Q. (CA-NP-43, footnote 1, Order No. P.U. 32(2007), p.39) On page 39 the Board states "The Board does not accept that the establishment of distribution and reliability service standards as proposed by the Consumer Advocate is necessary at this time, given the existing regulatory oversight and the generally positive reliability measures reported for NP's system. However the Board is interested in exploring the possible application of the CEA standard performance indicators which are currently being developed to existing regulatory reporting requirements. To that end, once the CEA standards are finalized and accepted, the Board will require NP to report as to how these standards could be used in this Province. This may assist the Board in considering whether further action in relation to reliability and service quality standards is warranted."

a) Please confirm that the Board ruled out the distribution and reliability service standard "at this time", meaning 11 years ago.

b) Have the CEA standards referred to by the Board been finalized? If so, please file supporting documentation.

c) Please file a copy of NP's report on how the CEA standards could be used in this Province and the Board's response in considering whether further action in relation to reliability and service quality standards is warranted.

A. a) Newfoundland Power confirms the Board deemed a distribution and reliability service standard as being unnecessary in 2007 as it was "*not persuaded that the establishment of a formal Distribution and Reliability Service Standard as proposed by the Consumer Advocate will provide incremental value to consumers, the utility or the Board at this time.*"[1] Ultimately, the Board concluded that it "*is satisfied that its current regulatory framework has adequate processes and requirements in place to monitor reliability and service quality."*[2] In Newfoundland Power's view, the findings of the Board in 2007 continue to be relevant today. For more information, see response to Request for Information CA-NP-043.

b) The development of CEA standards referenced in Order No. P.U. 32 (2007) relate to 2 performance indicators that were introduced by the CEA in 2012: (i) Customer Hours of Interruption per Kilometer ("CHIKM"); and (ii) Customers Interrupted per Kilometer ("CIKM"). Unlike SAIDI and SAIFI, these indices are based on kilometers of line and provide a better understanding of plant condition. These measures were introduced as part of Newfoundland Power's Distribution Reliability Initiative in the Company's *2015 Capital Budget Application*. The Board approved this application, including expenditures under the Distribution Reliability Initiative, in Order No. P.U. 40 (2014).

[1] See Order No. P.U. 32(2007), p.37 *et. seq*.
[2] Ibid.

A copy of the Distribution Reliability Initiative report filed with the *2015 Capital Budget Application* is provided as Attachment A to this response.

In 2013, the CEA issued a white paper detailing additional indices. A copy of this white paper is provided as Attachment B to this response. For the most part these new indices require smart metering or an Outage Management System ("OMS"). Newfoundland Power is in the process of implementing a new OMS and will assess the use of the new indices as part of that process.

c) See responses (a) and (b) above.

2015 Distribution Reliability Initiative Report

Distribution Reliability Initiative

June 2014

Prepared by:

Ralph Mugford, P.Eng.

NEWFOUNDLAND POWER
A FORTIS COMPANY

Table of Contents

Page

1.0 Introduction

The Distribution Reliability Initiative is a capital project focusing on the reconstruction of the worst performing distribution feeders. Customers on these feeders experience more frequent and longer duration outages than the majority of customers.

Newfoundland Power manages system reliability through capital investment, maintenance practices and operational deployment. On an ongoing basis, Newfoundland Power examines its actual distribution reliability performance to assess where targeted capital investment is warranted to improve service reliability.

The process used by Newfoundland Power to identify which distribution feeders will benefit from targeted capital investment involves (i) calculating reliability performance indices for all feeders, (ii) analysing the reliability data for the worst performing feeders to identify the cause of the poor reliability performance and (iii) where appropriate complete engineering assessments for those feeders where poor reliability performance cannot be directly related to isolated events that have already been addressed. The decision to make capital investment to improve the reliability performance of the worst performing feeders is based upon the engineering assessments completed as part of the process.

2.0 Background

Previously Newfoundland Power identified its worst performing feeders exclusively on the basis of System Average Interruption Duration Index ("SAIDI"), System Average Interruption Frequency Index ("SAIFI") and customer minutes of outage.[1] These are the indices most commonly used in Canada and are reflective of the overall system condition.[2] SAIDI and SAIFI are used to rank the reliability performance of distribution feeders on the impact outages have on individual customers. However, it is recognised that relying solely on these indices to identify worst performing feeders can lead to overlooking smaller feeders with chronic issues.[3]

In 2012 the Canadian Electricity Association began reporting on 2 additional indices; Customer Hours of Interruption per Kilometer ("CHIKM") and Customers Interrupted per Kilometer ("CIKM").[4] CHIKM and CIKM are used to rank the reliability performance of distribution feeders on the length of line exposed to the outage. These indices tend to be more reflective of

---

[1] System Average Interruption Duration Index (SAIDI) is calculated by dividing the number of customer-outage-hours (e.g., a two hour outage affecting 50 customers equals 100 customer-outage-hours) by the total number of customers in an area. Distribution SAIDI records the average hours of outage related to distribution system failure. System Average Interruption Frequency Index (SAIFI) is calculated by dividing the number of customers that have experienced an outage by the total number of customers in an area. Distribution SAIFI records the average number of outages related to distribution system failure.

[2] Over the period 1999 to 2011 Newfoundland Power spent approximately $17.5 million on Distribution Reliability Initiative projects almost exclusively in rural areas of its service territory.

[3] Smaller feeders will have fewer customers than larger feeders and as a result outages of similar duration will involve less customer minutes of outage.

[4] Customers Interrupted per Kilometer (CIKM) is calculated by dividing the number of customers that have experienced an outage by the kilometres of line. Customer Hours of Interruption per Kilometer (CHIKM) is calculated by dividing the number of customer-outage-hours by the kilometres of line.

infrastructure condition and better identify issues associated with shorter feeders. Similar to SAIDI and SAIFI, CHIKM and CIKM are used to rank worse performing feeders that require further analysis of reliability data, and where appropriate, complete engineering assessments to determine if targeted capital investment is warranted to improve service reliability.

Newfoundland Power's has incorporated CIKM and CHIKM into its reliability analysis in this report.[5] Appendix A contains the 5-year average distribution reliability data, excluding significant events, for the 15 worst performing feeders based on data for 2009 to 2013 utilizing SAIDI, SAIFI, customer minutes, CIKM and CHIKM.

Appendix B contains a summary of the assessment carried out on each of the feeders listed in Appendix A.

3.0 Project Description

The examination of the worst performing feeders, as listed in Appendix A and Appendix B has resulted in Distribution Reliability Initiative work being proposed on 2 St. John's distribution feeders, KBR-10 and MOL-09.

A detailed engineering assessment of each distribution feeder is included in Appendix C and Appendix D to this report.

Table 1 summarizes the reliability data for each of the 2 distribution feeders.

Table 1
Distribution Interruption Statistics
5-Years to December 31, 2013

Feeder	Customers	SAIFI	SAIDI	CHIKM	CIKM
KBR-10[6]	950	1.21	2.20	313.0	172.3
MOL-09[7]	1,930	1.73	2.13	403.4	327.2
Company Average	**-**	**1.12**	**1.68**	**57.3**	**44.5**

Table 1 clearly demonstrates that distribution feeders KBR-10 and MOL-09 are not outliers from the Company average for SAIDI and SAIFI. When you consider customer interruptions and circuit length it is clear that these 2 distribution feeders are outliers from the Company average

[5] It is anticipated that by using indices that consider customer interruptions and circuit length that the worst performing feeders will be found in urban settings where the Company has older poles and associated infrastructure.

[6] KBR-10 is ranked 6th in terms of CHIKM and 12th in terms of CIKM. The condition of the aerial cables along Kings Bridge Road and the complexity associated with replacement following an in service failure is the basis of the decision to upgrade this section of KBR-10 in 2015.

[7] MOL-09 is ranked 1st in terms of CHIKM and 3rd in terms of CIKM.

for CHIKM and CIKM. An analysis of the outage data reveals that equipment failure has been the cause of most of the outages experienced. Both feeders are constructed from some of the oldest poles and related infrastructure in service in the City of St. John's.[8]

4.0 Project Cost

The estimate to complete all work associated with the 2015 Distribution Reliability Initiative project is $863,000. Table 2 provides a detailed breakdown of the total project cost by distribution feeder.

Table 2
Project Cost

Description	KBR-10	MOL-09	Total
Engineering	15,000	43,000	58,000
Labour - Contract	56,000	211,000	267,000
Labour - Internal	57,000	137,000	194,000
Material	33,000	107,000	140,000
Other	50,000	154,000	204,000
Total	**211,000**	**652,000**	**863,000**

8 The average age of poles that comprise these 2 distribution feeders is 47 years for KBR-10 and 37 years for MOL-09. The average age of poles for the entire Company is 27 years. The poles on these 2 feeders are significantly older than the average pole used throughout the Company.

Appendix A
Distribution Reliability Data: Worst Performing Feeders

Unscheduled Distribution Related Outages Five-Year Average 2009-2013 Sorted By Customer Minutes of Interruption				
Feeder	**Annual Customer Interruptions**	**Annual Customer Minutes of Interruption**	**Annual Distribution SAIFI**	**Annual Distribution SAIDI**
DLK-03	2,532	466,006	1.95	5.98
KEN-04	6,186	456,537	2.41	2.96
KEN-03	5,694	443,433	2.09	2.72
GLV-02	2,284	425,622	1.53	4.74
DOY-01	3,582	417,383	2.13	4.14
GBY-03	3,209	388,540	4.17	8.42
CHA-02	4,981	379,453	2.11	2.68
DUN-01	1,890	366,002	1.91	6.18
SUM-01	3,591	363,405	1.99	3.35
RRD-09	4,221	362,935	2.23	3.20
HWD-07	4,503	362,328	1.74	2.34
GFS-02	4,937	360,067	3.06	3.73
BOT-01	2,560	355,644	1.52	3.51
GFS-06	3,709	337,154	2.12	3.21
LEW-02	1,889	324,545	1.29	3.69
Company Average	**918**	**82,398**	**1.12**	**1.68**

Unscheduled Distribution Related Outages Five-Year Average 2009-2013 Sorted By Distribution SAIFI				
Feeder	**Annual Customer Interruptions**	**Annual Customer Minutes of Interruption**	**Annual Distribution SAIFI**	**Annual Distribution SAIDI**
GBY-03	3,209	388,540	4.17	8.42
GBY-02	2,831	201,360	3.10	3.68
GFS-02	4,937	360,067	3.06	3.73
MSY-03	4,294	303,488	3.05	3.59
FER-01	1,806	170,049	2.82	4.43
GIL-01	2,737	245,803	2.71	4.06
LAU-01	1,830	140,962	2.63	3.37
CAB-01	3,294	248,357	2.61	3.29
MOB-01	3,741	156,372	2.58	1.79
GBY-01	1,565	156,097	2.53	4.20
KEN-04	6,186	456,537	2.41	2.96
HUM-09	1,283	160,593	2.23	4.65
RRD-09	4,221	362,935	2.23	3.20
DOY-01	3,582	417,383	2.13	4.14
MOL-06	2,903	312,687	2.13	3.82
Company Average	**918**	**82,398**	**1.12**	**1.68**

Unscheduled Distribution Related Outages **Five-Year Average** **2009-2013** **Sorted By Distribution SAIDI**				
Feeder	**Annual Customer Interruptions**	**Annual Customer Minutes of Interruption**	**Annual Distribution SAIFI**	**Annual Distribution SAIDI**
GBY-03	3,209	388,540	4.17	8.42
DUN-01	1,890	366,002	1.91	6.18
DLK-03	2,532	466,006	1.95	5.98
SUM-02	636	205,189	1.05	5.65
SCR-01	4	321,685	1.23	5.54
LGL-02	1,091	197,685	1.73	5.23
RVH-02	175	46,712	1.14	5.06
GLV-02	2,284	425,622	1.53	4.74
HUM-09	1,283	160,593	2.23	4.65
FER-01	1,806	170,049	2.82	4.43
GBY-01	1,565	156,097	2.53	4.20
BUC-02	135	40,260	0.85	4.19
DOY-01	3,582	417,383	2.13	4.14
ABC-01	1,373	193,747	1.76	4.14
NCH-02	739	162,430	1.11	4.08
Company Average	**918**	**82,398**	**1.12**	**1.68**

