# The Frequency of Large Blackouts in the United States Electrical Transmission System: an Empirical Study

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# Overview

- Blackouts have triggered system changes in the past.
- One might expect that these changes have resulted in a measurable decrease in the frequency of large blackouts.
- Therefore, we seek to study the following hypothesis empirically:
  - The frequency of large blackouts in the United States has decreased over the period for which data are available (1984-2003).

# Outline

- Historical background – Improvements brought about by past blackouts
- Data sources and filtering methods
- Statistical analysis of this data
- Some possible explanations for this finding
- Conclusions

# Historical blackouts and their consequences

- 1965, Eastern US/Canada
  - Reliability councils / NERC
  - backup relaying
- 1977, Eastern US
  - RAS / SPS
  - 5 stage control N-1 criterion
- 1996, Western US/Canada
  - Improvements to RAS / SPS
  - Emphasis on managing limits, contingency analysis
- 2003, Eastern US/Canada
  - Mandatory reliability standards
  - Emphasis on software, tree trimming, etc.

# Hypothesis

- Many improvements have been implemented.
- Technology has improved significantly
- Therefore, one might expect that:
  - the frequency of large blackouts in the United States has decreased over the period for which data are available (1984-2003).

- This paper seeks to confirm or refute this hypothesis using publicly available data.

