Distribution Reliability in Kentucky 2007

Status of Distribution Reliability as Reported to the Kentucky Public Service Commission by Jurisdictional Electric Distribution Utilities for Calendar Year 2007

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On December 12, 2006, the Kentucky Public Service Commission (Commission) initiated an investigation of the reliability measurement practices of all jurisdictional electric distribution utilities.[1] The order establishing the investigation stated that utilities are required to furnish adequate service, and that adequacy includes assurance of reasonable continuity of service. The Commission further noted that "electric utilities must make all reasonable efforts to prevent interruptions of service and to reestablish service as quickly as possible when they do occur."[2]

The reliability indices defined in the Institute of Electrical and Electronics Engineers (IEEE) standard are one method of measuring a utility's ability to provide adequate service.[3] The Commission determined that the utilities should collect reliability information and report annually three of the indices defined by the IEEE standard: System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), and Customer Average Interruption Duration Index (CAIDI). Since the Commission determined that it was not proper at this time to establish a reliability target,[4] reliability information will only be used to provide comparison of results. In other words, a single index value cannot be looked at and judged to be "good" or "bad." It must instead be compared to similarly situated systems resulting indices and judged as "better" or "worse."

There are many factors which determine a utility's reliability. Some of these are customer density, geography, vegetation density, animal activity, storm activity, system age, system design, management practices, load characteristics, and system growth. Due to the fact that several of these factors are beyond the ability of utility management to control (customer density, geography, animal activity, storms, etc.), and can vary widely from system to system, it is not appropriate to compare the results from one utility to another to make a judgment about the management of the utility. It is appropriate to compare the current results of a utility to the past results of the same utility and make a determination regarding the system's trend as either improving or degrading. It is also appropriate to compare one utility to another and determine that one has a higher or lower reliability, without making a judgment about the management practices.

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[1] An Investigation of the Reliability Measures of Kentucky's Jurisdictional Electric Distribution Utilities and Certain Reliability Maintenance Practices, Case Number 2006-00494, Dated December 12, 2006

[2] Case Number 2006-00494, Order dated December 12, 2006, pgs. 1-2

[3] IEEE Std 1366-2003 "IEEE Guide for Electric Power Distribution Reliability Indices" © 2004 by the Institute of Electrical and Electronics Engineers, Inc.

[4] Kentucky Public Service Commission, Case Number 2006-00494, Order dated October 26, 2007, pgs 9-11

The three indices selected by the Commission provide it with information about a utility customer's reliability experience for the report year. SAIDI provides the average number of minutes a system's customer experiences power interruptions. A SAIDI of 92 would mean that on average, a customer of the system had a total of 92 minutes without power for the report year. SAIFI is the average number of times a customer experienced power interruptions. A SAIFI of 2.3 would indicate that on average, customers experienced 2.3 interruptions in the report year. CAIDI is a measure of how long any given outage is expected to last. If CAIDI is 40, then a customer would expect each outage during the course of the year to last 40 minutes on average.

The indices are a method of measuring the results of the very complex process of delivering power to the retail customer. Like all processes, the results will have normal day-to-day and year-to-year variability. The variability is due to the changing environment in which the system functions; customer use, animal activity, temperatures, economic activity, wind velocity, number of lightning strikes, etc. all vary from period to period. Because there is variability in the results, simply comparing two results to make a determination of the relative long-term reliability may not be valid. A system with poor reliability may have an unusually good year while a normally well managed utility might have an unusually poor result in the same year. Simply comparing the results without taking into account the normal variability of the results may lead to incorrect conclusions.

Some events occur which are beyond the realm of normal system variability. Things such as ice storms, tornado outbreaks, hurricanes, earthquakes, floods, or other natural or man-made disasters can lead to a spike in outages. Such events can have a major effect on the reliability results of a system and can make an otherwise well managed, highly reliable system appear to be otherwise. *These special cause variations should be removed from the analysis so the results give a better measure of the system capabilities instead of, for example, a measure of how bad the 2008 ice storm was.*

The IEEE standard provides a statistical method for determining which events should be excluded from the data used to determine system reliability indices.[5] This method requires a system to review the daily SAIDI information for up to the previous five years. A mathematical formula is applied to determine the amount of expected variability for the system, and then a threshold value is established. For the current year, any day in which the SAIDI value exceeds the threshold value is excluded from the reliability analysis. These days are referred to as major event days. The threshold value is labeled T_{MED}. Statistically, 99.37% of all normal system variability will fall within the threshold value. This implies that any value beyond the threshold value has a 0.0063 probability of being normal variation, or 0.9937 probability of being special cause variation.[6]

[5] For a more detailed explanation of the calculation of the major event day threshold, see IEEE 1366-2003 section 4.5 and Annex B

[6] IEEE Std 1366, pg 32

Many utilities were unable to calculate major event days by the IEEE standard method due to the fact they did not record historical data in a form that would allow them to analyze the daily SAIDI values for previous years. For the purposes of the 2007 report, some utilities substituted a utility defined criteria for major events. While this has been accepted for the first report, the utilities are encouraged to fully implement the IEEE standard for recording and reporting reliability indices, including the definition of a major event day.

The first reports to incorporate the IEEE Std. 1366-2003 were required to be submitted to the Commission by April 1, 2008. All but three utilities met this deadline. All reports were received by April 28, 2008.[7] Initial reports were for the 2007 calendar year and included historical information for system performance for previous calendar years. The Commission requested at least five years of history, but some utilities were not able to provide more than one year because they were not tracking the information in prior years.

Of the twenty-two reports received, sixteen used some form of major event day threshold to exclude some days from the analysis. Sixteen reported indices which did not exclude major event days. Ten utilities reported results both ways. Three of these utilities applied the major event day criteria to the reported SAIDI, but did not provide SAIFI or CAIDI data with the major event days excluded.

Reports also included information about outage cause categories. The top ten causes for each index were reported, along with the contribution each cause made to the total index value. Several approaches were taken by the utilities performing this analysis. A plurality simply looked at each cause category separate from the others and calculated a SAIDI, SAIFI, and CAIDI value for the system using outages caused by that category only. Some calculated the total number of minutes caused by each category and reported the top ten outages by minutes. Some identified the number of outages caused by each category and reported the top ten most frequent outage causers. Regardless of the method, the causes were analyzed either by total outage time, frequency of outage, or length of time to restore.

The last item the reports were required to cover was a list of the ten worst performing circuits in each index category. Each circuit was to be analyzed as a separate system with a SAIDI, SAIFI, and CAIDI calculated. Some of the utilities developed different methods for identifying the ten worst performing circuits. The analysis was to include the major contributor to the poor reliability result for that circuit. The results of this analysis will be reviewed each year by the Commission's Division of Engineering to look for perpetually poorly performing areas of the system and determine if further investigation is warranted.

[7] Although the Licking Valley RECC report was received by 4/28/2008 it was after most of the analysis were completed and is not included in the results.

Conclusions

Note: *The results describe below are for overall system measurements. Individual customers may experience reliability results different from those described herein.*

- Reliability in Kentucky is improving.
- Overall customers are experiencing less time without service when compared to prior years.
- For 2007, half of the utilities reported that an average customer experienced between 49 and 135 minutes of power disruptions due to normal system operation during the year. This equates to power availability of 99.974% to 99.991% of time.
- Four utilities exhibit a statistically significant trend towards decreasing SAIDI (total power interruption time per customer) within a range of 4 minutes reduction per year to 46 minutes reduction per year over the past 5 years.
- For 2007, half of the utilities reported that an average customer experienced between 1.1 and 1.7 interruptions of service per year from normal system operations.
- When Major Event Days (MED) are considered, customers should expect between 1.3 and 2.0 interruptions per year.
- Six utilities demonstrated significant trends in their average number of interruptions per customer (SAIFI) over the past 5 years, three increasing and three decreasing.
- Overall, Kentucky customers experienced no change in the frequency of outages.
- In 2007, half the utilities reported that an average customer outage lasted between 80 and 97 minutes, with a median value of 86 minutes.
- Four utilities demonstrated significant trends in outage restoration time (CAIDI): one increasing by 0.2 minutes and three decreasing by 3.2, 5.5, and 20.2 minutes over the last 5 years.
- Trees and equipment were the two outage categories cited most often in 2007as the top causes of outage frequency and total outage time.
- Improvements in reliability appear to be the result of improved reaction to outages.

Follow Up Actions

1. Commission staff will distribute a standard reporting format for the utilities to use.

A common form will help the utilities provide consistent information for PSC staff to analyze over the course of years. It will also make the analysis more consistent since all parties will be reporting information in the same format. Forms should be available by the end of August to provide utilities with plenty of time to make any adjustments to their 2008 reports.

2. T_{MED} should be incorporated into the standard report format and reported.

Reporting T_{MED} will provide the Commission with more information about the level of reliability a given utility system provided. A high value would indicate a utility experienced a high degree of volatility in its results. A low number would indicate a relatively consistent reliability level. Reporting this value will also assure the Commission that the IEEE process has been implemented for determining major event days.

