*Philippine e-Journal for Applied Research and Development 10(2020), 35-49* ISSN 2449-3694 (Online)
*http://pejard.slu.edu.ph/vol.10/2020.12.30.pdf*

# Catastrophic Days Determination using Heuristic, and Box and Whisker Methods in the Philippines' Electric Power Distribution System

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Received, 30 October 2020; Accepted, 27 December 2020; Published, 30 December 2020



**Abstract**

In the Philippines, events like typhoons, earthquakes, and volcanic eruptions can cause widespread and lengthy power interruptions, resulting in days with unusually high reliability indices or major event days (MEDs). There can also be days with very high reliability indices, prompting a new classification called catastrophic days (CDs). As both MEDs and CDs increase the values of reliability indices, it is important to identify and remove them from the data set in order to better evaluate the performance of distribution utilities. However, the conventional method of determining MEDs is insufficient in identifying CDs. In this study, heuristic, and box and whisker methods were applied to the five-year outage data of an electric cooperative to determine the CDs. In addition, events that have occurred in the identified MEDs and CDs were traced back using reports from government agencies. Results showed that the number of identified CDs using the heuristic method is highly dependent on the chosen beta multiplier. In contrast, only a single CD was identified using the box and whisker method. The study's findings can be used as a policy guideline for distribution utility operators to identify CDs instead of subjectively removing days with high reliability indices.

**Keywords:** Power distribution utilities, reliability indices, major event days, catastrophic days, beta method

## Introduction

One way of evaluating the performance of power systems is through reliability indices, which account for the power supply interruption or the availability of power supply to end-users. These indices can be classified as customer-oriented where the number of interruption experienced by customers is counted, or load-oriented which considers the load of the affected customers. Customer-oriented indices include the system average interruption duration index (SAIDI) [1–9], system average interruption frequency index (SAIFI) [1–8, 10], momentary average interruption frequency index (MAIFI) [1–3, 10], and customer average interruption duration index (CAIDI) among others [1–2, 4].

Customer-oriented indices have been used in different studies as quality of service indicator whenever modifications are applied to existing electric distribution infrastructure. For instance, the utility performance improvement from adopting different business processes were measured in terms of SAIDI [2]. Meanwhile, the framework developed by Portuguese distribution system operator in reducing short interruption was evaluated with MAIFI as the parameter of interest [3]. By adopting the said framework, short interruptions within the utility have declined as evident in the decreasing trend of MAIFI over the years. Similarly, the use of satellite telemetry connectivity solution to complement cellular network operation in electric distribution utilities within Latin America led to significant electric power quality improvement based on SAIDI and SAIFI results [5]. Different optimization studies have also employed the use of reliability indices either as the objective function or as the constraint. Incorporating customer-oriented indices into the objective function ensures improvement in the reliability of the distribution system which leads to increased customer satisfaction in terms of power consumption and added economic benefits to distribution utility operators [9]. This has been the case for studies that determine the optimal network topology, allocation of multiple distributed generation system, and lightning system protection design of a distribution system which used SAIDI, SAIFI, and MAIFI as part of the objective function [6–7, 10]. In contrast, using these indices as the constraint ensures that the economic and social benefits derived from the proposed methodology are maximized while meeting the required reliability standards [8].

The reliability of a distribution system is a random process, with the reliability indices being the random variables [11]. These indices factor in the duration and frequency of power outages, as well as the number of customers served and those who are affected by the interruption. This means that the reliability indices can have a wide scatter of values. In addition, the statistical distribution of these indices can be skewed by events that exceed the operational limits of the electric power distribution system, thereby affecting the performance evaluation of distribution utilities. These outliers are known as major events, and the days where they occurred are known as major event days (MEDs) [11]. Normalization becomes necessary to better deal with the data and to remove outlier values.

High reliability index values due to major events affect the performance assessment of a distribution utility. A normalization process known as the beta method was chosen by the Institute of Electrical and Electronics Engineers (IEEE) working group on system design to account for these outlier values. In this methodology, days wherein the SAIDI value is greater than the threshold value or $T_{MED}$ shall be classified as MEDs. These days should be separated and analyzed along with the context or events in which they occurred or what circumstance might possibly explain their large SAIDI value [11]. The $T_{MED}$ can be computed using a data pool comprising of daily SAIDI values in a span of five years. The effectivity of the computed threshold value is reflected on the sixth year of data, although it can also be used to normalize the data from which it was obtained.

