Q. **<u>2015 Distribution Reliability Review, Page 5, Footnote 10</u>**

Please provide the working group whitepaper *"Worst Performing Feeders"* prepared by Canadian Electricity Association Analytics.

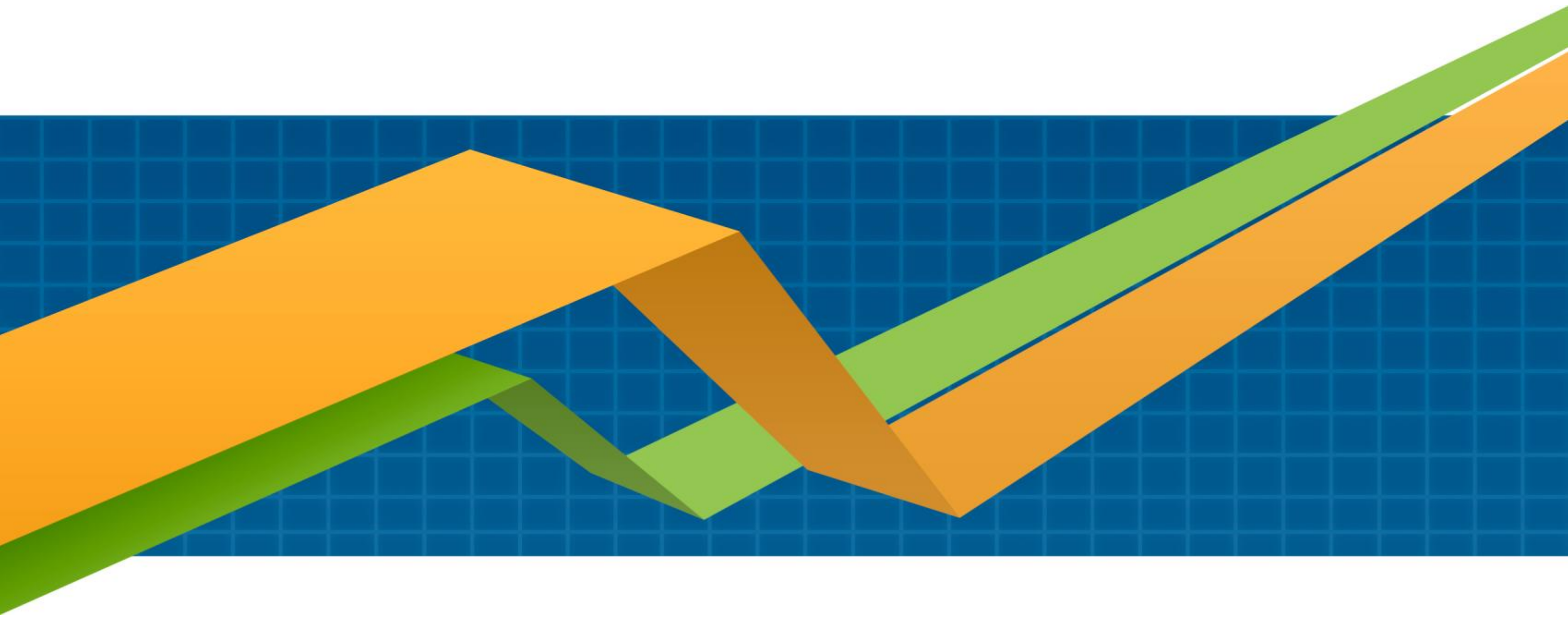
A. A copy of the requested working group whitepaper "Worst Performing Feeders" is provided as Attachment A.

Worst Performing Feeders

Analytics | Analyse

Worst Performing Feeders

Service Continuity Committee: A New Measures Working Group Whitepaper



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The Service Continuity Committee commissioned the New Measures Working Group (NMWG) to examine new measures. From their discussions, they determined that CAIFI and CEMI would be explored and additional research on worst performing feeder methodology would be undertaken.

