IEEE Standard 1366 – Classifying Reliability (SAIDI, SAIFI, CAIDI) into Normal, Major Event and Catastrophic Days

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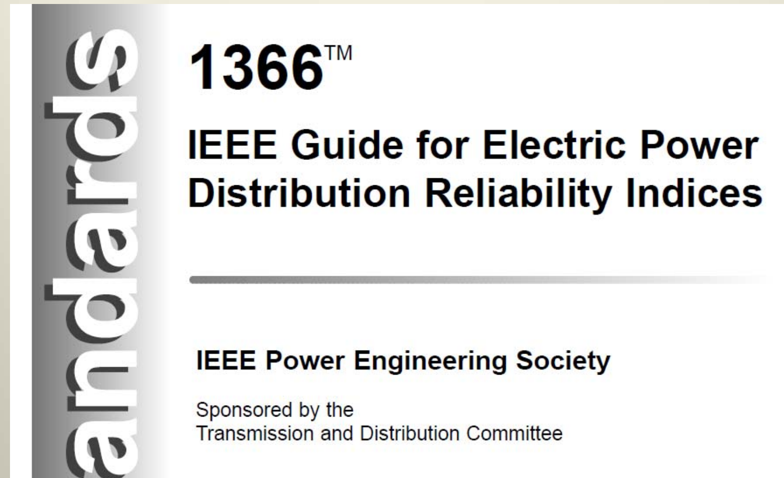
Overview

- IEEE Standard 1366
- Major Event Days
- Catastrophic Days
  - Heuristic
  - Box and Whiskers
  - Robust Estimation

IEEE Standard 1366


standards

1366™

IEEE Guide for Electric Power Distribution Reliability Indices

IEEE Power Engineering Society

Sponsored by the
Transmission and Distribution Committee

- Need to compare utilities
  - If regulators compare utilities, the comparison should be as equitable as possible
- First issued in 1998, then 2001, 2003
- Product of the IEEE Distribution Design Working Group

IEEE Standard 1366

- Defines 12 indices
  - SAIFI, SAIDI, CAIDI, CTAIDI, CAIFI, ASAI, $CEMI_n$, ASIFI, ASIDI, MAIFI, $MAIFI_E$, $CEMSMI_n$
- Defines how indices are calculated
  - $SAIDI = \frac{\sum Customer\ Interruption\ Durations}{Total\ Number\ of\ Customers\ Served}$
- Standardizes Computation
  - How many outages is a recloser event?
  - How long before an outage is sustained?
  - What is a customer?

IEEE Standard 1366

- Defines how to separate reliability into normal and major event reliability
  - Major Event Days (MEDs)