Unscheduled Distribution Related Outages Five-Year Average 2009-2013 Sorted By Distribution CHIKM	
Feeder	**Annual Distribution CHIKM**
MOL-09	403.4
MOL-04	357.2
KBR-02	326.3
KBR-01	325.3
SLA-09	317.2
KBR-10	313.0
KEN-03	306.9
GFS-02	275.2
KEN-04	269.3
HWD-07	241.6
MOL-06	234.4
MOL-08	232.6
PEP-01	197.4
HUM-09	194.9
RRD-09	186.9
Company Average	**57.3**

Unscheduled Distribution Related Outages Five-Year Average 2009-2013 Sorted By Distribution CIKM	
Feeder	**Annual Distribution CIKM**
RRD-09	582.0
GFS-02	452.8
MOL-09	327.2
KEN-03	236.4
KEN-04	218.9
KBR-01	192.1
KBR-02	185.2
MOL-04	180.3
HWD-07	180.1
SLA-09	178.5
RVH-02	175.0
KBR-10	172.3
MOL-08	171.5
KBR-04	167.3
GOU-01	156.1
Company Average	**44.5**

Appendix B
Worst Performing Feeders
Summary of Data Analysis

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
ABC-01	Reliability statistics were driven by a broken conductor related event in February 2010 and a faulted lightning arrestor in 2010. There was also a sleet related incident in 2011. No work is required at this time.
BOT-01	Reliability statistics in 2010 were poor due to damage caused by a vehicle accident. In 2013 trees falling across the line during a wind storm contributed to poor reliability. No work is required at this time.
BUC-02	Reliability problems in 2008 were due to 3 insulator failures in 2008. Insulators were replaced in 2009. There were 2 incidents of broken conductor in 2011 and a problem with a tree contacting the line in 2013. No work is required at this time.
CAB-01	Reliability was poor in 2012 principally due to 2 separate tree related incidents. A wind storm in 2013 also contributed to poor reliability. No work is required at this time.
CHA-02	Reliability statistics were driven by a single broken insulator event in June 2009. No work is required at this time.
DLK-03	Reliability statistics were driven by a broken conductor in November 2009, a single weather related event in 2011 and several incidents of trees contacting the line in 2013. No work is required at this time.
DOY-01	Overall reliability statistics on this feeder have been impacted by feeder unbalance caused by a number of long single-phase taps. The poor average statistics are also driven by weather related events in each of 2009, 2010 and 2012. Work is planned under the 2014 Feeder Additions for Load Growth project to address the single-phase taps issue. No further work is required at this time.
DUN-01	Poor reliability statistics were driven by a broken pole in 2009. Reliability improved greatly in 2010 and 2011. Poor reliability in 2012 was due to vegetation issues. No work is required at this time.

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
FER-01	Reliability statistics were driven by a tree related event in 2009. No work is required at this time.
GBY-01	GBY-01 has had good reliability over the years. A lightning related event resulted in poor overall reliability in 2012. In addition a tree contacted the line in late 2013. No work is required at this time.
GBY-02	GBY-02 has had good reliability over the years. A wind related event resulted in poor overall reliability in 2012. No work is required at this time.
GBY–03	Reliability statistics were driven by isolated weather related events in each of 2009, 2010, 2011 and 2013. This feeder had significant upgrades as part of the 2011 Rebuild Distribution Lines project. No work is required at this time.
GFS-02	Reliability statistics were driven by a tree related event in October 2009 and storm damage in November 2013. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
GFS-06	Reliability problems relate to vegetation issues in 2009 and 2011. A storm in November 2013 also contributed to reduced reliability statistics. No work is required at this time.
GIL-01	Reliability statistics were driven by a tree related event in October 2010 and blizzard conditions in December 2013. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
GLV-02	Poor reliability statistics in 2010 were due to problems accessing the line through Terra Nova Park in response to a tree related event. A sleet storm in 2012 impacted reliability as well as a vegetation related incident in 2013. No work is required at this time.

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
GOU-01	Reliability statistics were driven by a wind related event in 2010 and broken conductor in December 2013. No work is required at this time.
HUM-09	Reliability statistics were driven by a tree related event in 2010 and a failed lightning arrestor in 2013. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
HWD-07	Reliability statistics were driven by a failed cut-out in 2010 and issues related to high winds in February 2013 and December 2013. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
KBR-01	Reliability statistics were driven by a wind related outage in 2009 and a broken pole caused by a vehicle accident in 2011. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
KBR-02	Reliability statistics were driven by 3 incidents of equipment failure over the 2009 to 2013 period. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
KBR-04	Reliability statistics were driven by 2 tree related incidents, one in 2010 and one in 2013. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
KBR-10	Over the period 2009 to 2013 this feeder has had 6 feeder level outages due to equipment failure. The condition of the aerial cable along Kings Bridge Road is of particular concern. An engineering assessment determined work is required in 2015.
KEN-03	KEN-03 has had good reliability over the years. A sleet storm in 2009, a broken insulator in 2012 and issues which occurred with a new pole installation in 2013 led to reduced reliability. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
KEN-04	KEN-04 has had good reliability over the years. Two events, a pole hit by a vehicle and a lightning strike resulted in poor overall reliability in 2012. No work is required at this time.
LGL-02	Reliability statistics were driven by wind in 2010, salt spray and a broken conductor in 2013. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
LEW-02	Reliability statistics were impacted by fallen trees contacting lines in 2009 and 2011. A pole hit by a vehicle resulted in poor reliability statistics in 2013. No work is required at this time.

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
MOB-01	MOB-01 has had good reliability over the years. Broken conductor in 2011 and a broken pole and crossarm as a result of a vehicle accident in 2013 were the prime reasons for the poor reliability statistics experienced in recent years. No work is required at this time.
MOL-04	MOL-04 has had good reliability over the years. Several weather events resulted in poor overall reliability in 2012. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
MOL-06	MOL-06 has had good reliability over the years. Trees contacting the line caused problems in 2009 and 2013. Broken conductor caused an extended outage in 2011. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
MOL-08	Broken conductor in 2009 and 2010 and a broken insulator in 2012 were the only significant issues on MOL-08. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
MOL-09	Over the period 2009 to 2013 this feeder has had 6 feeder level outages due to equipment failure. The feeder also had multiple outages to long taps due to equipment failure. An engineering assessment determined work is required in 2015.
MSY-03	Reliability statistics were driven by a broken conductor event in each of 2012 and 2013. No work is required at this time.

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
NCH-02	Reliability statistics were driven by vegetation related event in 2011 and problems during a wind storm in 2013. No work is required at this time.
PEP-01	Reliability statistics were driven by broken conductor in September 2010. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
RRD-09	Reliability problems were due to broken conductor in 2011. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
RVH-02	Reliability problems were due to 2 events; a blizzard and a broken crossarm in 2011. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.
SCR-01	Reliability statistics were driven by a wind related event in November 2011 and a tree contacting the line in 2013. No work is required at this time.
SCT-02	Reliability problems were due a tree contacting the line in 2010. No work is required at this time.
SLA-09	Poor overall reliability is due to an underground cable fault in 2011. This feeder is one of the Company's worst performing from an interruption per kilometer perspective. An engineering assessment is required to determine if this feeder should be included for rebuilding in a future capital budget.

Worst Performing Feeders Summary of Data Analysis	
Feeder	**Comments**
SUM-01	Three events, one involving salt spray and the other broken conductor resulted in poor overall reliability in 2012. In 2013 an issue occurred with a broken insulator. No work is required at this time.
SUM-02	Reliability statistics were driven by 2 tree related events in May and December 2011 and a weather event in 2012. No work is required at this time.

Appendix C
Kings Bridge KBR-10 Feeder Study

June 2014

Table of Contents

1.0 General

The *Distribution Reliability Initiative* is a project that involves the replacement of deteriorated poles, conductor and hardware to reduce both the frequency and duration of power interruptions to the customers served by specific distribution feeders. Distribution feeders are identified for evaluation based on an analysis of reliability statistics over the past 5 years. Once identified, a detailed engineering assessment of the feeder is carried out to determine if any upgrade work is required. The assessment looks at the physical condition of plant, the risk of failure and the potential impact to customers in the event of a failure.

The 2015 Distribution Reliability Initiative identified the KBR-10 feeder as one the *worst performing feeders* on Newfoundland Power's distribution system. An engineering evaluation of the feeder was carried out in early 2014. This report summarizes the findings of that evaluation and presents a plan to improve reliability on the feeder.

2.0 KBR-10 Feeder

The KBR-10 feeder is one of 12 distribution feeders originating from Kings Bridge Substation ("KBR"). The feeder has ties to 3 other St. John's feeders making it a critical feeder for transferring load between feeders when needed in the east end of the City.[1]

KBR-10 is a 12.5 kV distribution feeder that was originally constructed in the early 1960's serving approximately 950 customers. The feeder leaves the substation located on Kings Bridge Road between Empire Avenue and Winter Avenue and extends south along Kings Bridge Road then splits to supply the east end of Gower Street and the east end of Water Street including Signal Hill and the Battery. KBR-10 exits the substation underground with 750 MCM cross-linked polyethylene ("XLPE") cable before transitioning to overhead aerial cable on Kings Bridge Road.[2] The first 700 meter section of the main trunk along Kings Bridge Road and Ordinance Street is aerial cable. KBR-10 is 1 of 4 aerial cable feeders that are all attached to a single pole line along Kings Bridge Road.[3]

The 600 meter 3-phase section extending down Gower Street as far as Prescott Street is constructed using 1/0 copper conductor. The approximate 1.0 km section along Water Street and heading up Signal Hill through the Battery is also constructed using 1/0 copper conductor.

All of the poles comprising KBR-10 are installed in the sidewalk immediately behind the curb. Due to the age of this part of the City of St. John's, the homes and buildings along these streets are constructed along the edge of the sidewalk. This has required the use of alley-arm

[1] Load is transferred between feeders during planned work and during unplanned emergencies to minimize the frequency and duration of customer outages.

[2] Aerial cable is an insulated cable assembled from 3 separate single-phase cables bundled together around a messenger wire. Aerial cables have wind and ice loading factors much larger than bare aluminum cable requiring larger poles with shorter span length. Most of the Company's aerial cable is more than 40 years old and is no longer a standard design for distribution feeders.

[3] Appendix C-1 includes a map showing the areas served by distribution feeder KBR-10.

construction for sections of the open wire 3-phase line to maintain clearance to homes and buildings.[4]

3.0 Engineering Assessment

Inspections have identified deterioration due to decay, splits and checks in the poles and crossarms, as well as deficiencies with guys, anchors, hardware and insulators on the feeder. Due to the proximity to the road, damage to the outer layers of the poles from vehicles and snowplows has impacted the structural integrity of the support structures. In addition 2-piece insulators are still in use on the main trunk section of the feeder. The 2-piece insulators have a documented high failure rate related to cement growth and are a particular concern on a heavily loaded urban feeder.[5] Due to the age and condition of the support structures they are susceptible to damage when exposed to severe wind, ice and snow loading. This distribution feeder was built to weather loading criteria that are less than the standard currently used for new construction.

The most critical reliability issue with this feeder in recent years has been the aerial cable running along Kings Bridge Road and Ordinance Street. The aerial cable has faulted twice in the past 3 years.[6] The age and physical condition of the aerial cable makes it highly likely that there will be further cable faults experienced.

The 1/0 copper conductor running along Gower Street as far as Prescott Street and along Water Street and heading up Signal Hill through the Battery is nonstandard and showing signs of deterioration.[7]

Table 1 summarizes the reliability data for KBR-10 distribution feeder for the most recent 5-year period.

Table 1
KBR-10 Distribution Interruption Statistics
5-Years to December 31, 2013

	Customers	SAIFI	SAIDI	CHIKM	CIKM
	950	1.21	2.20	313.0	172.3
Company Average	**-**	**1.12**	**1.68**	**57.3**	**44.5**

[4] Alley-arm construction is when a crossarm and bracing is placed on one side of a pole to provide clearance from a building or vegetation. The alley-arm structure appears to be an inverted "L". Appendix C-2, Figure 1 includes a photograph of an alley-arm structure showing nonstandard framing and clearances.

[5] Since the 1960's the term "cement growth" has been used to categorize a problem with premature failure of porcelain insulators. The cement joining the 2 insulating discs grows over time placing stress on the porcelain that fails in tension by cracking.

