BEFORE

THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Application of Duke Energy Ohio, Inc., to Establish Minimum Reliability Performance Standards Pursuant to Chapter 4901:1-10, Ohio Administrative Code.	)))))	Case No. 16-1602-EL-ESS

REPLY COMMENTS OF DUKE ENERGY OHIO, INC.

I. Introduction

Duke Energy Ohio, Inc. (Duke Energy Ohio or Company), submitted an application in this proceeding for approval of proposed reliability standards to the Public Utilities Commission of Ohio, (Commission) on July 22, 2016. The Office of the Ohio Consumers' Counsel, (OCC) moved to intervene October 5, 2016 and filed comments on February 22, 2017. The Staff of the Public Utilities Commission of Ohio, (Staff) submitted comments on March 6, 2017. Pursuant to the procedural schedule, Duke Energy Ohio submits the following comments in reply to those of the Staff and OCC.

II. Comments in Response to the Staff

1. Current Performance Standards

Staff's comments consist of a mix of factual observations and the conclusions that do not necessarily flow from the facts as stated. However, it is possible, after reviewing Staff's comments, to discern what issues are relevant in determining appropriate reliability standards. Staff's first factual finding is that the Company has met its approved performance standards for each of the last five years. Staff and the Company agree upon data that can be considered, in part, to establish new standards.

2. Customer Perception Survey

Staff next states that the Company has properly conducted a customer perception survey, and that results appear to establish that the Company's current reliability performance is exceeding customer expectations with respect to storm related outages. Staff further observes that with respect to outages not related to storms, customers expect service to be restored in approximately 65 minutes. Staff observes that this standard is not being met. This relates to the Customer Average Interruption Duration Index (CAIDI) which will be addressed further below.

3. Self-Healing Team Performance

Staff provided an overview of the successful operation of self-healing teams and states that it expects the Company to make continual progress toward improving the rate at which self-healing teams operate. Duke Energy Ohio agrees that this is the goal and it is anticipated that such improvements are occurring and will continue to do so.

4. Distribution Capital Investment Rider

In its comments, Staff provides details describing Duke Energy Ohio's Distribution Capital Investment Rider (Rider DCI). Staff correctly recognizes that this Rider is designed to permit the Company to be proactive in responding to maintenance and hardening of its distribution system. Rider DCI programs allow the Company to continuously maintain current standards and to avoid erosion of the system due to aging infrastructure. In Duke Energy Ohio's third electric security plan proceeding, the Commission recognized that the Company "is correct to aspire to move from a reactive to a more proactive maintenance program."[1] The Commission further recognized that "it is detrimental to the state's economy to require the utility to be reactionary or allow the performance standards to take a negative turn before we encourage the

[1] *In the Matter of the Application of Duke Energy Ohio for Authority to Establish a Standard Service Offer Pursuant to Section 4928.143, Revised Code, in the Form of an Electric Security Plan, Accounting Modifications and Tariffs for Generation Service*, Case No. 14-841-EL-SSO, *et al.*, Opinion and Order (April 2, 2015), p.71.

EDU to proactively and efficiently replace and modernize infrastructure... ."[2] Rider DCI was never proposed as a means by which to change the reliability indices, but rather to maintain existing conditions to avoid worsening of performance.

5. Staff's Conclusion and Recommendation

After detailing and summarizing the four factors above, Staff states that it does not believe the Company has appropriately accounted for impacts of SmartGrid or non-SmartGrid system improvements. After making this unsupported statement Staff then jumps to the conclusion and further recommends that the current standards remain in place until such time that the Company can demonstrate sufficient justification for reevaluation. How Staff got from its facts to its conclusion is unexplained.

The historic data provided by the Company in its application necessarily incorporates the effects of deployment of Smart Grid and non-smart grid improvements. Staff's claim that the Company has not appropriately accounted for impacts overlook this reality. Historic results demonstrate the positive effect that deployment of Smart Grid has had on the distribution system and the Company's consistently improving SAIFI bears this out.

With respect to CAIDI however, it appears that Staff misunderstands the dynamic of this number. As CAIDI is a calculation of SAIDI over SAIFI, it is mathematically certain that CAIDI will increase as the Company reduces the number of short duration outages that customers experience. Accordingly, the rise in CAIDI can be seen as a positive outcome in some respects. It is possible, indeed likely, for reliability to improve while CAIDI is increasing with both SAIFI and SAIDI improving, but at differing rates.

[2] Id.

Because of this counter-intuitive dynamic, CAIDI is generally regarded as a problematic measure of reliability. For example, a leading expert in distribution reliability and Institute of Electrical and Electronics Engineers (IEEE) Fellow, states as follows:

> "Although popular with many utilities and regulators, CAIDI is problematic as a measure of reliability. In this authors opinion, this is because CAIDI does not mean what most think. Many view CAIDI as a measure of operational efficiency; when the utility responds more quickly after a fault, CAIDI will go down. This is true, but only part of the story. In fact, CAIDI is mathematically equal to SAIDI divided by SAIFI. Therefore, CAIDI will increase if SAIFI improves more quickly than SAIDI. That is, reliability could be improving in both frequency and duration, but CAIDI could be increasing.
>
> Consider a utility embarking on reliability improvement initiatives. Typically, the most effective initial activities will focus on faults that occur frequently but are relatively quick and easy to fix (e.g. animal problems). When the quick and easy problems are solved, the remaining interruptions on the system will take longer to repair, causing CAIDI in increase. This situation is common and has caused frustration at many utilities; reliability is improving but CAIDI is increasing. To avoid this problem, the author recommends against using CAIDI, preferring the use of SAIFI and SAIDI, which are mathematically equivalent."[3]

For an even clearer picture of how improvements being made by the Company parallel the above text, see Attachment 1, illustrating that the total number of outages customers are experiencing is improving over time and a 15.8% reduction between 2011 and 2015. Additionally, the number of outage events between 6 and 120 minutes have reduced by 27% between 2012 and 2015, see Attachment 1 and related graphs. This supports the company's view that reliability is improving, and that it is also necessary to allow for an increased CAIDI standard.

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[3] Richard E. Brown, PhD, PE, *The Perils of Reliability Benchmarking*, IEEE Power and Energy Magazine (Volume 10, Issue 2, March/April 2012)(Attachment 2).

