

Operational and Planning Considerations for Resiliency (6.2)

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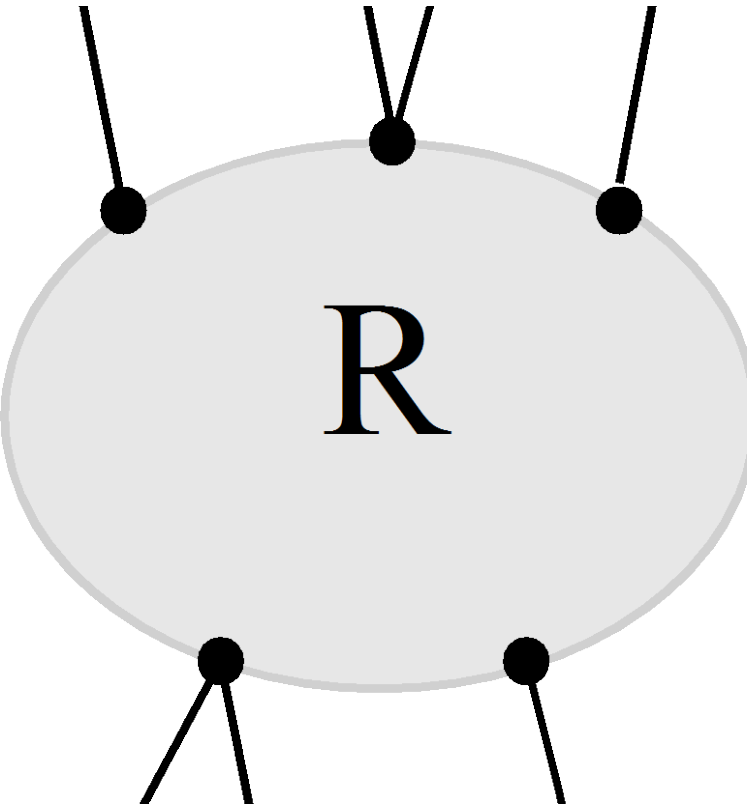
PSERC Future Grid Initiative
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Objective: **Quantify resilience**
from utility data so that
resilience can be engineered

1. Quantify area stress from
synchrophasor measurements
around the border of the area (one slide)
2. Quantify effect of cascading in terms of
number of line outages from one year
of standard utility data (rest of talk)

Angle across an area



- Combine together phasor measurements along border of an area to get a bulk angle across the area
- Satisfies circuit laws
- Responds to outages in area
- Specific to area

Goal: intuitive summary of area stress with actionable thresholds that can be monitored to give a quick alarm of serious outages

Quantify cascading from utility data

Cascading = initial outages + propagation

Quantifying and limiting propagation of outages is an important part of resilience.

Let us track number of line outages during cascading.

We can estimate **average propagation** of line outages from ~ one year of standard utility TADS data that is reported to NERC by all USA utilities.

(TADS = Transmission Availability Data System)

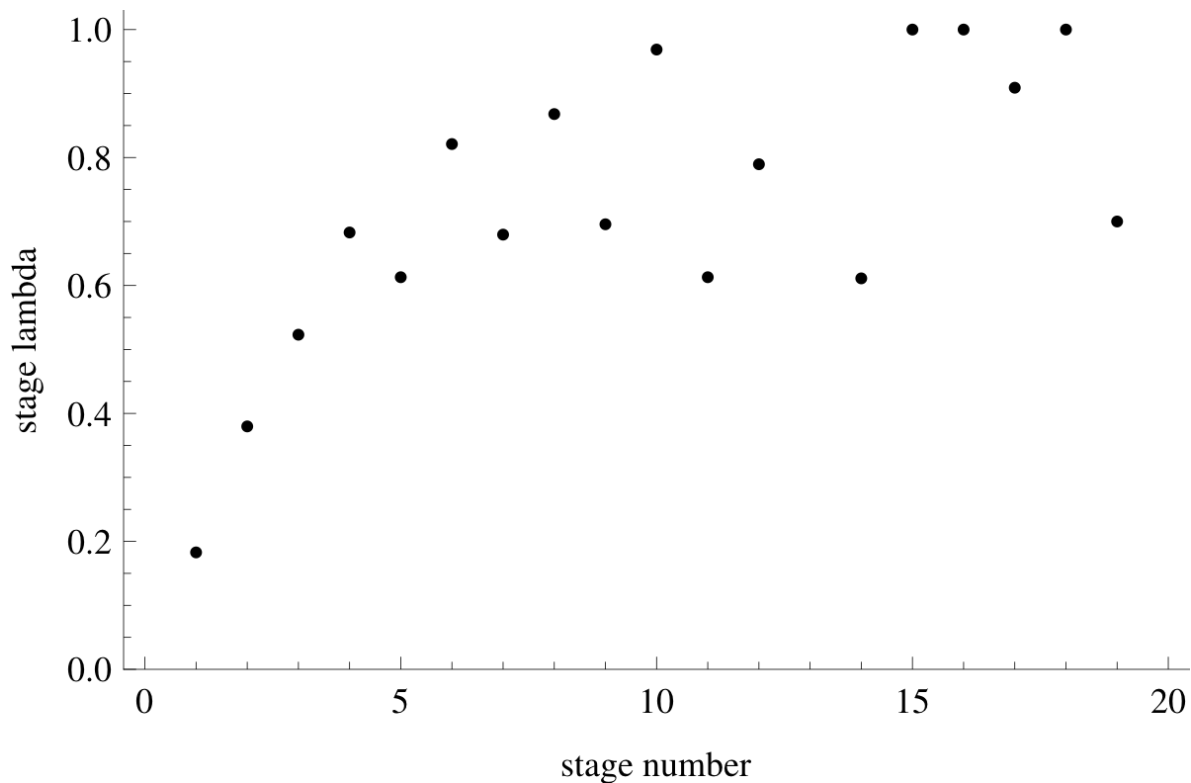
And then, given initial outages, we can predict statistics of the **total number of line outages** using a branching process model

