A Quantitative Assessment of Utility Reporting Practices for Reporting Electric Power Distribution Events

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***Abstract*--Metrics for reliability, such as the frequency and duration of power interruptions, have been reported by electric utilities for many years. This study examines current utility practices for collecting and reporting electricity reliability information and discusses challenges that arise in assessing reliability because of differences among these practices. The study is based on reliability information for year 2006 reported by 123 utilities in 37 states representing over 60% of total U.S. electricity sales. We quantify the effects that inconsistencies among current utility reporting practices have on comparisons of System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) reported by utilities. We recommend immediate adoption of IEEE Std. 1366-2003 as a consistent method for measuring and reporting reliability statistics.**

***Index Terms*-- Distribution system, power distribution reliability, reliability indices.**

I. Introduction

A common management precept is that you cannot manage something effectively unless you can measure it. Performance metrics, similar to the letter grades assigned in school, are a way to quantitatively measure reliability and improvements in it. The electric utility industry has developed a number of performance metrics for measuring reliability. These metrics, such as the frequency and duration of power interruptions, have been essential tools for managing reliability because they provide a quantitative, objective basis for judging the effectiveness of the organization's efforts to maintain or improve reliability.

Reliability metrics have been used by electric utilities for some time. While the basic principles underlying the formulation of these metrics were similar, the details of their definition and use often reflect local considerations including requirements agreed to in conjunction with state utility regulatory commissions. As a result, there are often differences in ways utilities track and record reliability metrics [1]-[2]. These differences make comparisons difficult, if not impossible. The Institute of Electrical and Electronics Engineers (IEEE) Standard 1366-2003, IEEE Guide for Electric Power Distribution Reliability Indices represents the most comprehensive effort by industry to date to increase consistency among reliability reporting practices [3].

Reliability depends on, among other things:

- Environmental conditions (e.g., severity of weather)
- Types of customers served (e.g., rural vs. urban)
- Design of electricity distribution system (e.g., radial vs. network)
- Operation and maintenance of the electricity distribution system (e.g., vegetation management)
- Restoration capabilities (e.g., outage management systems and staffing)

Reliability metrics play a central role in relating reliability performance to factors that are within the ability of a utility to influence (e.g., design, operation and maintenance, and restoration capabilities) as well as those that are outside the ability of a utility to influence (e.g., environmental conditions and types of customers).

Why is it important to eliminate inconsistencies among utility reliability reporting practices? First, inconsistencies among practices compromise our ability to determine whether differences among utility reliability performance are the result of differences in the material factors (listed above) that affect reliability or whether they are simply the result of differences in reporting practices. Second, until reliability performance can be tied to the factors that lead to true, material differences, it is not possible to confidently identify best practices or assess the transferability of the options available for improving reliability.

To further demonstrate the need for greater consistency in utility reliability reporting practices, this paper quantifies the significance of differences in utility reporting practices for two commonly reported reliability metrics, System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI). We pay special

The work described in this paper was funded by the Office of Electricity Delivery and Energy Reliability of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

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attention to the effect of the recent adoption of the IEEE Standard 1366-2003, which formally defines these metrics and the factors and procedures for calculating them. In a major enhancement to prior versions of the standard, the standard now provides a consistent method for segmenting non-routine events, called major events, from the calculation of SAIDI and SAIFI. A number of studies have been done that stress the importance of separating major event days and how best to do so [4]-[5].

To conduct the study, we gathered information from 123 utilities across the U.S. on practices and rules related to utility-reported reliability information for year 2006 [6]. The remainder of this paper is organized as follows: Section II presents and discusses the apparent significance of differences in regional trends of SAIDI and SAIFI. Section III examines the impact of differences in practices for defining sustained interruptions. Section IV examines the impact of differences in practices for segmenting SAIDI and SAIFI using major events, including the definitions of major events. Section V further examines the impact of these differences by comparing reported values for utilities that reported SAIDI and SAIFI both with and without major events included. Section VI examines whether we can detect bias in segmenting SAIDI and SAIFI using the definition of major event days from IEEE Standard 1366-2003 compared to segmentation using prior definitions of major events. Lastly, Section VII summarizes our findings and conclusions.