Thus, Staff is recommending that the Company maintain the status quo while at the same time continuing to make improvements to the system. However, it is certain that CAIDI will rise, and the Company will then miss the compliance standard that Staff proposes. As a result of setting the CAIDI standard at a level that is sure to be too restrictive, it will necessarily cause additional regulatory and administrative burden on both Staff and the Company. There is no value to be gained by doing so. Allowing a two standard deviations from the trend line, obviates this unnecessary exercise while still allowing for continued improvements to the system as a result of distribution investment or innovation.

III. Comments in Response to the OCC

1. Reliability Investment

While introducing its comments, OCC points to the investment made by customers for smart grid in Duke Energy Ohio's service territory, but OCC conspicuously neglects to also mention that the Company has returned over $58 million to customers from savings associated with smart grid deployment. Moreover, improved reliability that is established by the Company's lower SAIFI numbers over the past six years is directly tied to this investment. So customers have benefited significantly from their investment already. It is the Company's expectation that this investment will continue to provide value to customers over the long term despite OCC's efforts to argue the contrary.

2. Misapplication of the CAIDI Measurement

OCC's comments, like Staff's comments, point to an increase in CAIDI standards and argue that this demonstrates a lessening of service quality. These comments reflect a misunderstanding of how CAIDI is calculated and a misapplication of this reliability index. As outage frequency and duration improve, however at differing rates, CAIDI will rise. Staff acknowledged this fact in stating that CAIDI would have a lower result if not for self-healing team installations. Conversely, removing a self-healing team, will cause CAIDI to drop Moreover, when CAIDI rises mathematically, it does not mean that any individual customer sees a longer outage time. Outage times remain the same. Only the calculation changes due to changes in SAIDI and SAIFI. As an illustration of this dynamic, please see Attachment 3 included with these comments that illustrates the calculation and the increase in CAIDI resulting from an decrease in SAIFI.

3. Investment in Distribution System Maintenance and Hardening

OCC next explains that the Commission approved a Distribution Capital Investment Rider (Rider DCI) and that because of this investment, CAIDI should be lower. As noted above, this demonstrates a misunderstanding of CAIDI and also a misunderstanding of the purpose of Rider DCI. The Company proposed Rider DCI as a means by which to make investment in infrastructure modernization and system hardening. When explaining the need for updating and modernizing the distribution system, the Company explicitly noted that the work would not necessarily cause improvements in reliability indices, but rather, would help to sustain existing improvements and avoid degradations. Again, OCC seems to ignore this information and reargue matters that were dealt with in the Company's last ESP III proceeding.

4. Compliance with Staff Guidelines

OCC also argues that the Company's proposed standards do not comply with Commission Staff's Guidelines because the Company based its proposal on numbers obtained from a trend line rather than from historic data. However, the trend line itself is established from historic data as required by Staff Guidelines. Thus, the methodology proposed is entirely consistent with the Guidelines and is a logic basis for establishing future compliance standards.

5. Determination of the Case on the Record

Finally, OCC requests that the Commission hold a hearing on these matters and also hold local public hearings. With respect to the request for local hearings, OCC states that "The local public hearing(s) would help the PUCO be better informed about consumers' views on the reliability of service provided by Duke." However, OCC overlooks the fact that the Commission does take consumer views into account by requiring that the Company conduct and provide the results of a customer survey along with its Application. As noted by Staff, the Company did provide its survey and the Company's current reliability performance is exceeding customer expectations in respect to outages, etc. So it would be unduly burdensome and redundant to require additional local public hearings in this case.

IV. Conclusion

For the foregoing reasons, and those set forth in the Company's Amended Application, Duke Energy Ohio respectfully requests that the Commission approve its proposed SAIFI and CAIDI standards as set forth therein.

Respectfully submitted,

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CERTIFICATE OF SERVICE

I hereby certify that a true and accurate copy of the foregoing was delivered via U.S. mail (postage prepaid), personal, or electronic mail delivery on this the 24th day of March 2017, to the following:

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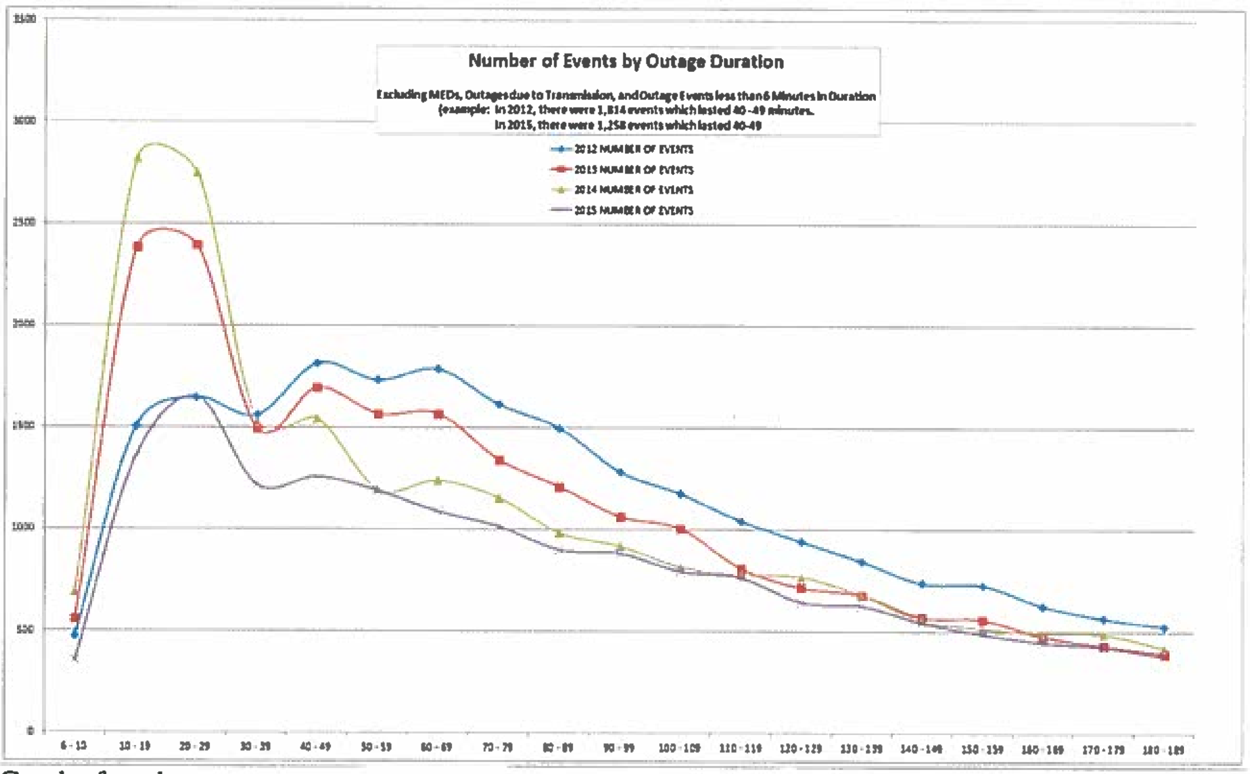
ATTACHMENT 1