The purpose of this brief is not to identify one solution to fit into all utility models for the calculation of worst performing feeders, but to explore current utility practices and look at solutions that may be useful to utilities in identifying worst performing feeders.

Initial research was conducted by surveying over fifteen participants from the SCC group. Research was provided by a consulting group on Australia, and additional research performed to identify additional methodologies that may exist in the United States and Europe.

Survey Results

A Worst Performing Feeders (WPF) survey was conducted to assist in determining a recommendation for a standardized method of identifying worst performing feeders. The results showed how some members already use a methodology for this process, and point to whether or not to continue with a recommendation for a standard solution for Canadian utilities.

There were a total of sixteen respondents who completed this survey. The demographic of these respondents was 58% from a rural setting, and 42% considered urban.

The respondents were asked “Does your utility use any methodology for identifying worst performing feeders?” 81% of respondents identified they did identify worst performing feeders.

Of those who replied ‘Yes’, the number of methods utilized for identifying the worst performing feeders can be observed below.

- 31% used more than one method for identifying a WPF.
- 69% used only one method.

For those utilities with no methodology, their responses are as follows:

- The data outage storage system does not allow filtering by customer or feeder.
- The worst performing feeder list was not accurate.

The respondents were asked, “If a standardized method of identifying worst performing feeders was identified, would your utility be interested in using it?”

A large 94% said yes, but several of these respondents were not sure that a standardized method would fit their needs. In addition, there are shared concerns that some utilities do not have the resources to collect the appropriate data for a more in-depth analysis.

Many respondents gave insight to their current methodologies for determining worst performing feeders. SAIDI and SAIFI were the most popular choices among methodologies. Of those who use SAIDI and SAIFI, some selected the feeders with the highest SAIDI and SAIFI, while others find the worst feeders by weighing each index as they deem appropriate.

Example methods based on some of the respondents can be observed below.

Table 1: Sample Data

Year	CMI	CI	Total Outages	Total Customers
1	312	108	22	48
2	328	140	23	48
3	299	97	18	48
(average)	313	115	21	48

- CMI = Customer Minutes of Interruption (excluding Loss of Supply and Major Event Days);
- CI = Total Customer Interruptions (excluding Loss of Supply and Major Event Days);
- Total Outages = Total Number of Outages including Momentary Outages (Excluding Loss of Supply and Major Event Days);
- Total Customers = Total Number of Customers Served.

Example 1: Feeder Score Equation

Values must be normalized so they can be used in the Feeder Score equation.

$$\boldsymbol{Normalized\ CMI = \frac{CMI_{avg} - CMI_{min}}{CMI_{max} - CMI_{min}}}$$

$$\boldsymbol{Normalized\ CMI = \frac{313 - 299}{328 - 299} = 0.483}$$

$$\boldsymbol{Normalized\ CI = \frac{CI_{avg} - CI_{min}}{CI_{max} - CI_{min}}}$$

$$\boldsymbol{Normalized\ CI} = \frac{115 - 97}{140 - 97} = 0.419$$

$$\boldsymbol{Normalized\ Total} = \boldsymbol{\frac{Total\ Outages_{avg} - Total\ Outages_{min}}{Total\ Outages_{max} - Total\ Outages_{min}}}$$

$$\boldsymbol{Normalized\ Total} = \frac{21 - 18}{23 - 18} = 0.6$$

Now the normalized values can be used in the Feeder Score equation.

$$Feeder\ Score = (0.5 * Normalized\ CMI) + (0.25 * Normalized\ CI) + (0.25 * Normalized\ Total)$$
$$Feeder\ Score = (0.5 * 0.483) + (0.25 * 0.419) + (0.25 * 0.6)$$

$$Feeder\ Score = 0.496$$

Example 2: FAIDI and FAIFI Feeder Score Equation

FAIFI (Feeder Average Interruption Frequency Index) and FAIDI (Feeder Average Interruption Duration Index) will be calculated with the values from table 1 (the 3-year averages will be used).

