

BENCHMARKING OF RELIABILITY: NORTH AMERICAN AND EUROPEAN EXPERIENCE

John MCDANIEL
IEEE Member – USA

John.mcdaniel@nationalgrid.com

Werner FRIEDL
E-Control - Austria

werner.friedl@e-control.at

Heide CASWELL
IEEE Member - USA

heide.caswell@pacificcorp.com

ABSTRACT

This paper presents details and results of European and North-American reliability benchmarking. A reliability benchmarking for North America (Canada and United States) is done annually by the IEEE Working Group on Distribution Reliability and published on the group's webpage. Continuity of supply benchmarking takes place in Europe by the Council of European Electricity Regulators (CEER) in collaboration with the Energy Council Regulatory Board (ECRB):

INTRODUCTION

The electric power industry and its regulators discuss and evaluate reliability on a routine basis and in great detail. This seems to happen regardless where in the world you happen to be. Generally defining reliability and then understanding the level of reliability is the beginning point. Sometime the level of reliability can only be roughly bounded when you quantify the level within a target region, such as a continental view. It begins with a question of “how reliable is reliable enough?”; what should be spent to achieve the next level of reliability? At its core, underlying all of this are the fundamental definitions of various reliability indices and what might be industry “norms”. As policy makers become further informed, broadening the peer group that informs the range of “normal” performance is beneficial for the conversation. This has led to the recognition that consistent definitions for each metric are essential to ensure viable conclusions are reached, as is the need to create venues for this assessment. This paper will review the basis for the North American and European benchmark studies and discuss next steps to advance this work further.

NORTH AMERICAN EXPERIENCE

Background

In the late 1990s, the IEEE's Distribution Reliability Working Group (previously name the Group on System Design) undertook efforts to devise standard identification of key reliability metrics as a foundation from which to determine distribution best practices. These were memorialized in IEEE Std. 1366-1998 IEEE Trial-Use Guide for Electric Power Distribution Reliability Indices [1]. This early work described system availability metrics and metrics regarding unreliability, in addition to detailing the wide range of methods by which major events were determined. Subsequent work by this

group established a new and much more widely-applicable method for determining a major event, which uses statistics to establish a performance threshold, the outcome of which was established in IEEE Std. 1366-2003 Guide for Electric Power Distribution Reliability Indices [2]. As an annex to this work a benchmark of which reliability metrics across North America were collected was also provided. The metrics most-widely collected focused on 1) how often does the average customer experience an interruption; 2) when a service interruption occurs, how long on average does it take to restore power; and 3) throughout the measurement period, what is the cumulative time the average customer's power is interrupted? These questions are answered by indices that practically every power company uses:

- SAIFI (system average interruption frequency index),
- CAIDI (customer average interruption duration index) and
- SAIDI (system average interruption duration index).

Benchmarking Survey

In 2003, the Distribution Reliability Working Group began a benchmarking study, which is conducted annually from companies who voluntarily provide this data. It is designed to assemble a wide spectrum of reliability results, with a goal of creating a broad understanding of a variety of recent reliability metrics and metric trends. Participants have generally been from North America, although there is no limitation of utilities who submit data. Utilities that participate are extremely diverse, ranging from small systems serving just a few thousand customers to multimillion customer systems.

Process

Utilities are given an anonymous identifier, and segmented by size and continental region. Each utility provides company information, such as the state in which they provide service, the amount of overhead and underground mileage of their systems, etc. The summarized daily interruption data is processed to segregate Major Event reliability from “Day to Day” events, consistent with IEEE Std. 1366-2012 major event day concept. The summary daily data includes the number of customers across the system that was interrupted during each day and the total minutes of customer interruption. This is divided by the number of

customers served by the system, which leads to daily SAIFI and SAIDI values and designation of major event days, major event day performance, underlying event days and underlying event day performance, categorized by SAIFI, CAIDI and SAIDI. Quartile performance levels are calculated and trends of those values are provided. The presentation materials are shared with the IEEE Distribution Reliability Working Group and the graphic data is available on the Working Group's website. Only contributing utilities are allowed access to the anonymous data for subsequent granular analysis.