[6] The condition of the aerial cable is such the refurbishment of KBR-10 should take place in advance of other distribution feeders with worse reliability indices. Figure 2 of Appendix C-2 is a photograph of a faulted section of the KBR-10 aerial cable.

[7] Newfoundland Power no longer uses 1/0 copper conductor in new construction.

Table 1 clearly demonstrates that distribution feeder KBR-10 is not an outlier from the Company average for SAIDI and SAIFI. Considering customer interruptions and circuit length it is clear that this distribution feeder is an outlier from the Company average for CHIKM and CIKM. Distribution feeder KBR-10 is constructed from some of the oldest poles and related infrastructure in service in the City of St. John's. This distribution feeder has reached a point where continued maintenance is no longer feasible and the feeder has to be rebuilt to current construction standards for continued safe and reliable operation.

4.0 Recommendations

The KBR-10 feeder is a critical part of the Company's distribution system in the east end and downtown areas of St. John's. The majority of the reliability issues on this line are due to aging and substandard infrastructure and particularly the aerial cable running along Kings Bridge Road and Ordinance Street.

To improve the performance and reliability of this feeder, it is recommended that:

- The pole line along Kings Bridge Road and Ordinance Street be upgraded including the replacement of 24 deteriorated poles and 19 anchors;[8]

- The nonstandard 1/0 copper conductor be replaced. The 25 spans of standard 3-phase open wire construction will be rebuilt with 477 mcm AASC conductor and the 26 spans of single-phase line will be rebuilt with 1/0 ASC conductor;

- All remaining 2-piece insulators on the main trunk of KBR-10 feeder be replaced with 34 kV clamp top insulators and V-brace crossarms; and

- The existing aerial cable be replaced with standard 3-phase open wire construction.

It is proposed to complete the required work in 2015 at an estimated cost of $211,000.

8 There are 413 poles on this distribution feeder. The poles being replaced range in age from 26 to 47 years in service. The primary reason for replacement of the younger poles is excessive loading and damage from vehicles and snow plows.

Appendix C-1
Map Showing Areas Serviced by KBR-10


KBR
Substation
KBR
LAKE AVE
EMPIRE AVE
KBR-10
UG
KINGS BRIDGE RD
PORTUGAL COVE RD
CIRCULAR RD
FRASERS LANE
FOREST RD
COLLIERS LANE
CAVELL AVE
FOREST AVE
QUIDI VIDI RD
POWERS CRT
ST JOSEPHS LANE
SIGNAL HILL RD
KBR-10
UG
KBR-10
The Battery
CABOT AVE
CURRY RD
RENNIES MILL RD
BANNERMAN RD
STEWART AVE
ORDNANCE ST
PLYMOUTH RD
DEVON ROW
TEMPERANCE ST
LOWER BATTERY RD
BATTERY RD
U S ARMY DOCK RD
KBR-10
MONKSTOWN RD
CAREW ST
COLONIAL ST
BANNERMAN ST
COCHRANE ST
YORK ST
WATER ST
MILITARY RD
BOND ST
KINGS RD
PILOTS HILL
BARNES RD
PRESCOTT ST
QUEENS RD
BRITISH SQ
KBR-10
UG
GILLS COVE
OUTER BATTERY RD
Atlantic Ocean
GOWER ST
DUCKWORTH ST
VICTORIA ST
QUEENS COVE
FEVERS LANE
HARVEY RD

Appendix C-2
Photographs of KBR-10 Feeder

Figure 1 - KBR-10 Pole with Alley Arm Type Crossarm

Figure 2 - KBR-10 Faulted Aerial Cable

Figure 3 - Pole Leaning Towards Traffic

Figure 4 - Loss of Pole Diameter at Base

Figure 5 - Guy Bent Towards Sidewalk

Figure 6 - Deteriorated Pole

Figure 7 – Aerial Cable Splice

Appendix D
Molloy's Lane MOL-09 Feeder Study

June 2014

Table of Contents

1.0 General

The *Distribution Reliability Initiative* is a project that involves the replacement of deteriorated poles, conductor and hardware to reduce both the frequency and duration of power interruptions to the customers served by specific distribution feeders. Distribution feeders are identified for evaluation based on an analysis of reliability statistics over the past 5 years. Once identified, a detailed engineering assessment of the feeder is carried out to determine if any upgrade work is required. The assessment looks at the physical condition of plant, the risk of failure and the potential impact to customers in the event of a failure.

The 2015 Distribution Reliability Initiative identified the MOL-09 feeder as one the *worst performing feeders* on Newfoundland Powers distribution system. An engineering evaluation of the feeder was carried out in early 2014. This report summarizes the findings of that evaluation and presents a plan to improve reliability on the feeder.

2.0 MOL-09 Feeder

The MOL-09 feeder is one of 8 distribution feeders originating from Molloy's Lane Substation ("MOL"). The feeder has ties to 5 other St. John's feeders making it a critical feeder for transferring load between feeders in the City's core when needed.[1]

MOL-09 is a 12.5 kV distribution feeder that was originally constructed in the early 1970's serving approximately 1,930 customers. The feeder extends from the substation located on Topsail Road just east of Columbus Drive and heads east on Topsail Road and Cornwall Avenue. The feeder also has 3-phase lines extending down Craigmillar Avenue, Hamilton Avenue and Blackmarsh Road.[2]

The main 3-phase trunk portion of MOL-09 on Topsail Road and Cornwall Avenue is approximately 1.8 km in length. The conductor on this section of line is a mixture of 397 Aluminum Conductor Steel Reinforced ("ACSR"), 4/0 Aluminum Alloy Stranded Conductor ("AASC") and 477 Aluminum Stranded Conductor ("ASC").

There are 2 long 3-phase taps on Craigmillar Avenue, Hamilton Avenue and Blackmarsh Road. The Craigmillar Avenue section is approximately 1.0 km in length and has a tie point with SJM-11 distribution feeder. This entire section has 1/0 copper conductor.

The Hamilton Avenue/Blackmarsh Road section is approximately 1.1 km in length. There is 1/0 copper conductor on Hamilton Avenue and 477 ASC on Blackmarsh Road. There is a tie point with distribution feeder MOL-08 at the Hamilton Avenue and Blackmarsh Road intersection and a tie point with distribution feeder SJM-13 on Blackmarsh Road.

---

[1] Load is transferred between feeders during planned work and during unplanned emergencies to minimize the frequency and duration of customer outages.

[2] Appendix D-1 includes a map showing the areas served by distribution feeder MOL-09.

There are also various sections of single-phase construction throughout the distribution feeder, half of which are within the first 0.9 km of the MOL-09 feeder.

3.0 Engineering Assessment

Inspections have identified deterioration due to decay, splits and checks in the poles and crossarms, as well as deficiencies with guys, anchors, hardware and insulators on the feeder. Due to the proximity to the road, damage to the outer layers of the poles from vehicles and snowplows has impacted the structural integrity of the support structures. In addition 2-piece insulators are still in use on the main trunk section of the feeder. The 2-piece insulators have a documented high failure rate related to cement growth and are a particular concern on a heavily loaded urban feeder.[3] Due to the age and condition of the support structures they are susceptible to damage when exposed to severe wind, ice and snow loading. This distribution feeder was built to weather loading criteria that are less than the standard currently used for new construction.

The poles along the Topsail Road and Cornwall Avenue section of the line are heavily loaded. This heavy loading is a significant concern for failure along this section given the extent of the deterioration identified on some of the poles and importance of the line as a tie point with other feeders in the area.

The 1/0 copper conductor running along Hamilton Avenue to Blackmarsh Road is substandard and showing signs of deterioration. In addition to reliability concerns the substandard conductor impairs load transfer capability.

Table 1 summarizes the reliability data for MOL-09 distribution feeder for the most recent 5-year period.

Table 1
MOL-09 Distribution Interruption Statistics
5-Years to December 31, 2013

	Customers	SAIFI	SAIDI	CHIKM	CIKM
	1,930	1.73	2.13	403.4	327.2
Company Average	**-**	**1.12**	**1.68**	**57.3**	**44.5**

Table 1 clearly demonstrates that distribution feeder MOL-09 is not an outlier from the Company average for SAIDI and SAIFI. Considering customer interruptions and circuit length it is clear that this distribution feeder is an outlier from the Company average for CHIKM and CIKM. Distribution feeder MOL-09 is constructed from some of the oldest poles and related

---

3 Since the 1960's the term "cement growth" has been used to categorize a problem with premature failure of porcelain insulators. The cement joining the 2 insulating discs grows over time placing stress on the porcelain that fails in tension by cracking.

infrastructure in service in the City of St. John's. This distribution feeder has reached a point where continued maintenance is no longer feasible and the feeder has to be rebuilt to current construction standards for continued safe and reliable operation.

4.0 Recommendations

The MOL-09 feeder is a critical part of the Company's distribution system in the west end of the City of St. John's. Over the past 5 years the majority of the reliability issues on this line have been due to aging and substandard infrastructure and heavy loading.

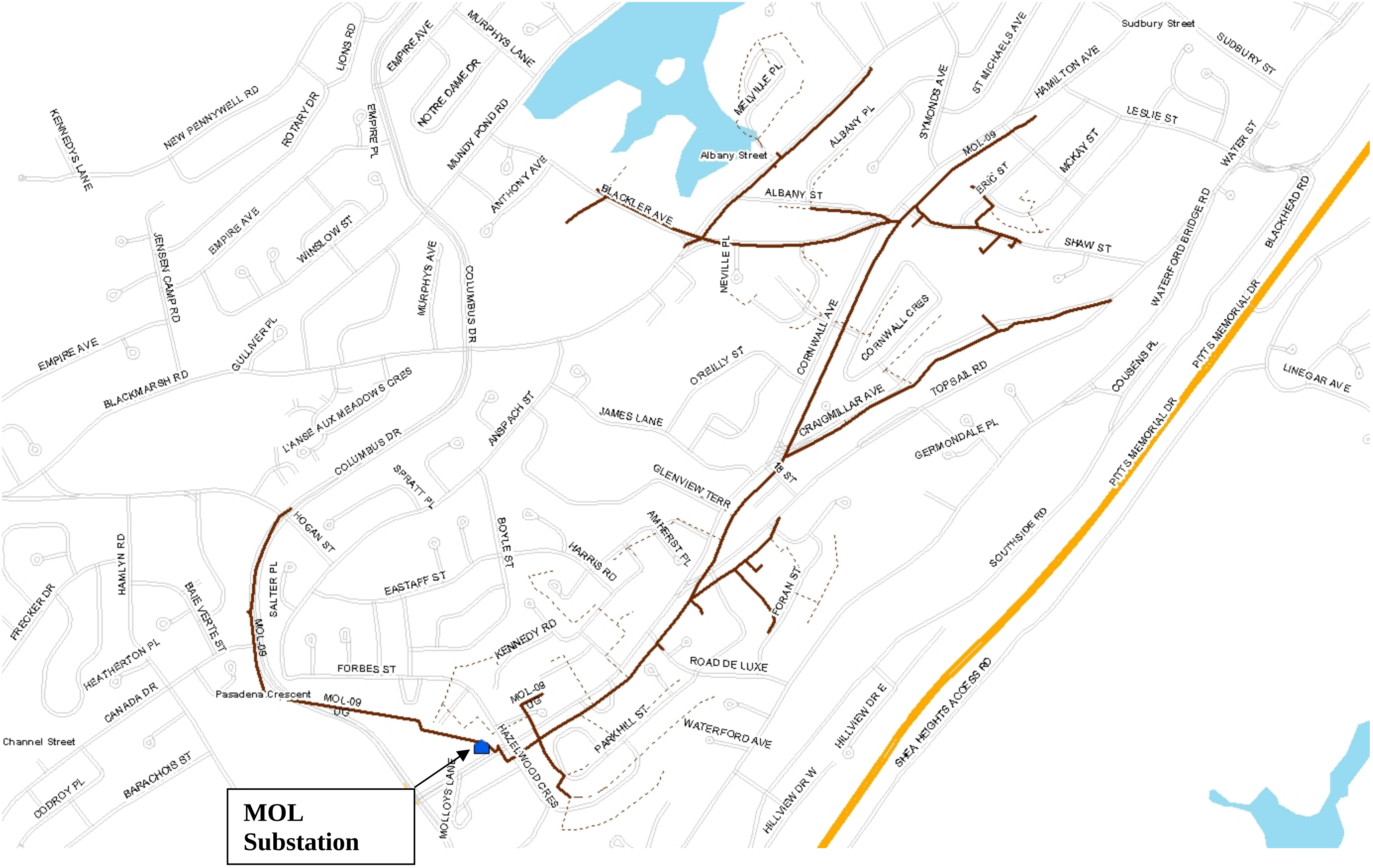
To improve the performance and reliability of this feeder, it is recommended to:

- Re-conductor the 0.5 km section of line from Hamilton Avenue to Blackmarsh Road with 477 ASC (Aluminum Stranded Conductor).
- Upgrade 71 deteriorated or overloaded poles and 33 anchors throughout the feeder.[4]
- Replace remaining 2-piece insulators on the main trunk portion of MOL-09 feeder with 34 kV clamp top insulators and V-brace crossarms.