$\boldsymbol{FAIDI = \frac{CMI_{avg}}{Total\ Customers}}$	$\boldsymbol{FAIDI = \frac{313}{48} = 6.52\ min/year}$
$\boldsymbol{FAIFI = \frac{CI_{avg}}{Total\ Customers}}$	$\boldsymbol{FAIFI =} \frac{115}{48} = 2.40\ occ/year$

FAIDI and FAIFI can be used in the Feeder Score equation.
Note: The denominator of the FAIDI and FAIFI must be the total customers of the system, this will allow the utility to compare all feeders to each other on the same syste.

$Feeder\ Score = (0.5 * FAIDI) + (0.5 * FAIFI)$
$Feeder\ Score = (0.5 * 6.52) + (0.5 * 2.40)$

$Feeder\ Score = 4.46$

One of the drawbacks of selecting feeders based on the FAIDI/FAIFI method is that it looks at the feeder level indices and ignores the impact the feeder has on overall system reliability indices; directing resources on these feeders will not significantly improve the system level statistics.

The WPF feeder method based on outage duration, number of customers impacted and the total number of outages (including the momentary outages) ranks the feeder based on the overall impact to the system statistics and can lead to ignoring smaller feeders with chronic issues. It is proposed that a blended approach be adopted when selecting the Worst Performing Feeders.

CEMI and CELID

Some utilities look towards CEMI (*Customers Experiencing Multiple Interruptions*) and CELID (*Customers Experiencing Long Interruption Durations)* to identify worst performing feeders. These indicators provide a means to identify chronic problems in specific areas. By identifying the level or number of outages and the length of outages a utility can be specific and identify which feeders are causing system performance problems at specific levels of interruptions or length of time.

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

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

Australian Experience

Each Australian jurisdiction determines the reliability standards for its distribution networks. Almost all jurisdictions use SAIFI and SAIDI for reporting and planning purposes, although the detail of reporting differs. Many distribution utility companies report and utilize the worst feeder by using SAIFI and SAIDI per feeder. Some also use it to compensate the affected customers based on provincial regulations, e.g. paying compensation for energy not served. [1]

Table 2: Australian Indicator usage for Worst Performing Feeders

Jurisdiction	Summary
Australian Capital Territory	Does not report or use the worst performing feeder info
New South Wales	SAIFI and SAIDI by feeder types (urban, rural, etc.)
Queensland	SAIFI and SAIDI by feeder types (urban, rural, etc.)
South Australia	SAIFI and SAIDI by region (city, town, etc.)
Tasmania	SAIFI and SAIDI by region (city, town, etc.) and type (urban, rural, etc.)
Victoria	SAIFI and SAIDI by feeder types (urban, rural, etc.)
Western Australia	SAIFI and SAIDI by region (city, town, etc.)
Northern Territory	Performance by region (city, town, etc.)

South East Europe Findings

South East European utilities perform feeder analysis on their own. There is no standard from one utility to the next. However, such analysis [2] is broken down by voltage class and urban and rural definitions. Urban and rural definitions vary by country and therefore are not consistent across all of Europe.

In South East Europe, only Croatia was found to examine feeders and determine reliability levels per feeder, by using SAIDI and SAIFI.

U.S. Findings

Additional work was performed to determine what can be learned from U.S. utilities.

PEPCO

PEPCO had a comprehensive reliability plan for the District of Columbia. [3] A composite performance index (CPI) methodology is used to evaluate and rank the feeder performance. CPI is a weighted calculation measuring past performance data. This is done by using the following values:

- Number of customer interruptions (CI);
- Number of customer hours of interruption (CHI which when multiplied by 60, gives customer minutes of interruption);
- System average interruption frequency index (SAIFI);
- System average interruption duration index (SAIDI).

A CPI value is calculated for each individual feeder; the top 2% of ranked feeders in each jurisdiction will be identified as the worst performing feeders.