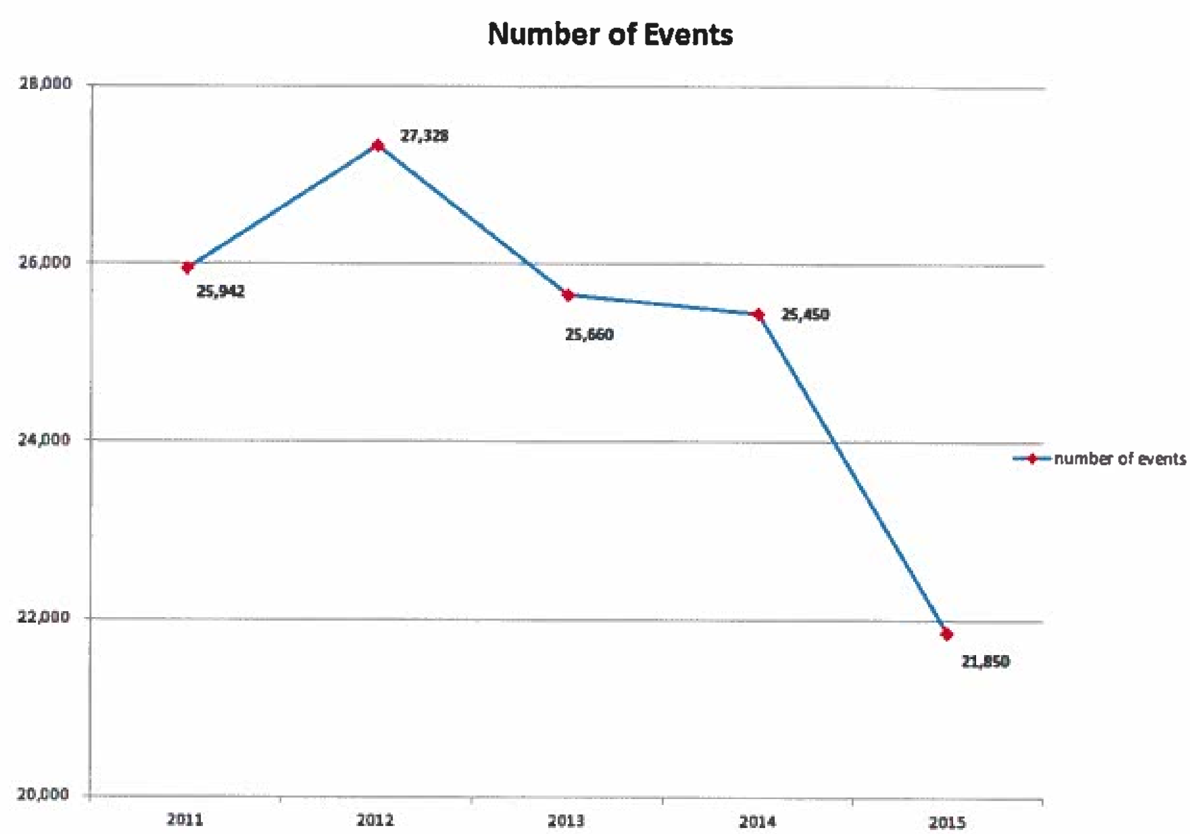
The chart below illustrates reductions of outages in increments of up to 179 minutes.

Duration of outages in Minutes	2012 - # of Outages	2013 - # of Outages	2014 - # of Outages	2015 - # of Outages
6 - 10	475	558	690	354
10 - 19	1,506	2,382	2,819	1,360
20 - 29	1,646	2,396	2,751	1,653
30 - 39	1,560	1,495	1,528	1,219
40 - 49	1,814	1,695	1,544	1,258
50 - 59	1,732	1,567	1,196	1,190
60 - 69	1,786	1,567	1,239	1,088
70 - 79	1,613	1,343	1,155	1,015
80 - 89	1,497	1,210	983	901
90 - 99	1,283	1,064	918	883
100 - 109	1,176	1,005	816	795
110 - 119	1,042	810	779	764
Sub Total	17,130	17,092	16,418	12,480
% Change from 2012		-0.2%	-4.2%	-27.1%
120 - 129	942	716	768	644
130 - 139	845	678	680	626
140 - 149	738	571	557	545
150 - 159	728	560	516	489
160 - 169	627	478	494	448
170 - 179	566	433	489	427
Totals	21,576	20,528	19,922	15,659
% Change from 2012		-4.9%	-7.7%	-27.4%
CAIDI % Change from 2012		14.1%	4.9%	13.6%

Graphs of outages less than 180 minutes:



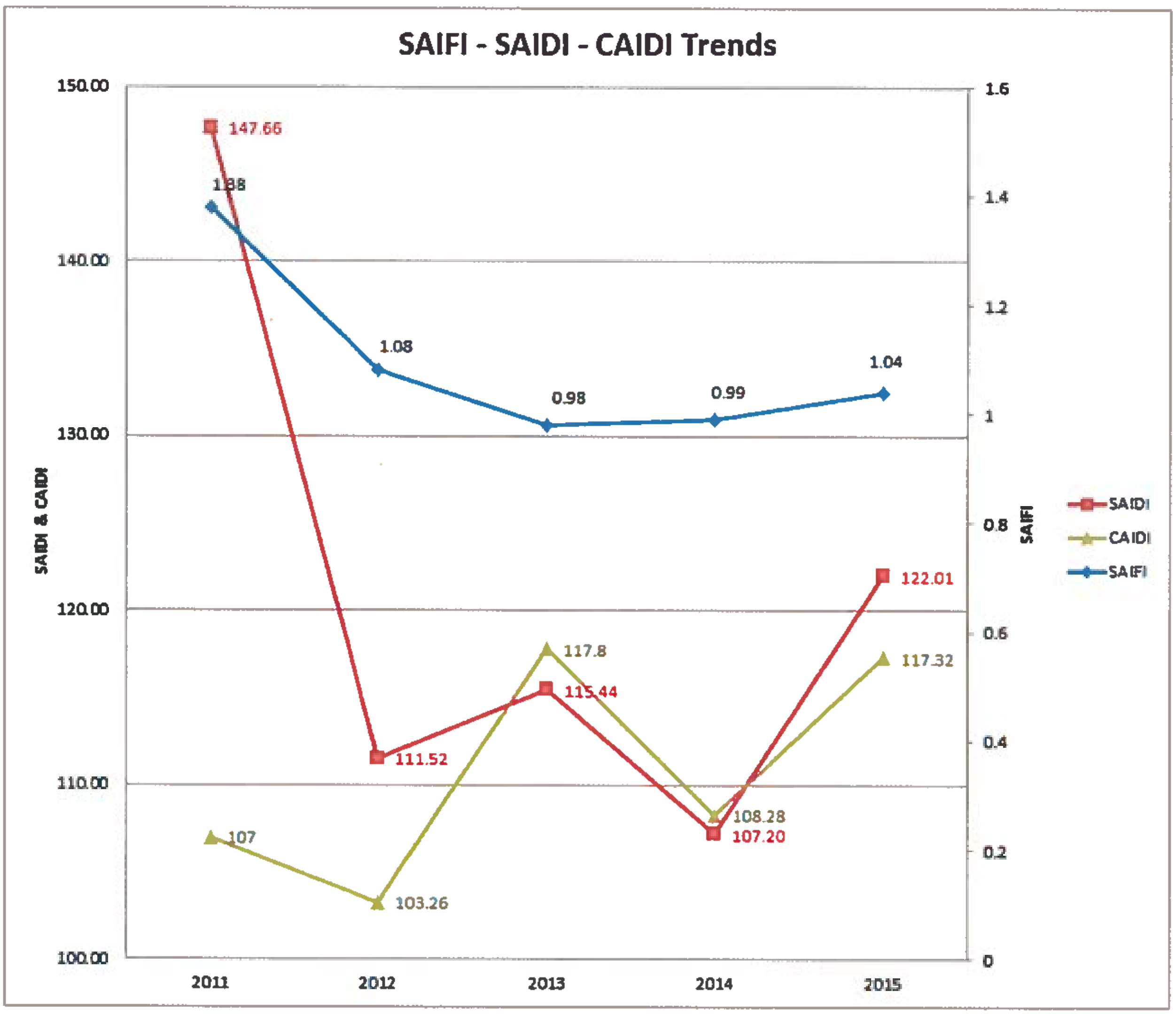
Graph of total outages:



Comparison of SAIFI – SAIDI – CAIDI

Change in SAIFI - SAIDI - CAIDI

Year	SAIFI	Change in SAIFI	SAIDI	Change in SAIDI	CAIDI	Change in CAIDI
2011	1.38		147.66		107	
2012	1.08		111.52		103.26	
2013	0.98		115.44		117.8	
2014	0.99		107.20		108.28	
2015	1.04		122.01		117.32	
% Changes from 2011		-24.6%		-17.4%		9.6%



Note: SAIFI = -3.2% Rate of Change SAIDI = -1.29% Rate of Change

The Perils of Reliability Benchmarking

There are many problems with benchmark comparisons. This article recommends their proper use, and suggests an approach for setting appropriate reliability improvement targets.

SAIFI

SAIDI

It is becoming increasingly common for utility commissions to compare the reliability of utilities in their state to industry benchmark surveys. Utilities are typically categorized into performance quartiles, with the top quartile corresponding to 25% of participating utilities with the best reliability indices. Taken at face value, this type of benchmark comparison is of little to no worth. Of more concern is the tendency of people to draw incorrect conclusions, to unfairly criticize certain utilities, to unfairly praise others, and to set inappropriate reliability improvement targets. Reliability benchmarking activities can be extremely valuable when used appropriately, but often it is not. This article discusses the many problems with benchmark comparisons, recommends their proper use, and suggests an approach for setting appropriate reliability improvement targets.

Reliability Indices

Virtually every utility that provides electricity to retail customers keeps track of distribution reliability indices. By far, the most commonly used indices are SAIFI (System Average Interruption Frequency Index), SAIDI (System Average Interruption Duration Index), and CAIDI (Customer Average Interruption Frequency Index).

SAIFI is a measure of how many sustained interruptions an average customer will experience over the course of a year. It is calculated by dividing the total number of customer sustained interruptions by the total number of customers served. For a fixed number of customers, the only way to improve SAIFI is to reduce the number of sustained interruptions. Typical SAIFI improvement strategies focus on fault reduction activities such as increased vegetation management, deployment of animal guards, and replacement of unreliable equipment. SAIFI can also be improved by better protection selectivity so that faults affect fewer customers.

SAIDI is a measure of how many interruption minutes an average customer will experience over the course of a year. It is calculated by dividing the total number of customer interruption minutes by the total number of customers served. For a fixed number of customers, SAIDI can be improved by reducing the number of sustained interruptions or by reducing the duration of these interruptions. An improvement in SAIFI will result in an improvement in SAIDI, but not necessarily the other way around. Typical SAIDI reduction techniques focus on faster

By Richard E. Brown, PhD
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fault location, faster crew deployment, and more aggressive post-fault system reconfiguration to restore service to more customers more quickly.

CAIDI is a measure of how long an average interruption lasts, and is mathematically equal to SAIDI divided by SAIFI. Many utilities and regulators like CAIDI since it seems to be an indication of restoration time. However, CAIDI will go up if SAIFI improves proportionally faster than SAIDI. It is very possible for reliability to improve but for CAIDI to increase. Consider a utility that installs animal guards in its heavily wooded areas. The number of animal-caused faults will decrease, but these faults are typically short in duration. Elimination of these short-duration events will increase average event length, causing CAIDI to increase even though the system is more reliable. Since CAIDI is a confusing measure of reliability, it should not be used for benchmarking and will not be considered further in this article.

Utilities are increasingly looking at the number of momentary interruptions experienced by customers. This is typically tracked through the reliability index $MAIFI_E$ (Momentary Event Average Interruption Frequency Index). A momentary event is defined as one or more short interruptions experienced by a customers within a five-minute interval, provided that these are not followed by a sustained interruption. $MAIFI_E$ is calculated by dividing the total number of momentary events experienced over a year by the total number of customers served.

> "Although not yet in the mainstream, more and more utilities and regulators are starting to use the reliability index CEMIN (Customers Experiencing Multiple Interruptions)."