Major Event Days

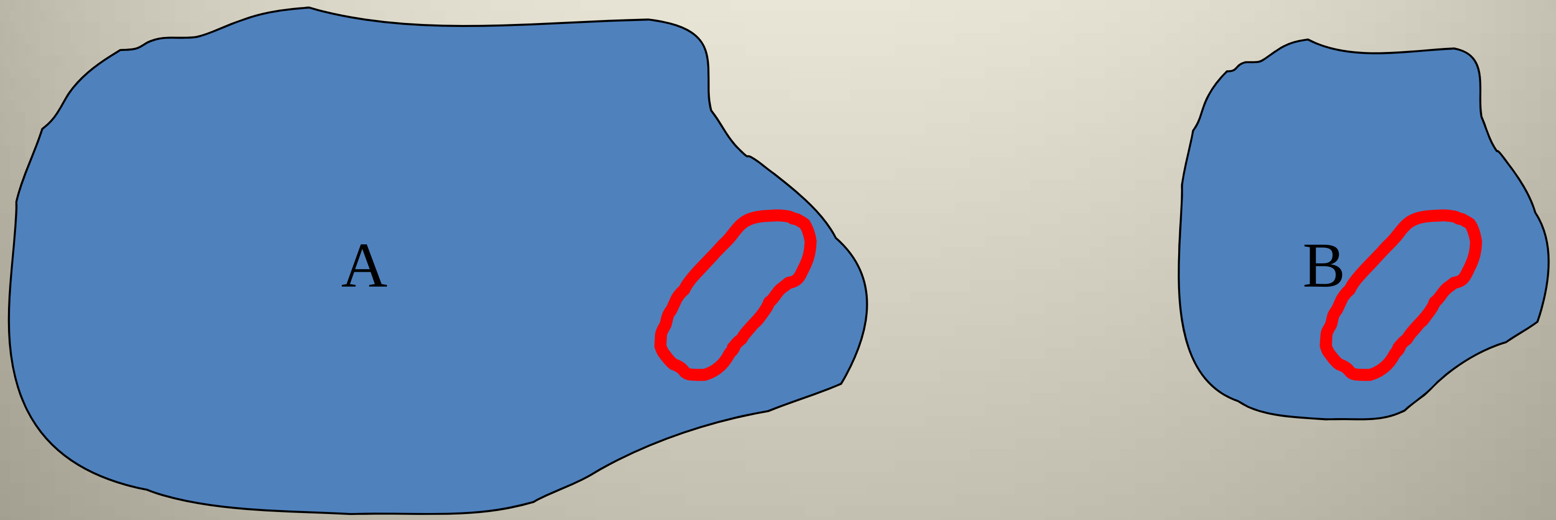
- Some days, reliability r_i is a whole lot worse than other days
  - r_i is SAIDI/day, actually *un*reliabilty
- Usual cause is severe weather: hurricanes, windstorms, tornadoes, earthquakes, ice storms, rolling blackouts, terrorist attacks
- These are Major Event Days (MED)
- Problem: Exactly which days are MED?

Phenomenological MEDs

Designates a catastrophic event which exceeds reasonable design or operational limits of the electric power system and during which at least 10% of the customers within an operating area experience a sustained interruption during a 24 hour period.

- In 1366-1998
- Reflected broad range of existing practice
- Subjective: “catastrophic,” “reasonable”
- Inequitable (10% criterion)
- No one design limit
- No standard event types

10% Criterion



Same geographic phenomenon (e.g. storm track) affects more than 10% of B, less than 10% of A. Should be a major event for both, or neither - inequitable to larger utility.

Frequency Criteria

- Agree on average *frequency* of MEDs, e.g. "on average, 3 MEDs/year"
  - Quantitative
  - Equitable to different sized utilities
  - Easy to understand
  - Translates to probability theory, e.g. "3σ"
  - Consistent with design criteria (withstand 1 in N year events)