Over the eleven years that the survey has been conducted, there have been more than 200 participant systems, approximately 60 of whom have participated in every survey.

2014 Survey Results

For the survey performed in 2014 for prior calendar year results, the companies who participated were geographically dispersed as shown in Figure 1 below.

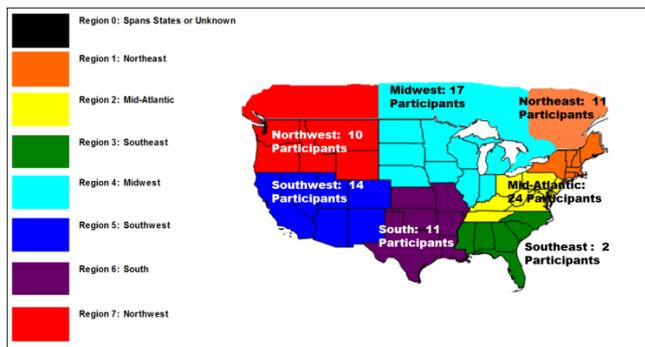


Figure 1: Geographic Participation of 2014 Benchmark Companies

Companies are designated by size, based on the number of customers they serve. Figure 2 shows the distribution of participating companies from the 2014 Benchmark.

Company Size		
Size	Customers Served	Number of Companies
Small	<=100,000	8
Medium	>100,000 <1,000,000	53
Large	=>1,000,000	32

Figure 2: Company Size Distribution of 2014 Benchmark Companies

Each year quartile performance levels are calculated for both IEEE (excluding major event performance) as well as designated by size, based on the number of customers they serve. Figure 3 below shows the performance within each quartile for all (not segregated by company size) and segregated by size (Small/Med/Large).

Quartile All								
		99	SAIDI ALL	SAIDI IEEE	SAIFI ALL	SAIFI IEEE	CAIDI ALL	CAIDI IEEE
0	MIN		28	25	0.35	0.35	27	27
1	Q1		122	85	1.01	0.85	111	92
2	MEDIAN		181	115	1.21	1.08	142	107
3	Q3		285	158	1.53	1.36	193	127
4	MAX		1854	435	3.51	2.34	831	252
Quartile Small								
		8	SAIDI ALL	SAIDI IEEE	SAIFI ALL	SAIFI IEEE	CAIDI ALL	CAIDI IEEE
0	MIN		32	25	0.46	0.39	60	60
1	Q1		117	77	1.14	0.96	94	75
2	MEDIAN		179	118	1.58	1.24	122	92
3	Q3		413	194	2.41	1.81	158	110
4	MAX		1854	258	3.51	2.34	831	141
Quartile Medium								
		53	SAIDI ALL	SAIDI IEEE	SAIFI ALL	SAIFI IEEE	CAIDI ALL	CAIDI IEEE
0	MIN		28	28	0.35	0.35	56	56
1	Q1		122	88	1.07	0.87	111	93
2	MEDIAN		180	121	1.24	1.10	139	107
3	Q3		245	158	1.56	1.36	180	123
4	MAX		785	383	2.39	2.14	670	194
Quartile Large								
		32	SAIDI ALL	SAIDI IEEE	SAIFI ALL	SAIFI IEEE	CAIDI ALL	CAIDI IEEE
0	MIN		47	47	0.63	0.55	27	27
1	Q1		124	87	0.98	0.83	117	94
2	MEDIAN		209	102	1.19	0.96	162	109
3	Q3		325	139	1.43	1.16	251	138
4	MAX		1108	435	2.31	1.96	738	252

Figure 3: Quartile Performance for All and by Company Size of 2014 Benchmark Companies

Charts depicting performance are also produced, where each bar represents the metric being displayed for each of the companies, using their anonymous code, with the bar color designating the region in which they serve. Figure 4 below shows the range of performance for SAIDI, average customer cumulative interruption duration (minutes) for the study.

