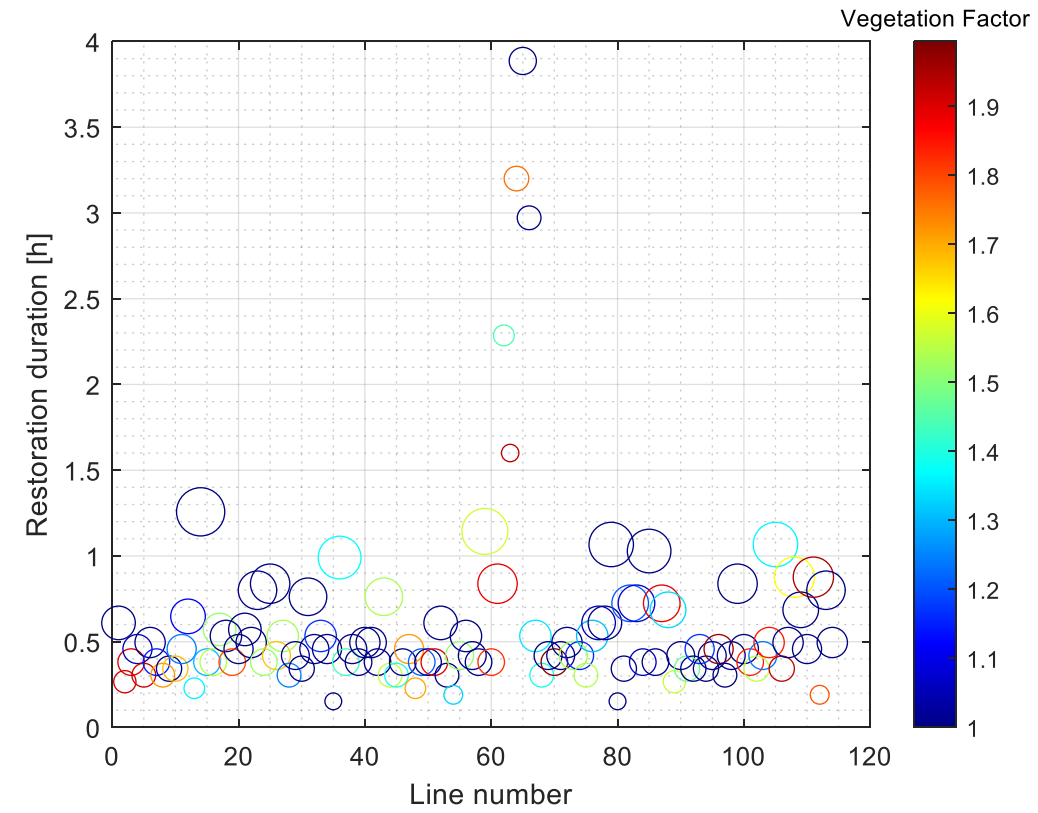
Trade-off between customer experience, employee impact, and wildfire risk mitigation



M. Davoudi, B. Efav, M. Avendaño-Mora, J. L. Lauletta and G. B. Huffman, "Reclosing of Distribution Systems for Wildfire Prevention," in *IEEE Transactions on Power Delivery*, vol. 36, no. 4, pp. 2298-2307, Aug. 2021, doi: 10.1109/TPWRD.2021.3050973.

# Measuring the differences

## The need for new metrics

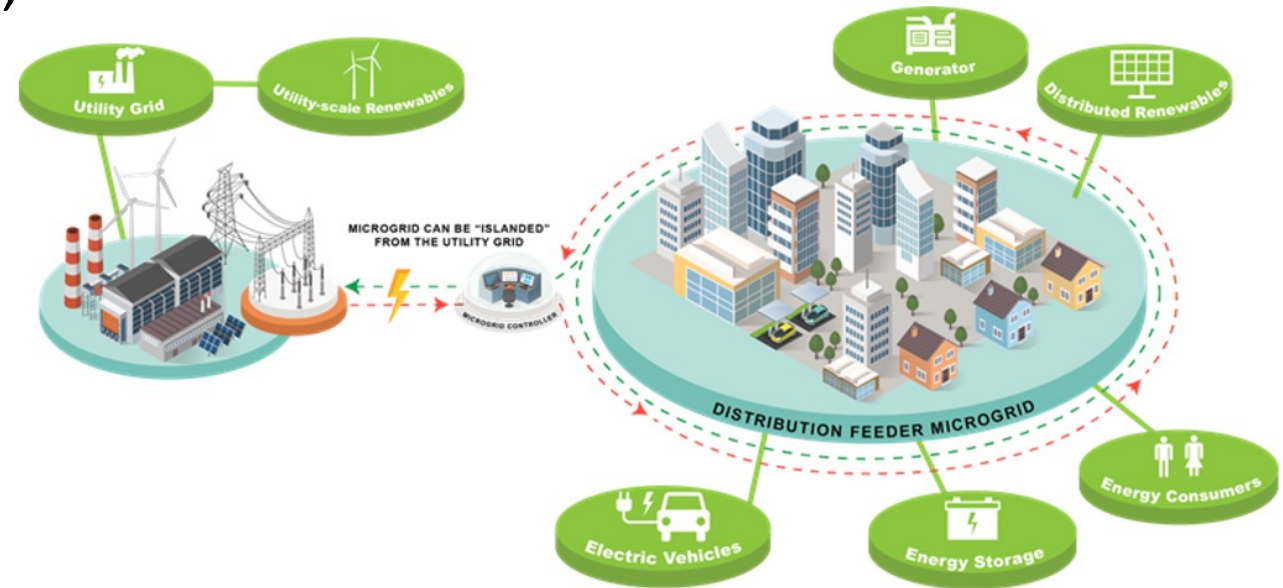


IEEE 123 Bus Test System: Annual failure rate, restoration duration, and vegetation factor for all lines.