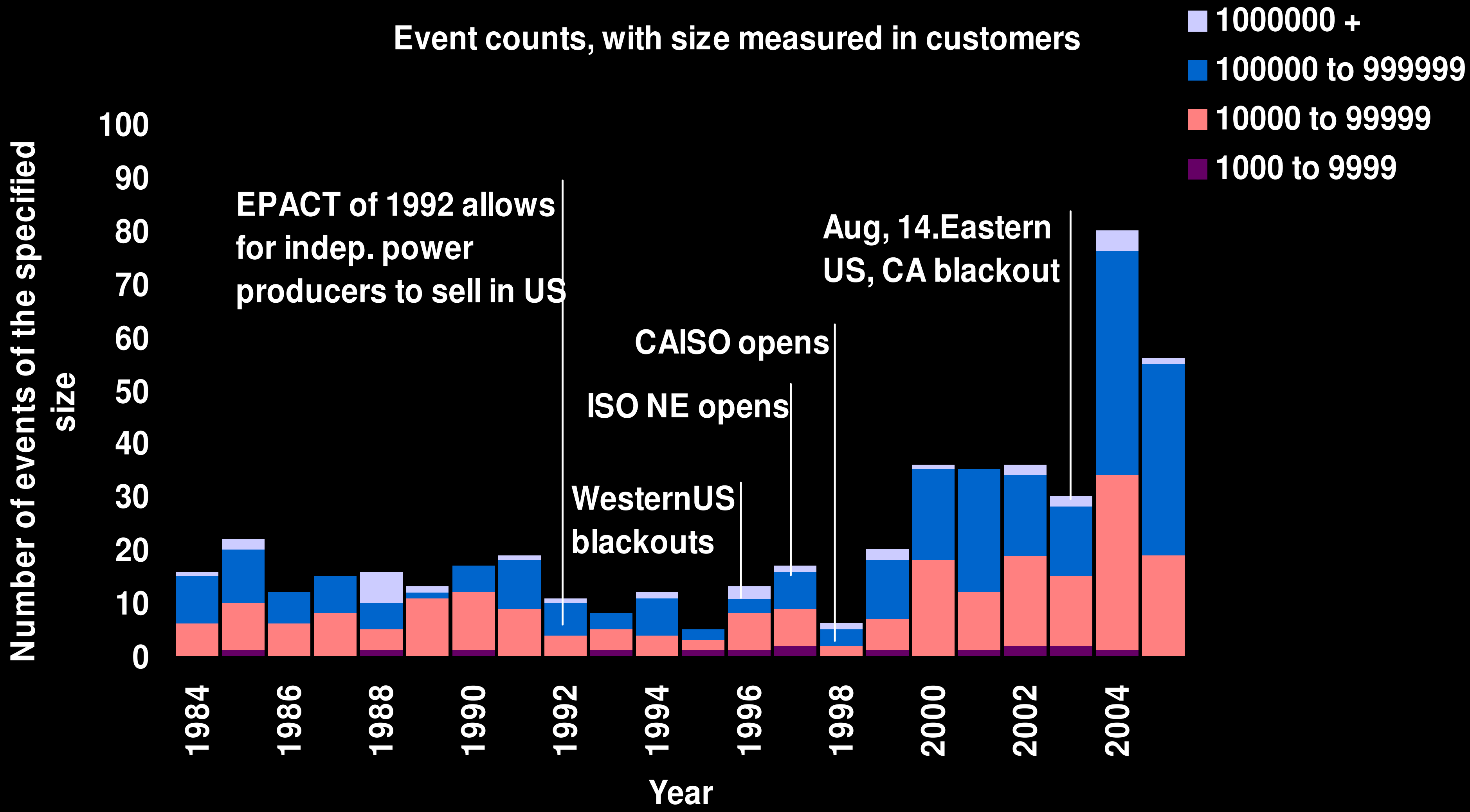
# Data sources

- Primary data source: NERC Disturbance Analysis Working Group.
- Secondary data (for 2004, 2005) from DOE Energy Information Agency form 417 data.
- Data include date, time, size (in MW and/or customers affected), and the cause of hundreds of events
  - 715 events for 1984-2003 in DAWG data
  - 164 events for 2004, 2005 in EIA data