3. A staff analysis of the reliability information should be created each year.

A report similar in scope to this one should be issued by Commission staff each year within three months of the utilities filing their annual results. This will provide the Commission and the electric consumers in the Commonwealth with timely up to date information on the status of electric reliability in Kentucky.

4. An informal public meeting may be scheduled by staff to review this report with any interested parties, and to exchange ideas.

An informal public meeting will allow for the sharing of information and ideas which could improve the reporting and analysis process. Questions about the report and analysis can be addressed directly with interested parties or individuals.

5. Staff will follow up with utilities providing out of the ordinary results to determine if there is an opportunity to improve the reporting, or if there is an opportunity to improve the results.

Staff analysis has identified a number of data points which are outliers. Staff will follow up with the utilities reporting these outlying data points to determine if they are accurately reported. If the results are verified, then staff will conduct some investigation to identify best practices that utilities might copy to improve their results and improve reliability across Kentucky.

APPENDIX A: Analysis Techniques

The data were analyzed using three simple statistical tools: box plots, regression analysis, and Pareto analysis. These tools were used because of the limited number of data points, and the uncertainty of the shape of the data distribution. Box plots allow for limited analysis of the distribution of the data as well as a rough indicator of data outliers. Regression analysis provides a mathematical tool to analyze a time series of results and determine if there are any significant trends. The Pareto analysis points out the relative importance of the various causes of power supply problems.

Box Plots

A box plot is a graphical representation of the data which provides at a glance the amount of spread within the data, how balanced (or skewed) the data is, and whether any points represent data "outliers." Refer to the example in Figure 1. The chart shows the minimum (2.3) and maximum (334.2) values for the data set. It also indicates the median value of 89.7.

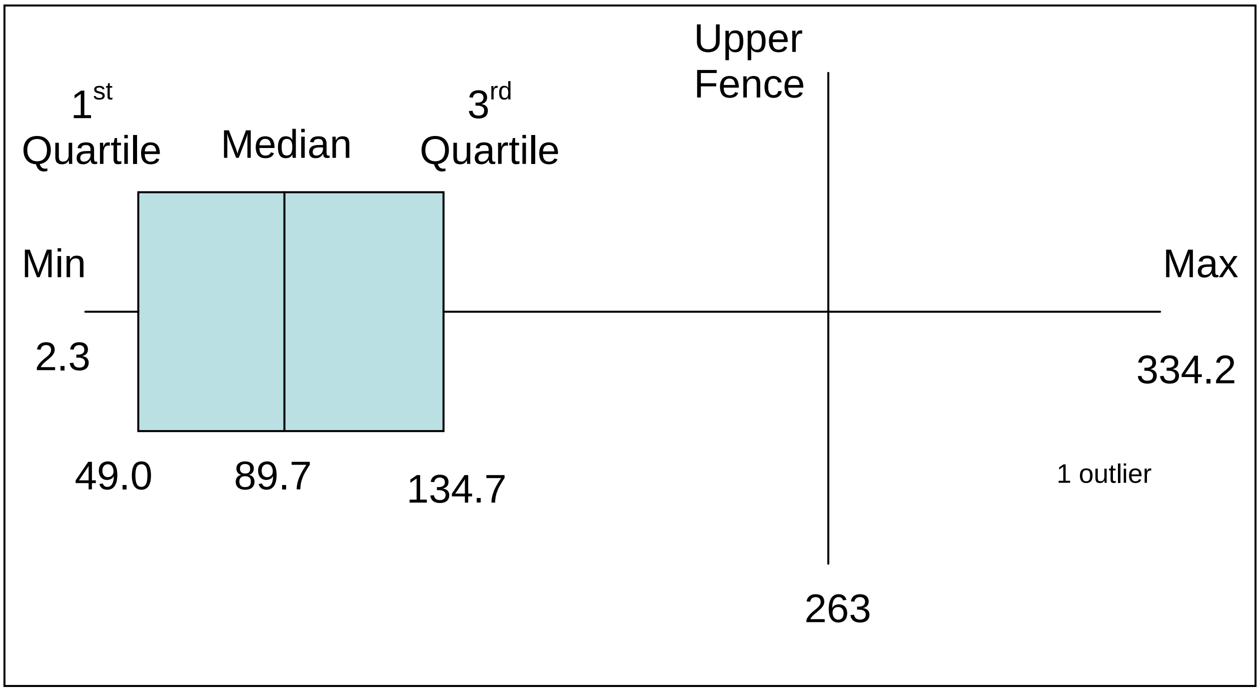

Figure 1: Box Plot

A median differs from an average or mean value. An average is determined by summing all the values and then dividing the sum by the number of data points. A median is determined by placing all the data points in order by value, from lowest to highest. The median is the value of the data point in the middle of the ordered data set. In the case of an even number of data points, it is the value half-way between the two middle data points.

The 1st quartile is the value which 25% of the data points are less than or equal to. The 3rd quartile is the value which 75% of the data points are less than or equal to. They are determined from the same ordered data set used to determine the median. Figure 2 is a sample ordered data set indicating the minimum (0.32), 1st quartile (the value halfway between the 4th and 5th points, or 1.25), median (the value halfway between the 8th and 9th points, or 1.50), 3rd quartile (the value halfway between the 12th and 13th points, or 2.0183), and maximum (2.375).

0.32	Min
1.02	
1.13	
1.22	
	1st Quartile
1.28	
1.35	
1.377	
1.41	
	Median
1.59	
1.67	
1.82	
1.99	
	3rd Quartile
2.0466	
2.142	
2.266	
2.375	Max

Figure 2: Ordered Data Set

The difference in values between the 1st quartile and 3rd quartile is referred to as the inter-quartile range (IQR). This value is used to determine the "upper fence" and the "lower fence" of the data set. Any value below the lower fence or above the upper fence is considered an outlier of the data set. Outliers are important because they can indicate exceptional problem areas or opportunities for improvement by copying an outstanding performer. An outlier can also be indicative of a problem with the data point.

Using a principle known as Tukey's Rule, the lower fence is set at a value equal to the 1st quartile less one and a half inter-quartile ranges (1st Q – 1.5 * IQR). The upper fence is set at a value equal to the 3rd quartile plus one and a half inter-quartile ranges (3rd Q + 1.5 * IQR).

Linear Regression Analysis

Linear regression analysis is a mathematical tool used to determine the 'best fit' line through a set of data organized by time or some other potential causal variable. It will determine a line which passes through the data with the least amount of total error as measured from the predicted result (the line) to the actual result (the data point). The tool also calculates statistic, the R^2 value, which measures the degree to which the calculated line actually describes the results. An R^2 value of 1.0 indicates perfect alignment between the line and the data points. An R^2 value of 0 indicates no correlation between the measured result and time.

Figure 3 is an example of a time-series data set. It shows the reported SAIFI for each year from 2001 to 2007. Reasonable people can look at the data and argue that the trend is increasing due to the high value in 2006. Another person could argue that the trend is decreasing because of the low values in 2004 and 2005. An argument could also be made that there is no trend, that the high and low values are just anomalies.

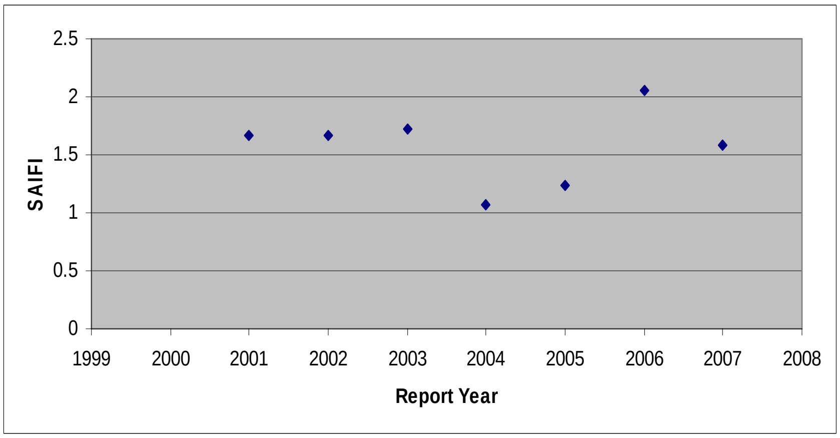

Figure 3: Time Series Data

In an effort to remove opinion from the analysis, statistical tools can be applied to the data set. In this case, as shown in Figure 4, a least squares error, linear regression analysis produces a line with the equation of SAIFI = 0.0021 * Year – 2.7229. This is a nearly horizontal line, the slope of which is increasing 0.0021 outages per year. The conclusion is that there is a very slight trend towards increasing frequency of outages.

The second part of the regression analysis is an analysis of the degree to which the observed data (the actual data points) agree with the predicted results (the regression line). The result of this calculation, known as the R^2 value, can loosely be read as the percent of variability accounted for by the x (time) variable. A value of .90 would indicate that 90% of the variability in the SAIFI is explained by the change in time. A value of 0.01 would indicate that only 1% of the variability is explained by time. For this report, it is assumed that any trend with an R^2 less than 0.3 will be considered insignificant (the variability in the index is not related to the change in time).