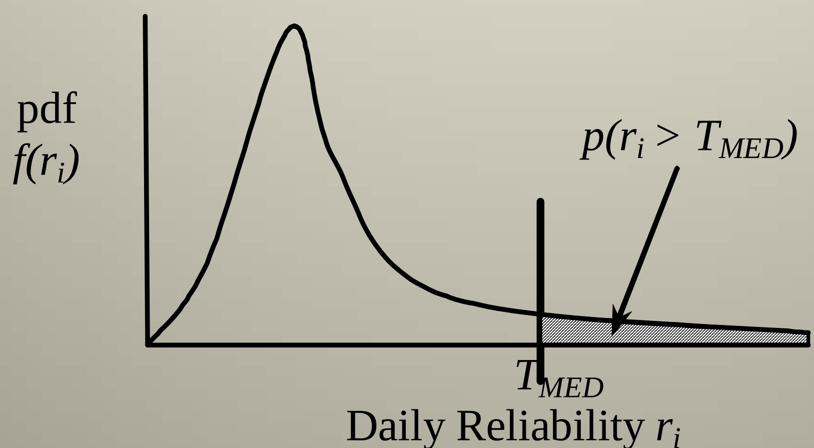
Probability of Occurrence

- Frequency of occurrence *f* is probability of occurrence *p*

$$p = \frac{f}{365}$$

Reliability Threshold T_{MED}

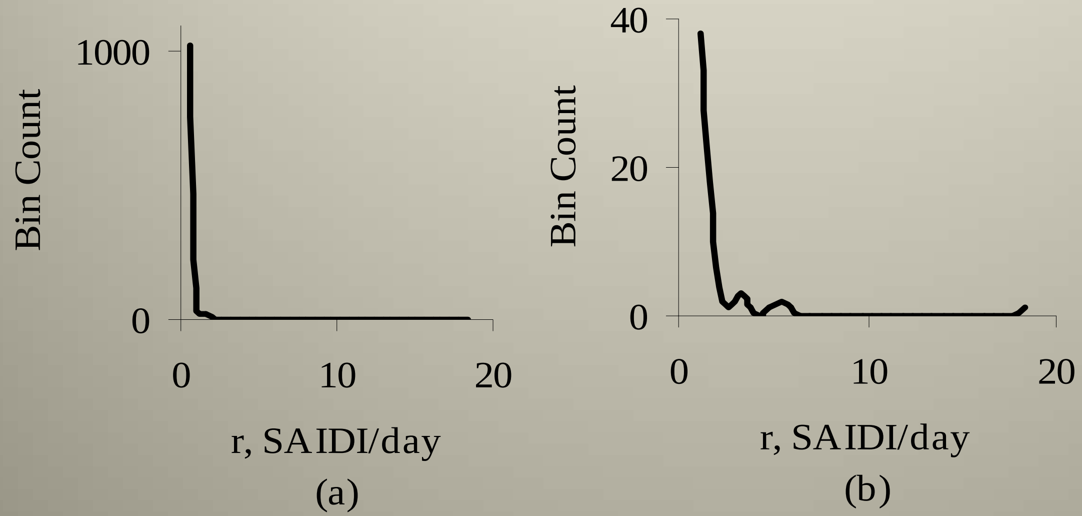
- Find threshold T_{MED} from probability p and probability distribution



- MEDs are days with reliability $r_i > T_{MED}$

Probability Distribution

- 3σ only works for Gaussian (Normal) distribution
- Examine distribution of daily SAIDI:

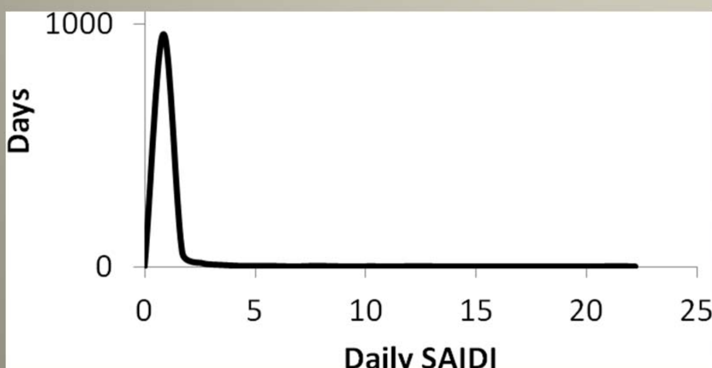


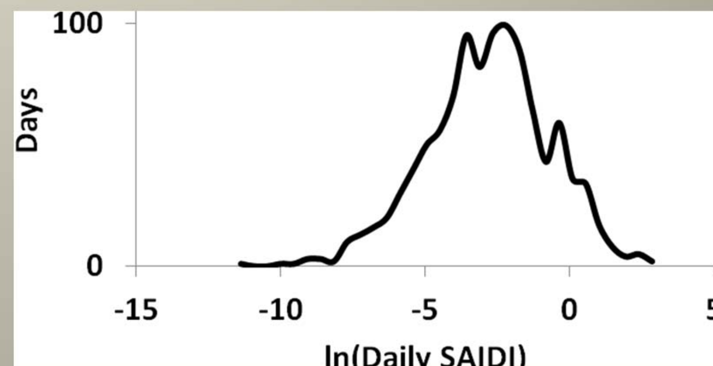
3 yrs of utility data

- Not Normal!