A U.S. Study

Davies Consulting Inc. [4] conducted a study on the state of reliability regulation in the United States. This study gave a few examples of specific targets that determine the worst performing feeders, and whether those methodologies used a standard indicator or not. They are listed below:

- Feeders with Feeder Average Interruption Duration Index (FAIDI) exceeding SAIDI by 300 percent;
- Feeders with 10,000 customers out for more than 24 consecutive hours for two consecutive years;
- FAIDI greater than four times SAIDI or in the top 10 percent for two consecutive years.

World Comparison

Many utilities use different methodologies for calculating their worst performing feeders. Some use SAIDI and SAIFI, while some use others (ex. Customer Outage Minutes (COM), Customer Hours of Interruption, etc.). Even those who share reliability indices may use them in different ways.

Table 3: World View

Country	Indicators Used	Comments
Canada	SAIDI, SAIFI, CELID, CEMI	The indices used by each utility differ in methodology and use due to the lack of standardization.
USA	SAIDI, SAIFI	The indices reported to regulators are often the same within the state. Additional criteria is used to determine the worst performing feeders, from utility to utility. WPF reporting at the moment does not appear to be mandated by a regulatory body.
Australia	SAIDI, SAIFI	It is a requirement for many utilities to provide to their regulator the SAIDI and SAIFI of each feeder.
South East Europe	SAIDI, SAIFI	SAIDI and SAIFI are broken down by voltage levels and by urban/rural classification. There is no standard across all countries, with only one country reporting at the feeder level (Croatia).

Exclusions of Outages

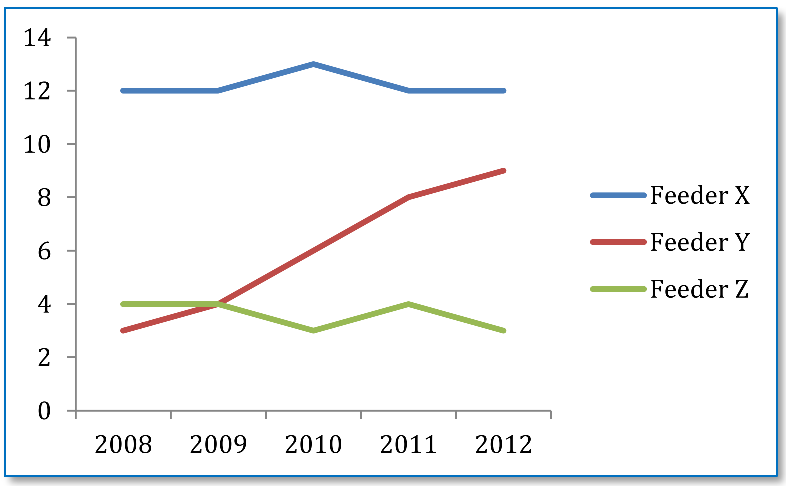
While performing an analysis of feeder outages, it is highly recommended that specific outages related to events outside of the utility's control be excluded. Standard practice is to exclude outages due to loss of supply, as well as scheduled events. Most Prominent Events are also excluded, as these are events outside the utility's control and significantly impact utility performance measures.

Trending

Many utilities identified the use of trending to identify worst performing feeders. The number of years varied from three to seven years, and is dependent on the amount of changes to the network that occurred in the utility. Utilizing a trend line will provide additional insight into all feeders, not just WPFs.

The graph below illustrates the ability to identify feeders that are showing progressively worsening performance, allowing the analyst to flag these feeders for maintenance and/or follow-up analysis. It is suggested that trending be used with the recommendations provided.

Graph 1: Trends



Customer Base:

Some of the survey respondents and some of the research indicates that utilities may wish to look at the criticality of customers and apply a weight to the formula based on the number of customers the feeder provides electricity to along with the type of customers. Feeders within an urban center generally have a higher critical impact as they service a larger population than a rural feeder. Additional weights can be calculated into formulas so that the utility provides 'due consideration' in terms of reviewing the impacts to the community services and population.