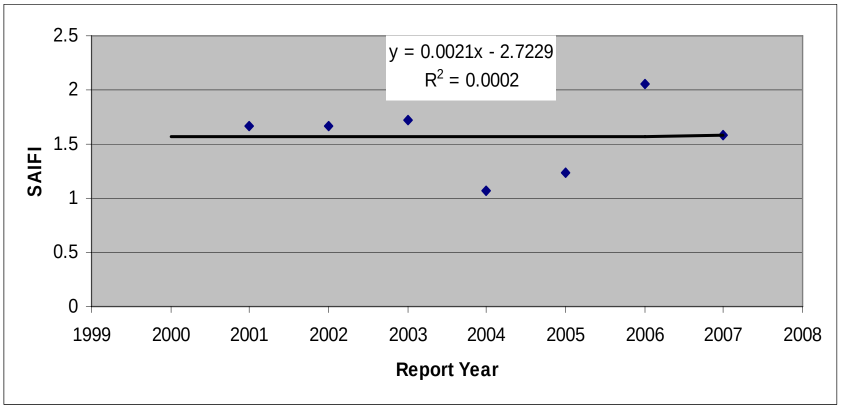

Figure 4: Best Fit Line

Figure 4 illustrates a data set where there does not appear to be a significant correlation between the year of the report and the result. Figure 5 provides an example of a data set which appears to be dependant on the year, indicating a significant trend (R^2 is 0.7762 or about 77.6% of the change in SAIDI is explained by the change in years). Note that since the coefficient on x is negative, this is a trend towards decreasing SAIDI values. Based on this analysis, it is reasonable to expect the system SAIDI to be 6.2 minutes lower in 2008 than it was in 2007.

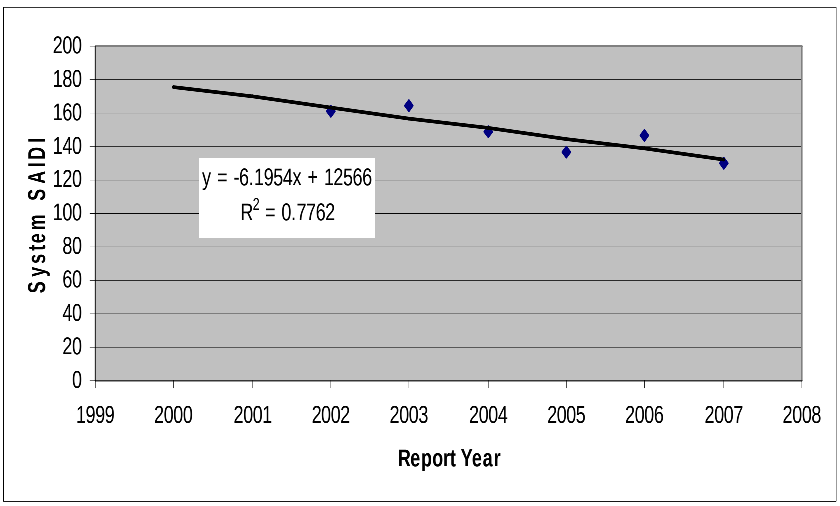

Figure 5: High Correlation Example

Pareto Analysis

A Pareto chart is a way of displaying a prioritized list of categorical data. The categories are listed along the x-axis and the number of times that category occurs (the frequency) is listed on the y-axis. The categories can be listed in order from most frequent to least, or from least to most. This provides a visual method for indicating the relative importance of one category when compared to the others. In the example provided in Figure 6, Trees and Equipment are listed most frequently and with approximately the same number of times. Then there is a large step down to storms, and then another relatively large step to the last four remaining categories.

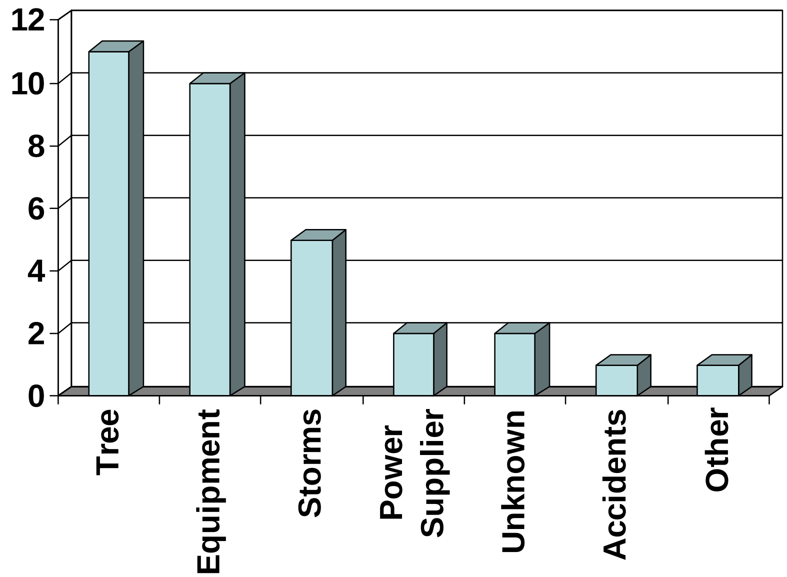

Figure 6: Pareto Chart

For this report, Pareto charts will be used to analyze the outage cause categories provided in the annual reports. Since utilities were required to report the top ten cause categories, reviewing all the listed causes would just result in an analysis of the commonalities in cause categorization. Instead this analysis will attempt to show which cause categories are the most important for reliability. Therefore the top two categories from each utility's report are included in the analysis. In the example given in Figure 6, one would be able to say that trees were listed as one of the top two cause categories by 11 utilities.

APPENDIX B: Reliability Analysis

This report will analyze each of the reported indices to try to determine the state of reliability in Kentucky. The results from all the utilities will be reviewed as a group to draw conclusions about what a typical electric utility customer in the Commonwealth can expect to experience.

First the results for the report year are separated into two groups: a group including major event days, and a group excluding major event days. The data in each of the groups is placed in order from lowest to highest and box plots are constructed. If an outlier is found, the data is reviewed to see if there is reason to believe the value is improperly calculated. If the outlier data appears to be correct, then further investigation can be done to understand why that utility's result was significantly different from the others. Such investigation will be carried out independent of this report.

Results containing at least five years of history are analyzed to determine the trend. The slopes of the resulting trend lines are then used to develop a box plot of the trends. This is done to better understand the overall trend of the electric utility industry in Kentucky. Last the R2 value from the regression analysis is reviewed to determine if the trends are statistically significant.

SAIDI

SAIDI excluding major events

Sixteen utilities reported SAIDI excluding major event days for 2007. A box plot of the results is presented in Figure 7.

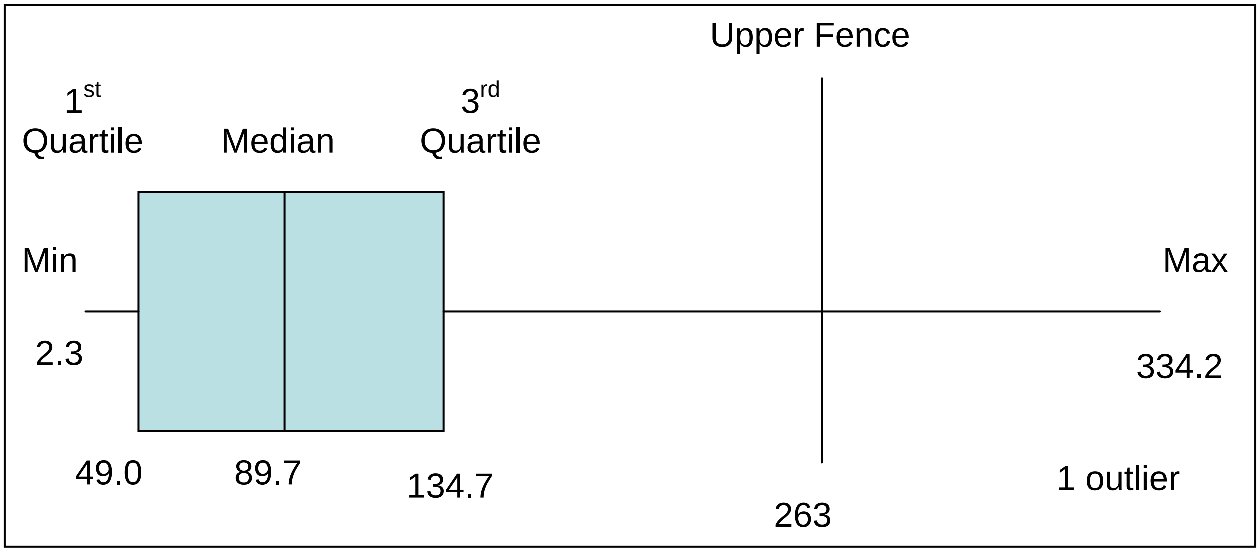

Figure 7: 2007 SAIDI results excluding major event days

One utility reported just 2.3 minutes of interruption per customer. While this point is not an outlier of the data set, it is an extraordinary result and warrants further investigation by Commission staff. At the other extreme, one utility reported 334.2 minutes (5.57 hours) of interruption per customer. This result is an outlier of the data set, but it is consistent with the results reported by the same utility for previous years. As will be pointed out in the trend analysis section, this utility creates an outlier for the trend (decreasing more per year than the data set would predict) as well.