Moreover, the beta method provides solution to zero SAIDI and SAIFI days or days when there is no power interruption. The technical working group found out that the number of zero SAIDI and SAIFI days had minimal effect on the determination of $T_{MED}$. Hence, these days can be excluded from the analysis. This information is especially useful for small utilities like electric cooperatives which frequently see days with no power interruptions due to relatively small geographic size within their franchise area [12]. Altogether, the working group validates the beta method as a useable statistical method for determining MEDs even for utilities with large number of zero SAIDI and SAIFI days [12–15].

However, because the Philippines experiences many calamities such as typhoons, earthquakes, and volcanic eruptions, long and widespread power interruptions can be expected. As a result, there will be days with very high reliability indices [16–17]. To take this into account, a new classification known as catastrophic days (CDs) was recommended for adoption and further study [11]. This new category has a higher threshold than MEDs which needs to be quantified in order to better gauge the system performance. The goal of determining CDs is to have an objective way to remove extreme values on top of MEDs so that the reliability indices will accurately reflect the actual performance of a distribution utility [18]. Although only SAIDI is considered in identifying CDs, all indices on the identified day are removed when computing the adjusted reliability indices [11–12].

In addition, solely basing on the unadjusted reliability indices does not explicitly explain the events that may have led to the high values of the reliability indices. As a consequence, the Energy Regulatory Commission (ERC) issued guidelines for monitoring the reliability indices and conducted a number of assessments to determine the reasonable values of SAIFI and SAIDI for identifying reward and penalty levels of on-grid distribution utilities [19–20].

In the existing literature, beta method was reapplied to the data set to obtain a new $T_{MED}$ after the CDs have been identified and removed [21]. This approach eventually led to higher number of identified MEDs in the succeeding five years, to which the new threshold was applied, as the prior removal of CDs from the data set yielded a lower $T_{MED}$ value. That is, some days with relatively low SAIDI values may be classified as MEDs, which amounts to more days being analyzed in terms of how the distribution network was affected. Thus, this study will not reapply the beta method after the CDs have been identified. Moreover, the treatment in this study is to simultaneously remove both MEDs and CDs from the data set to determine the adjusted annual SAIDI and SAIFI values which will then be measured against the ERC standards. Lastly, this study will trace back the events that have occurred on the identified MEDs and CDs to have a full understanding of what caused the high reliability index values.

## Methods

### *Data Collection*

Distribution utilities in the country are mandated to submit every quarter monthly reports of power interruptions using the prescribed format as shown in Figure 1. The recorded information includes the affected feeder, start and end time of interruption, number of customers affected, and cause codes of interruption. The sustained and momentary interruptions are recorded separately since the computations of their respective indices are different.

This study utilized the 2010 to 2014 outage data from the Batangas I Electric Cooperative, Inc. (BATELEC I). The said electric cooperative records their interruption data as spreadsheet files, with one file corresponding to one year [22]. In each spreadsheet file, one tab is allocated per month. The aforementioned information pertaining to interruptions are recorded daily. Meanwhile, days where no interruption happened are no longer included in the table. BATELEC I calculates the SAIFI, SAIDI, and CAIDI from the sustained interruptions. It must be noted, however, that planned interruptions and interruptions from the National Grid Corporation of the Philippines (NGCP) are not included in computing for the reliability indices.

### *System Average Interruption Frequency Index (SAIFI)*

SAIFI is defined as the ratio of the number of customers who experienced interruption for a period of time to the total number of customers served, which is expressed in equation (1). It may be evaluated for the whole distribution system or on a per feeder basis [11].

$$SAIFI = \frac{CI}{N_T} \tag{1}$$

where:

$CI$ is the total number of customers who experienced interruption

$N_T$ is the total number of customers served

SAIFI indicates the size of the affected customers as compared to the total number of end-consumers served. A value of unity means that all the customers experienced at least one interruption over a certain time duration. Meanwhile, a value exceeding unity means that some customers experienced more than one interruption event.

Moreover, SAIFI may be computed over different periods of time. In this study, SAIFI values were computed per day for the data tabulation, and per annum for comparison with the ERC standard value.