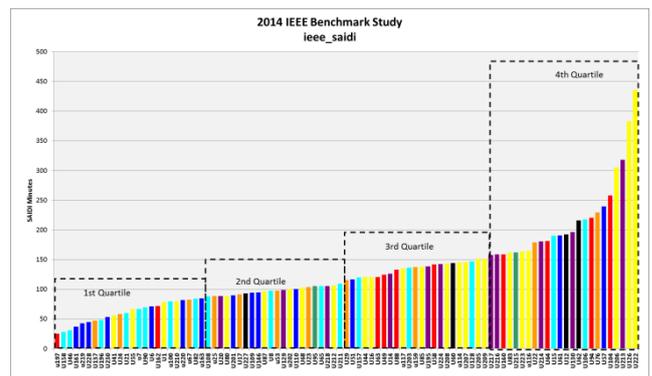


Figure 4: Graphic Results of SAIDI IEEE for 2014 Benchmark Companies

Finally annual trends are provided to evidence recent changes in reliability results delivered, as shown below in Figure 5.

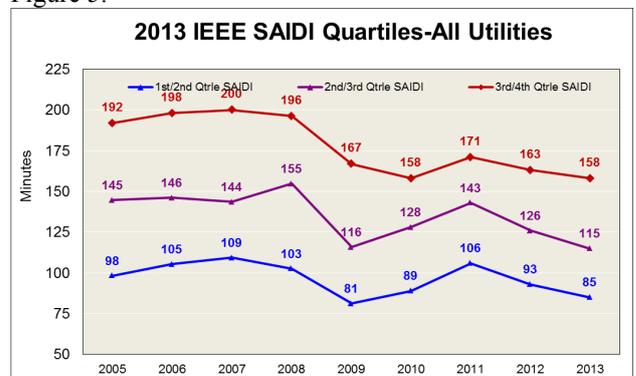


Figure 5: Quartile Trend Results for 2014 Benchmark Study

Benchmarking Restrictions and Caveats

Benchmarking results can be problematic, and are only useful when the analyst understands what the results do and do not mean. Data collection methods, calculation processes and other fundamental parameters may vary substantially and influence how any given utility’s data is characterized. In spite of those traps, they provide value to the astute analyst. For the North American experience the Distribution Reliability Working Group makes no assumption about “good” performance or “bad” performance. However, as early analysis into reliability metrics demonstrated, weather (and resulting major events) can be one of the most substantial influencers into annual reliability delivered. Years with notable hurricane and storm activity have been evident in both the Total performance results, as well as the count of Major Event days which were experienced during the year.

Metric Collaboration

The IEEE Distribution Reliability Working Group is highly concerned that the indices it has further be properly interpreted and applied and to that end it has produced IEEE Std. 1782: Guide for the Collection, Categorization and Utilization of Reliability Data. This guide touches upon this benchmark, and also demonstrates a variety of methods by which reliability data can be collected and analysed. In order to ensure consistent approaches to benchmarking and the application of reliability metrics, it also collaborates with such organizations as Lawrence Berkeley National Laboratories on research into trends in reliability. It has been a contributor to data collection initiated by the Department of Energy’s Energy Information Agency, (DOE EIA) in its annual data collection, for which reliability metrics began being collected in 2014 for results in 2013. Finally, the Working Group is actively interested in being the principal industry source for developing conclusions about reliability measurements and its application to improve reliability. The Working Group further wishes to ensure conformity to reliability standards, promote understanding of the calculation and application of key reliability metrics and facilitate development of future reliability metrics to support more effective analysis of distribution system performance. In its most recent activities it has begun collaborating with European regulators.