Utilities reporting 2007 SAIDI excluding major event days include:

- Blue Grass Energy Cooperative Corporation
- Clark Energy Cooperative, Inc.
- Cumberland Valley Electric, Inc.
- Duke Energy Kentucky
- Fleming-Mason Energy Cooperative
- Jackson Energy Cooperative
- Jackson Purchase Energy Corporation
- Kentucky Power
- Kentucky Utilities Company
- Louisville Gas and Electric Company
- Meade County RECC
- Nolin RECC
- Owen Electric Cooperative, Inc.
- Shelby Energy Cooperative, Inc.
- South Kentucky RECC

Half the utilities reported ninety minutes or less of power disruption per customer in a year from normal system operation. The customers of most utilities will find their experience ranges from forty-nine minutes to one hundred thirty-five minutes. Given that a year is made up of 525,600 minutes, losing power for forty-nine minutes would mean that power is available 99.991% of the year. One hundred thirty five minutes of disruption equates to power availability of 99.974%.

Fourteen utilities provided at least five years of SAIDI data excluding major events. The reported SAIDI values for each utility were entered into a Microsoft Excel spreadsheet and a linear regression analysis was performed. The calculated line slopes (or the trend in the change in SAIDI per year) are displayed in Figure 8.

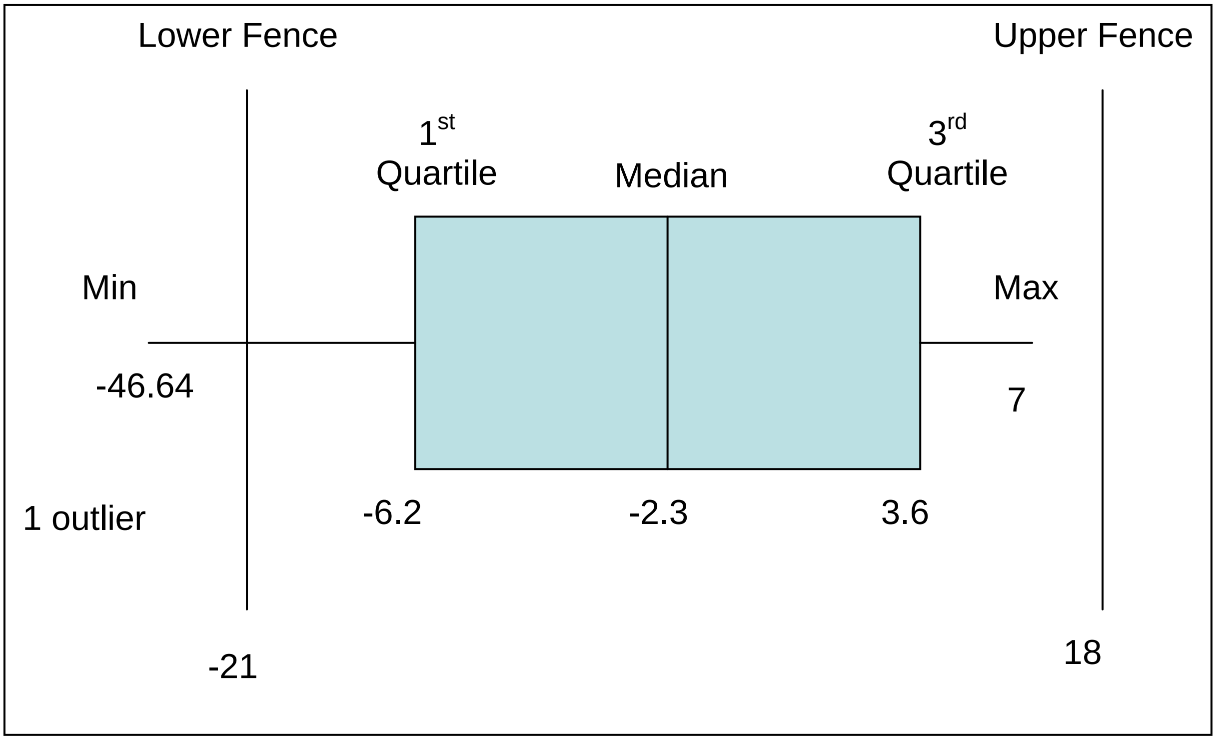

Figure 8: SAIDI trend excluding major event days

There is one outlier to the data set. This outlier is caused by the same utility reporting the high value outlying data point in figure 7. If the trend in data is accurate, then this utility should be commended for taking actions over the course of the last five years to continually reduce the number of minutes customers are without power (about 46 minutes less each year). However, if the SAIDI value is correct, this utility has the greatest opportunity for improvement.

The more typical SAIDI trends range from a 6.2 minute per year reduction to a 3.6 minute per year increase. The worst trend was a 7.0 minute per year increase. Fortunately, the trends for increase turn out to be insignificant since the R^2 value for these time series is less than 0.3. Four of the time series resulting in declining trends are significant. The four utilities with significant declining trends experienced reductions of 46.6, 16.9, 6.2, and 4.4 minutes per year.

The only significant trends are towards declining SAIDI. The other utilities are experiencing year to year variability, but are not significantly impacting the total minutes of outages experience by their customers. Therefore in general, the SAIDI for Kentucky is expected to improve year over year.

SAIDI including major events

Sixteen utilities reported SAIDI including major event days for 2007. A box plot of the results is presented in Figure 9.

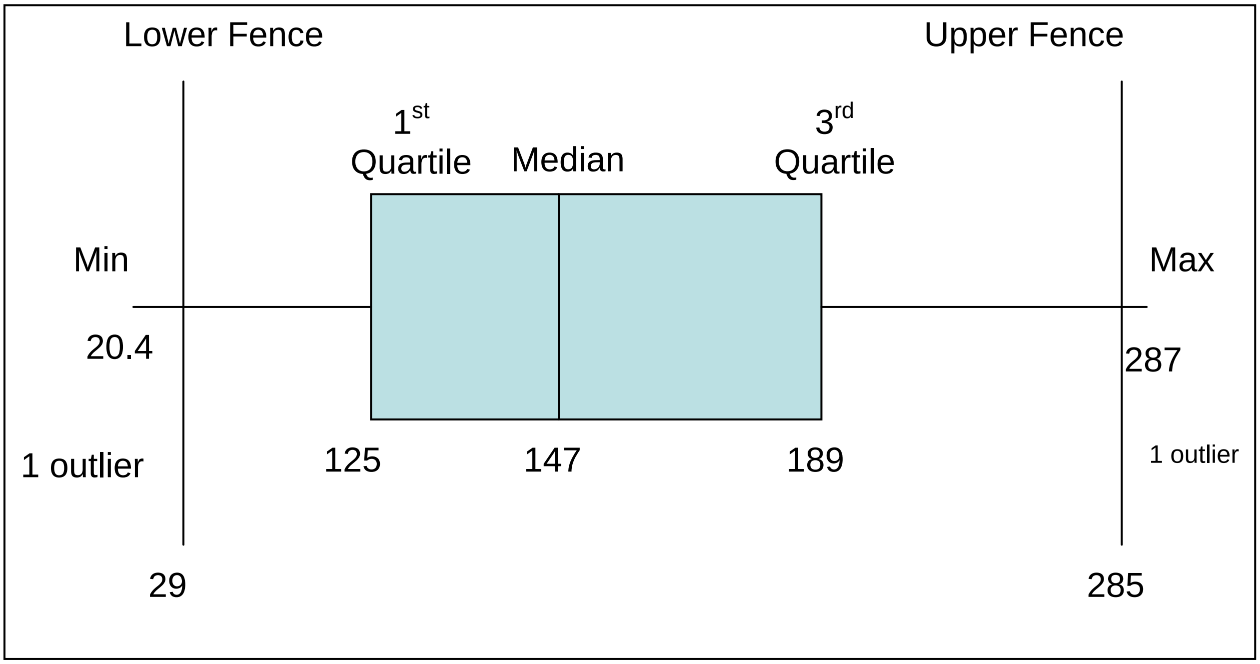

Figure 9: 2007 SAIDI results including major event days

Two data points are outliers of this data set. One point is unusually low, and one is unusually high. Given that the data contains unusual events such as severe storms, it is not unexpected that large variations in results are reported. Note that in both cases the outlying point is very close to the upper or lower fence value indicating that while it is an outlier of the data set, it is not an outlandish value.

Comparing the results of the SAIDI excluding major events to the results including major events, the latter has a higher 1st quartile, median, and 3rd quartile. When major event days are included in the analysis, utilities can expect their SAIDI value to increase significantly. Based on the change in median values, that increase is approximately 60% of the value excluding major event days.[8]

Utilities reporting 2007 SAIDI including major event days include:

- Big Sandy RECC
- Blue Grass Energy Cooperative Corp.
- Clark Energy Cooperative, Inc.
- Duke Energy Kentucky
- Farmers RECC

[8] The median changes from 90 to 147. This is a 63% increase.