EXAMPLE OF PROCESSING OBSERVED TRANSMISSION LINE OUTAGES

- 860 automatic line outages per year
- Simple approach: only look at time of outages
- Group outages into about 500 cascades and then into generations by their timing
- This gives, for example,
625 outages in generation 0,
114 outages in generation 1,
43 outages in generation 2, etcetera...

The increasing propagation λ from data

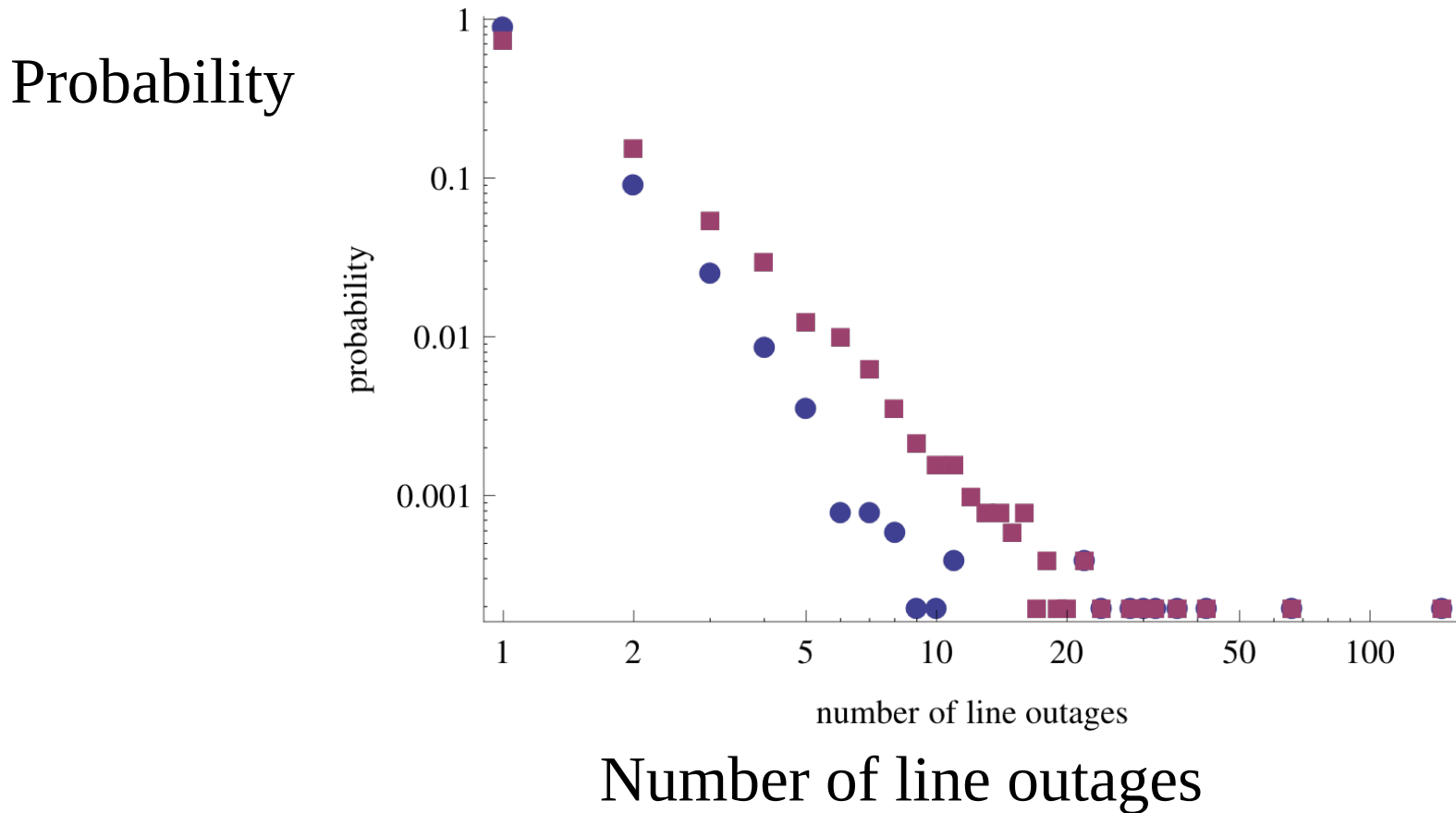
Propagation
 λ
in each
generation



Generation number

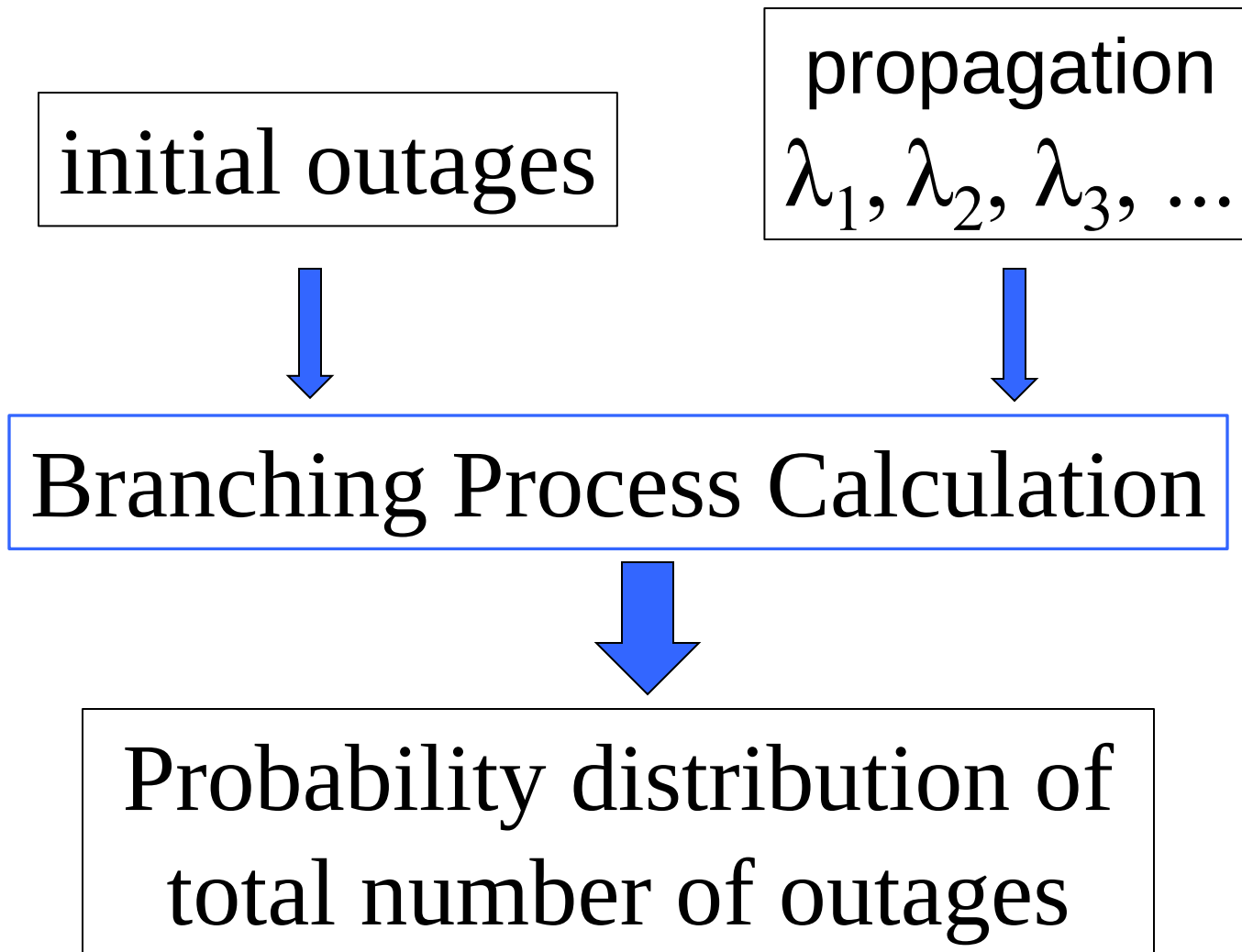
$$\lambda_1 = 0.18, \lambda_2 = 0.38, \lambda_3 = 0.52, \lambda_4 = 0.68, \lambda_{5+} = 0.75$$