EUROPEAN EXPERIENCE

Background

Continuity of supply benchmarking takes place in Europe by the Council of European Electricity Regulators (CEER) in collaboration with the Energy Council Regulatory Board (ECRB): reliability indices for almost all European countries are published in the fifth Benchmarking Report (BR) on quality of supply [4] and the follow-up report BR 5.2 [5]. Data for the

benchmarking exercise is provided by the national regulatory authorities in each participating country. Data is collected and reported at national level; no further geographical details are given. Values for SAIFI and SAIDI are given for each of the participating countries, allowing a direct comparison between countries. Next to the reliability data, the report also gathers information on regulation related to continuity of supply (reliability) allowing a benchmarking of this as well. The benchmarking report further includes a number of finding drawn from the benchmarking and gives a number of recommendations to national regulatory agencies and other stakeholders.

Benchmarking results

SAIFI and SAIDI Trends

Some of the benchmarking results are reproduced below. The annual values for SAIFI and SAIDI, for each of the participating countries are shown in Figure 6 and Figure 7 for the period from 1999 through 2013. The different colours refer to different countries. In the benchmarking report, the countries are identified so that a comparison is possible with countries having similar conditions. In this paper, the countries have not been identified however.

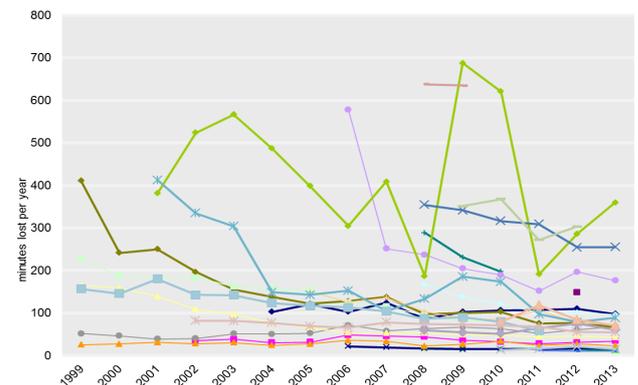


Figure 6: Unplanned long interruptions excluding exceptional events; minutes lost per year (SAIDI).

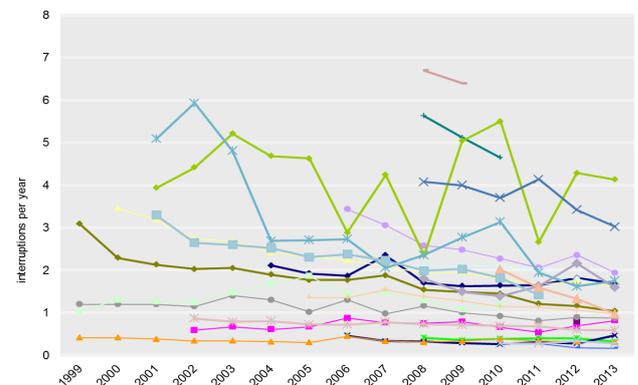


Figure 7: Unplanned long interruptions excluding exceptional events; number of interruptions per year (SAIFI).

The figures show that both SAIFI and SAIDI show a

large variation between countries; also do both SAIFI and SAIDI show an improvement through the 15-year period over which data is available. That improvement appears to have stopped however. The large difference between countries is also worth noticing.

A subject of major discussion in an earlier benchmarking report [6] is the method to be used for identifying “exceptional events”. Contrary to North America, no common method is in use for this and each country has its own approach. The indices shown in the previous figures were obtained after removing the exceptional events. The benchmarking report however also includes the values when considering all events; those are shown in Figure 8 and Figure 9.

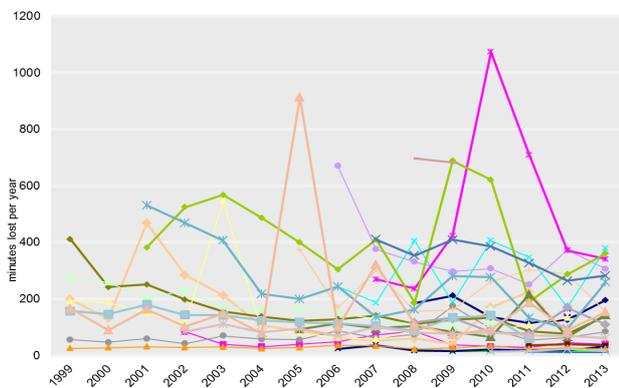


Figure 8: Unplanned long interruptions including all events; minutes lost per year (SAIDI).