- Grayson RECC
- Inter County Energy Cooperative
- Jackson Energy Cooperative
- Jackson Purchase Energy
- Kenergy Corp.
- Meade County RECC
- Nolin RECC
- Owen Electric Cooperative, Inc.
- Salt River Electric Cooperative
- South Kentucky RECC
- Taylor County RECC

When all outage events are included in the analysis, Kentucky electric consumers can expect to experience about one hundred fifty minutes (2 ½ hours) of service interruption per year. The expected range is from one hundred twenty-five to one hundred eighty-nine minutes. In terms of availability Kentucky consumers can expect power to be available 99.964% to 99.976% of the year.

Fourteen utilities provided at least five years of SAIDI data including major events. As before, the values were entered into a spreadsheet and Regression analysis was performed. The calculated line slopes are displayed in figure 10.

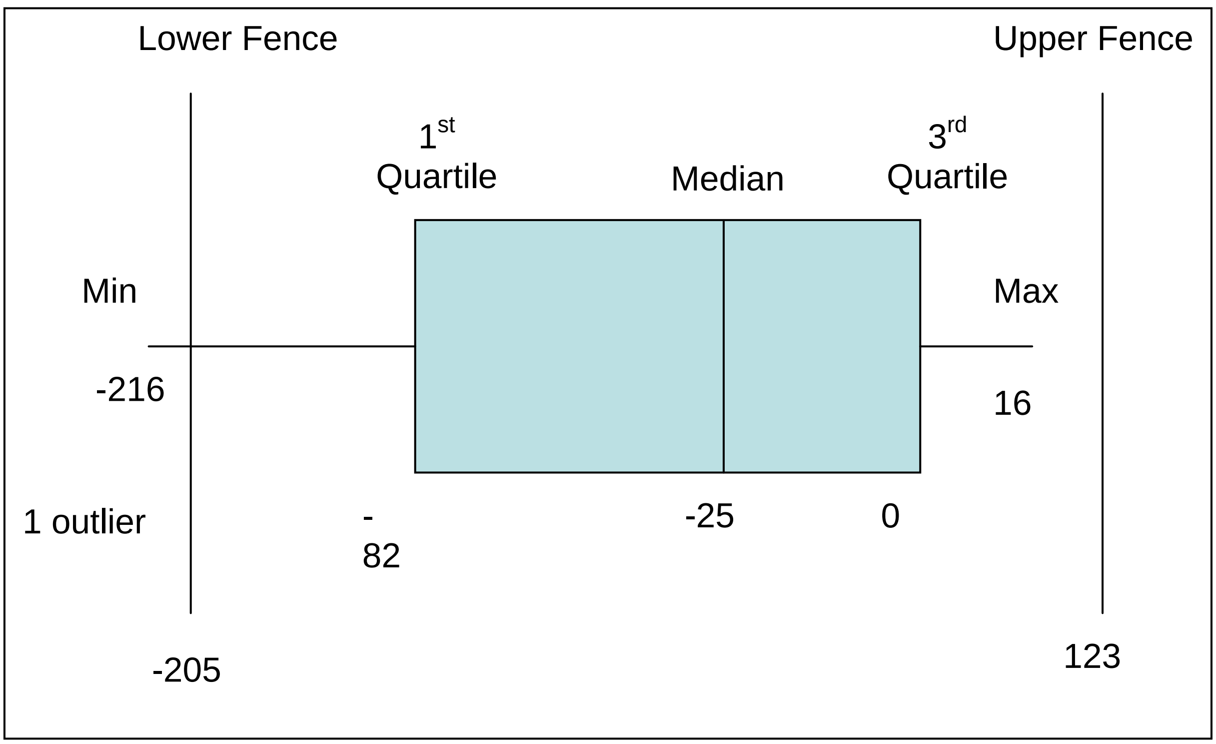

Figure 10: SAIDI trend including major event Days

The value of -216 minutes per year is an outlier of the data set. This data point turns out to be from a utility which was significantly impacted by the 2003 ice storm and the large reduction in SAIDI values is due to the fact that no major event of similar magnitude has happened to the utility since that year. This example points out a quirk with trends which needs to be taken into account. Had the ice storm occurred in 2004, or if the data would have included 2002, the resulting slope would have been much lower and the R^2 value would have been insignificant.

Most Kentucky consumers can expect a reduction of twenty-five minutes per year of outages when including all outages. The expected range is a reduction of zero minutes to eighty-two minutes per year reduction. This number is highly dependant on major storms in Kentucky, and will likely move the other way when information for 2008 is received due to the major ice related outages experienced by the utilities in West Kentucky this year.

Three utilities exhibit significant trends, all declining. The values are two hundred sixteen minutes per year, eighty-nine minutes per year, and twenty-five minutes per year. As discussed above, these results are highly dependant on major events and may not be indicative of utility operations.

SAIFI

SAIFI excluding major events

Thirteen utilities reported SAIFI excluding major event days for 2007. A box plot of the results is presented in figure 11.

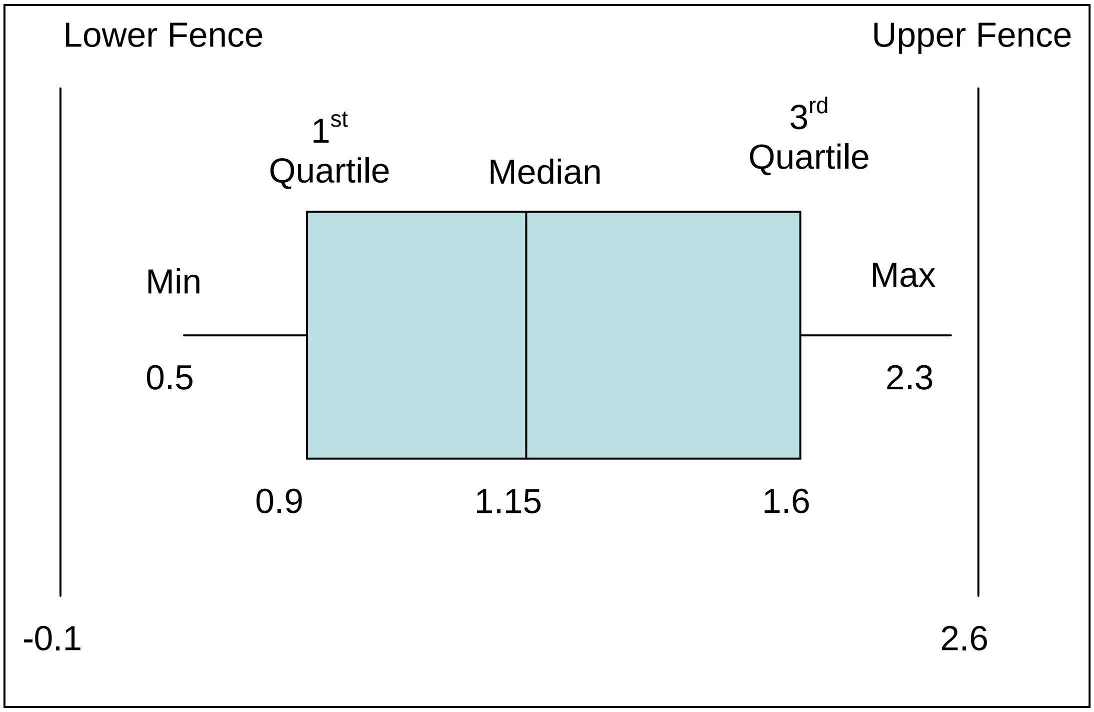

Figure 11: 2007 SAIFI results excluding major event days

The data set does not present any outliers and ranges from 0.5 outages per customer per year to 2.3 outages per customer per year. Most utilities customers experienced between 0.9 and 1.6 outages per customer per year with 1.15 representing the median experience.

Ten utilities provided at least five years of SAIFI data excluding major event days. A time series linear regression analysis was completed for each utility and the resulting line slopes are displayed in figure 12. Note that in this case the line slope can be considered as the change in outage frequency per customer per year.