Most people instinctively think of momentary interruptions as bad, since customers would prefer not to have them. However, momentary interruptions are a result of intentional operating practices that are designed to improve reliability, not degrade it. When a fault occurs on an overhead line, it will often self-clear if the circuit is de-energized and then re-energized through one or more reclosing operations. A successful reclosing operation eliminates sustained interruptions for many customers, and avoids the cost of having a crew drive out to the fault location. For sure, $MAIFI_E$ can be reduced by reducing the use of reclosing, but there will always be a corresponding increase in SAIFI and SAIDI. Therefore, like CAIDI, $MAIFI_E$ is a confusing measure of reliability and should be avoided for benchmarking purposes.

Although not yet in the mainstream, more and more utilities and regulators are starting to use the reliability index $CEMI_N$ (Customers Experiencing Multiple Interruptions). $CEMI_N$ measures the percentage of customers that experience more than N sustained interruptions over the course of a year. This measure has a certain appeal since customers are often tolerant of an occasional interruption, but become unhappy when experiencing many interruptions within a short time period. $CEMI_N$ is different in that it is a threshold measure; it will not increase until a customer moves from N interruptions to N+1, and will not increase further even if this customer experiences a thousand more interruptions later in the year.

Consider a utility using $CEMI_4$, with an area of particularly bad reliability that is experiencing 12 interruptions per year. Assume that the utility halves the number of interruptions experienced in this area to 6. The reliability of customers in this area is significantly better, but $CEMI_4$ remains unchanged since no customers were reduced to 4 interruptions or below. The most cost effective way to manage $CEMI_N$ is to focus on customers at the threshold – make sure that those just below the threshold stay there and try to move those just above to just below. This gaming behavior is generally not in the best interest of customers and, therefore, $CEMI_N$ is not recommended from a benchmarking perspective.

In summary, many reliability indices are not suitable for reliability benchmarking. SAIFI and SAIDI are the least problematic, and will be the focus of the rest of this article.

Apples to Apples

There are many reasons why reliability indices are higher and lower for different utilities. Reliability characteristics are heavily influenced by geography, climate, customer density, system design, equipment age, traffic congestion, overhead versus underground construction, the mix of residential/commercial/industrial customers, and many others. These differences make comparisons between utilities essentially impossible. Is it really fair to compare the reliability of Manhattan, New York to Manhattan, Kansas? The SAIFI and SAIDI values of Westar Energy (serving Kansas) are higher than Consolidated Edison (serving New York) because it is appropriate for them to be higher, not necessarily because one utility is worse than the other.

The only fair "apples to apples" benchmark comparison for a utility is with its own past performance. Trends can be established such as whether reliability indices are getting better, worse, or staying the same. Analyses can determine whether various contributing factors to reliability indices are increasing or decreasing, such as tree-related interruptions. Tests can show whether reliability improvement initiatives are having the expected impact, such as a reduction in reliability indices or a reduction in specific contributing factors.

Still, there is an irresistible urge to compare utility indices. Sometimes these imperfect comparisons can be properly interpreted and result in insight. Unfortunately, benchmarking data is often misused to demonstrate that "Greedy Utility" is doing a terrible job. Consumer advocates will argue, "Many similar utilities have lower reliability indices, and the customers of Greedy Utility deserve better. Clearly, Greedy Utility is skimping on reliability to boost profits." Similarly, benchmark data is often used to show that "Incompetent Utility" doesn't know what it is doing, as evidenced by the superior reliability indices of neighboring "Has-Its-Act-Together Utility."

Unsubstantiated attack aside, there are two truths about reliability management: (1) utilities can spend more or less on reliability, and (2) utilities can be more or less cost effective with this spending. These two issues cannot be examined through simple benchmark comparisons, even if the comparison utilities seem similar. Best practice in reliability management identifies the costs and benefits for a wide range of reliability improvement options, develops cost-versus-reliability curves, sets future reliability targets based on the tradeoff between cost and reliability, develops a multi-year reliability plan, executes this plan efficiently, tracks actual versus predicted levels of reliability, and periodically updates the plan. Reliability index benchmarking has little place in this process, in the evaluation of this process, or in the evaluation of the outcome of this process.

> "Following the IEEE standard helps to improve the comparability of utility reliability, but there are many other issues that the standard cannot address to insure consistency."

Apples to Oranges

Although different utilities will naturally have different reliability indices, a bigger problem is that reliability index calculation details vary from utility to utility. Even though two utilities report SAIFI and SAIDI, they are not quite talking about the same thing. It is like asking two people how much money they make a year. At first glance, these two numbers might seem comparable. However, are their answers just base salary? Do they include an expected bonus, 401K contribution, pension contribution, other benefit contributions, use of a company car, tuition reimbursement, and/or unvested stock grants? Without knowing, it is difficult to compare.

Consider the seemingly simple SAIFI and SAIDI. Most utilities exclude momentary events from SAIFI calculations, but different utilities use different time thresholds to define a momentary event. Assume that two utilities have a SAIFI of 1/yr and a SAIDI of 150 min/yr. Both decide to spend millions of dollars on distribution automation, where dispatchers can use SCADA systems to remotely operate switches to aid in restoration. Previous switching actions that took an hour or more can now be performed in two to three minutes. It is expected that about 25% of interruptions will be reduced by an average of 60 minutes.

The first utility has a momentary interruption threshold of 1 minute. Therefore, automated switching does not improve SAIFI at all since automated switching takes longer than the 1-minute threshold. For this utility, SAIFI remains at 1/yr and SAIDI dramatically falls to 135 min/yr, due to the large number of short interruptions.

The second utility has a momentary interruption threshold of 5 minutes. Therefore, automated switching results in the reclassification of all quick restorations from sustained to momentary events. SAIFI will improve to 0.75/yr, but SAIDI will actually increase to 180 min/yr since the previous benefit from manual switching is reduced.

In this example, two utilities have significantly different reliability indices, even though the customer experience is identical. The first has a SAIFI of 1/yr and a SAIDI of 135 min/yr. The second has a SAIFI of 1/yr and a SAIDI of 180 min/yr. Clearly, this is an apples-to-oranges comparison due to the use of different momentary interruption thresholds.

The IEEE has developed a Standard 1366 in order to address certain issues related to reliability index definitions. For example, it defines the momentary event threshold as five minutes. It also contains its recommended approach to major event exclusion, which is often a large contributor towards apples-to-oranges comparison.