II. Regional Trends in SAIDI and SAIFI

The data in Table I represent summary statistics (number of observations, simple and weighted averages, and standard deviation) for the reliability information (SAIDI and SAIFI) we received aggregated to regions as defined by the nine U.S. Census Divisions [7]. Table I also provides two indicators of the representativeness of the information we received for each region: 1) the electricity sales by the utilities for which we have reported information as a percentage of the total electricity sales by all state-regulated investor-owned utilities within that region; and 2) the electricity sales by the utilities for which we have reported information as a percentage of the total electricity sales by all electric utilities (both state-regulated and non-state-regulated) within that region. Information on electricity sales is taken from EIA Form 861 [8].

As reflected in Table I, the information we collected accounts for over three-quarters of total electricity sales by state-regulated utilities or nearly 60% of total U.S. electricity sales. However, the representativeness of the information we collected varies by region. For some regions (Middle Atlantic, New England, and Pacific), we received information representing essentially all electricity sales by state-regulated utilities within these regions. For other regions (East North Central, South Atlantic, and West South Central), we received information representing more than 70% of electricity sales by state-regulated investor-owned utilities within these regions. For the remaining regions (Mountain, West North Central, and East South Central) we received information representing progressively lower proportions of electricity. For East South Central, we received no information for any of the ten state-regulated utilities within this region.

All 123 utilities reported SAIDI and SAIFI (and/or CAIDI, which along with SAIFI can be used to calculate SAIDI).

In general, one might expect reliability to vary because of regional differences in climate, vegetation, and population. Visual review of the information we collected averaged by region shows greater variation in SAIDI than in SAIFI. A greater than two-to-one difference can be seen in average SAIDI, ranging from a low of 118 minutes in the Mountain region to a high of 498 minutes in East North Central. Variations in average SAIFI are smaller, ranging from a low of 1.22 in Mountain to a high of 1.99 in Pacific. However, despite the ranges observed in average SAIDI and SAIFI, the high standard deviations associated with them indicate that the differences among regions are not statistically significant.

TABLE I. SUMMARY OF UTILITY-REPORTED SAIDI AND SAIFI BY CENSUS DIVISION

Census Division	Sales as Percentage of Total IOU Sales in Region	Sales as Percentage of Total U.S. Sales in Region	SAIDI (minutes)				SAIFI			
			N	Avg	Std Dev	Wgt Avg	N	Avg	Std Dev	Wgt Avg
New England	99%	68%	16	198	130	252	16	1.44	0.62	1.46
Middle Atlantic	100%	75%	21	225	188	305	21	1.28	0.55	1.13
East North Central	75%	62%	19	498	895	448	19	1.46	0.48	1.48
West North Central	57%	35%	12	166	202	112	12	1.31	0.68	1.09
South Atlantic	71%	53%	18	320	200	245	18	1.86	0.62	1.43
East South Central	0%	0%	ND	ND	ND	ND	ND	ND	ND	ND
West South Central	88%	30%	18	134	56	137	18	1.38	0.46	1.38
Mountain	35%	27%	7	118	58	133	7	1.22	0.54	1.47
Pacific	99%	62%	12	296	214	254	12	1.99	1.21	1.37
U.S.	77%	58%	123	244	243	236	123	1.49	0.64	1.35

Note: ND = no data

Although we observe discernable (though not statistically significant) trends or differences among regions, the process of aggregating the data regionally made us aware of differences among utility practices for defining and presenting reliability information. As noted in the introduction, without a better understanding of the impact of these differences on the reported information, it is difficult to ascribe the trends we observe to material differences in reliability among utilities.

We then focused on reviewing and attempting to quantify the impact of selected differences in reporting practices on reported reliability metrics.

III. Utility Practices for Defining Sustained Interruptions

The SAIDI and SAIFI indices measure the duration and frequency, respectively, of sustained interruptions. A sustained interruption is any interruption that is not classified as a momentary event. Although this definition ensures that all power interruptions are classified as either sustained or momentary, utility definitions of the difference between sustained and momentary vary. Fig. 1 shows the definitions for sustained interruptions that we found in the utility-reported reliability information we collected.

The most common definition of a sustained interruption is one that is greater than or equal to 5 minutes in duration, which is consistent with IEEE Standard 1366-2003 (and prior versions of this standard). Still, a fair number of utilities use other definitions. For example, nearly a quarter of the utilities (28) use a shorter duration (one or two minutes) for sustained interruptions.