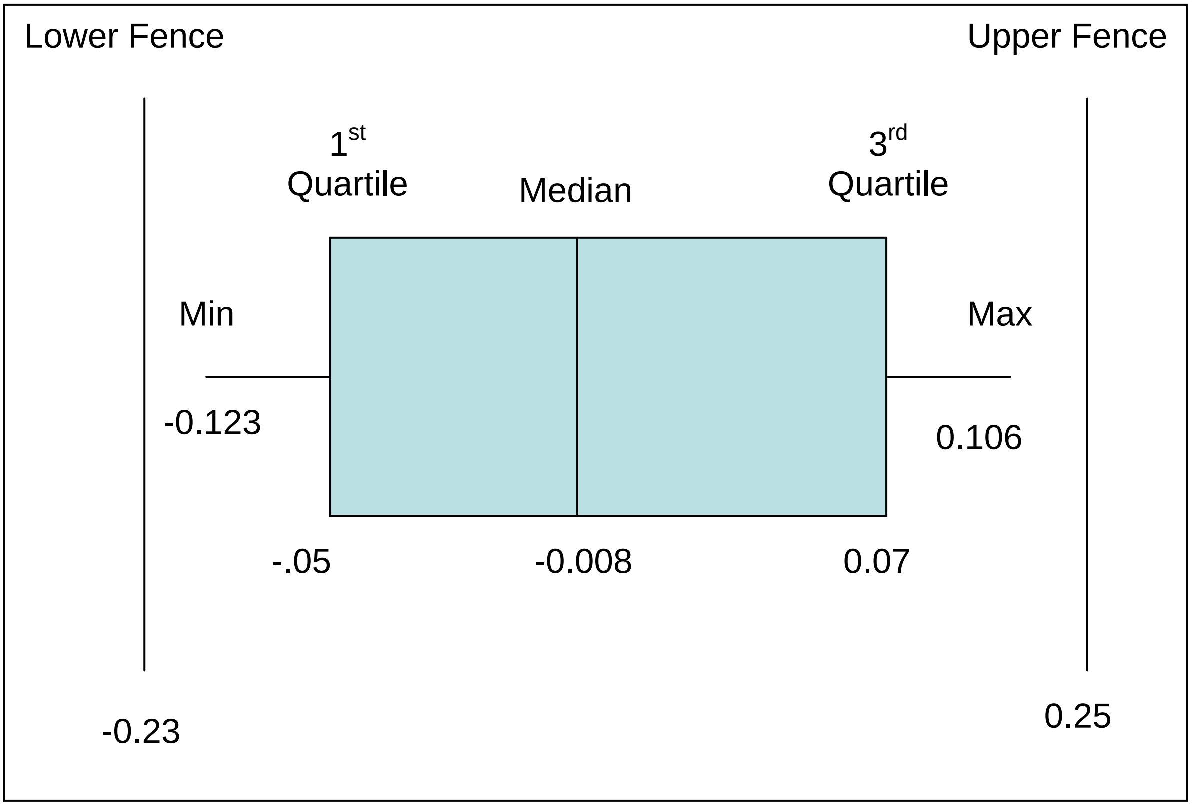

Figure 12: SAIFI trend excluding major event days

Most utility customers experienced a change in the frequency of outages ranging from a 0.05 decrease to a 0.07 increase, with an 0.008 decrease being the median result. Overall the results suggest that a typical customer in Kentucky would experience the same number of outages from year to year. This is reinforced when the significant trends are reviewed.

Six utilities demonstrated significant trends. Three have increasing trends of 0.063, 0.094 and 0.106, and three have decreasing trends of 0.051, 0.084, and 0.123. Some customers are experiencing a year to year increase in frequency while others are experiencing a trend towards a decrease in frequency. The increasing trends are approximately equal to the decreasing trends both in number and magnitude resulting in an overall result of no change.

SAIFI including major events

Sixteen utilities reported SAIFI including major event days for 2007. A box plot of the results is presented in figure 13.

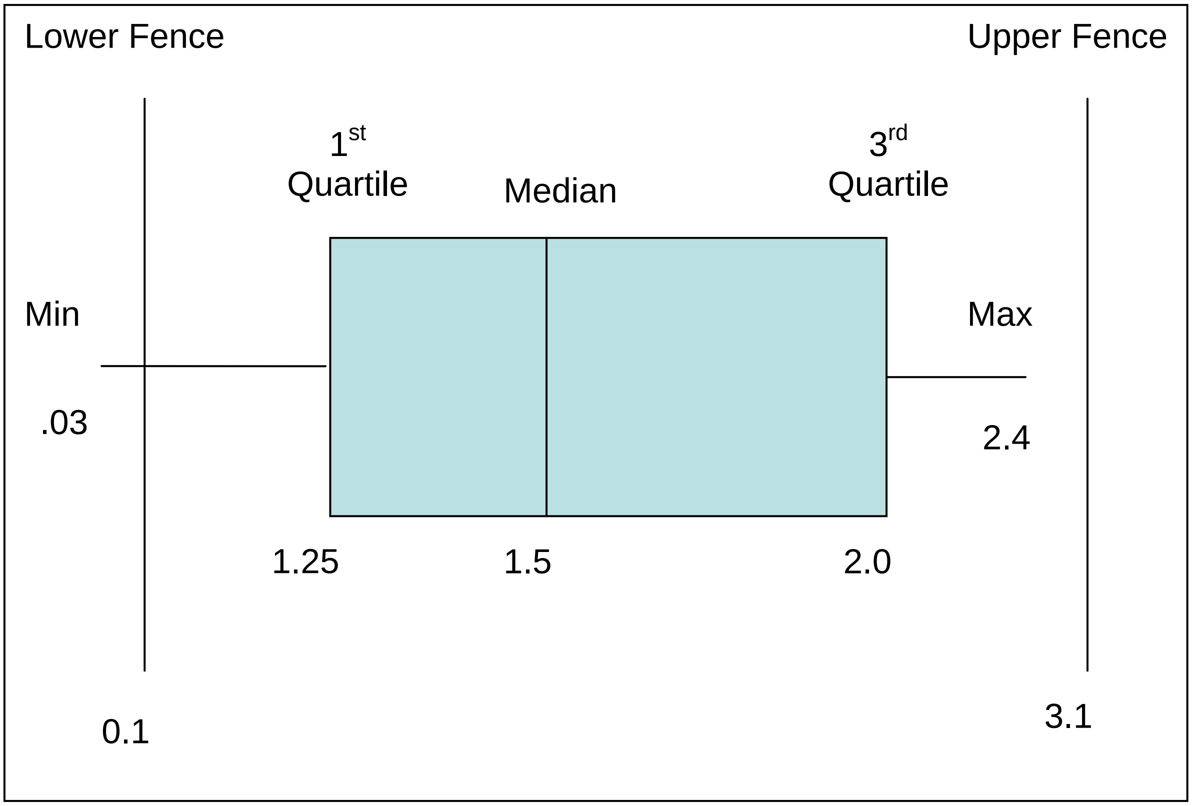

Figure 13: 2007 SAIFI results including major event days

One data point is an outlier. A utility reported a SAIFI of 0.03 outages per customer per year. This is an exceedingly low number and should be reviewed with the utility to understand whether it is correct or a reporting error.

When major events are included, most Kentucky electric consumers experienced between 1.25 and 2.0 power interruptions during 2007. The median value was 1.5 interruptions.

Thirteen utilities provided at least five years of SAIFI data including major events. A time series linear regression analysis was completed for each utility and the resulting line slopes are displayed in figure 14. The calculated line slopes can be interpreted as the change in outage frequency per customer per year.

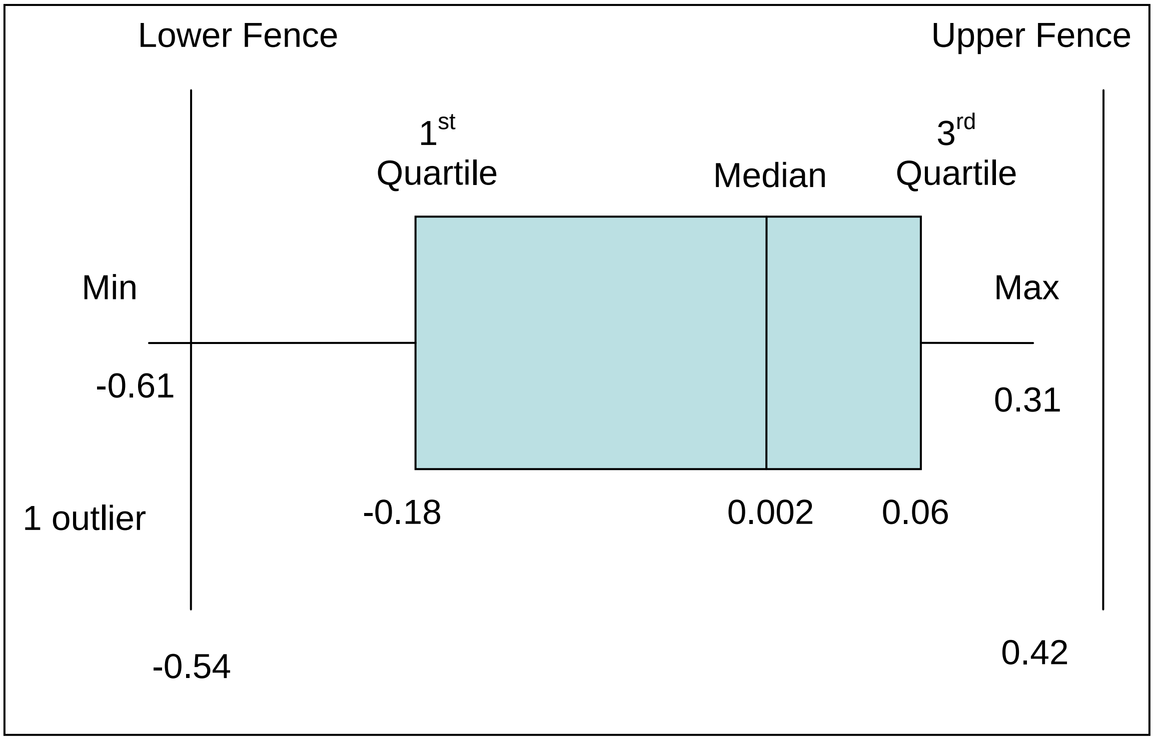

Figure 14: SAIFI trend including major event days

One data point is an outlier. This point was not from a significant trend and was highly influenced by the change in the number of major events from year to year for the utility. The analysis indicates that for Kentucky, when major events are included, most customers can expect the frequency of outages to change by a reduction of 0.18 to an increase of 0.06 outages per year. The median value is 0.002.