Annex "A-1"

**Table-1R**

**INTERRUPTION REPORTS**

**For the month of ______________, Year __________**

**Distribution Utility: ________________________________________________**
**District/Zone/or Load Center: ___________________________________________**
**Number of Customers Served during the month: ____________________________**

| Date | Town/City/ Barangay/or Subdivision Affected | Ckt. No. | Start Time | Restored | | Duration (min.) | No. of Cust. Affected | Interruption | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Date | Time | | | Cause | Weather | Isolation Device | Equipment Failed |
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| | | | | | | | | | | | |
| | | | | | Total | | | | | | |

**SAIFI = ________________**

**SAIDI = ________________**

**MAIFI = ________________**

______________________________
**Signature over Printed Name of Person Reporting**

**Date _________**

**Figure 1.** Monthly interruption report format [19].

*System Average Interruption Duration Index (SAIDI)*

SAIDI relates the total duration of interruption experienced by the customers to the total number of customers served, which is expressed in equation (2). The usual unit of duration used is in minutes, which is then multiplied by the number of consumers who experienced the interruption [11]. However, for this study, minutes were converted to hours for computational convenience.

$$SAIDI = \frac{CMI}{N_T} \tag{2}$$

where:

$CMI$ is the total duration of interruption experienced by the customers

$N_T$ is the total number of customers served

Moreover, similar to SAIFI, SAIDI can also be computed over different periods of time. In this study, the daily SAIDI values were computed as part of identifying the MEDs and CDs, while the annual SAIDI values were obtained for comparison with the ERC standard. In addition, for interruptions that spanned two or more consecutive days, the SAIDI was recorded as belonging to the day when the interruption started for to properly associate the interruption with the event that caused it [23].

*Beta Method*

The established method in identifying MEDs is the beta method [11]. It requires obtaining the $T_{MED}$ from the average, α, and the standard deviation, ß, of the natural logarithmic values of SAIDI. For its implementation, the zero SAIDI and SAIFI days are first removed from the five-year interruption data. The remaining data set are then arranged from least to greatest SAIDI value, after which, the SAIDI values are expressed as natural logarithms. The average value, as well as the standard deviation, of the converted SAIDI values are then computed. The expression for α and ß are shown in equations (3) and (4), respectively [24], while the $T_{MED}$ is determined from these two variables as shown in equation (5) All days with SAIDI values beyond the computed $T_{MED}$ are considered MEDs.

$$\alpha = \frac{\Sigma x}{N} \tag{3}$$

$$\beta = \sqrt{\frac{\Sigma(x-\alpha)^2}{N}} \tag{4}$$

$$T_{MED} = e^{(\alpha+2.5\beta)} \tag{5}$$

where:

| | |
|---|---|
| α | is the log-average value |
| $x$ | is the natural logarithm value of SAIDI |
| $N$ | is the total number of non-zero SAIDI and SAIFI days |
| ß | is the log-standard deviation value |
| $T_{MED}$ | is the threshold SAIDI value |

An important assumption in using the beta method is that the natural logarithmic SAIDI values must closely resemble a Gaussian distribution, which is a normal distribution that tends to be centered on a mean value. This is due to the fact that the expression for calculating $T_{MED}$ as presented in equation (5) was mathematically derived from the said statistical distribution [11].

*Heuristic Method*

The heuristic method implementation is a straightforward process as presented in Figure 2. This method essentially follows the same process flow as that of the beta method implementation, with the end goal of finding a threshold value for CDs or $T_{CD}$, using the same form of expression as presented in equation (5). For this method, however, a suitable ß multiplier that is greater than 2.5 is used [25].

The ß multiplier of 2.50 used in the beta method has already been verified to be equitable across distribution utilities of different sizes [11]. However, there is yet to be an agreed upon analytical method in establishing a suitable ß multiplier in identifying CDs [21]. As the name implies, the heuristic method employs a trial-and-error approach and is not dependent on statistical analysis.

*Box and Whisker Method*

The box and whisker method follows the same process flow up to the computation of natural logarithmic SAIDI values as shown in Figure 2. To proceed, the statistical variables comprising of the median, first quartile (Q1), and third quartile (Q3) value were computed. The interquartile range (IQR) is obtained from the difference between Q3 and Q1 values. The resulting IQR value is multiplied by 3, which is then extended from Q3 and Q1 to obtain the upper and lower values, respectively. The required statistical variables for this method are illustrated in Figure 3. All days with natural logarithmic SAIDI value exceeding the upper value are considered as CDs.