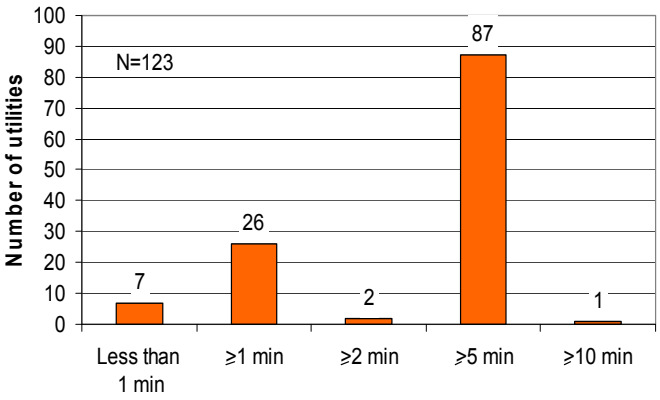

Fig. 1. Utility Practices for Defining Sustained Interruptions

First principles suggests that differences in utility practices regarding the minimum duration used to classify an interruption as sustained would tend to affect SAIFI more than SAIDI. We examined this suggestion by comparing the reliability metrics reported by the two largest subsets of utilities grouped according to the definitions they used to specify the duration of a sustained interruption.

Table II compares SAIDI and SAIFI (both not including major events as defined by each electric utility) for the 76 utilities that define a sustained interruption as lasting 5 minutes or longer to the 19 utilities that define a sustained interruptions as lasting 1 minute or longer. We find that these differences in definitions do not represent, by themselves, statistically significant differences in reported SAIDI or SAIFI between these two groups.

TABLE II. SUMMARY OF UTILITY-REPORTED SAIDI AND SAIFI WITH MAJOR EVENTS NOT INCLUDED FOR UTILITIES USING 1-MINUTE AND 5-MINUTE DEFINITIONS FOR SUSTAINED INTERRUPTIONS

	SAIDI		SAIFI	
	5 min	1 min	5 min	1 min
Average	165	143	1.3	1.4
Std Dev	97	63	0.5	0.7
Median	145	151	1.3	1.3
N	78	19	78	19

IV. Utility Practices for Segmenting Reliability Information Based on Major Events

Major events are defined by a variety of criteria that seek to differentiate between routine power interruptions and non-routine or extraordinary power interruptions. Utility practices vary regarding the treatment of major events in reporting reliability metrics, including SAIDI and SAIFI. Some utilities report reliability metrics with major events included; others report these metrics with major events not included. And some utilities report the metrics both with major events included and not included.

Table II was developed by averaging a single SAIDI and SAIFI value from each utility for which we had reported information. We sought first to include values reported with major events included. However, when a utility reported only values with major events not included, we used that value. Table III gives a more complete picture of all the reliability information we received as it presents summary statistics on SAIDI and SAIFI both with major events included and not included.

Table III indicates that we received more SAIDI and SAIFI values without major events included than with major events included. The averages of SAIDI and SAIFI with major events are generally larger than those with major events not included and the differences can be significant. For example, the average SAIDI with major events is more than twice the average SAIDI with major events not included for the East North Central region.

Higher averages for figures that include major events is a predictable result; i.e., if some events are not included, then the resulting values of SAIDI and SAIFI should be lower. However, this is not always the case. The average SAIDI with major events not included is higher than the average SAIDI with major events included for the West South Central region.

TABLE III. SUMMARY OF GROSS UTILITY-REPORTED SAIDI AND SAIFI WITH MAJOR EVENTS INCLUDED AND NOT INCLUDED

Census Division	SAIDI						SAIFI					
	With Major Events Included			With Major Events Not Included			With Major Events Included			With Major Events Not Included		
	N	Avg	Std Dev	N	Avg	Std Dev	N	Avg	Std Dev	N	Avg	Std Dev
New England	7	260	196	17	148	88	7	1.40	0.66	17	1.26	0.61
Middle Atlantic	7	399	239	21	156	97	7	1.54	0.73	21	1.13	0.44
East North Central	19	498	895	15	150	60	19	1.46	0.48	15	1.24	0.19
West North Central	6	256	263	12	107	84	6	1.58	0.87	12	1.25	0.64
South Atlantic	15	350	207	18	212	111	15	1.94	0.65	18	1.50	0.40
East South Central	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
West South Central	10	114	47	18	126	58	10	1.24	0.50	18	1.33	0.46
Mountain	5	126	68	5	112	60	5	1.22	0.61	5	1.20	0.58
Pacific	9	332	238	12	156	71	9	1.93	1.21	12	1.59	0.95
U.S.	78	292	269	118	146	79	78	1.54	0.71	118	1.31	0.53

Although the number of utility reports contributing to these averages is identical, comparison between Table III and Table I confirms that different utilities comprise each of these averages. Although there is some overlap between the utilities whose reported information contributes to both averages (i.e., utilities that report SAIDI and SAIFI both with major events included and not included), many reported values are also included from utilities that reported SAIDI and SAIFI either with major events included or with major events not included (but not both).