It is proposed to complete the required work in 2015 at an estimated cost of $652,000.

[4] There are 358 poles on this distribution feeder. The poles being replaced range in age from 36 to 64 years in service. The primary reason for replacement of the younger poles is excessive loading and damage from vehicles and snow plows.

Appendix D-1
Map Showing Areas Served by MOL-09


MOL Substation
MOL-09
MOL-09 UG
Pasadena Crescent
Albany Street
Sudbury Street
Channel Street

Appendix D-2
Photographs of MOL-09 Feeder

Figure 1 – MOL-09 Pole Damage

Figure 2 - Pole Damage at Base

Figure 3 - Pole Damage

Figure 4 - Outer Shell Damage

Figure 5 – Pole Damaged by Vehicles

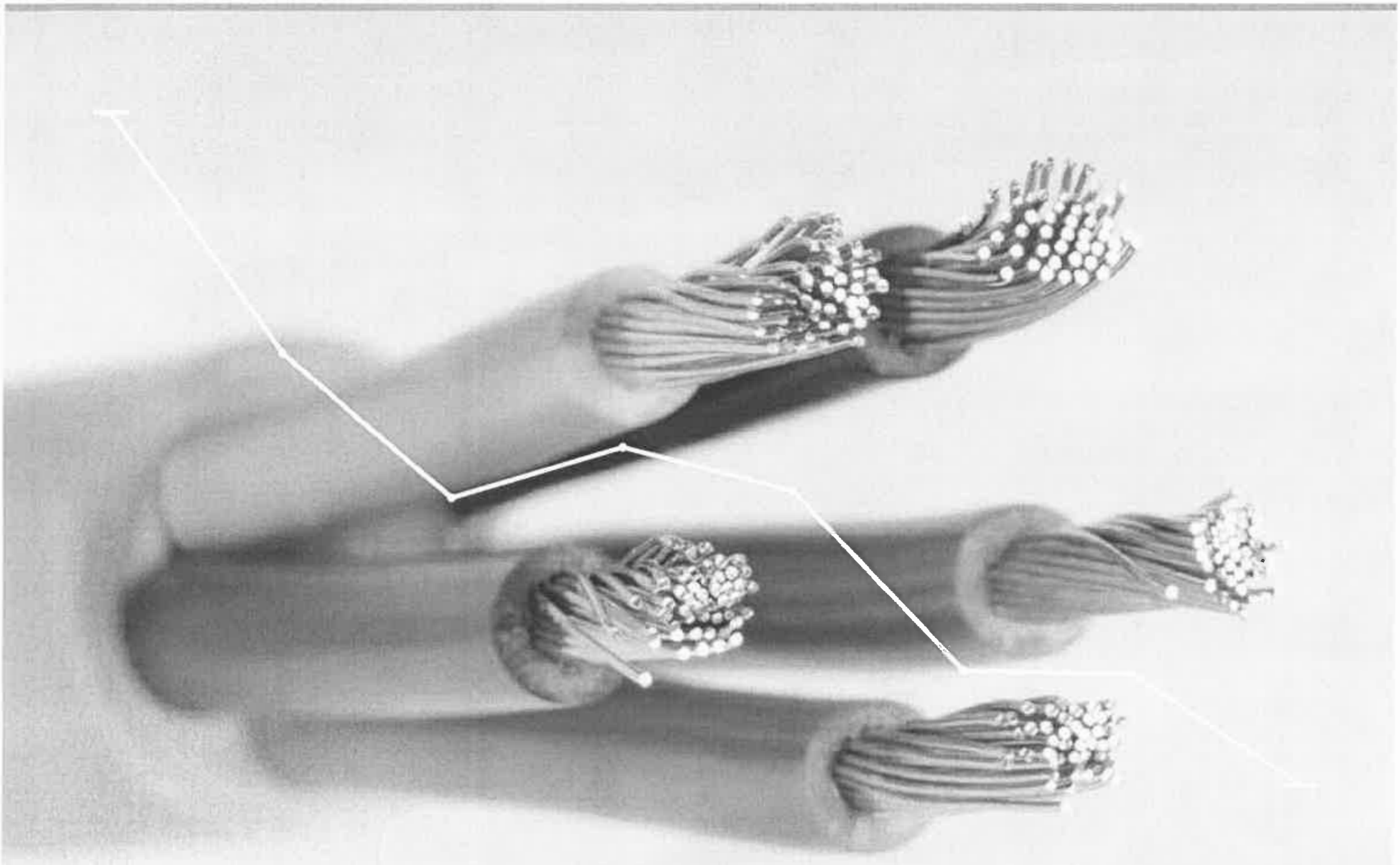
Figure 6 – Pole Damage near Base

Figure 7 – Pole Deteriorated at ground line

Figure 8 - Broken Crossarm, Leaning Pole, and Pole Replacement in Progress

2013 CEA Analytics White Paper

www.electricity.ca/analytics



CAIFI and CEMI Reporting

2013 CEA Analytics White Paper

Analytics | Analyse

Canadian Electricity Association | Association canadienne de l'électricité

Preface

This research was undertaken by Power System Solutions International Inc. (PSSI) for the New Measures Working Group of the Service Continuity Committee (SCC), a Consultative Committee on Outage Statistics in the Analytics programs of the Canadian Electricity Association. The research methodology was conducted and determined by Paul Kos, M.Sc. P.Eng., of PSSI. The content was determined by the New Measures Working Group of the SCC.

About the Service Continuity Committee

The Service Continuity Committee on Distribution Performance was developed to collect data on the overall electric distribution supply system. The data enables utilities to document the effectiveness of their service to customers and how major segments of the system have performed.

The Reporting System was inaugurated on January 1st, 1986. The system for service continuity is based on interruptions due to primary causes.

Acknowledgements

Special thanks to the New Measures Working Group of the SCC for facilitating the group:
Tom Janzen, Riaz Shaikh, Falguni Shah, Paul Kuner, Bo Ji, Cesar Rivasplata.

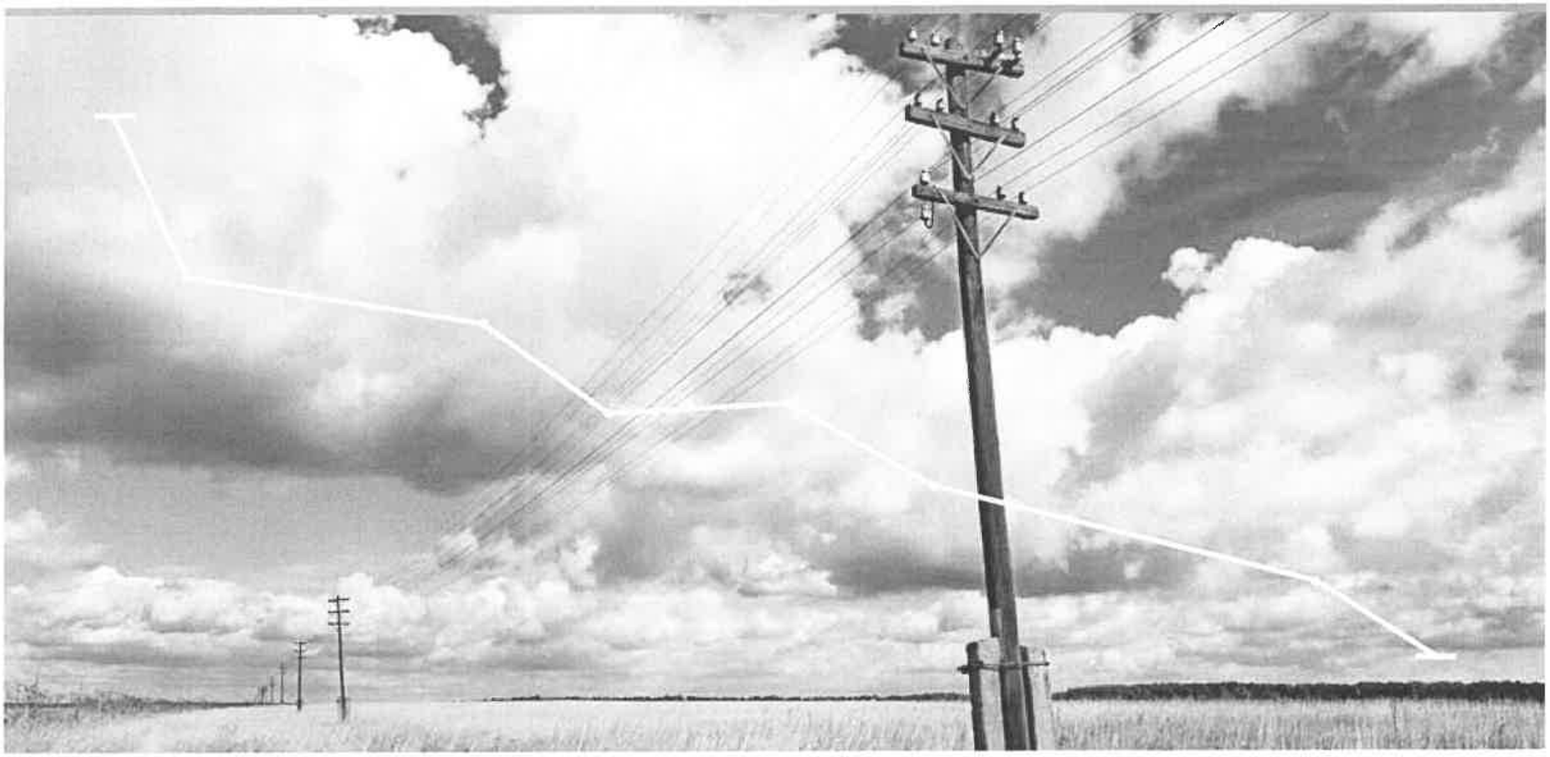
For CEA Analytics program inquiries:

Daniel Gent
Director, Analytics
Tel: 613.230.2959
gent@electricity.ca

www.electricity.ca/analytics

Canadian Electricity Association (CEA)
Ottawa, Ontario
Canada

Table of Contents



Preamble

In support of the Service Continuity Committee (SCC), a New Measures Working Group was formed to examine distribution performance indicators that are not currently used by SCC. Narrowing in on several indicators, the working group tested them in actual utility settings.

With the advent of new 'smart' technology and the expected increased flow of data to the utility world, there was a desire to explore the benefits of the CAIFI and CEMI indicators for electricity utilities, and to see how they are being used not just in Canada, but elsewhere around the world.

There are identified benefits for both indicators, but capturing the required data for each will have its own challenges for utilities as they learn to deal with not only vast amounts of data, but with data collection on outages for each individual customer. In turn, such challenges may not be currently possible for some utilities as their internal systems may be incompatible. If that is the case, the utility in question would incur additional costs to make adjustments for capturing the required data.

The intent of this document is not to promote CAIFI and CEMI, but to explore their effectiveness for utilities' to improve reliability, how to leverage them and identify the challenges to the readers.

Power Quality and Reliability

As consumers of electricity, electrical customers are in a broad sense concerned with the electrical supply capability to meet the requirements of their electrical equipment. Such capability is typically expressed in terms of power quality and supply reliability.