All reliability indices in the identified MED or CD are excluded from the computation of the adjusted reliability indices. In addition, unlike in the literature, the beta method will not be reapplied to obtain a new $T_{MED}$ after the identified CDs have been removed since this may lead to an undesirable number of MEDs. The adjusted annual SAIDI and SAIFI values are obtained by taking the summation of the remaining daily SAIFI and SAIDI values. The ERC sets the standard values for SAIFI and SAIDI as 25

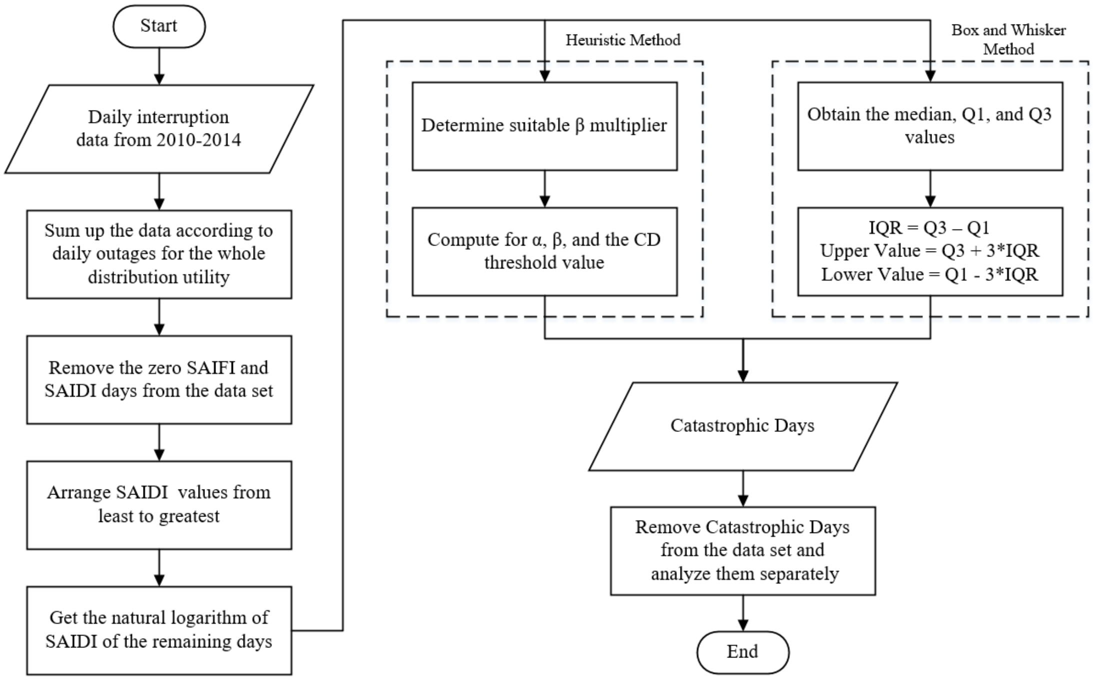


**Figure 2.** Flowchart of the heuristic, and the box and whisker method [21, 25].

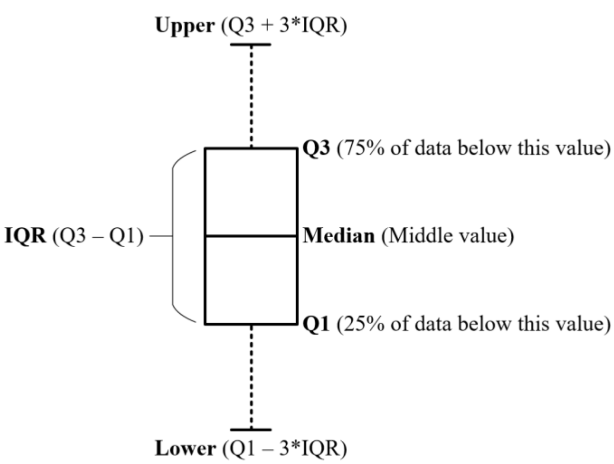


**Figure 3.** Illustration of the variables used in the box and whisker method [21].

interruptions/customer-year and 56.25 hours/customer-year, respectively [20]. These are the maximum values in which the penalty level for a distribution utility is zero.

The aforementioned methods were applied to BATELEC I outage data. As a radial system, the franchise area of BATELEC I is connected to a 100 MVA power transformer through 69 kV lines. A radial distribution system is one that is connected only to a single source (i.e., transformer connection). This system is less reliable as it is prone to periodic interruptions because of cable or device failure [26].

## Results and Discussions

### *Summary of Interruption Data*

The daily SAIFI and SAIDI values were obtained by aggregating the number of customers affected by interruptions and the corresponding duration for a single day over different feeders within the BATELEC I franchise area. Meanwhile, days with no interruption or with interruption that extended from the previous day were noted with zero SAIFI and SAIDI. The data were tabulated from January 1, 2010 to December 31, 2014 for a total duration of five years. Lastly, the annual SAIFI and SAIDI values were determined from the aggregated daily values for each corresponding year. Table 1 summarizes the number of zero SAIFI and SAIDI days per year, as well as the corresponding annual SAIFI and SAIDI values.