There are two significant trends. One trend is for increasing SAIFI by 0.137 outages per year. The other is for decreasing SAIFI by 0.292 outages per year. As when major events are excluded, there appears to be no overall change in the frequency of power interruptions for Kentucky consumers.

CAIDI

CAIDI excluding major events

Thirteen utilities reported CAIDI values excluding major event days for 2007. A box plot of the results is presented in Figure 15.

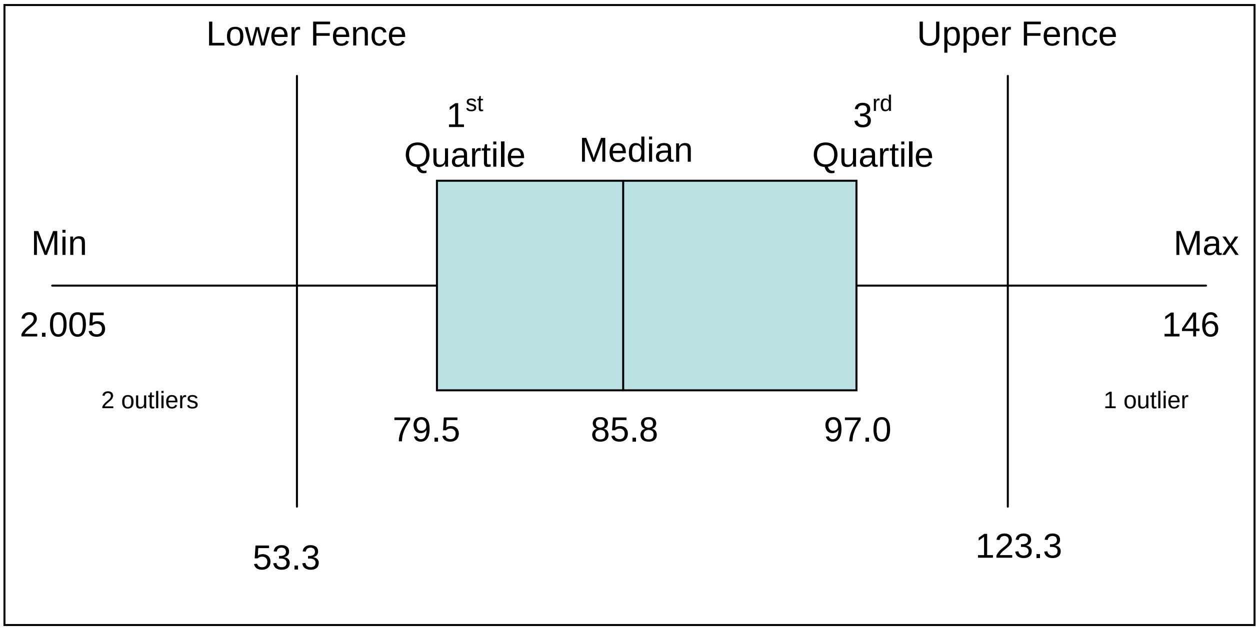

Figure 15: 2007 CAIDI results excluding major event days

There are three outliers in the data set. The most suspicious point is the minimum value of 2.005 minutes per outage. This value would be very difficult for a utility to obtain and is most likely an error in calculation. The utility will be contacted by commission staff to review the data and try to determine where the error is occurring.

The other two outliers are values of 44.3 minutes and 146.9. Both of these are in the realm of possibility and probably represent actual results. If so, then the utility with the low value should be analyzed to understand what is different about it that others may copy. The utility with the high value may want to review its own practices and determine if modeling some of the other utilities may benefit the customers.

Most electric customers in Kentucky can expect an outage to last from seventy-nine to ninety-seven minutes. The median value is about eighty six minutes.

Eleven utilities provided at least five years of CAIDI data excluding major events. A time series linear regression analysis was completed for each utility and the resulting line slopes are displayed in figure 16. The calculated line slopes can be interpreted as the change in average outage restoration time.

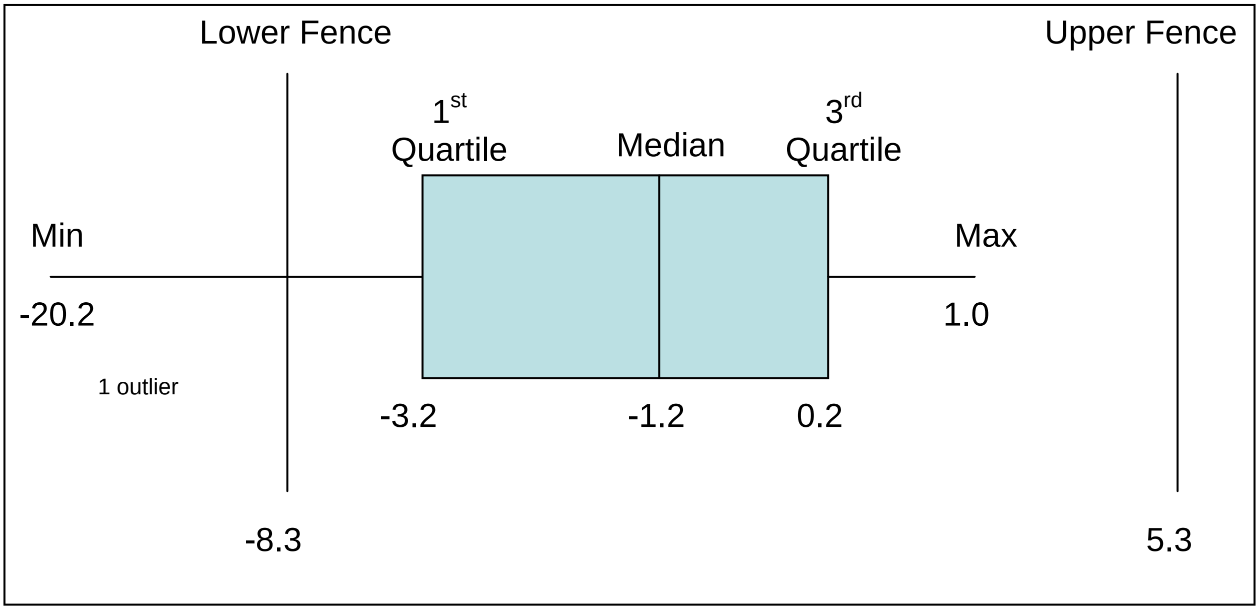

Figure 16: CAIDI trend excluding major event days

There is one outlier in the data set. The minimum value of -20.2 minutes per year is attributable to the same utility which presents the outlying high value in figure 15. It is therefore likely that this utility has recognized an opportunity for improvement and has had some success in implementing changes to its operation.

Four utilities have significant trends in the change of CAIDI from year to year. One is an increasing trend of 0.20 minutes per year. The other three are all decreasing trends of 3.2, 5.5, and 21.2 minutes per year. Overall there appears to be a trend towards reduction of time required to restore outages not caused by major events.

CAIDI including major events

Sixteen utilities provided CAIDI data including major events for 2007. A box plot of the results is provided in Figure 17.

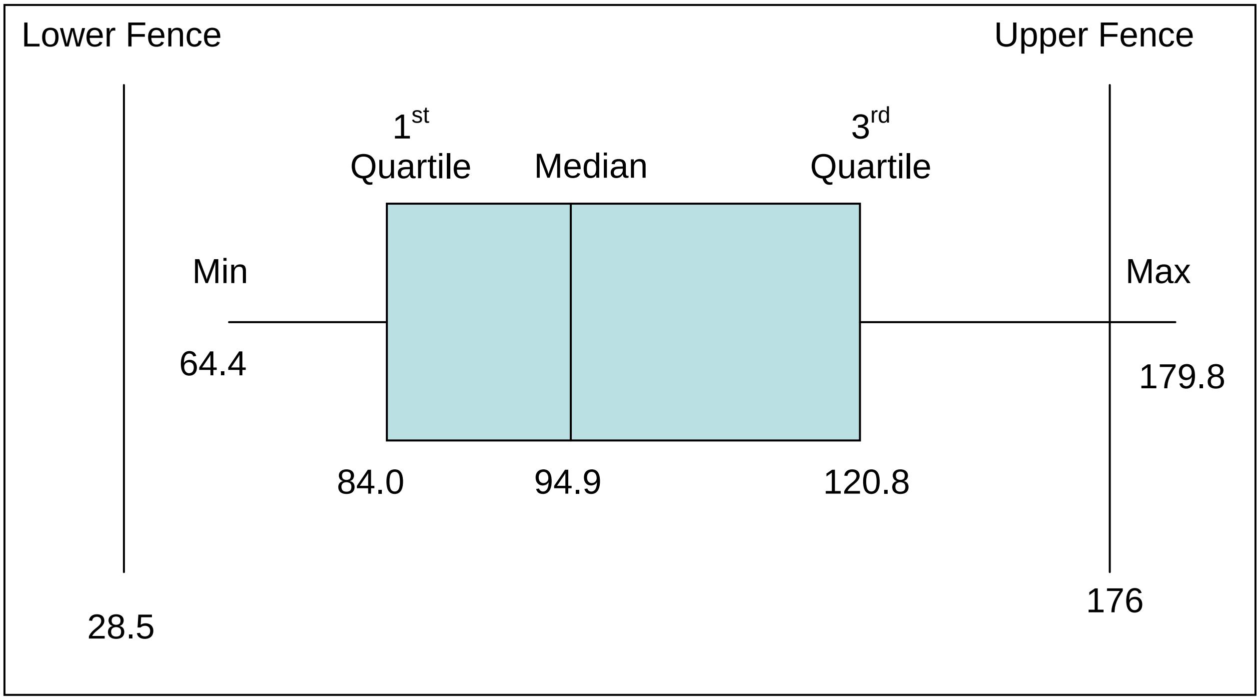

Figure 17: 2007 CAIDI results including major event days

There is one outlier to the data set. One utility reported nearly one hundred eighty minutes (three hours) per outage. This data point is consistent with the balance of the information provided by the company and is not too outlandish when compared to the other utilities so it will be considered a valid point.