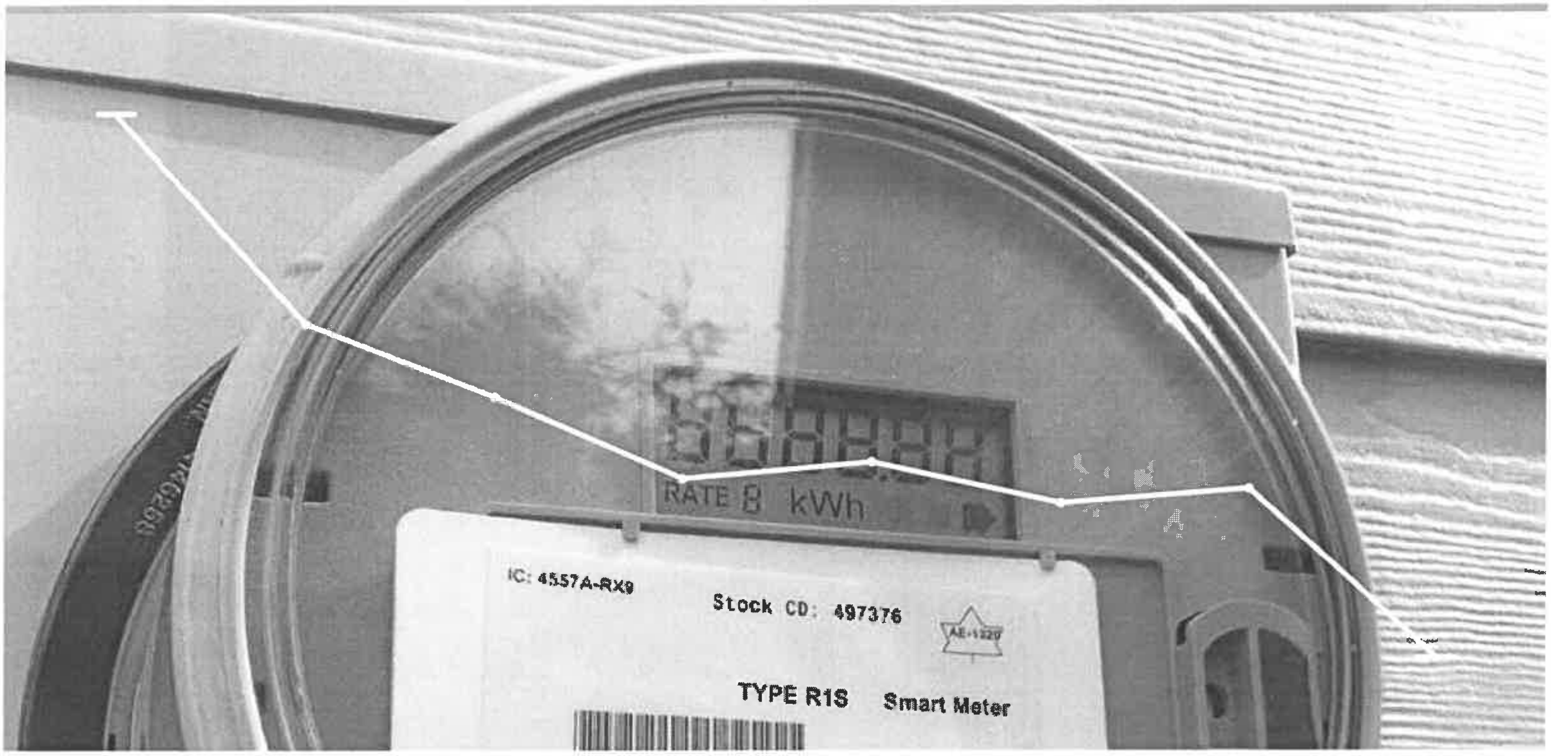
Power quality typically refers to the quality of supply voltage as measured against a perfect sinusoidal wave with constant and correct amplitude and with constant and correct frequency. Deviations from such target are referred to as harmonic distortion, frequency deviation, voltage sag or flicker, voltage swell or spike. Power quality is addressed by number of standards such as ANSI C84.1, EU HD 472 S1, IEEE Std. 446, "CBEMA curve" and "ITIC curve" to name a few.

Supply reliability typically refers to complete cessation of power with either momentary (less than five minutes) or sustained duration.

While power quality deviations can have significant consequences that may compare to or exceed those resulting from complete loss of supply, this White Paper focuses only the latter, namely the reliability.

Reliability Metrics and Indices

Distribution reliability relates primarily to equipment outages and customer interruptions. While the equipment reliability is of primary interest only to utility personnel concerned with planning operation and maintenance of the distribution systems, the reliability as seen by customers has a broader reach to utility management, customers and regulators since it is used to measure performance of the distribution utility. Indeed, reliability indices such as SAIFI (System Average Interruption Frequency Index) and SAIDI (System Average Interruption Duration Index) are commonly used in PBR (Performance Based Regulation) based tariffs. As such, these indices often directly affect the corporate rate of return.



1 Reliability Indices

Over the years, a relatively large number of "de facto standard" reliability indices were developed by industry and academia to measure the power system reliability from the end user point of view. Many of these indices were formally adopted in the official standards such as IEEE 1366 and others.

The reliability indices are effectively statistical aggregations (averages, expected values, etc.) for a well-defined set of loads or customers. Most common reliability indices can be divided as either customer based or load based. The same index can often be also calculated for only momentary or only sustained outages.

Next two sections present a summary of common reliability indices and their definitions.

1.1 Customer Based Indices

The definitions of common customer based reliability indices are summarized in this section. These indices are referred to as "customer based" since they do not appropriately distinguish between customers. For example, the industrial customer with demand in MW range is accounted for in the same manner as a residential customer with demand in range of a few kW.

1.1.1 Sustained Customer Based Indices

Most common customer based reliability indices recognize, by definition, only the sustained customer outages. Definition of sustained outages differs from jurisdiction to jurisdiction with respect to the considered maximum duration. Typically, the maximum duration ranges between one and five minutes.

The definitions of reliability indices for sustained outages are summarized in this section.

1.1.1.1 Availability

Availability is the most basic of the reliability indices. It is the probability of a customer being energized. It is typically measured in percent or on per unit basis. Unavailability is the reverse of Availability, namely the probability of not being energized. Mathematically, this is given in:

$$Availability = \frac{\text{Time energized}}{\text{Total time period}}$$

$$Unavailability = \frac{\text{Time not energized}}{\text{Total time period}}$$

Availability and Unavailability are typically not used directly in the utility performance reporting systems. Instead, the ASAI or ASUI indices are used as described below.

1.1.1.2 SAIFI: System Average Interruption Frequency Index

The System Average Interruption Frequency Index (SAIFI) indicates how many sustained interruptions an average customer will experience over a predefined period of time, typically a year. Mathematically, this is given in the equation below:

$$SAIFI = \frac{\sum \text{Total Number of Customers Interrupted}}{\text{Total Number of Customers Served}} \quad \text{[occ/year]}$$

1.1.1.3 SAIDI: System Average Interruption Duration Index

System Average Interruption Duration Index (SAIDI) is a measure of how many interruption hours an average customer will experience during a predefined period of time, typically a year. It is also commonly expressed in minutes per year.

$$SAIDI = \frac{\sum \text{Total Customer Interruption Durations}}{\text{Total Number of Customers Served}} \quad \text{[hours/year]}$$

1.1.1.4 CAIFI: Customer Average Interruption Frequency Index

The Customer Average Interruption Frequency Index (CAIFI) indicates how many sustained interruptions an affected customer will experience over a predefined period of time, typically a year. This index differs from SAIFI only by the numerator: instead of using total number of customers served, the frequency is expressed in terms of customers experiencing at least one interruption per year.

Mathematically, this is given in the equation below:

$$CAIFI = \frac{\sum \text{Total Number of Customer Interruptions}}{\text{Total Number of Customers Interrupted}} \text{ [occ/year]}$$

1.1.1.5 CAIDI: Customer Average Interruption Duration Index

Customer Average Interruption Duration Index (CAIDI) is a measure of how long an average interruption will last. This index differs from SAIDI only by the numerator: instead of using total number of customers served, the duration is expressed in terms of total number of customer – interruptions. As such, CAIDI is a measure of restoration time.

$$CAIDI = \frac{\sum \text{Total Customer Interruption Durations}}{\text{Total Number of Customer Interruptions}} \text{ [hours/occ]}$$

1.1.1.6 ASAI: Average Service Availability Index

Average Service Availability Index (ASAI) is the customer-weighted availability of the system or, from a customer's point of view, the fraction of time (percentage of time) an average customer received power.

$$ASAI = \frac{\text{Customer hours of available service}}{\text{Customer hours demanded}} \chi \text{ 100 [\%]}$$

ASUI is complimentary index defined as 1-ASAI.

1.1.1.7 CTAIDI: Customer Total Average Interruption Duration Index

Customer Total Average Interruption Duration Index (CTAIDI) represents the total time in the reporting period that customers who actually experienced an interruption were without power. This index is complimentary to CAIDI and is similarly calculated, except that those customers with multiple interruptions are counted only once.

$$CTAIDI = \frac{\sum \text{Total Customer Interruption Durations}}{\text{Total Number of Customers Interrupted}} \text{ [hours/occ]}$$

1.1.1.8 $CEMI_n$: Customers Experiencing Multiple Interruptions

Customers Experiencing Multiple Interruptions ($CEMI_n$) indicates the ratio of individual customers experiencing n or more sustained interruptions to the total number of customers served.

$$CEMI_n = \frac{\text{Total Number of Customers Experiencing n or more interruptions}}{\text{Total Number of Customers Served}} \quad [\text{occ/year}]$$

1.1.1.9 $CELID_t$: Customers Experiencing Long Interruption Durations

The Customers Experiencing Long Interruption Durations Index ($CELID_t$) indicates the ratio of individual customers that experience interruptions with durations longer than or equal to a given time. That time is either the duration of a single interruption (s) or the total amount of time (t) that a customer has been interrupted during the reporting period. Caution has to be exercised when interpreting the $CELID_t$ index since sometimes the t is considered as cumulative and sometimes as pertaining to individual outages.

$$CELID_t = \frac{\text{Total Number of Customers Experiencing interruptions longer than t}}{\text{Total Number of Customers Served}} \quad [\text{occ/year}]$$

1.1.2 Customer Based Indices Recognizing Momentary Interruptions

Several common reliability indices recognize the momentary interruptions. The representative listing of most common indices is shown in this section.

1.1.2.1 MAIFI: Momentary Average Interruption Frequency Index

The Momentary Average Interruption Frequency Index (MAIFI) indicates the average frequency of momentary interruptions. It is analogous to SAIFI except that it counts only the momentary outages.

$$MAIFI = \frac{\sum \text{Total Number of Customer Momentary Interrupted}}{\text{Total Number of Customers Served}} \quad [\text{occ/year}]$$

1.1.2.2 $MAIFI_e$: Momentary Average Interruption Event Frequency Index

The Momentary Average Interruption Event Frequency Index ($MAIFI_e$) indicates the average frequency of momentary interruption events. This index counts multiple momentary interruptions related to the same event as one. This index does not include the momentary outages related to the events immediately preceding a sustained interruption as such events are reflected in SAIFI.

$$MAIFI_e = \frac{\sum \text{Total Number of Customer Momentary Interrupted}}{\text{Total Number of Customers Served}} \quad [\text{occ/year}]$$

1.1.2.3 $CEMSMI_n$: Customers Experiencing Multiple Sustained and Momentary Interruptions

Customers Experiencing Multiple Sustained and Momentary Interruptions ($CEMSMI_n$) is similar to $CEMI_n$ except that it includes both momentary and sustained outages.

$$CEMSMI_n = \frac{\sum \text{Customer Experiencing More than n Combined Momentary and Sustained Outages}}{\text{Total Number of Customers Served}} \quad \text{[occ/year]}$$

1.1.3 Load Based Reliability Indices

Two of the oldest distribution reliability indices weigh customers based on connected kVA as opposed to weighting each customer equally. These indices precede the customer based indices since in the past utilities did not have knowledge of exactly how many customers are connected to each distribution transformer but knew the size of the transformer. With development of customer information systems (CIS), the customers can be readily identified with each feeder and use of load based reliability indices dropped in favor of customer based indices.