Most utilities exclude major events when calculating indices (but not all). Definitions vary widely such as "10% of customers out over a 24 hour period" to "an approved major event by our regulators." The IEEE has its own approach called "2.5 Beta." This method examines daily SAIDI for the previous five years and statistically calculates a major event threshold. Based on the previous five years, and day with a daily SAIDI that exceeds the threshold is excluded from reliability index calculations. Even this method, vetted through a many-year process involving dozens of utilities, has its problems.

Consider a utility that had had five normal years. On average, this utility has an exclusion threshold of 1.5 min/day and excludes about four to five days per year. Now the utility experiences a once-in-fifty year event that leaves many customers without power for more than a week. This large event results in a dramatic increase in the exclusion threshold to 2.5 min/day. Because of this, not as many days will be excluded in the upcoming five years, resulting in worse reliability indices. If this extreme event had not occurred, reported future reliability would be better. Similarly, any utility with five years of worse-than-average reliability will generally exclude fewer days than any utility with five years of better-than-average reliability – apples to oranges.

Following the IEEE standard helps to improve the comparability of utility reliability, but there are many other issues that the standard cannot address to insure consistency. Some of the more common issues are:

Data collection. Utilities rely on field data to compute reliability indices. Older manual processes tend to under-collect and result in reliability indices that are better than what would occur under a more robust process. It is common for SAIDI and SAIFI to increase significantly after a utility deploys or significantly upgrades its outage management system. Reported reliability indices are worse, but the customer experience is essentially unchanged. Many utilities have relatively low reliability indices not because they are more reliable, but because they have worse data collection processes.

Customer count. When an outage occurs, it is necessary to determine the number of interrupted customers. With manual systems, crews or dispatchers may just guess. More advanced systems might be based on a connectivity model that identifies downstream service transformers and customers served by these transformers. This connectivity model may not be adjusted in real time, and therefore may not always make accurate customer counts. Furthermore, the definition of a customer is not always consistent from utility to utility. Is an apartment building with a master meter and 200 sub-meters one customer or 200? Does a supply outage to a 5000 customer cooperative represent a single interruption or 5000?

Year	SAIDI (min/yr)			SAIFI (/yr)			No. of Responses	1Q in both SAIFI & SAIDI
	1Q	2Q	3Q	1Q	2Q	3Q		
2004	70	100	145	0.90	1.09	1.42	78	—
2005	98	145	192	1.09	1.39	1.63	88	15.9%
2006	105	146	198	1.11	1.36	1.70	95	16.8%
2007	109	144	200	1.06	1.33	1.71	64	17.2%
2008	124	162	200	1.12	1.35	1.60	77	18.2%
2009	81	116	167	0.98	1.12	1.49	107	18.7%
2010	89	128	158	0.93	1.17	1.46	109	16.5%
Average	96.6	134.4	180.1	1.03	1.26	1.57	88.3	17.2%
St. Dev.	19%	16%	13%	9%	10%	7%	19%	0.6%

Table 1. Quartile thresholds for the IEEE surveys from 2004 through 2010

Step restoration. After an outage, most utilities attempt to restore customers through automated and manual switching, where blocks of customers are restored in sequential steps. Some utilities have accurate ways to calculate the impact of step restoration on indices and some do not. Even those that do are often limited to the inclusion of one or two steps.

Bulk power events. It is unclear whether distribution reliability indices should include interruptions that result from generation or transmission system outages. This is especially true for distribution utilities that do not own generation or transmission assets. Many utilities include bulk power events and many do not, resulting in significant differences in reported indices.

Scheduled outages. It is also unclear whether indices should include interruptions that result from scheduled outages needed for construction, planned maintenance activities, intentional load shedding, or disconnections for bill payment delinquency. Some utilities take an "all in" approach, and some utilities do not.

Because of all these and other factors, any reliability index comparison of two utilities is inevitably apples to oranges. Differences are due strictly to index calculation, and are apart from real reliability differences resulting from system and operational issues.

IEEE Quartiles

The first reliability benchmark survey by the IEEE occurred in 1990. Surveys were sent to 100 utilities, 49 responded, and results were grouped into quartiles. Ever since, the concept of quartiles has taken on an almost magical quality. Utilities are often defined by their quartile placement. With inflated chests, proud utilities announce that they are in the first quartile. Slinking in shame, fourth quartile utilities avoid eye contact. Ambitious utilities make statements like "we are lower third quartile now, but we have plans to become an upper second quartile utility within five years." State regulators preach that their customers deserve first quartile performance, and set reliability targets accordingly.

Framing reliability in terms of quartiles is semantically comfortable, but problematic for many reasons. If 100 utilities participate in a benchmark survey, 25 will always be in the bottom quartile by definition, even if all utilities are exceptional in all aspects related to reliability. Similarly, 25 will always be in the top quartile, even if all have terrible data collection processes, shoddy system designs, unmaintained equipment, and incompetent outage response practices.

Table 1 shows the quartile thresholds for the IEEE surveys from 2004 through 2010. These numbers, especially SAIDI, have high variation from year to year. Therefore, comparing a utility to IEEE quartiles is a strong function of the benchmark year that is chosen. A utility with a SAIDI of 120 min/yr will be in the first quartile according to 2008, but be in the third quartile according to 2009. Quartile thresholds may change for a variety of reasons such as national trends (e.g., reliability is getting worse) or national weather (e.g., lots of minor storms across the country). But more important is that the same utilities do not participate in the survey from year to year. How can 2008 with 77 participants be fairly compared to 2009 with 107 participants? It is possible that first quartile thresholds went down because a lot of utilities with low numbers decided to participate, precisely because they had low numbers and know that they would do well!

Most states with regulator-set reliability have targets for both SAIFI and SAIDI (or equivalently SAIFI and CAIDI). When setting targets, it is often forgotten that it is easier to achieve first quartile reliability in either SAIFI or SAIDI than in both. This is evident in Table 1, where in each year less than 19% of utilities achieve top quartile in both SAIFI and SAIDI in a given year. Some utilities may find it easier to keep SAIFI low but not SAIDI, such as mostly-underground utilities where faults are rare but take a long time to fix. Other utilities may find it easier to keep SAIDI low but not SAIFI, such as mostly-overhead utilities where faults occur frequently but can be repaired quickly. A utility achieving first quartile in both SAIFI and SAIDI is better thought of as best one-in-six and not best one-in-four. Just think how popular utility employees could be proclaiming top sextile performance!