It can be concluded from Table 1 that all annual SAIFI values of BATELEC 1 are compliant with the ERC standard of 25 interruptions/customer-year. The same conclusion applies to the 2010 to 2013 SAIDI values of the electric cooperative which did not exceed the 56.25 hours/customer-year limit. However, one striking observation from Table 1 is the 2014 SAIDI value which is almost twice the limit set by the ERC. Also, the number of zero SAIFI and SAIDI days for the year 2014 is nearly twice the reported value for 2013, but the SAIDI value of the former is almost five times higher than that of the latter. This indicates that some customers of BATELLEC 1 had experienced a prolonged power outage within a short duration of this year.

*Natural Logarithm of SAIDI Values*

After arranging the non-zero daily SAIDI value from least to greatest, each entry was converted to its natural logarithmic form. Figure 4 shows the plot of natural logarithmic values of SAIDI and their corresponding frequency of occurrence.

In order for the beta method to be applicable in the data set, the natural logarithmic SAIDI values must closely resemble a Gaussian distribution. Based on the histogram presented in Figure 4, it can be observed that the distribution of the natural logarithm of SAIDI values follows a bell-curve pattern that is centered between -4 and -3. On top of verifying that normalization is indeed applicable for the considered data set, presenting the SAIDI values in their natural logarithmic form made it easier for data handling and ensured that the values were close to each other without compromising extreme values.

It is worthwhile to note that the ideal daily SAIDI value is zero as it implies that no customer experienced an interruption for the day. In contrast, high SAIDI values are undesirable as it means that customers experienced a prolonged interruption. However, it was emphasized that zero SAIDI days were excluded from the computation of natural logarithm of SAIDI values. Therefore, a more negative natural logarithmic SAIDI value is desired since it corresponds to a SAIDI value that is close to zero. It is further implied that a highly positive natural logarithmic SAIDI value is undesirable since it corresponds to a high SAIDI value.

*Beta Method Implementation*

The beta method was applied to the outage data of BATELEC I in order to determine the MEDs within the five-year period under consideration. In implementing the said method, α and β were obtained using a spreadsheet

**Table 1.** Number of zero SAIFI and SAIDI days and annual SAIFI and SAIDI of BATELEC I.

| YEAR | Number of zero SAIDI and SAIFI days | SAIFI (interruptions/customer-year) | SAIDI (hours/customer-year) |
|---|---|---|---|
| 2010 | 230 | 12.67 | 12.44 |
| 2011 | 162 | 12.65 | 10.70 |
| 2012 | 91 | 18.24 | 18.70 |
| 2013 | 66 | 20.37 | 21.48 |
| 2014 | 121 | 20.05 | 105.78 |

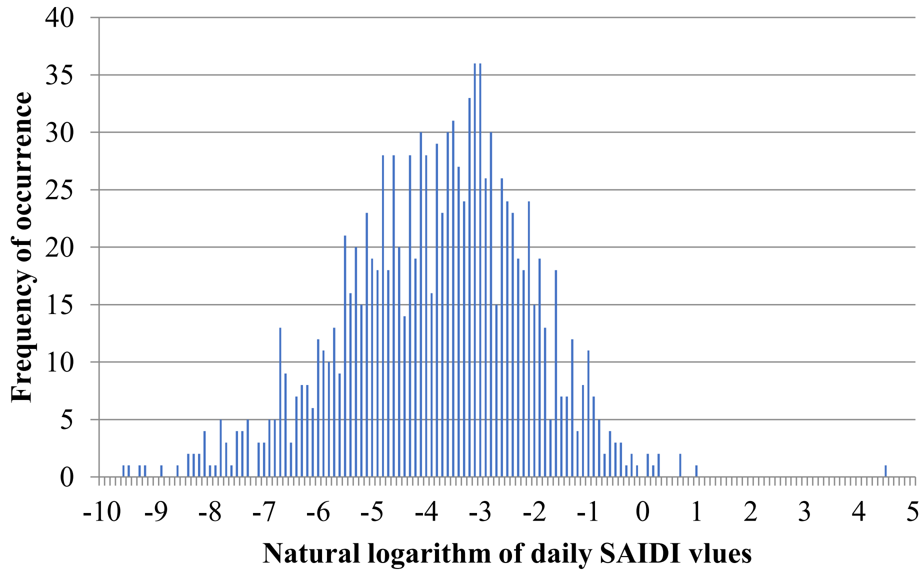


**Figure 4.** Frequency distribution of the natural logarithm of SAIDI values.

program, while equation (5) was used to compute for the $T_{MED}$. Table 2 summarizes the values of these three variables, while the following expression shows the $T_{MED}$ computation:

**Table 2.** Beta method variables and values.

| VARIABLE | VALUE |
|---|---|
| α | -3.86 |
| β | 1.70 |
| $T_{MED}$ | 1.48 |

$$T_{MED} = e^{(-3.86 + 2.5(1.70))} = 1.48$$

Days with SAIDI value greater than 1.48 hours/customer-day were considered MEDs. Using this criterion, the identified MEDs are tabulated in Table 3. The corresponding SAIFI value for each day was included since it provides information on the number of customers who experienced interruptions relative to the number of customers served.