1.1.3.1 ASIFI: Average System Interruption Frequency Index

The calculation of the Average System Interruption Frequency Index (ASIFI) is based on load rather than number of customers affected. ASIFI is sometimes used to measure distribution performance in areas that serve relatively few customers or that have relatively large concentrations of industrial or commercial customers.

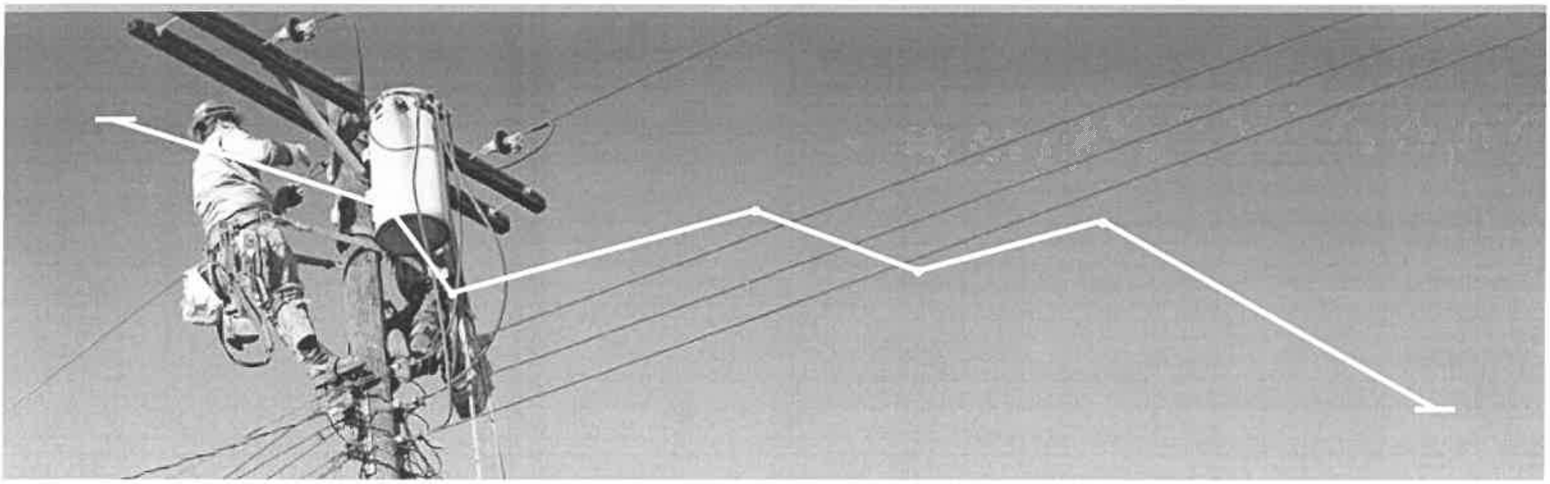
Theoretically, in a system with homogeneous load distribution, ASIFI would be the same as SAIFI.

$$ASIFI = \frac{\sum \text{Connected kVA Load Interrupted}}{\text{Total Connected kVA Served}} \quad \text{[occ/year]}$$

1.1.3.2 ASIDI: Average System Interruption Duration Index

The calculation of the Average System Interruption Duration Index (ASIDI) is based on load rather than customers affected.

$$ASIDI = \frac{\sum \text{Connected kVA Hours Interrupted}}{\text{Total Connected kVA Served}} \quad \text{[hours/year]}$$



2 Comparison of Reliability Indices

The use of distribution reliability indices can be loosely divided into three overlapping areas, namely:

1. Distribution system planning
2. Benchmarking
3. Regulatory process and Performance Based Regulation (PBR)

Since ideally the objectives of each of these areas of reliability indices use are similar, namely the optimization of investment and operating expenditures to maximize reliability to utility customers, the comparison of the indices can focus on the planning aspect without any loss of generality.

The two most reported distribution reliability indices are SAIFI and SAIDI. These indices are complimentary; the former reflects frequency of power outages, the latter the average duration. Both are expressed in terms of an average customer. SAIFI and SAIDI are good set of indices to use when prioritizing the expenditures; however the means of how to improve each differs. Fortunately, the actions used to improve reliability either improves both indices or at least does not affect adversely one of them.

The two most common ways to improve SAIFI is to reduce the number of overall sustained outage events (such as effective reclosing) and to reduce the number of customers affected by such events (such as by sectionalizing). All else being equal, a reduction in SAIFI will also reduce the SAIDI since the total customer minutes of interruption will be reduced.

The most common way of reducing the SAIDI is to reduce the restoration time. Such improvement will not affect the SAIFI. As discussed above, a reduction in the frequency of events resulting in sustained outages or a reduction in the number of affected customers during such events also reduces SAIDI.

Common criticism of SAIFI and SAIDI use alone revolves around targeting expenditures. Often, the greatest improvement in SAIFI and SAIDI can be achieved in urban, high density areas where the reliability may already be adequate for customer needs. In extreme circumstances, the funds would be diverted from low density areas to high density areas, exposing customers in low density areas to an unacceptable level of sustained outages and to long restoration times.

The concern described above also often relates to levels of customer satisfaction which is typically non-linear. Further improvement of already satisfactory levels of reliability in high density areas may not result in further improvement in customer satisfaction while the dissatisfaction of customers experiencing large number and/or prolonged outages in low density area remains high or even increases.

Another issue arises from pitting SAIFI against SAIDI. If the customer interruption cost were increasing proportionately with duration, more specifically, if customer impact of interruption lasting twice as long would equal double the cost, there would be no difference between improvements in SAIFI and SAIDI. However, should the customer cost of interruption be reasonably independent of duration (at least within a given range), improvement in SAIDI caused solely by a reduction in interruption duration will be less valuable than the improvement in SAIFI. In extreme cases, it may not lead to any appreciable improvement in customer utility.

Use of CAIDI, although prevalent, is often problematic. CAIDI is typically seen as a measure of efficiency when responding to outages. All else being equal, a reduction in restoration time will reduce CAIDI. Problems arise when SAIFI does not remain constant, more specifically, when SAIFI improves more quickly than SAIDI. Since CAIDI is simply SAIDI divided by SAIFI the CAIDI can actually increase while both SAIFI and CAIDI decrease. For example, should SAIFI improve from 2 occ per year to 1 occ per year (a rather dramatic improvement), and SAIDI improves from 100 minutes to 90 minutes, CAIDI will increase from 50 minutes to 90 minutes. It is true that in this example, the average response time for affected customers actually increased, but the system as a whole is certainly more reliable.

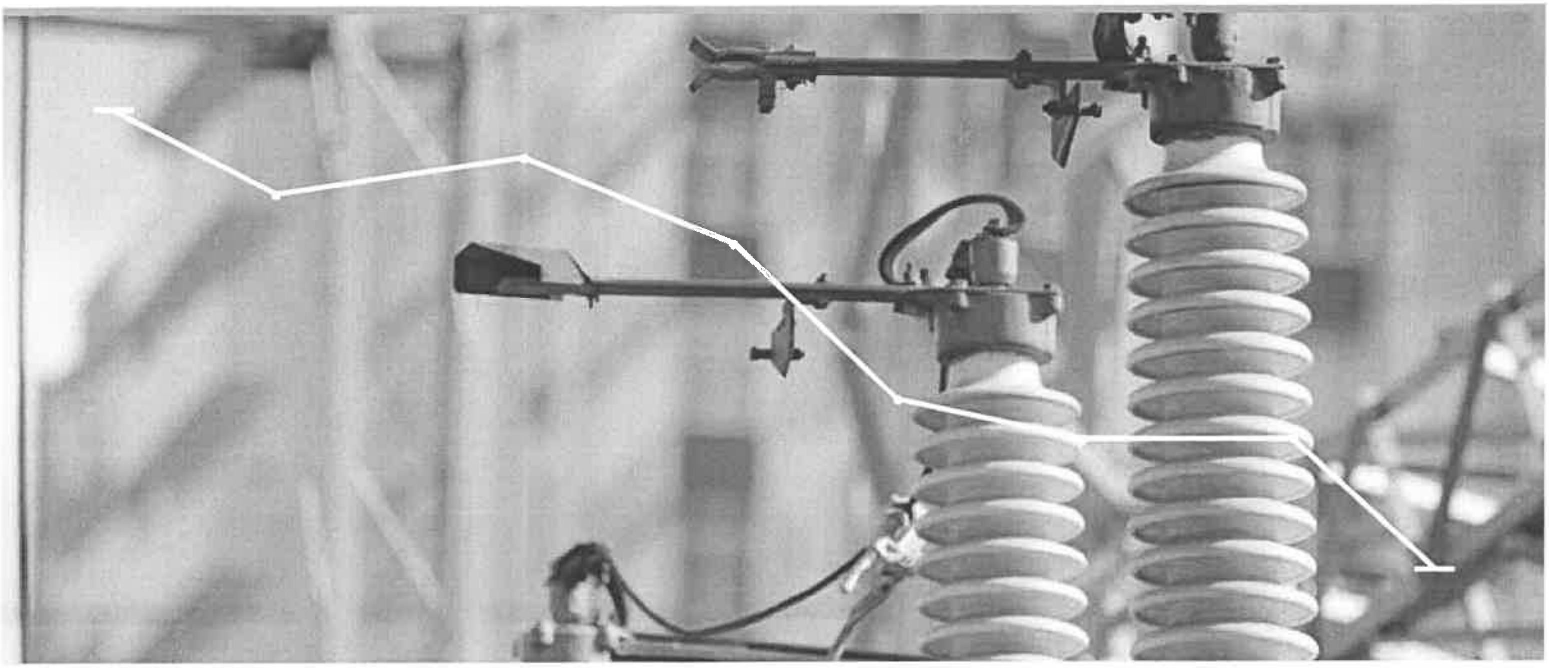
As demonstrated, CAIDI is best used as a supplementary index that augments SAIFI and SAIDI.

Similar to SAIFI and SAIDI, MAIFI will also drive investment towards the highest density areas where reliability may be already satisfactory. Furthermore, in its most basic form, MAIFI will discourage investment in automated switching schemes, since these will typically lead to an increased number of momentary outages to customers (i.e. will only reduce the frequency and duration of sustained outages).

MAIFI addresses the above concern to some degree by eliminating momentary outages preceding the sustained outage from inclusion and by focusing on the event rather than on each momentary outage. However, the association of momentary outages with events requires additional considerable effort during data collection and processing.

CEMI and CAIFI address some of the concerns with SAIFI and SAIDI expressed above. More specifically, by focusing only on the customers experiencing outages, it inherently addresses the area with lower reliability. Since this White Paper is focused on the need for collecting data required for reporting CAIFI and CEMI, their benefits and shortcomings are discussed in specific sections below.

Strengths and weaknesses of ASIFI and ASIDI indices stem from their focus on size of interrupted load. As such, they favor industrial and commercial customers over residential. While such focus may be supported by the results of studies investigating customer costs resulting from power supply interruptions, it is typically not politically acceptable. Consequently, these indices are often used only on feeders with predominantly industrial or commercial load.



3 CAIFI and CEMI

As previously stated, CEMI and CAIFI address some of the concerns with SAIFI and SAIDI and other indices described in this Report.

3.1 CAIFI

3.1.1 Description

CAIFI is a measure of the frequency of power supply interruptions for customers who experience interruptions. CAIFI is similar to SAIFI except for the denominator that comprises only customers who experienced at least one interruption. As such, the best possible value attainable is 1 (as opposed to 0 for SAIFI). In situations where each customer experiences at least one outage, CAIFI would in fact equal SAIFI. CAIFI was defined in Section 1.1.1.4.

3.1.2 Benefits

The major benefit of CAIFI stems from its focus on customers who experience outages, namely the poorly performing feeders typically found in the low density parts of a service area.

CAIFI shortcoming revolves around its behavior when reliability on some feeders is improved to the point that a number of customers do not experience any outages at all. In this case, assuming all else being equal, the customers are no longer counted in the denominator, and CAIFI can actually increase. The only way to show that the reliability actually increased is to show a drop in SAIFI. In fact, the CAIDI by itself does not show whether its reduction was due to an improvement in reliability or by an increase in the number of customers experiencing at least one interruption.

CAIFI displays highly desirable information pertaining to feeders that experience outages. However, to properly interpret any trends, it has to be augmented by the information on trend in a number of customers that experience at least one interruption. Such information is contained in the CEMI index, discussed later on in this White Paper.