The time-varying characteristics of quartiles are graphically shown in Figure 1 and Figure 2 for SAIFI and SAIDI, respectively. Consider a regulator looking at SAIDI trends from 2004 through 2008. It seems reasonable to conclude that SAIDI is gradually getting worse

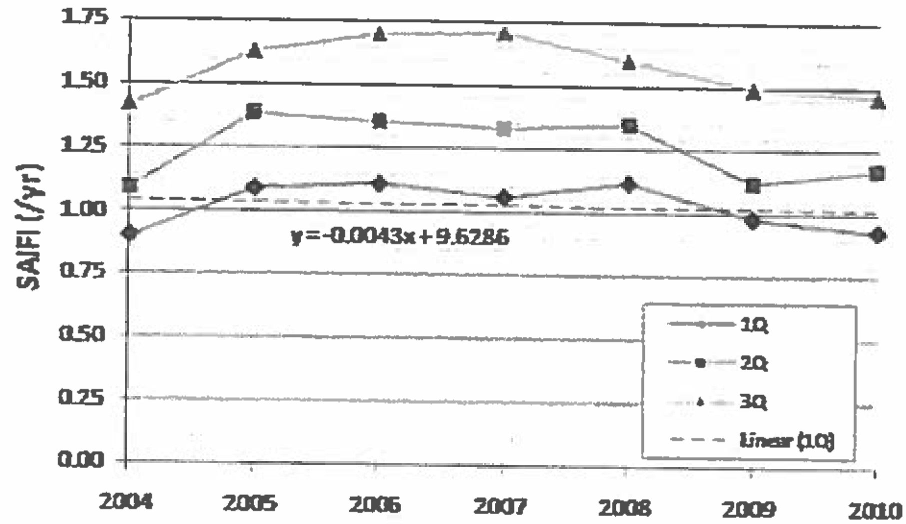

Figure 1. IEEE Benchmark Results for SAIFI

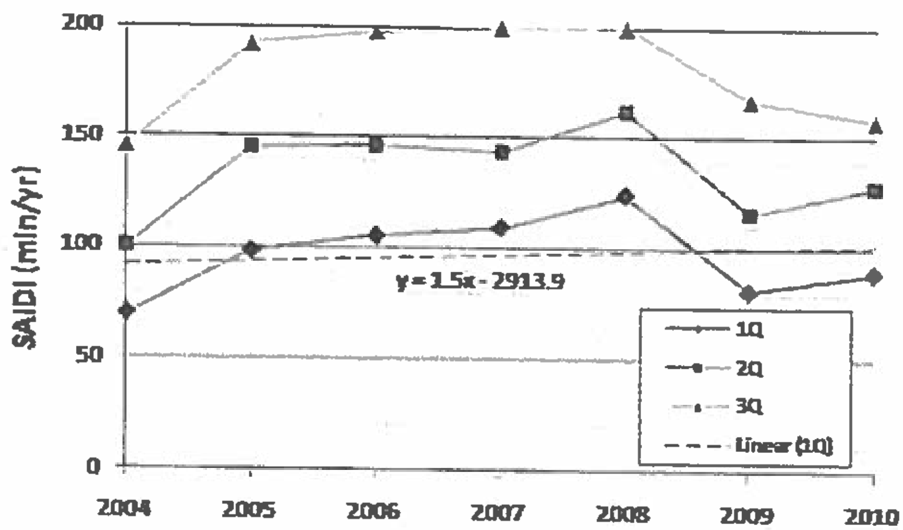

Figure 2. IEEE Benchmark Results for SAIDI

over time, and the regulator sets reliability targets accordingly. Two years go by and the benchmark results tell an entirely different story. Results in 2009 and 2010 effectively eliminate any meaningful trend in the dataset. Has reliability been constant over time, but highly variable? Was reliability getting worse and now is quickly getting better? These questions cannot be answered in a statistically meaningful way. Data points from year-to-year are not entirely comparable, since they are based on responses from different utilities.

Natural Variations

Reliability varies naturally each year, both due to weather severity and due to completely random processes. Major event exclusion is an attempt to partially adjust for random variations due to the most extreme weather, but the number of minor storms experienced by a utility can dramatically impact reliability indices, as can residual effects of excluded events.

It is not uncommon for utilities to have reliability indices with standard deviations of 10% or higher (sometimes much higher). Each utility has an "inherent reliability" that will, on average, occur over time. If inherent reliability has a 10% standard deviation, there is about a 16% chance of reliability being more than 10% worse than average and about a 16% chance of reliability being more than 10% better than average. This level of natural variation makes it very difficult to examine reliability with a single year of data. Consider a utility with an inherent reliability of 150 min/yr with a 10% standard deviation (i.e., a standard deviation of 15 minutes). It is quite possible for the utility to have a SAIDI of 135 min/yr one year (one standard deviation below) and 165 min/yr the next (one standard deviation above). Year-to-year reliability indices vary widely, even though inherent reliability has not changed.

Similarly, natural variation must be considered when comparing utilities. Even if two utilities have similar inherent SAIDI, it is possible in a particular year for one to have a significantly lower SAIDI than the other just due to random variation.

Benchmark surveys like the IEEE are generally large enough to average out random variations from results. One utility with great inherent reliability will have an unlucky year and miss the first quartile, offset by a utility with that has a lucky year and makes the first quartile, even though its inherent reliability is worse. This process of "averaging out" misses the point. Many utilities in the first quartile are there because they had a lucky year, and many utilities in the fourth quartile are there because they had an unlucky year. Utilities that are consistently in the top quartile each year have inherent reliability significantly higher than the first quartile threshold.

It is critical that natural variation be considered when setting reliability targets. Consider a utility that has an inherent SAIDI of 150 min/yr. As chance has it, they have also averaged 150 min/yr over the last few years. If a reliability target is set at 150 min/yr, and inherent reliability remains the same, this utility will miss its SAIDI target half of all years due to random variation.