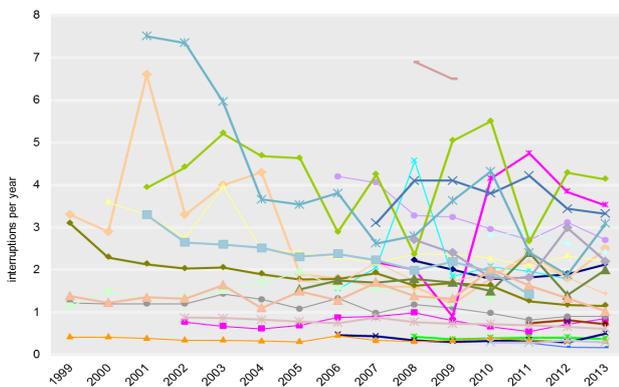


Figure 9: Unplanned long interruptions including all events; number of interruptions per year (SAIFI).

The values are overall higher when including all events. Most noticeable are peaks in the SAIDI values in Figure 8: one in 2003 corresponds to an almost national-wide blackout in Italy and one in 2005 corresponds to a major storm passing the southern part of Sweden, with very long restoration times as a result.

Further Benchmarking Results

The main emphasis in the benchmarking report is on the values for SAIFI and SAIDI, as presented above. Almost all countries have this data available now. Next to that some other data is gathered, where not (yet) all countries

have the data available. This includes the following:

- Data on number of short interruptions is available from 8 countries, most of them for five or more years. The average number of short interruptions varies between slightly less than one and around ten per customer per year.
- Data on number and duration of planned interruptions. This data is available for most countries. The values are less than one per customer per year for all but three of the countries. The duration of planned interruptions is up to 200 minutes per customer per year for several of the countries.
- Energy not supplied and average interruption time are given for interruptions on the transmission network.
- A comparison is made between urban and rural areas in five countries.

Next to data on reliability performance, the benchmarking report also contains a detailed description and comparison of regulation towards improving or maintaining continuity of supply in the different European countries.

Impact of Underground Cables

The 2011 benchmarking report also contains a study after the relation between reliability and the amount of underground cables. The improvement of reliability when replacing overheads lines by underground cables is often mentioned but rarely quantified.

The correlation between the reliability (expressed as total SAIDI) and the amount of underground cables, is shown in Figure 10. The indicator used corresponds to “total SAIDI” (unplanned SAIDI including exceptional events plus planned SAIDI), averaged over the three most recent years available (often 2008-2010 or 2007-2009). The percentage of underground cables in MV networks in 2009 is used when available (otherwise it is 2008 or 2007).

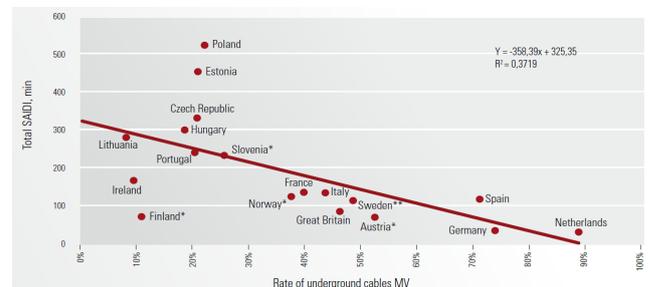


Figure 10: Statistical correlation between the percentage of underground cables in MV networks and “total SAIDI” (unplanned SAIDI including exceptional events plus planned SAIDI) averaged over 3 years, in Europe.

There is an obvious trend with increasing reliability going together with increasing amount of underground cables. Some countries are however doing significantly better

than the trend (most noticeably Finland), while some are doing significantly worse (most noticeable Poland).