Log-Normal

- Natural logs of the sample data are normally distributed
- Sample data itself is skew





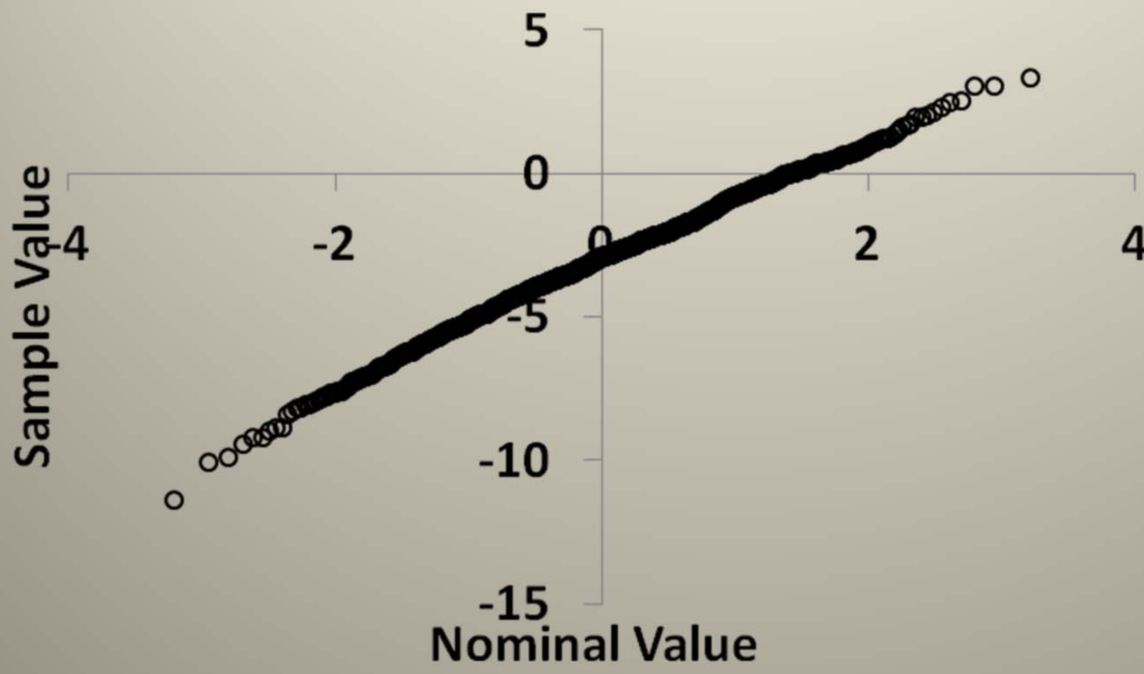
5 years of data, anonymous utility U2

Log-Normal

- Best fit of distributions tests
- Computationally tractable
  - Pragmatically important that method be accessible to typical utility engineer
- Weak theoretical reasons to go with log-normal
  - Loosely, normal process with lower limit has log-normal distribution

Log-Normal

- Not completely Log-Normal – note ends



5 years of data, anonymous utility U2

Finding T_{MED}

- Five years of data
- Find average and standard deviation of distribution of ln of daily SAIDI

$$\alpha = \frac{1}{n}\sum_{i=1}^{n} \ln(r_i)$$

$$\beta = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} \left(\alpha - \ln(r_i)\right)^2}$$