While CAIFI is valuable supplementary information, it does not replace the need for SAIFI and SAIDI. Rather, it provides additional insight into the performance of feeders with lower reliability. Care has to be exercised to interpret properly trends in CAIFI since they can be counterintuitive.

3.1.3 Data Collection Requirements and Incremental Effort

The CAIFI data collection requirement is similar to that of SAIFI except that the identity of the interrupted customers has to be retained in the collection system to determine which customers were interrupted at least once over the reporting period. With the proliferation of CIS and its connectivity to the reliability data collection systems, this requirement is not prohibitive since the information will be available and only a programming change will be required.

It should also be noted that CAIFI can be calculated from $CEMI_n$ for n=1 and SAIFI as follows:

$$CAIFI = \frac{SAIFI}{CEMI_1} \quad \text{[occ/year]}$$

3.2 CEMI

3.2.1 Description

CEMI, as its name suggests, is a measure of how many customers experience n interruptions. Its calculation was described in Section 1.1.1.8.

CEMI can be determined for any value of n ranging from 1 to maximum set by the number of interruptions experienced by the most interrupted customer on the system.

3.2.2 Benefits

The benefits of collecting data and reporting on CEMI have been recognized by a growing number of utilities. The two primary benefits relate to an understanding of the distribution of the frequency of interruptions among the more frequently interrupted customers and its relation to customer satisfaction.

As stated previously, utilities have recognized the potential disconnect between the SAIFI and SAIDI and the level of customer satisfaction. This is chiefly because the customer satisfaction is typically non-linear with dissatisfaction triggered after the customer experiences a certain number of outages. While studies have shown that such triggering number of outages can differ from jurisdiction to jurisdiction and between rural and urban areas, it is possible to find the applicable threshold and calculate CEMI for such number of outages. The resulting CEMI will correlate well with customer satisfaction levels.

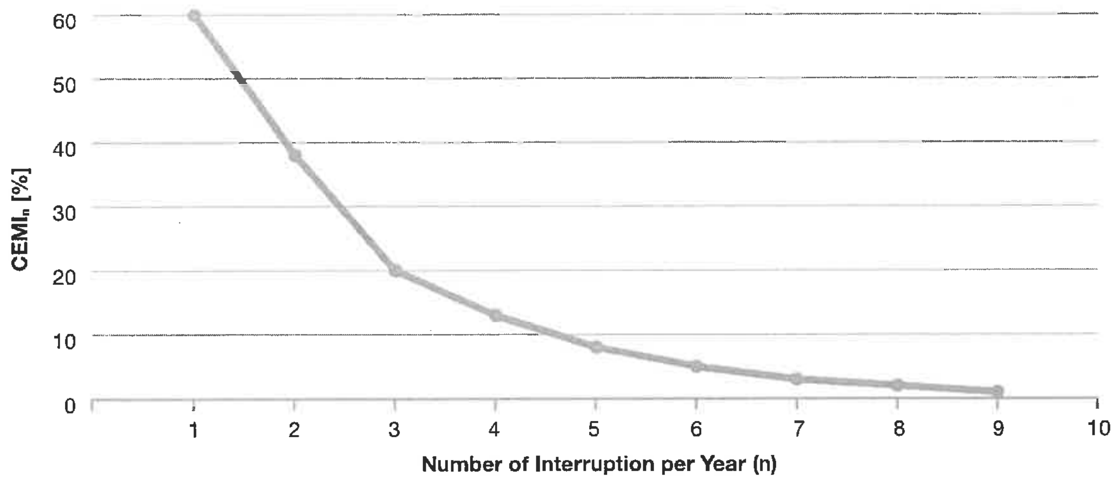
When used to trigger the expenditure (or provide regulatory feedback), CEMI will direct the investment towards areas experiencing less reliability and hence serves well the objective of equalizing the reliability to customers in different regions.

By preferring CEMI for different values of n, valuable insight can be obtained into distribution of customer experience with reliability of power delivery.

It should be appreciated that CEMI is a strictly frequency based index and reduction in outage duration without reduction in outage frequency will not reduce CEMI.

Furthermore, CEMI is not sensitive to improvements that do not lead to crossing the n interruptions per year. For example, in the case of $CEMI_4$, an

FIGURE 1: Percentage of Multiple Interruptions ($CEMI_n$)

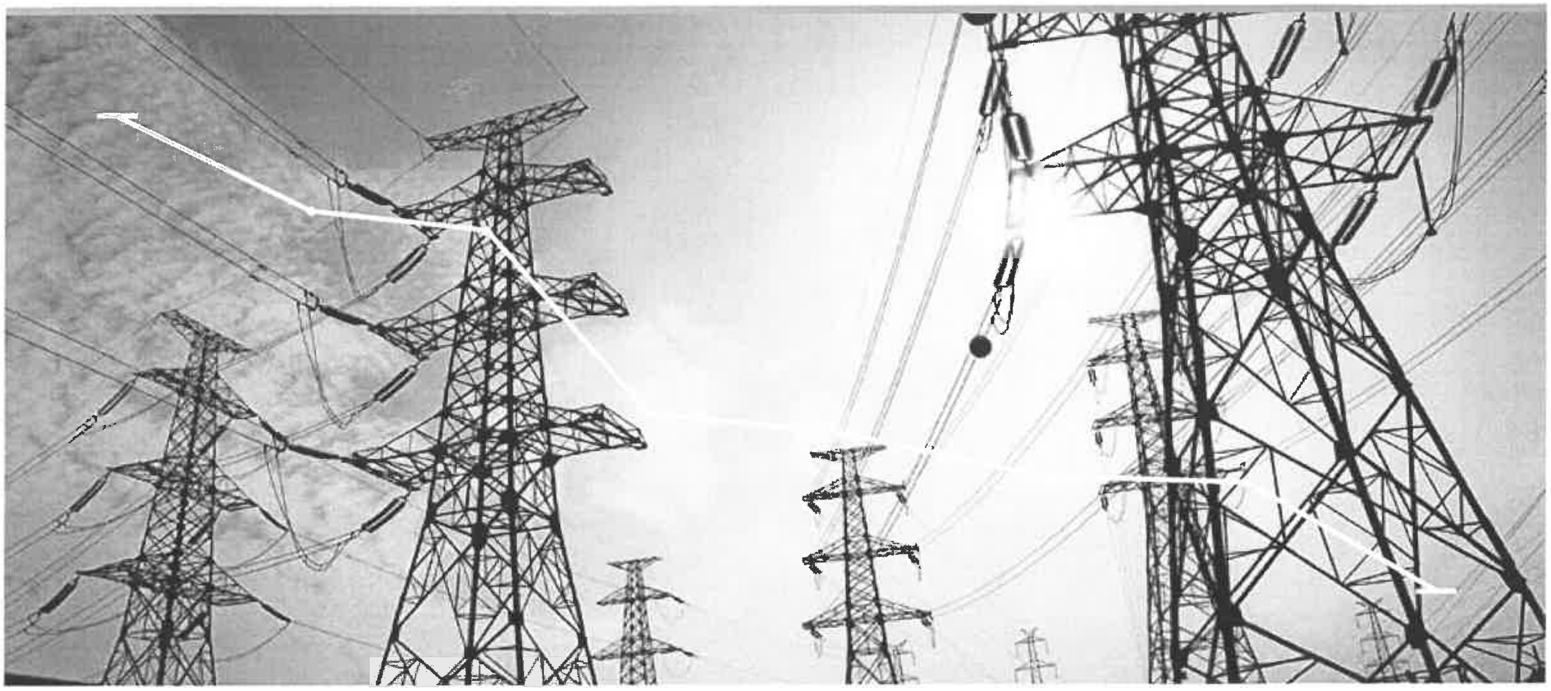


improvement in reliability that results from a reduction of the number of outages on a given feeder from 10 to 5 will not register in $CEMI_4$. Selection of n for calculation of $CEMI_n$ is consequently very important and should reflect the maximum acceptable number of interruptions for customer per year. One of the risks of using CEMI to allocate expenditures without proper consideration to SAIFI and SAIDI is that emphasis may be put on improving feeders that will achieve a jump from "over n" to "under n" and hence register in CEMI, as opposed to focusing on worst performing feeders that may be impossible or impractical to improve upon to the point of falling below n interruptions per year.

In summary, CEMI is a valuable complimentary index to SAIFI and SAIDI which helps to show the extent of presence of feeders with unsatisfactory performance. This benefit can be further increased by reporting $CEMI_n$ for several values of n as shown in the figure below. If $CEMI_n$ is reported for only one value of n, great care has to be exercised when selecting the value since it will be directly tied to the strategic target for the reduction of the number of interruptions seen by customers.

3.2.3 Data Collection Requirements and Incremental Effort

$CEMI_n$ data collection requirements are similar to that of SAIFI except that the identity of the interrupted customers has to be retained in the collection system to determine which customers were interrupted over the reporting period and how many times. The requirement to record the number of interruptions for each customer at least once represents additional data collection demand above and beyond that required for CAIFI. With the proliferation of CIS and its connectivity to the reliability data collection systems, this requirement is not prohibitive since the information will be readily available and only a programming change will be required. Recording the number of interruptions for each customer would be preferable over recording by feeder or segment of a feeder since the former system could accommodate customer relocations and other system changes.



4 Experience of Different Jurisdictions

This section summarizes the experience of calculating and reporting reliability indices from different jurisdictions. It is intended to be representative rather than exhaustive.

4.1 Summary

By far, the indices most commonly used and reported by the utilities are SAIFI and SAIDI. Many utilities also report CAIDI; some explicitly and some implicitly by pointing to the formula used to calculate CAIDI from SAIFI and SAIDI.

Relatively few utilities are presently calculating CEMI and even fewer are reporting it. Those who do point to the significant benefit obtained from a better understanding of issues pertaining to poorly performing feeders. In addition, there is a significant improvement understanding the ranges of outage magnitudes to location and sources of outages.

As noted by one of the reporting utilities: *It was difficult to accept that with a system SAIFI of less than 1.5, greater than 20,000 customers had experienced more than six interruptions.*

Relatively few utilities are currently reporting CAIFI. All utilities that report CAIFI and/or CEMI also report basic indices such as SAIFI, SAIDI and CAIDI.

Typically, utilities that report CAIFI and/or CEMI reported on more indices, indicating that their data collection is closely tied to their Customer Information Systems. They also had the ability to distinguish exactly which customers were affected by each outage and determine what characteristics these customers had that differed from others.

In most cases, the reported indices coincide with those ordered by the corresponding regulatory body. For example, most regulators are requesting SAIFI and SAIDI as a part of the score card from all distribution companies within their jurisdiction, ensuring consistency in calculation methodology within each jurisdiction. However, such consistency is not maintained between jurisdictions.

Reliability indices are often used by regulators to impose performance targets for utilities. In some cases, these are tied to incentives and penalties, such as within the Performance Based Regulation (PBR) frameworks. Furthermore, reliability indices calculated on a per customer or per feeder basis are sometimes used to determine the financial compensation offered to customers if the power supply fails to perform up to applicable minimum standard.

4.2 Canadian Experience

Reliability indices calculated and reported in Canada are shown in Table 1. Canada is unique compared to the United States and other countries, as the Canadian Electricity Association (CEA) has been collecting distribution reliability performance data on behalf of its member utilities for over 20 years. The data reported includes:

- System Average Interruption Frequency Index (SAIFI)
- System Average Interruption Duration Index (SAIDI)
- Customer Average Interruption Duration Index (CAIDI)
- Index of Reliability (IOR)
- Customer interruptions per kilometer
- Customer hours per kilometer

The results are reported to member utilities and aggregate values are available to the public at a cost.

In addition, the utilities typically either report the reliability indices to their respective regulatory agencies, include them in annual or other performance reports, or post them on line.

Most of the utilities/jurisdictions are reporting SAIFI and SAIDI indices.

BC Hydro has one of the most detailed reporting systems and is the only utility reporting $CEMI_4$ both to the regulators and on line. The British Columbia Utilities Commission is expecting BC Hydro to produce SAIFI, SAIDI, CAIDI, ASAI, SARI and MAIFI. BC Hydro has chosen to report on $CEMI_4$ in addition to the regulator's requirements.