# Microgrids

## For Improving reliability and resilience

- Microgrids, as small-scale power systems, can operate in both grid-connected and islanded modes.
- What is the impact of substation, feeder, circuit, and secondary system microgrids on resilience?
- What resilience metrics should be considered for evaluating the impact of microgrids?



# Electric Vehicles

## For Improving reliability and resilience

- How can solid-state transformers (SST) help with microgrid implementation and resilience enhancement?
- What is the role of electric vehicles?

Vehicle	Available Capacity	Serving time (days) based on load scenario			
		Emergency		Ext. Emergency	
		Summer	Winter	Summer	Winter
Prius	Full	4.9	4.0	6.5	4.8
	Half	2.5	2.0	3.3	2.4
Camry Hybrid	Full	7.3	6.0	9.6	7.1
	Half	3.6	3.0	4.8	3.6
Chevrolet Volt	Full	4.0	3.3	5.3	3.9
	Half	2.0	1.6	2.7	2.0
Nissan Leaf	Full	0.6	0.5	0.8	0.6
	Half	0.3	0.3	0.4	0.3
Tesla S	Full	2.2	1.8	2.9	2.2
	Half	1.1	0.9	1.5	1.1

Electric vehicles used in emergency:

Kaveh Rahimi, Masoud Davoudi, Electric vehicles for improving resilience of distribution systems, Elsevier, 2018

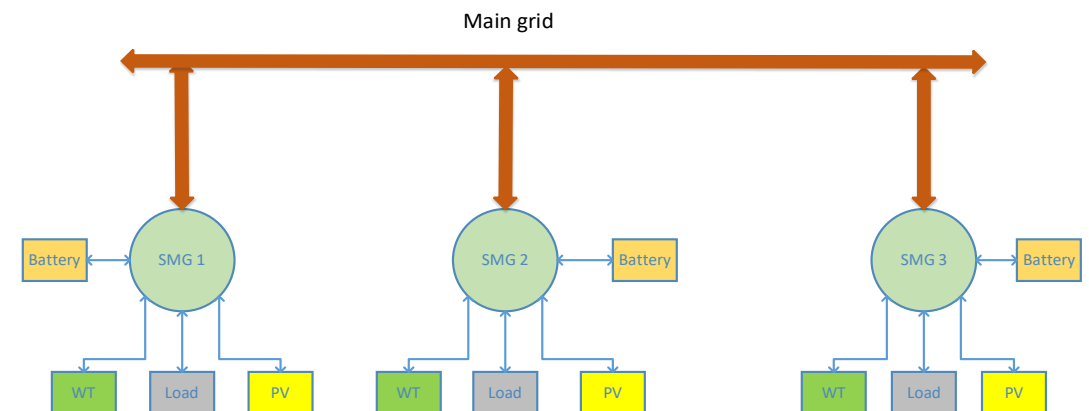
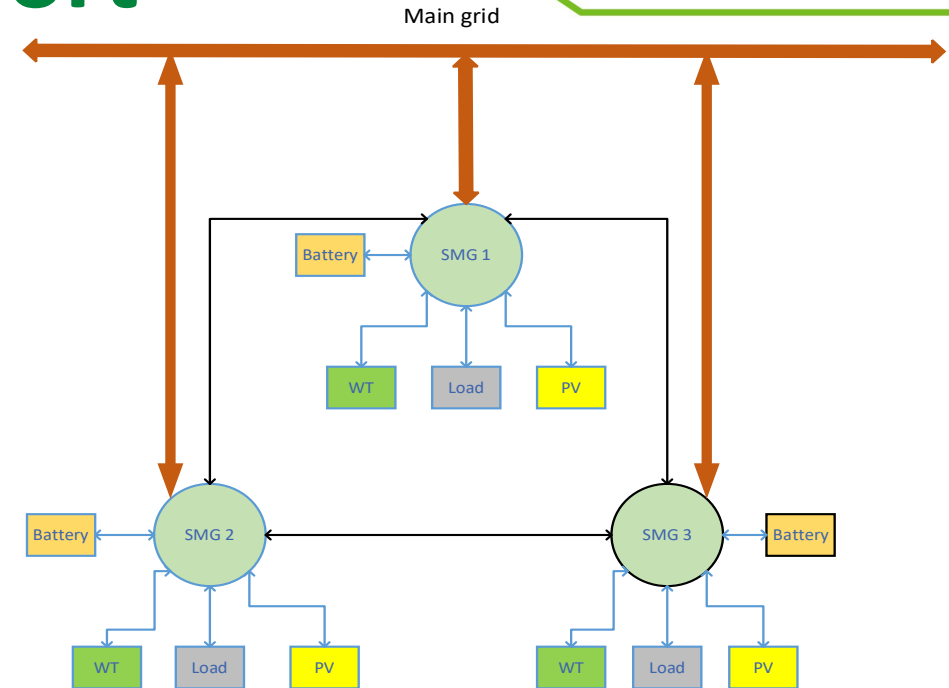


# Microgrids and mutual support

## Impact of clustered microgrids on resilience

We need to identify the most optimized clustered microgrid architecture considering resilience enhancement:

- Independent single microgrid (SMG) operation
- Multi microgrid operation



# Energy Storage Technologies

## Considering differences in decision making