The above review makes clear that treatment of major events in SAIDI and SAIFI must be taken into account when reviewing utility-reported reliability information. In the next section, we focus on direct examination of the significance of differences in practices for reporting SAIDI and SAIFI.

V. REPORTING SAIDI AND SAIFI WITH MAJOR EVENTS INCLUDED AND NOT INCLUDED

As discussed above, it is difficult to assess the effect of reporting SAIDI and SAIFI with major events included and not included when the utility reports that represent this information do not all include both pieces of information. Fortunately, 71 of the 123 utility reports we reviewed reported SAIDI and SAIFI both with and without major events included. By focusing on these 71 reports, we can directly examine the effect of this difference in reporting practices.

Fig. 2 and Fig. 3 represent the distributions of the reported values and summary statistics for these 71 utility reports of SAIDI and SAIFI, respectively.

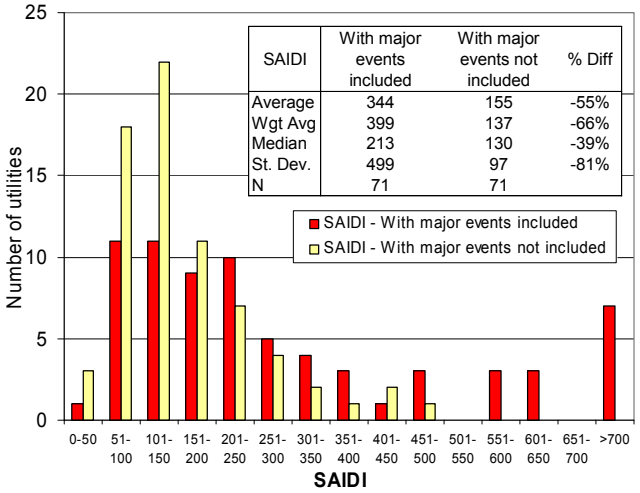

Fig. 2. Distribution of and Summary Statistics for SAIDI Reported With Major Events Included and Not Included

The effect of reporting with major events not included is clearly visible in the shift of the distributions for SAIDI and SAIFI when major events are included. The average SAIDI decreases by more than half (-55%) and the standard deviation is reduced by more than three quarters (-81%). The average, median, and standard deviation for SAIFI decrease by about one-quarter (-21%, -24%, and -28%, respectively). This significant shift highlights the need to derive a consistent approach for treating major events in the reported statistics.

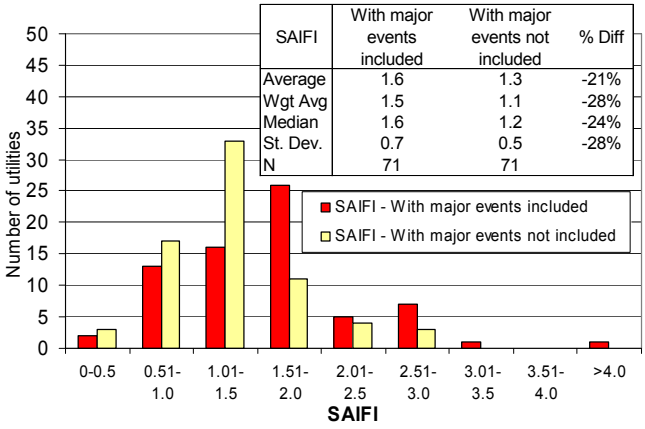

Fig. 3. Distribution of and Summary Statistics for SAIFI Reported With Major Events Included and Not Included

VI. USING IEEE STANDARD 1366-2003 TO SEGMENT SAIDI AND SAIFI WITH MAJOR EVENT DAYS

IEEE Standard 1366-2003 is a voluntary industry effort to develop standard definitions and procedures for measuring and reporting reliability performance. Adoption of such a standardized approach would greatly simplify review of this information and improve assessment of utility-reported reliability information because it would eliminate differences in the reported information that are due solely to differences in reporting practices.

However, adoption of the standard is in its infancy. As noted earlier, only four states formally require utility reporting using the standard and, among the 123 utilities for which we have information, 14 utilities reported reliability information using the standard.