In addition, institutions such as hospitals, mental health facilities and correctional facilities should be considered with a greater weight than a simple residential zone, as they pose additional safety and health concerns for both staff and patients/visitors at those locations. In addition, industrial and commercial sites will have an implied economic impact. Reducing outages by feeder to those areas will only help maintain customer satisfaction and lessen negative impacts to the local economy.

The application of weights based on the population and who the feeder services is not a new concept. However, for now it is not mentioned in the recommendations although the idea can be applied to any of the recommendations in this document.

Consult

After all analysis of the feeders has been performed, it is recommended that the reliability analyst consult with the control center and maintenance crews to confirm that the feeder in question is problematic. Once confirmed, the analyst would be able to perform a root cause analysis with the appropriate staff on the reason(s) the feeder is problematic, and the utility would be able to take corrective action.

Recommendations:

1. Hanging out with Popular Kids

The majority of utilities worldwide look at the SAIDI and SAIFI (including SAIFI-Momentary) values per feeder (or FAIDI and FAIFI) and identify the worse performing feeders based on the worse values. The worse feeders are then identified based on specified criteria (worse top ten for that year; worse top 2% for that year; worse top three feeders based on two years in the top ten).

All utilities look towards SAIDI and SAIFI for system performance, and it is acceptable for utilities to measure WPF with these indicators, as additional resources and effort would be required with the following two recommendations.

2. The Devil is in the Details

Incorporating indicators such as CEMI (*Customers Experiencing Multiple Interruptions*) and CELID (*Customers Experiencing Long Interruption Durations*) on feeder performance provides additional insight into feeder performance. Collecting data on these indicators has much to do with the utilities' ability to track outages per customer. Both indicators are described in the '*CAIFI and CEMI Reporting*' discussion paper by SCC.

A threshold may be applied to each indicator, for example, $CEMI_6$ or $CELID_{6,}$ where '6' signifies the number of interruptions per customer for CEMI and the total length of interruptions for CELID. Feeders that rank consistently in the utility-defined bracket would be considered the worse performing feeder.

3. Lifting Weights:

Another option would be to incorporate a weighting system. This system would be modified based on the utilities' desire to determine which indicator holds the most weight (SAIFI, SAIDI, CEMI, etc.), as seen in Example Method 1 and 2.

Applying weights is a well-rounded way to determine the worse performing feeder by applying the largest weight to the most critical element of the equation, whether it be duration, frequency or even customer-based.

Conclusion

At this time, the most widely used indices used for calculating worst performing feeders are SAIDI and SAIFI. This is due to the minimum amount of resources needed to collect the required data for these measures. The most effective way of using these indices would be to calculate the SAIDI and SAIFI of each feeder (FAIDI and FAIFI) and then compare it to the SAIDI and SAIFI of the distribution system as a whole.

Using a certain methodology for calculating worst performing feeders requires a thorough understanding of what each index or factor represents. By taking into account factors such as the feeder type (rural or urban) or previous years' data, a more accurate representation of the worst performing feeders can be obtained. A blended approach utilizing any combination of the recommendations and/or value-add techniques to the recommendations (such as trending or consulting) will only help facilitate what is best for your utility's situation and business. Once measures have been applied, it is up to the utility to determine the percentage of feeders on which to undertake corrective maintenance activities.

References

[1] P. Kos, "Reporting and Utilization of Worst Performing Feeder Information," Power System Solutions International Inc., Calgary, AB

[2] "5th CEER Benchmarking Report on the Quality of Electricity Supply", CEER, Belgium, 2011

[3] "Potomac Electric Power Company Comprehensive Reliability Plan for District of Columbia," PEPCO, Washington, DC, September 2010.

[4] "State of Distribution Reliability Regulation in the United States," Davies Consulting Inc., Chevy Chase, MD, September 2005.

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