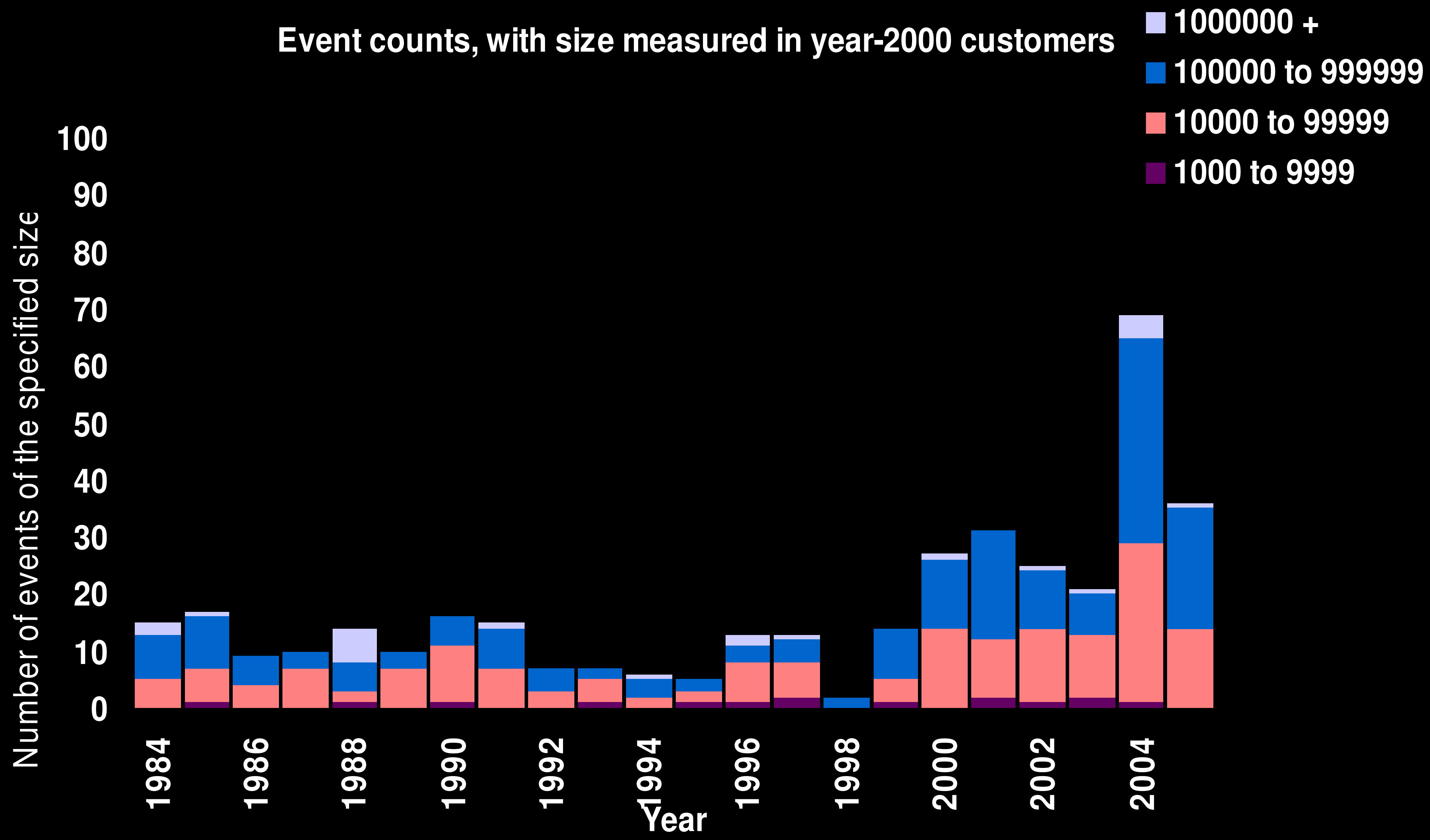
# Data filtering

- If MW or customers blank or reported n/a we interpolated using the average customers / MW (768 customers / MW)
- In order to adjust for load growth and population growth we normalized the data to year-2000 MW and year-2000 customers.
- 1998, 2004, 2005 data not included in statistics
  - For 1998 data a large portion of the year's data is missing in the DAWG database.
  - 2004, 2005 data come from EIA, not DAWG.