- Compute T_{MED}

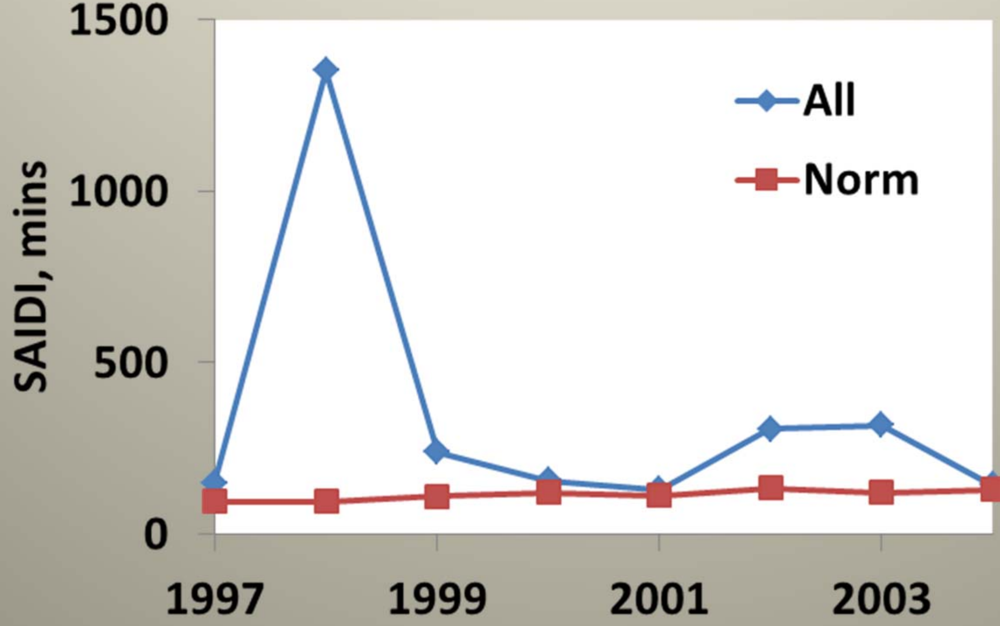
$$T_{MED} = \exp(\alpha + 2.5\beta)$$

Finding T_{MED}

- Why 2.5 (giving the "2.5β Method")?
- Theoretical number of MEDs per year: 2.43
- Real reason is that the Working Group members liked the results using 2.5 better than 2 or 3.
- Liked means:
  - Does not identify too many or too few MEDs
  - Identifies days that ought to be MEDs as MEDs
  - Better MED consistency among subdivisions

2.5β Method

- Method still subjective – but less so
- Adopted in P1366-2001

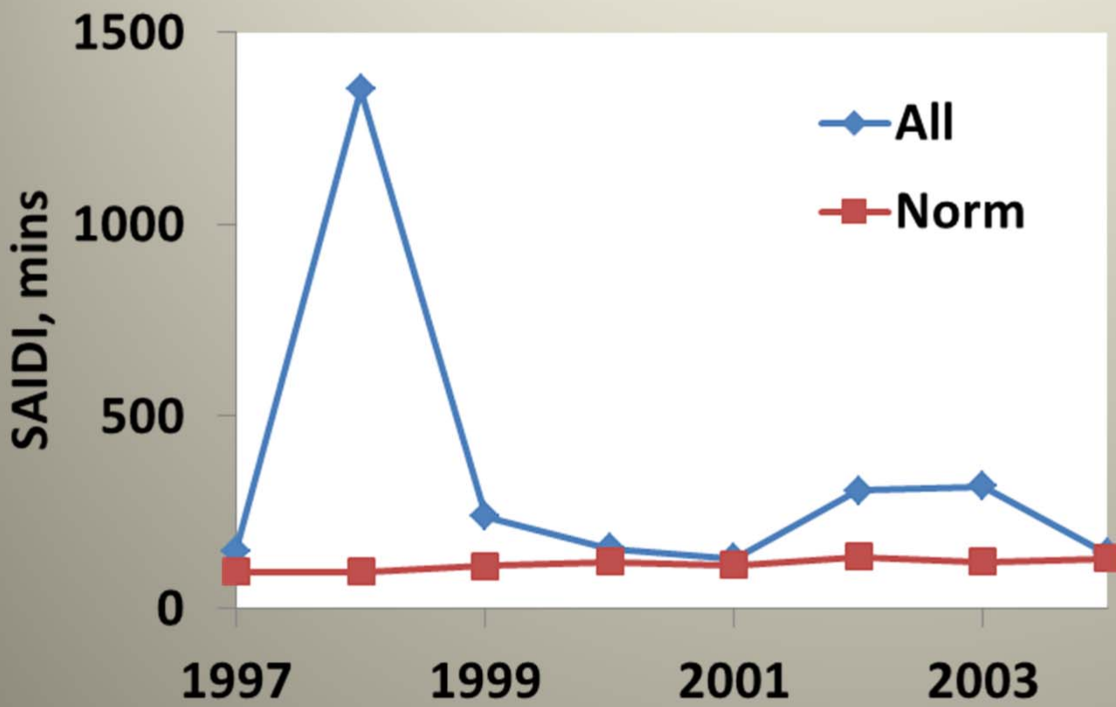


Anonymous utility U29

Catastrophic Days

- Some days are ***really***, ***really*** worse than other days – catastrophic days
- 2.5β removes these days from normal reliability
- But catastrophic days affect the value of T_{MED} for the next five years
- This affects the number of MEDs identified
- This affects normal reliability values