Among the identified MEDs, July 16, 2014 registered the highest SAIFI and SAIDI values. This day also corresponds to the rightmost natural logarithmic value in Figure 4. The computed values suggest that all customers of BATELEC 1 experienced at least one sustained interruption event for a prolonged period of time during this day.

*Heuristic Method Implementation*

The only difference between the implementation of the beta method and the heuristic method is the choice of a suitable β multiplier for the computation of the threshold value. The resulting threshold value for different β multiplier values from 0 to 5 at 0.01 intervals is plotted in Figure 5.

The exponential nature of the $T_{MED}$ formula as shown in equation (5) explains why the graph increases rapidly at higher β multipliers as observed in Figure 5. The MED threshold corresponding to the 2.50 β multiplier is highlighted using an orange square. It may seem at first that the threshold value starts to increase rapidly after this point. However, this perception is only brought about by the chosen y-axis values. If a range of 0 to 50 was used instead of 0 to 100, the perceived point where the threshold value starts to rapidly increase also changes.

Due to the subjective nature of choosing a single β multiplier to determine the CD threshold, certain β-multipliers values were investigated instead. The chosen multipliers where from 2.50

**Table 3.** Identified MEDs from 2010 to 2014.

| DATE | SAIFI (interruptions/ customer-day) | SAIDI (hours/ customer-day) | ln (SAIDI) |
|---|---|---|---|
| July 14, 2010 | 0.32 | 1.83 | 0.61 |
| July 13, 2010 | 0.13 | 1.95 | 0.67 |
| June 9, 2014 | 0.46 | 2.54 | 0.93 |
| July 16, 2014 | 1.00 | 88.45 | 4.48 |

and higher. This is the logical approach since a CD must be a part of the MED subset [25]. The CD threshold, as well as the corresponding identified CDs, from the chosen multipliers is summarized in Table 4.

The chosen multipliers were the transition point wherein the identified CDs is reduced by one. To illustrate, the following shows the threshold value computation for a 2.62 ß multiplier:

$$T_{CD} = e^{(-3.86 + 2.62(1.70))} = 1.81$$

Looking back at Table 3, July 14, 2010 registered the lowest SAIDI among the identified MEDs at 1.83 hours/customer-day. With a 2.62 multiplier, this day is considered as a CD as the daily SAID value is greater than the obtained threshold. In contrast, a 2.63 multiplier will yield a threshold value of 1.85. As the daily SAID value of July 14, 2010 is now lower than this threshold, it is no longer considered as CD. The same reasoning was applied to the other multipliers presented in Table 4.

*Box and Whisker Method Implementation*

The box and whisker method requires the formation of a boxplot similar to the one illustrated in Figure 3 from the statistical parameters of the natural logarithmic SAIDI values. The required