Among these 14 utility reports, 9 give sufficient information to enable a preliminary assessment of the impact of using the new standard. That is, these 9 reported SAIDI and SAIFI calculated using both the concept of Major Event Days embodied in the standard as well using the former definition for major events to segment the reliability information.

Fig. 4 shows the differences in the reported SAIDI and SAIFI that result from application of the two different procedures for segmenting the information. The differences are expressed as a percentage difference between the two values that result from use of each procedure.

From this preliminary examination, we find that there is no discernable bias introduced by use of the segmentation procedure embodied in the new IEEE standard compared to former practices for segmenting the information. That is, in several instances use of the procedure in the new standard leads to higher SAIDI and SAIFI values; in other instances it leads to lower values. Moreover, in this limited sample, the number of higher and lower values is roughly equal.

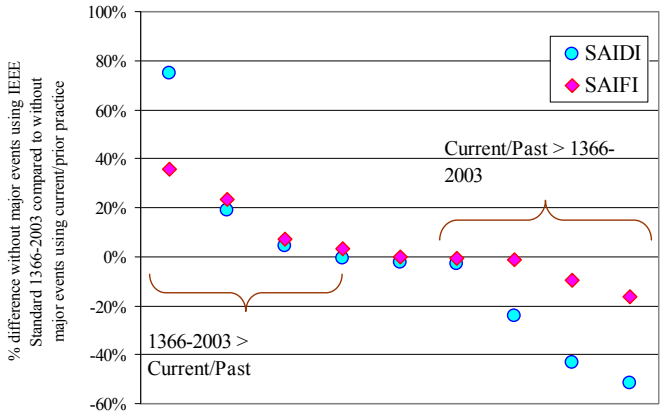

Fig. 4. Comparison of SAIDI and SAIFI Without Major Events for 9 Utilities that Reported Using both IEEE Standard 1366-2003 and Current/Prior Practice for Segmenting

VII. Findings and Conclusions

We reviewed reliability information provided by 123 utilities from 37 states. In aggregate, the information of reliability performance for utilities represents nearly 60% of total U.S. electricity sales. We assessed quantitatively aspects of utility practices for collecting and reporting on the two most common reliability metrics: SAIDI and SAIFI.

Our findings regarding utility practices for collecting and reporting reliability information are summarized as follows:

- Differences in the definition of a sustained interruption do not appear to affect SAIDI or SAIFI in a statistically significant manner.
- Utilities define major events as a means for distinguishing between utility performance in planning for and responding to routine interruptions versus that for non-routine or extraordinary interruptions.
- The definition of a major event is not consistent among the majority of utilities.
- IEEE Standard 1366-2003 introduces a consistent means for defining major events using the concept of "major event days."
- Some utilities report SAIDI and SAIFI both including and not including major events; other utilities only report SAIDI and SAIFI not including major events.
- When major events are not included, SAIDI is lowered relatively more than SAIFI compared to when major events are included.
- Many utilities report descriptive information on each major event
- Use of IEEE Standard 1366-2003 does not appear to bias SAIDI or SAIFI values compared to using prior definitions of major events.

From these findings, we draw the following conclusions and recommendations:

- Differences in utility reporting practices hamper meaningful comparisons of reliability information reported by utilities and, therefore, may limit the effectiveness of efforts to measure the effectiveness of efforts to improve reliability.
- Efforts to eliminate differences that are solely due to reporting practices are just beginning. These efforts, which focus on using standard definitions, such as those promoted by IEEE Standard 1366-2003, are promising and should be encouraged.
- Until IEEE Standard 1366-2003 or some other consistent measure of quantitatively measuring the reliability of the electric utility industry is adopted universally, those concerned about the definition and treatment of major events in reporting reliability information should consider reporting of SAIDI and SAIFI both including and not including major events, as well as descriptive information on each major event.

VIII. References

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IX. Biographies

Joseph H Eto (M'1987) is a staff scientist in the Environmental Energy Technologies Division of the Lawrence Berkeley National Laboratory. He has authored over 150 publications on electricity policy, electricity reliability, transmission planning, cost-allocation, demand response, distributed energy resources, utility integrated resource planning, demand-side management, and building energy-efficiency technologies and markets. He holds an A.B. in philosophy and an M.S. in energy and resources, both from the University of California, Berkeley, and a registered professional Mechanical Engineer in the State of California.

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