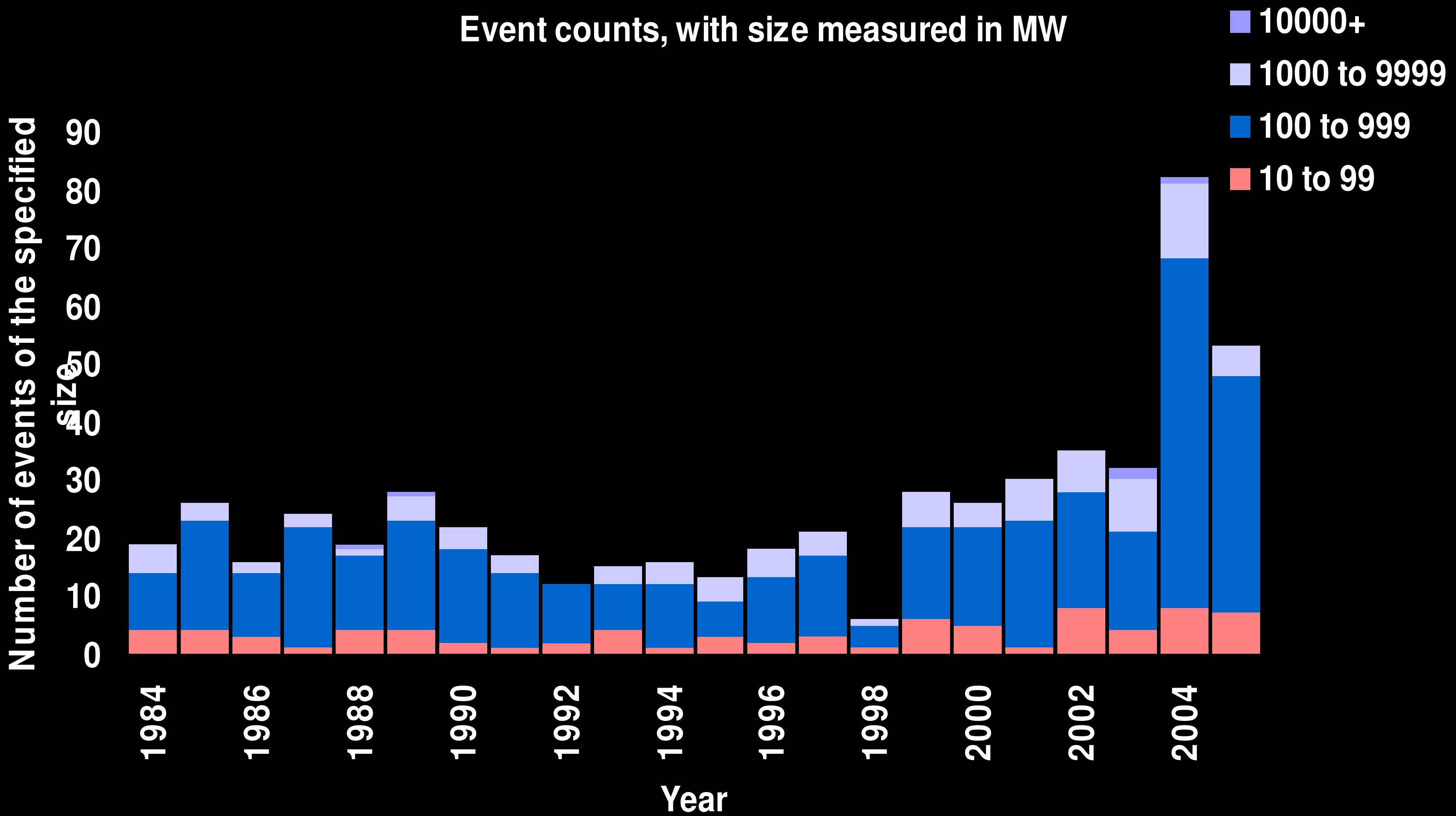
# Customer event counts before scaling



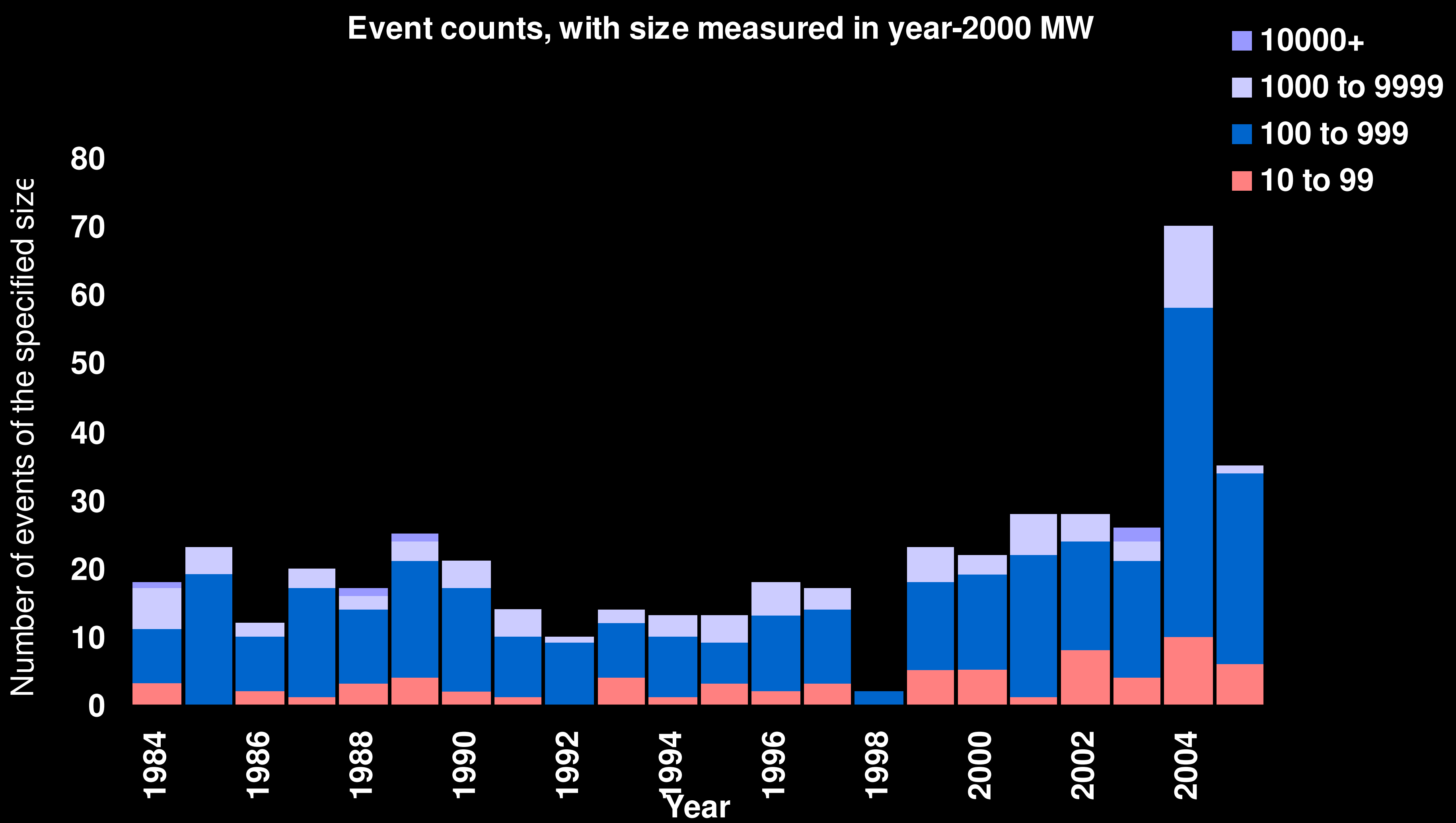
# Customer event counts after scaling



# MW event counts before scaling



# MW event counts after scaling



# Year – frequency correlation

- Tests the hypothesis that the (centered) correlation between years and frequency is significantly different than zero.
- Results:
  - For events 10,000 customers and larger
    - corr. coef = 0.48, P = 0.03
  - For events 10 MW and larger
    - corr. coef = 0.13, P=0.59
- Therefore, there is a slight positive correlation between years and event frequency for customers, not for MW.  No evidence of a negative correlation exists.

# T-test – compare distributions

- Kruskall Wallis t-test
  - Compares the distributions of non Gaussian data.
  - Tests the hypothesis that the medians are significantly different
  - Divide data at 1998.
    - Significant changes after ’96 blackouts.
- Results
  - Events 10,000 customers and larger:
    - Sets significantly different, P=0.005
    - Mean for ’84 – ’97 = 11
    - Mean for ’99 – ’03 = 22
  - Events 10 MW and larger:
    - Sets significantly different, P=0.04
    - Mean for ’84 – ’97 = 15
    - Mean for ’99 – ’03 = 18

# In summary

- There is some statistical evidence that the frequency of blackouts in the US in increasing with time.
- We can therefore safely reject the hypothesis that the frequency is decreasing.
- Why?

# Some possible explanations

- Lack of transmission investment
  - though some increase in last 5 years,
  - new construction in areas where most needed unlikely solution
- Inherent complexity of the system
  - Carrerras, Newman, Dobson, Poole (2005)
  - Proposed solutions are difficult to verify (Talukdar et al., 2003)
- Lack of system-level control of a system-level problem
  - Apt, Lave, Talukdar, Morgan, Ilic (2004)
- Failure of the protection system to address the cascading failure problem.

# Conclusions

- The existing data shows clearly that we are not winning the battle against large blackouts.
- There is some evidence that we may be losing.
- Potential measures include:
  - System-level control.  Changes to the Air Traffic Control system reduced fatal accidents by 97% between 1960 and 2000.
    - ref. Apt. et al 2004
  - Changing the protection system to specifically ensure that the system solves the right problem:
    - Protect the systems ability to deliver energy to customers.
    - ref. Talukdar talk from Wed.