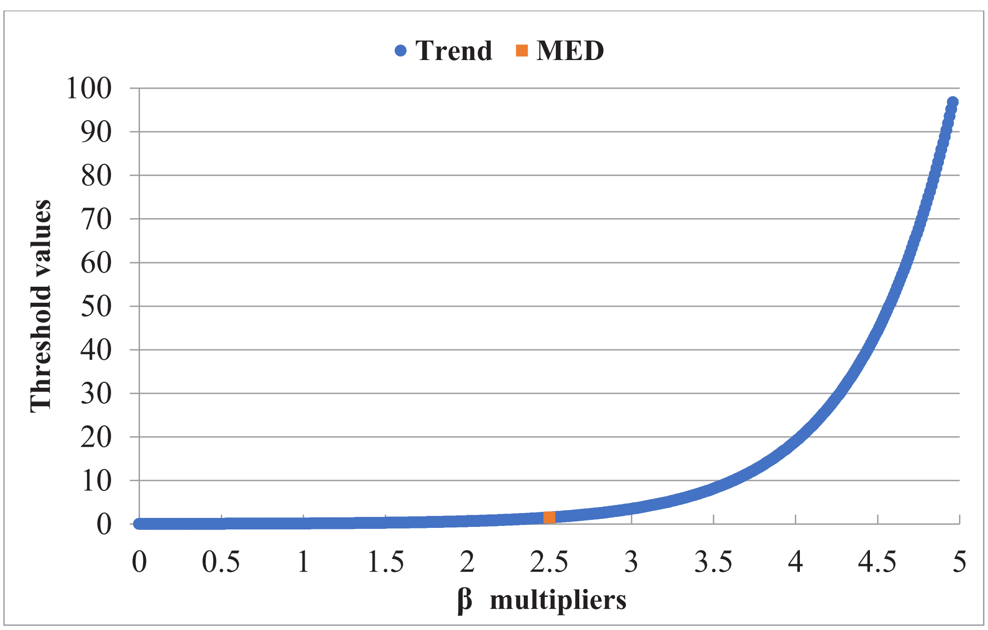


**Figure 5.** Plot of the corresponding threshold value with respect to the ß multiplier.

**Table 4.** Effect of increasing β multiplier to the threshold value and the removed day(s).

| β MULTIPLIER | CD THRESHOLD VALUE | IDENTIFIED CD(S) |
|---|---|---|
| 2.5 | 1.48 | July 13, 2010<br>July 14, 2010<br>June 9, 2014<br>July 16, 2014 |
| 2.63 | 1.85 | July 13, 2010<br>June 9, 2014<br>July 16, 2014 |
| 2.67 | 1.98 | June 9, 2014<br>July 16, 2014 |
| 2.82 | 2.55 | July 16, 2014 |
| 4.91 | 88.87 | None |

variables for the implementation of this method and their corresponding value are summarized in Table 5.

**Table 5.** Box and whisker method variables and corresponding values.

| VARIABLE | VALUE |
|---|---|
| Median | -3.70 |
| Q1 | -4.94 |
| Q3 | -2.70 |
| IQR | 2.25 |
| 3*IQR | 6.74 |
| Lower | -11.69 |
| Upper | 4.05 |

The calculated upper value serves as the threshold in identifying the CD. Based from the results, only July 16, 2014 has a natural logarithmic SAIDI value of 4.48 that exceeded the upper value of 4.05. Therefore, this is the single CD identified from this method.

*Actual Events on Major Event and Catastrophic Days*

Events which have occurred on the identified MEDs and CDs that may have caused the high reliability index values were tracked using reports from Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) and National Disaster Risk Reduction and Management Council (NDRRMC) or formerly known as National Disaster Coordinating Council (NDCC). The monthly interruption reports from BATELEC 1 when the identified days occured were also reviewed. The summary of the findings is presented in Table 6.

From Table 6, the prevailing weather disturbance on July 13 and 14 of year 2010 was Typhoon Basyang with international name *Conson*. It greatly affected Regions III, IV-A, and V, with Public Storm Signal No. 2 being hoisted over the Batangas Province [27–28]. Facilities such as distribution substation and primary lines of BATELEC I were affected by the strong winds and rains brought about by the typhoon [27]. Although only some circuits of some substations were affected by the interruptions, their restoration took quite some time as evident on more than half a day of power outage experienced by the affected customers.

Meanwhile, there was no significant event reported on June 9, 2014. In fact, weather codes reported for the day indicate that the weather is relatively calm. The mixed cause codes indicate that the recorded interruptions for the day were only isolated events.

**Table 6.** Summary of reports on the identified MEDs and CDs.

| DATE | NO. OF AFFECTED CUSTOMERS | AVERAGE POWER OUTAGE DURATION[a] (hours/affected customers) | CAUSE CODE[b] | WEATHER CODE[c] | SIGNIFICANT EVENT |
|---|---|---|---|---|---|
| July 13, 2010 | 18,273 | 14.52 | 006<br>011 | 103<br>105 | Typhoon Basyang |
| July 14, 2010 | 43,162 | 5.78 | 003 | 105 | |
| June 9, 2014 | 73,284 | 5.54 | 001<br>005<br>010 | 101<br>104 | None |
| July 16, 2014 | 158,453 | 88.45 | 003 | 105 | Typhoon Glenda |

[a]obtained by multiplying the SAIDI value by $N_T$ then divided by number of affected customers
[b]001 (human being), 003 (major storm disaster), 005 (trees), 006, (overload), 010 (other), 011 (unknown)
[c]101 (wind), 103 (rain), 104 (clear day), 105 (typhoon)

Lastly, July 16, 2014 laid witness to the onslaught of Typhoon Glenda with international name *Rammasun*. Public Storm Warning Signal Number 3 was raised over Batangas as maximum sustained winds peaked at 150 kph and gustiness of 180 kph were experienced in the province [29–30]. A large number of people within BATELEC I franchise area experienced, on average, almost 90 hours of power outage. Restoration time took three to four days in some affected areas, leading to very high SAIDI value.