The Ontario Energy Board publishes Electricity Reporting & Record Keeping Requirement (RRR) specific reliability indices that are to be collected and reported by Ontario distribution utilities. These include SAIDI, SAIFI, CAIDI and MAIFI. However, distributors that do not have system capabilities enabling them to capture or measure MAIFI are exempted from this reporting requirement.

Alberta Utilities Commission (AUC) Rule002 specifies the requirement for distribution utilities to report SAIDI and SAIFI in the province. AUC also defines the maximum SAIFI and SAIDI for each distribution company subject to Rule002. This differs between utilities.

Other Canadian jurisdictions have similar requirements.

TABLE 1: **Representative example of reliability indices collected by Canadian Utilities**

Province	Utility	
British Columbia	BC Hydro	SAIFI, SAIDI, CAIDI, ASAI, SARI, $CEMI_4$
	Fortis BC	SAIFI, SAIDI
Alberta	AUC	SAIFI, SAIDI
	Enmax	SAIFI, SAIDI
	EPCOR	SAIFI, SAIDI
	Fortis Alberta	SAIFI, SAIDI
	ATCO Electric	SAIFI, SAIDI, CAIDI
Saskatchewan	SaskPower	SAIFI, SAIDI
Manitoba	Manitoba Hydro	SAIFI, SAIDI, CAIDI, Availability
Ontario	Ontario Energy Board	SAIFI, SAIDI, CAIDI, MAIFI
	Toronto Hydro	SAIFI, SAIDI, CAIDI
	Hydro Ottawa	SAIFI, SAIDI
	Hydro One	SAIFI, SAIDI, CAIDI
Quebec	Hydro Quebec	SAIFI, SAIDI
Nova Scotia	Nova Scotia Power	SAIFI, SAIDI
New Brunswick	New Brunswick Power	SAIFI, SAIDI
Newfoundland	Newfoundland and Labrador Hydro	SAIFI, SAIDI

4.3 USA Experience

The indices reported by US utilities are summarized below.

With few exceptions, the indices reported are those ordered by the corresponding regulatory body. Consequently, the reported indices are often the same within the state. A number of exceptions apply, most notably in Florida, where smaller utilities are not required to produce the indices that would require significant additional effort and/or upgrade of CIS, such as CEMI.

It should be emphasized that the reported indices are not necessarily calculated the same way and that many utilities produce several versions of the same indices, such as coastal vs. inland for maritime utilities, worst feeder vs. average etc.

DC's Pepco calculates multiple CEMI's, e.g. $CEMI_8$, $CEMI_6$ and $CEMI_3$, which correspond to more than 8, 6 and 3 interruptions per year.

The Delaware Public Service Commission has ordered collection and reporting of CEMI for 8 or more interruptions ($CEMI_8$).

The Florida Public Service Commission has ordered and is reporting detailed statistics which include CEMI for 6 or more interruptions ($CEMI_6$). Utilities with fewer than 50,000 customers are presently exempt from the reporting requirements.

PacifiCorp, one of the Western United States leading utilities, is reporting CEMI-based statistics the show the range of interruptions between the two limits ranging from 0 to 30 in seven categories. PacifiCorp also displays the information graphically, where each category is represented by a different color on a map to show regions or feeders with higher and lower reliability.

The state of Illinois is reporting CAIFI in addition to SAIFI. Missouri is also reporting CAIFI in addition to SAIFI.

TABLE 2: Representative example of reliability indices collected by US utilities

State/Utility	Indices Reported
Alabama	SAIFI, SAIDI, CAIDI, MAIFI
California (CPUC)	SAIDI, SAIFI, MAIFI
Colorado	SAIFI, SAIDI,CAIDI
Connecticut	SAIFI, SAIDI
D.C. (Pepco)	SAIDI, SAIFI, CAIDI, $CEMI_8$, $CELID_8$
Delaware	SAIDI, SAIFI, CAIDI, $CEMI_8$, $CELID_8$
Florida	SAIDI, SAIFI, CAIDI, MAIFI, $CEMI_5$
Georgia	SAIFI, SAIDI,CAIDI
Hawaii	SAIFI, SAIDI,CAIDI
Idaho (PacifiCorp)	SAIFI, SAIDI, CEMI
Illinois	SAIFI, CAIFI, CAIDI
Indiana	SAIFI, SAIDI,CAIDI
Iowa	SAIFI, SAIDI,CAIDI
Kansas	SAIFI, SAIDI,CAIDI
Kentucky	SAIFI, SAIDI,CAIDI
Louisiana	SAIDI, SAIFI
Maine	SAIFI, CAIDI
Maryland	SAIFI, SAIDI, CAIDI
Massachusetts	SAIFI, SAIDI
Minnesota	SAIFI, SAIDI, CAIDI
Missouri	SAIFI, SAIDI, CAIDI, CAIFI
Nevada	SAIFI, SAIDI, CAIDI, MAIFI
New Jersey	SAIFI, CAIDI
New Mexico	SAIFI, SAIDI, CAIDI, ASAI
New York	SAIFI, CAIDI
North Dakota	SAIFI, SAIDI
Ohio	SAIFI, SAIDI, CAIDI, ASAI
Oklahoma	SAIFI, SAIDI, MAIFI
Oregon	SAIFI, SAIDI, CAIDI, MAIFI
Pennsylvania	SAIFI, SAIDI, CAIDI, MAIFI
Rhode Island	SAIFI, SAIDI
Texas	SAIFI, SAIDI
Utah	SAIFI, SAIDI
Vermont	SAIFI, CAIDI
Virginia	SAIFI, SAIDI, CAIDI
Washington	SAIFI, SAIDI, CAIDI, MAIFI, CEMI
Wisconsin	SAIFI, SAIDI, CAIDI

continued

4.4 Europe Experience

A range of indicators are used in different countries across the globe. SAIFI and SAIDI remain as the basic calculated and reported indicators, albeit often under different names (due to non-English speaking countries). Different methods are often used to weigh the interruptions, which makes it difficult to directly compare results. Weighting by demand, consumption, contracted demand or other entities reflecting the customer size typically biases the results towards larger industrial and commercial customers who are often supplied from more reliable urban feeders. Weighting by distribution transformers leads to bias towards smaller transformers and hence towards rural customers, as they are typically supplied from smaller transformers.

Indices that outline ENS and others that indicate the magnitude of unsupplied energy correlate better with the financial consequences of outages than the indices that treat each service equally, irrespective of size. However, the ENS will always be an approximation, since the demand during the outage can only be estimated.

Norway and Slovenia are using the CAIFI index in addition to SAIFI and SAIDI, reporting information about the number of interruptions experienced by those customers that actually get interrupted.

Sweden appears to be the only jurisdiction that calculates and uses the CEMI index. In fact, Sweden has upgraded its CIS after 2010 to include interruption information for each unique customer. This allows it to calculate just about any of the indices discussed in this White Paper.

A number of countries are using penalties or incentives in their regulatory regimes that are based on the reported reliability indices. Several countries even offer compensation to customers whose reliability indices are not met. The discussion of such schemes falls outside the scope of this White Paper.

TABLE 3: Representative example of reliability indices collected by European utilities

Country	Indices Reported
Austria	SAIDI, SAIFI, ASIDI, ASIFI, CAIDI, (CML, ENS)
Bulgaria	SAIDI, SAIFI
Cyprus	SAIDI, SAIFI,
Czech Republic	SAIFI, SAIDI, CAIDI, CENELEC
Denmark	SAIDI, SAIFI, ENS
Estonia	SAIDI, SAIFI, CAIDI, total annual interruption time for each customer
Finland	SAIDI and SAIFI
France	SAIFI, SAIDI, MAIFI, Percentage of customer with “insufficient” quality of supply
Germany	SAIDI (LV), ASIDI (MV), SAIFI
Great Britain	Customer Interruptions (CI) and Customer Minutes Lost (CML)
Greece	SAIFI, SAIDI

continued

Country	Indices Reported
Hungary	SAIFI, SAIDI, CAIDI, MAIFI
Ireland	Customer Interruptions (CI) and Customer Minutes Lost (CML)
Italy	SAIFI, SAIDI, MAIFIE
Lithuania	SAIDI, SAIFI (calculated for both long and momentary)
The Netherlands	SAIDI, SAIFI, CAIDI (calculated for both long and momentary)
Norway	SAIFI, SAIDI, CAIDI, CTAIDI, CAIFI
Poland	SAIFI, SAIDI, MAIFI
Portugal	SAIFI, SAIDI, ENS, AIT, MAIFI
Romania	SAIFI, SAIDI, ENS, AIT
Slovakia	Average Time of Interruption
Slovenia	SAIDI, SAIFI, CAIDI, CAIFI, MAIFI
Spain	TIEPI, NIEPI
Sweden	SAIFI, SAIDI, CEMI, ENS, MAIFIE

4.5 Australian Experience

Reliability indices calculated and reported in Australia consist almost exclusively of SAIFI and SAIDI. These indices are embedded in the regulatory regime in each jurisdiction. While the methodology for calculation differs between jurisdictions, the indices are used almost universally to define minimum acceptable standards. This is because the basis for the use of the indices is in the National Electricity Rules (NER). The NER contains a reliability incentive mechanism called the Service Target Performance Incentive Scheme, or STPIS. It provides for incentive arrangements under which reliability performance is measured using standard metrics (for example, SAIDI), and distributors receive a financial bonus for exceeding reliability targets. Alternatively, they are penalized if they miss the targets. The Rules can be superseded by the applicable electrical code or local regulatory body.

For example, in Tasmania, the target SAIDI and SAIFI are set by Tasmanian Electricity Code and differ by location.

In New South Wales (NSW), the reliability standard is set out by distributor's license. The license sets SAIFI and SAIDI that differ by location. The license defines the minimum acceptable levels and provides for payments to customers whose minimum guaranteed reliability levels are not met.

In Queensland, the distribution reliability regulations are set out in the Queensland Electricity Code. It sets minimum reliability standards in terms of SAIDI and SAIFI, which differ for different feeder types. Distributors must use best endeavors to ensure that the minimum standards are met. The code also sets the minimum acceptable levels and provides for customers being compensated if these levels are not met.

TABLE 4: **Representative example of reliability indices collected by Australian utilities**

Jurisdiction	Indices Reported
ACT (Australia Capital Territory)	SAIFI, SAIDI, CAIDI
New South Wales	SAIFI, SAIDI (average and for each feeder)
Queensland	SAIFI, SAIDI
South Australia	SAIDI, SAIFI, maximum time to restore supply
Tasmania	SAIFI, SAIDI
Victoria	SAIFI, SAIDI, MAIFI
Western Australia	SAIFI, SAIDI

Conclusion

Presently, the most used distribution reliability indices are SAIFI, SAIDI, CAIDI and to a lesser extent MAIFI.

While these indices provide very good indications of the reliability of the distribution system as a whole, they do not provide any information about frequency of outages on poorly performing feeders. Such frequency can be orders of magnitude higher than the overall SAIFI, yet the overall SAIFI may not be significantly affected. Worse still, improvement in performance of the poorest performing feeders may not show in SAIFI and SAIDI at all, since any movement may be smaller than the natural variability of those indices from year to year.

Some jurisdictions address this issue by reporting performance of the worst feeder. In extreme cases, utilities can report performance of each individual feeder, but this approach results in large amounts of data and makes it difficult to compare year to year results. This makes meaningful trending challenging.

In conjunction with basic indices such as SAIFI and SAIDI, CAIFI, and CEMI in particular, address this problem well.

The selection of "n", the triggering number of interruptions in $CEMI_n$, is critical. The value should reflect the maximum number of interruptions customers are willing to accept without expressing dissatisfaction. The values used can differ from 3 to 8. Another approach is to show a histogram of CEMI for each different n, or show this information graphically on a topographical map for each distribution area. Such use is still practical for trending while conveying significantly more information than $CEMI_n$ calculated for single n.

Calculation of CAIFI and CEMI typically requires the modification of existing data collection since the information about the number of outages for each customer (or feeder block) has to be stored. However, for any utility capable of calculating customer based indices, such modification represents only a programing change.

Utilities that choose to move ahead with recording data for CAIFI and CEMI will need to investigate the impacts to their reporting systems. Moving into the 21st century, new technology and measures will facilitate the improvement of reliability for all utility customers.

Analytics | Analyse

Canadian Electricity Association | Association canadienne de l'électricité