When random variation is considered, reliability targets become somewhat meaningless unless they are associated with a level of confidence. Do you want the utility to achieve its reliability targets one year out of two (50% confidence), four years out of five, nine years out of ten, or 99 years out of 100? Higher levels of confidence requires that the reliability target be set correspondingly lower

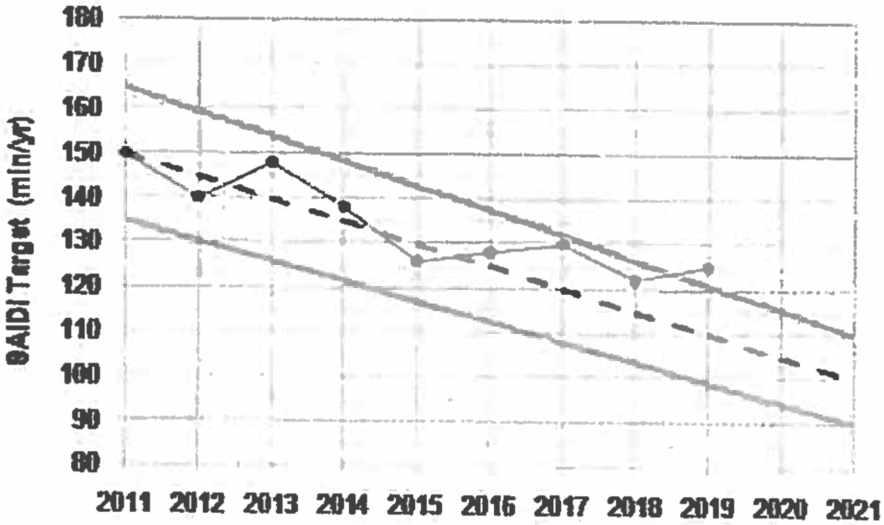

Figure 3. Example of Reliability Targets with Confidence Intervals

than the desired level of inherent reliability, allowing for more random variation without missing the target. Consider a utility with an inherent SAIDI of 150 min/yr with a 10% standard deviation (assume normal distribution). This utility can achieve a target of 150 min/yr with 50% confidence, a target of 163 min/yr with 80% confidence, and a target of 169 min/yr with 90% confidence.

A good approach to reliability targets is to set them based on inherent reliability, but to add upper and lower confidence intervals. Consider again a utility with an inherent SAIDI of 150 min/yr and a standard deviation of 10%. Targets are set to reduce inherent reliability by 5 min/yr over the next ten years. Confidence intervals are set according to best and worst expected one-in-five year performance. Results are shown in Figure 3, with the dashed blue line corresponding to the target and the solid red lines corresponding to the confidence intervals. Each year, actual SAIDI can be expected to jump above and below the target, but stay within the confidence interval during most years while trending downwards on average.

The approach of Figure 3 allows for the future goal to be influenced by benchmark data, if desired. The visual representation of confidence intervals reinforced the concept of random variation and eliminates the expectation of achieving inherent reliability targets in all years. An example of actual results is shown as the thin black line with circle markers in Figure 3. Through 2016, this utility seems to be achieving its reliability improvement goals, even though it was above its target for several years. That 2019 is above the confidence interval is not a big concern in itself, since this is expected to happen twice over the ten-year period. However, results from 2016 to 2019 were all above the target, indicating that inherent reliability is probably above the target level.

Confidence intervals are similar to a "dead band" in performance-based ratemaking. Reliability targets are supplemented by an upper and lower value. If reliability is between these values, reliability is deemed acceptable. If reliability is worse than the upper limit, penalties are assessed. If reliability is better than the lower limit, rewards are potentially granted. The approach of Figure 3 is functionally equivalent, but adds the benefit of visualization.

Conclusions

Reliability benchmarking is here to stay. It does not matter whether a utility participates in benchmarking or not; they will be compared to benchmarking data regardless. Utilities may as well participate in benchmark surveys so that they can better understand how all of the various factors addressed in this article apply to each survey, helping to avoid improper interpretations by others.

More importantly, participation in benchmark surveys helps utilities engage in dialogue with one another about deeper and more substantial reliability issues. How is aging infrastructure affecting reliability and what are you doing about it? What reliability benefits do you expect from your Smart Grid initiatives? Has anyone tried this-or-that new technology? What happened to your reliability indices when you upgraded your outage management system? How are you prioritizing cable replacement? How do you balance spending on reliability index improvement versus worst-performing circuits? How do you set internal reliability targets? And so forth. Hopefully, quartile results are only a small sliver of benchmarking results, and will be de-emphasized as much as possible.

In the end, reliability benchmarking tends to guide reliability index expectations, often leading to reliability improvement targets. This puts a utility in an undesirable position. It is very possible that benchmarking-based targets could result in targets that are not cost-effective and may not even be achievable.

To avoid this, each utility must proactively develop a reliability roadmap, complete with multi-year reliability index targets and confidence intervals. This roadmap should be based on historical statistical data, detailed cost-to-benefit analyses, specific improvements in current spending, and proposed specific new initiatives considering a comprehensive and coordinated set of tactics. This roadmap should convince any reader that reliability targets are cost-effective and achievable. The roadmap should also address the impact of reduced spending, and the potential benefits of increased spending. If a reliability roadmap of this type is credible, it will allow utilities to avoid the perils of reliability benchmarking.

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ATTACHMENT 3

Below is an example of a reliability improvement related to the installation of a self-healing team and the associated impact on SAIDI, SAIFI, and CAIDI:

Prior to installing a self-healing system, a circuit has an outage caused by a tree falling on the line beyond the circuit midpoint switch. The crew finds the site of the damage and then opens the switch. This step allows restoration of power to the customers between the substation and the switch. Then the crew restores power to the rest of the customers beyond the switch after removing the tree off the line. The reliability data for this event is:

- 1,000 total customers interrupted; CI = 1,000.
- 500 customers are off for 30 minutes (section from substation to the switch) so CMI = 15,000.
- 500 customers are off for 90 minutes (section from switch to end of feeder) so CMI = 45,000

Reliability indices for this event are:

- SAIFI = 1.00 (1,000/1,000)
- SAIDI = 60 minutes (60,000/1,000)
- CAIDI = 60 minutes (60,000/1,000)

During reliability improvements for this circuit, a line recloser is added to the circuit midpoint switch location and fault location technology is added to the substation. Afterwards, another tree falls at the same location as before. This time, the line recloser opens and isolates the fault to only 500 customers. The 500 customers between the substation and the recloser location are never off. The fault location is also found more quickly due to a more limited search zone and use of the new fault location technology. Therefore, the crew is able to restore power more quickly than before. Reliability data is:

- 500 total customers interrupted; CI = 500.
- 500 customers are never off.
- 500 customers are off for 75 minutes, which is 15 minutes faster than before, so CMI = 37,500

Reliability indices for this event are:

- SAIFI = 0.50 (500/1,000)
- SAIDI = 38 minutes (37,500/1,000)
- CAIDI = 75 minutes (37,500/500)

Reliability has improved as reflected in improved SAIFI and SAIDI. Less customers are interrupted and restoration is faster. Furthermore, CAIDI is a misleading measure of reliability since it incorrectly reflects a decrease in reliability.