*Adjusted Annual Reliability Indices*

From the implementation of box and whisker method, only a single CD was identified. In contrast, the number of identified CDs using the heuristic method was found to be highly dependent on the chosen β multiplier. For illustrative purposes, it shall be assumed in this section that the chosen β multiplier for the heuristic method implementation is between 2.82 and 4.91 so that the two methods identify July 16, 2014 as the lone CD.

After identifying the MEDs and CDs, they were removed from the computation of the new annual SAIDI and SAIFI. The results and comparisons are summarized in Table 7.

The unadjusted values in Table 7 refer to the annual SAIFI and SAIDI values of the original outage data as presented in Table 3, while the adjusted values refer to the new annual SAIFI and SAIDI values after the MEDs and CDs have been removed from the data set. In the unadjusted reliability indices, only the 2014 SAIDI value exceeded the ERC standard. This means that BATELEC I will incur penalty for the year 2014 shall they report their outage data as it is.

After the MEDs and the CD were removed from their respective year of occurrence, the adjusted SAIFI and SAIDI for year 2010 and 2014 have decreased in value. Meanwhile, the adjusted SAIFI and SAIDI values for years 2011 to 2013 were unchanged. This is expected as there was no MED identified in these years.

For the year 2014, two sets of adjusted reliability indices were computed. The first

**Table 7.** Unadjusted and adjusted annual reliability indices.

| YEAR | SAIFI (interruptions/customer-year) | | SAIDI (hours/customer-year) | |
|---|---|---|---|---|
| | Unadjusted | Adjusted | Unadjusted | Adjusted |
| 2010 | 12.67 | 12.22 | 12.44 | 8.66 |
| 2011 | 12.65 | 12.65 | 10.70 | 10.70 |
| 2012 | 18.24 | 18.24 | 18.70 | 18.70 |
| 2013 | 20.37 | 20.37 | 21.47 | 21.48 |
| 2014 | 20.05 | 19.05[a]<br>18.56[b] | 105.78 | 17.33[a]<br>14.79[b] |

[a]only the CD (July 16) is removed
[b]both MED (June 9) and CD (July 16) are removed

set corresponds to the scenario where only the CD (July 16) is removed, while the second set corresponds to the case where both MED (June 9) and CD (July 16) are removed. The adjusted 2014 SAIDI value significantly went down for both cases. In fact, removing the CD from the data set alone is enough to make the adjusted SAIDI value compliant with the ERC standard of 56.25 hours/customer-year. This illustrates how a single CD can greatly affect the reliability index values for a given year.

## Conclusion

In this study, heuristic, and box and whisker methods were applied to the 2010-2014 outage data of BATELEC 1 in order to identify the CDs. The reliability indices that were considered in the analysis were SAIFI and SAIDI, the latter of which was used in the computation and evaluation of the two methods.

From the implementation of the heuristic method, it was observed that the number of identified CDs is highly dependent on the choice of an appropriate β multiplier, which by itself is a subjective decision. In contrast, only a single CD was identified from the implementation of the box and whisker method. Even though there is no measure to quantify which method is better, the results from this study suggest that the box and whisker method offers a more statistical and objective approach in identifying the CDs.

The methodology outlined in this study can serve as an initial step in crafting a revised policy guideline for distribution utilities to identify CDs, instead of subjectively removing days which have high reliability indices. Along with the standard set for determining MEDs, the study could potentially save distribution utility operators from unnecessary penalties due to poor reliability indicators brought about by frequent natural calamities in the country.

For future research, other methods can be developed to identify CDs. The reliability indices used, evaluated, and considered in the study are SAIDI and SAIFI. It is recommended that other reliability indices be included in the evaluation as well. In addition, further study can be conducted to standardize the process of obtaining a threshold value for the heuristic method. Lastly, the correlation between the number of zero SAIDI and SAIFI days and the number of identified CDs can be investigated.

## Acknowledgments

The authors thank Batangas I Electric Cooperative, Inc. particularly Engr. Marlon Manalo, Chief of Engineering Service Division, and his cadet engineer, Engr. Jeanfel Tumbaga; Mr. Jeciel Cabasis, Head of Facility, Analysis, Research, and Development; and, Engr. Alvin

Velasco, General Manager of BATELEC I. Appreciation is also extended to Asst. Prof. Elvin D. Dulce for his comments on the paper.

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