Distributions of line outages (raw data)

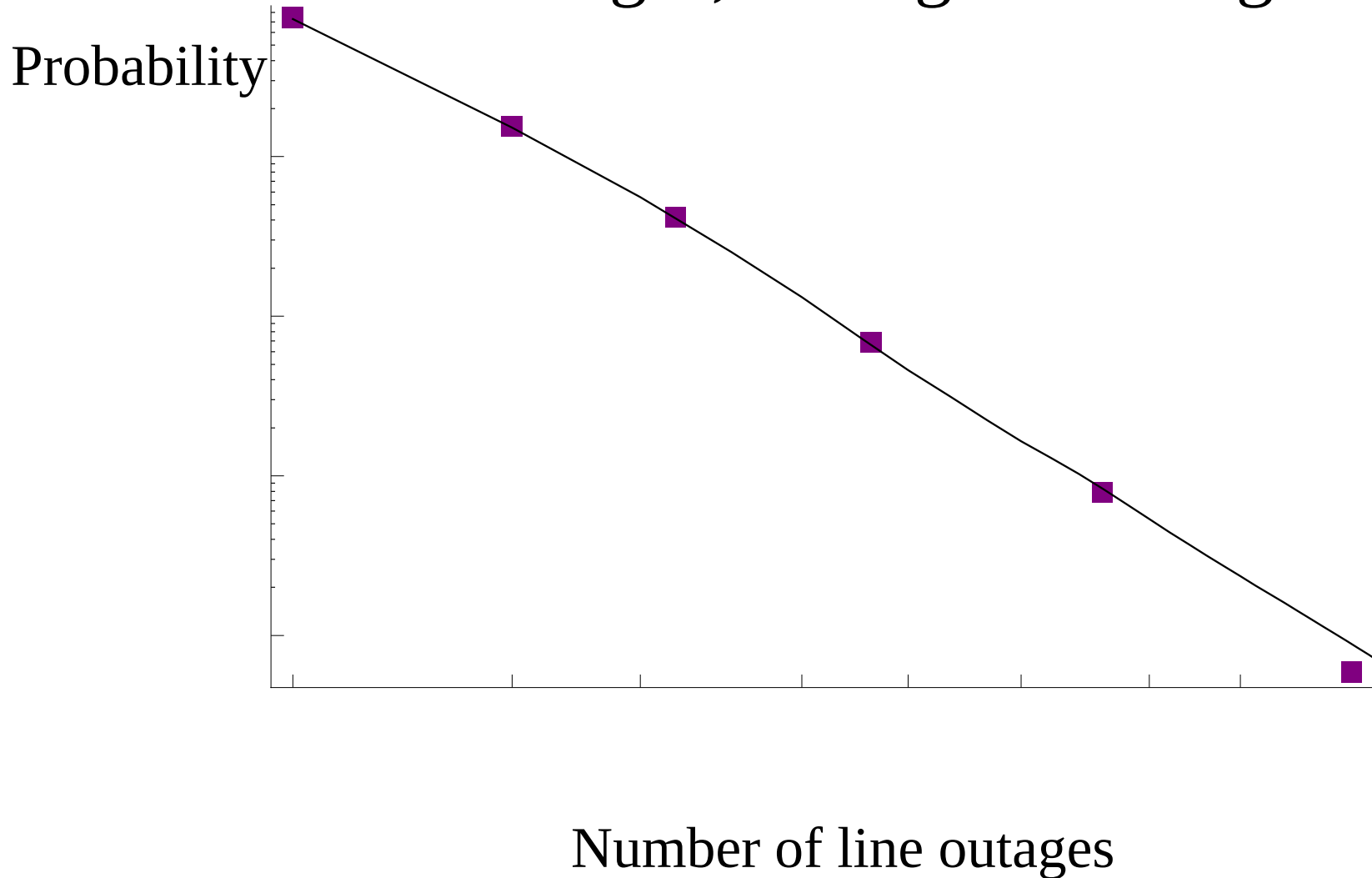


Blue dots: initial line outages (generation 0) in each cascade
Purple squares: total line outages in each cascade