When interpreting the results it should be noted that: *) four countries (Austria, Finland, Norway and Slovenia) do not take into account incidents on LV networks and therefore underestimate SAIDI. **) SAIDI in Sweden has been very variable these past years: SAIDI is usually around 100 min, except for 2005 (946 min) and 2007 (345 min) due to large storms.

Undergrounding is more expensive in areas with lower population density; hence a correlation is expected between these two parameters. As shown in Figure 11, such a trend is indeed identified but there are several outliers. For example, Spain and Greece have similar population density, but completely different levels of undergrounding.

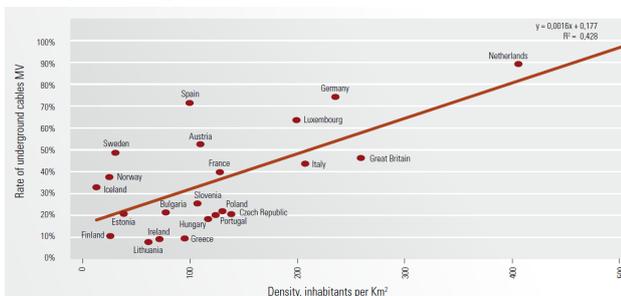


Figure 11: Statistical correlation between the percentage of underground cables in Medium Voltage (MV) networks and population density in European countries

Recommendations

CEER uses the benchmarking report to give recommendations on continuity of supply. Those recommendations are mainly directed towards their members, i.e. the national regulatory agencies, but sometimes also towards other stakeholders.

The 2011 edition of the benchmarking report contained the following recommendations:

- Expand the monitoring of continuity of supply
- Harmonise continuity of supply indicators and data collection procedures
- Investigate continuity of supply trends for a periodic review of regulation
- Assess disaggregated continuity data in order to identify priorities
- Promote cost-benefit analysis to improve the efficiency of expenditure on networks
- Implement an incentive scheme for maintaining or improving general continuity levels
- Implement compensation payments for network users affected by very long interruptions

DISCUSSION

Since many of the elements of the European and North

American benchmarking studies rely on similar concepts, the opportunity for cross-continental assessments are rich. At its most elementary, a direct comparison of interruption duration, interruption frequency and outage restoration are immediately able to be accomplished. Subsequently, correlations between overhead versus underground percentages and reliability metrics, between customers per distance and reliability, as well as assessment of weather impacts per year are viable and may serve to provide key findings to both benchmark communities. The authors intend to use this opportunity to further those studies and determine to what extent such comparisons provide value to their study stakeholders.

CONCLUSIONS

Benchmarking of power-system reliability takes place in North America as well as in Europe. Although the approaches and the way of presenting the results are rather different, the underlying concepts are the same and there are sufficient opportunities for cooperation and to learn from each other. For the future a continuation of these kinds of comparisons would be very valuable.

ACKNOWLEDGMENTS

John McDaniel is vice-chair of the IEEE Working Group on Distribution Reliability. Werner Friedl is chairman of the Electricity Quality of Supply Task Force (EQS) task force within the Council of European Energy Regulator. It is the EQS task force that is responsible for the benchmarking report. Heide Caswell is the Chair of the Benchmarking task force within the IEEE Working Group on Distribution Reliability.

The numerous contributions by members of the IEEE Working Group on Distribution Reliability and by the Council of European Energy Regulators to the benchmarking process are gratefully acknowledged.

REFERENCES

- [1] IEEE Standard 1366-1998, "IEEE Trial Use Guide for Electric Power Distribution Indices".
- [2] IEEE Standard 1366-2012, "IEEE Guide for Electric Power Distribution Indices" (revision of IEEE Std. 1366-2003).
- [3] IEEE Standard 1782-2014, "IEEE Guide Collecting, Categorizing, and Utilizing Information Related to Electric Power Distribution Interruption Events".
- [4] "5th CEER benchmarking report on the quality of electricity supply 2011", CEER, April 2012.
- [5] "CEER Benchmarking Report 5.2 on the Continuity of Electricity Supply", CEER, February 2015
- [6] "4th benchmarking report on quality of electricity supply 2008, CEER, December 2008.