Catastrophic Days



U29 had a possible catastrophic day in 1998

Catastrophic Days

YR	NORM SAIDI	NOCAT SAIDI	T_{MED}	NOCAT T_{MED}	MEDS	NOCAT MEDS
97	94.47	94.47	3.58	3.58	6	6
98	94.91	94.91	3.53	3.53	14	14
99	109.76	105.58	4.30	3.77	9	10
00	121.87	121.87	4.74	4.17	3	3
01	113.58	108.97	4.73	4.33	2	3
02	134.98	130.36	4.74	4.17	8	9
03	121.65	121.65	5.38	4.75	8	8
04	129.98	129.98	4.90	4.90	2	2

Catastrophic Days

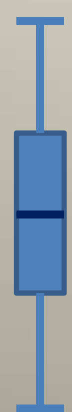
- What to do?
- Outlier removal problem
  - Identify outliers
  - Omit them from the T_{MED} calculation
- How?
  - Heuristic (Xβ)
  - Box and Whiskers
  - Robust Estimation

Heuristic

- Work by Jim Bouford, TRC Engineers LLC
- A Catastrophic Day has SAIDI > Xβ
  - X found heuristically
- 10 utility data sets with subjective “catastrophic days”
- Vary X, examine identified catastrophic days
- X = 4.14 gave good results
- X = 4.15 or X = 4.16 did not
- Clearly not a viable method

Box and Whiskers

- Work by Heidemarie Caswell, Pacific Power
- Use Box and Whisker plot to identify outlying Catastrophic Days



Box and Whiskers

- Tested on a dozen utility data sets
- Subjective assessment – unsatisfactory
- Why?
  - IQR is a robust estimator of standard deviation, β
  - $\hat{\beta} = \frac{IQR}{1.35}$
  - Whiskers at $3.5 \cdot IQR = 4.725\hat{\beta}$
  - Given 4.14β, seems unlikely 4.725 would be better

Robust Estimation

- Work by me
- Sample average and standard deviation are estimates of process average and standard deviation
- There are other ways to estimate
  - Median estimates average

$$\hat{\alpha} = \ln\left(r_{n/2}\right)$$

  - Difference of quartile values (Inter-Quartile Range, IQR) estimates standard deviation

$$IQR = \ln\left(r_{n/4}\right) - \ln\left(r_{3n/4}\right) \qquad \hat{\beta} = \frac{IQR}{1.35}$$

Robust Estimation

- So, just use robust estimates $\hat{\alpha}$ and $\hat{\beta}$ instead of α and β

Robust Estimation

- Example
  - Sample set 0.5, 2.0, 3.1, 3.9, 4.6, 5.4, 6.1, 6.9, 8.0, 9.5 (artificial, normal)
  - Mean 5.0, robust estimate of mean 5.0
  - Standard deviation 2.76, robust estimate 2.81
- With outlier – replace last sample by 100
  - Mean 14.1, robust estimate of mean 5.0
  - Standard deviation 30.3, robust estimate 2.81
- Looks pretty good for the example

Robust Estimation

- More accurate when outliers are present
- Less accurate when outliers are not present

Parameter	Computed Value	Robust Estimate
α	-2.98	-2.91
β	2.15	1.98
T_{MED}	10.9	7.59

Data from U2, which did not have a potential catastrophic day

- Working Group members did not like the routine inaccuracy

Conclusions

- 2.5β does a pretty good job with catastrophic days.
  - Utilities still want a method to identify them.
- No proposed method is subjectively satisfactory.
- The search continues.