Branching process can compute extent of cascading

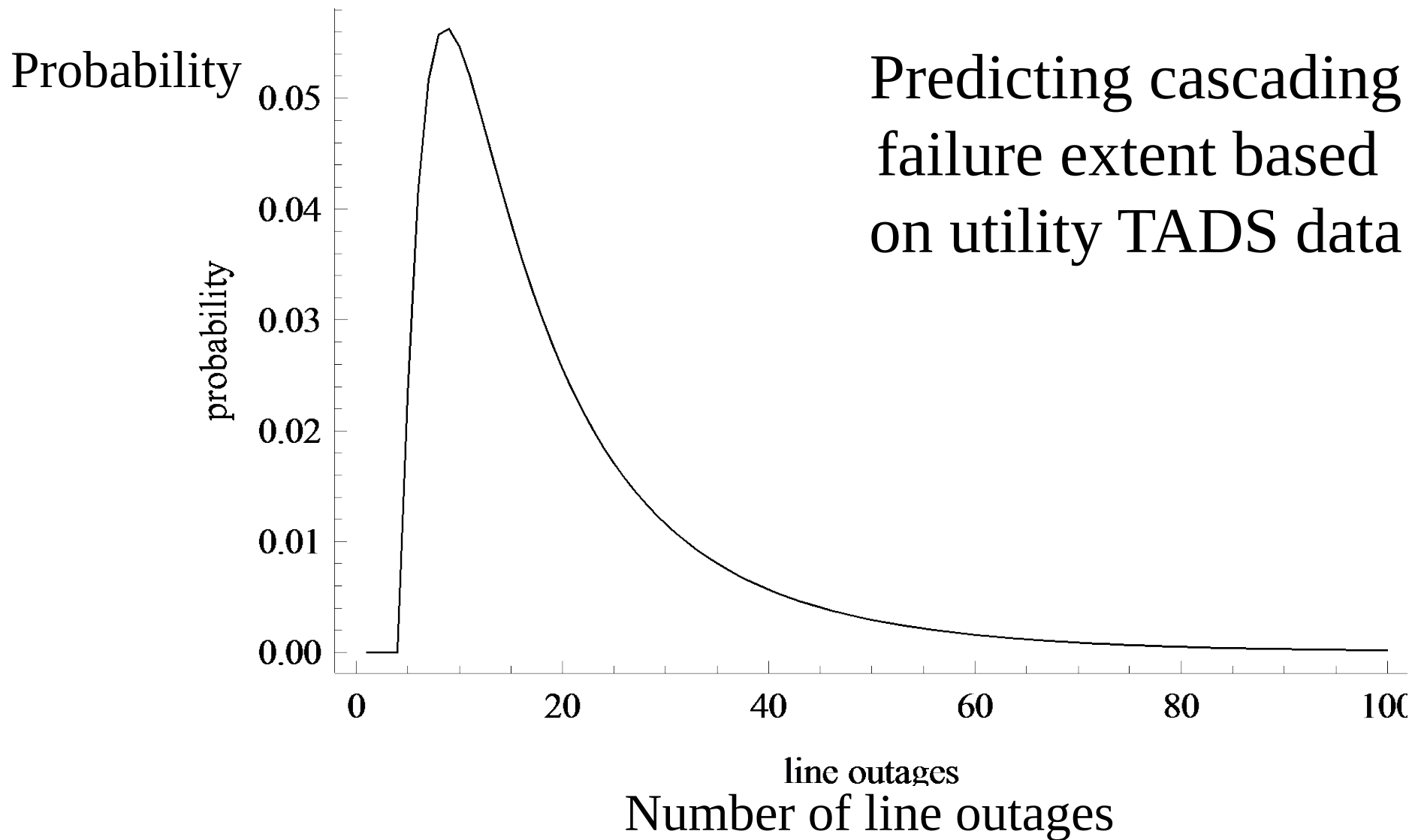


Distributions of outages; testing branching model



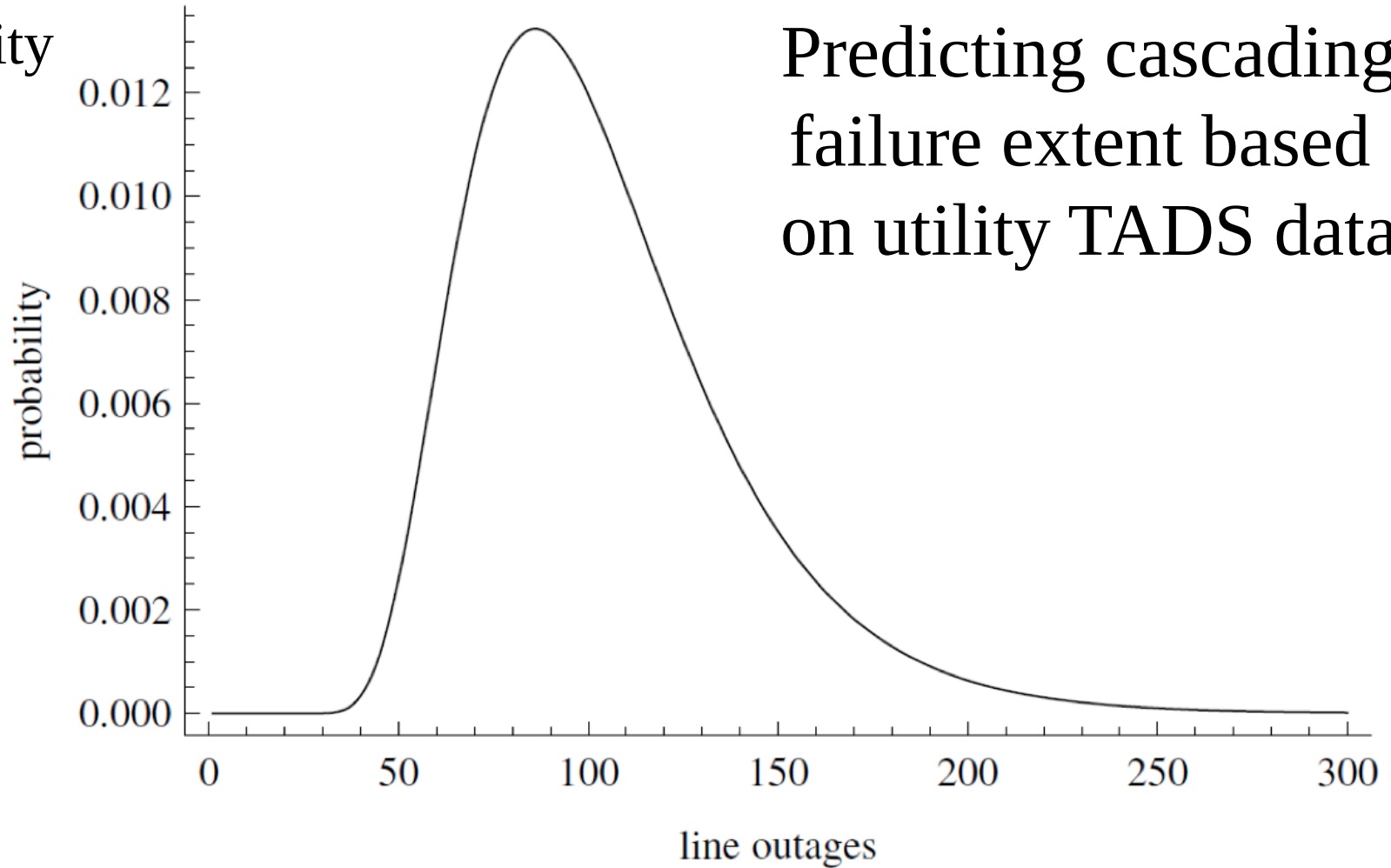
Purple squares: Empirical from observed data

Line: Predicted by branching process with the varying λ



Probability distribution of total number of line outages assuming 5 initial line outages

Probability



Number of line outages

Probability distribution of total number of line outages assuming 26 initial line outages

CONCLUSION

- We have validated with industry data from BPA and several others.
- The annual tendency to cascade (propagation and distribution of total number of outages) can be monitored and quantified from standard utility data that is already collected
- We are developing prototype software to share so that others can do these calculations
- Questions or TADS data to share?... please contact Ian at dobson@iastate.edu

Papers at <http://iandobson.ece.iastate.edu>