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

• 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 unreliability
• 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

• $3\sigma$ 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

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

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

- 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
Catastrophic Days

• Some days are **really, really** worse than other days – catastrophic days
• $2.5\beta$ removes these days from normal reliability
• But catastrophic days affect the value of $T_{\text{MED}}$ 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

<table>
<thead>
<tr>
<th>YR</th>
<th>NORM SAIDI</th>
<th>NOCAT SAIDI</th>
<th>T&lt;sub&gt;MED&lt;/sub&gt;</th>
<th>NOCAT T&lt;sub&gt;MED&lt;/sub&gt;</th>
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<th>NOCAT MEDS</th>
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<td>8</td>
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<tr>
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<td>129.98</td>
<td>4.90</td>
<td>4.90</td>
<td>2</td>
<td>2</td>
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</tbody>
</table>
Catastrophic Days

• What to do?

• Outlier removal problem
  – Identify outliers
  – Omit them from the $T_{MED}$ calculation

• How?
  – Heuristic ($X\beta$)
  – 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

**Inter-Quartile Range**

- $IQR = Q3 - Q1$
- $Q1 - 3IQR$
- $Q3 + 3IQR$

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Catastrophic Days
Box and Whiskers

• Tested on a dozen utility data sets
• Subjective assessment – unsatisfactory
• Why?
  – IQR is a robust estimator of standard deviation, $\beta$
    
    $\hat{\beta} = \frac{IQR}{1.35}$
  – Whiskers at $3.5 \cdot IQR = 4.725\hat{\beta}$
  – Given $4.14\beta$, 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
    \[ \hat{\alpha} = \ln(r_{n/2}) \]
  – Difference of quartile values (Inter-Quartile Range, IQR) estimates standard deviation
    \[ IQR = \ln(r_{n/4}) - \ln(r_{3n/4}) \]
    \[ \hat{\beta} = \frac{IQR}{1.35} \]
Robust Estimation

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

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>COMPUTED VALUE</th>
<th>ROBUST ESTIMATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>-2.98</td>
<td>-2.91</td>
</tr>
<tr>
<td>$\beta$</td>
<td>2.15</td>
<td>1.98</td>
</tr>
<tr>
<td>$T_{MED}$</td>
<td>10.9</td>
<td>7.59</td>
</tr>
</tbody>
</table>

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.