Most customers can expect to experience between eighty-four and one hundred twenty one minutes of disruption for each outage. The median value is about ninety-five minutes

Thirteen utilities provided at least five years of CAIDI values including major event days. A time series linear regression analysis was completed for each utility and the resulting line slopes are displayed in figure 18. The calculated line slopes can be interpreted as the change in average outage restoration time.

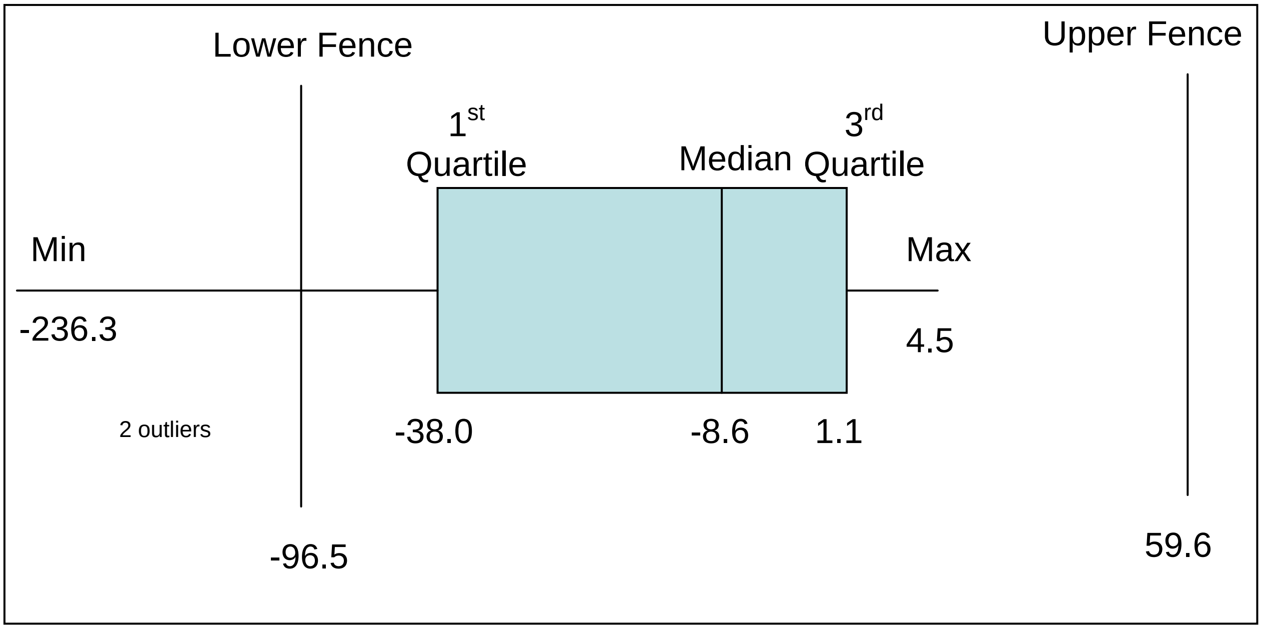

Figure 18: CAIDI trend including major event days

The two outliers were caused by utilities which experienced a single with an exceptionally high CAIDI and then normal results for the remainder of the years. Since the abnormally high CAIDI occurred at the first or second year of the five year history, it appears as a trend towards decreasing CAIDI. When the year with the extraordinary result is removed from the analysis, the trend returns to a value more consistent with the data set.

Most Kentucky customers can expect the change in the amount of time required for restoration to range from a decrease of thirty eight minutes to an increase of one minute. Three utilities have experienced a significant trend with values of decreasing CAIDI. The rates of decrease are 15.5, 51.1, and 81.4 minutes per year. Overall there appears to be an improvement in restoration times for Kentucky electric consumers.

Cause Categories

The following three figures provide information on the number of times outage categories were listed as one of the top two reasons for causing a utility's reliability problems. Figure 19 lists the top contributors to the frequency of outages (SAIFI). Figure 20 lists the top contributors to the total system minutes (SAIDI). Figure 21 lists the top contributors to average outage duration (CAIDI)

In all cases the "Tree" category is listed more often than any other cause category. "Tree" includes trees in the right-of-way (ROW), and trees out of the ROW. Equipment is the second most often listed cause of outages.

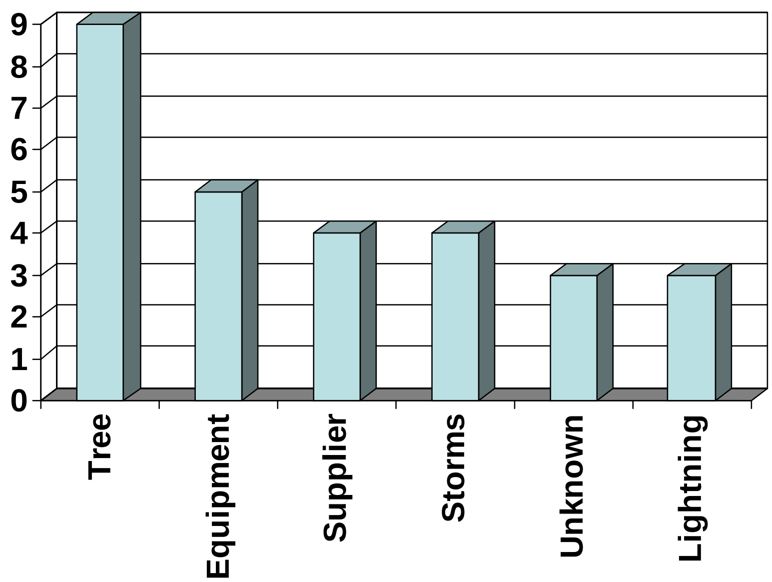

Figure 19: 2007 Top two reported causes of outage frequency

Figure 19 depicts the categories cited most often as one of the top two cause categories for the frequency of outages on a system. Nine utilities listed trees as one of their top two cause categories for outage frequency. Five listed equipment as one of their top two categories. Fourteen utilities reported information about the cause categories associated with outage frequency (SAIFI).

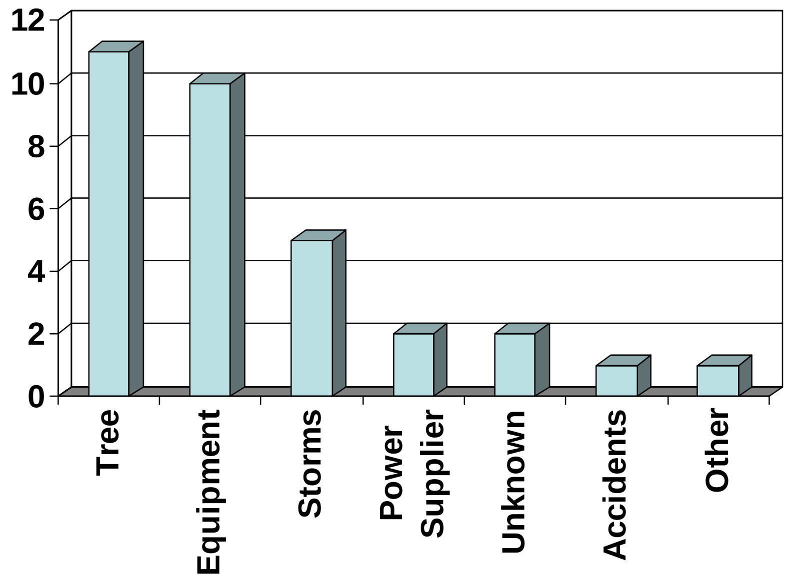

Figure 20: 2007 Top two reported causes of total outage minutes

Figure 20 illustrates the top two outage cause categories listed by utilities for causing the total number of customer outage minutes in 2007. Trees were listed as one of the top two categories by eleven of the sixteen utilities reporting. Equipment was listed as one of the top two categories by ten of the sixteen utilities.

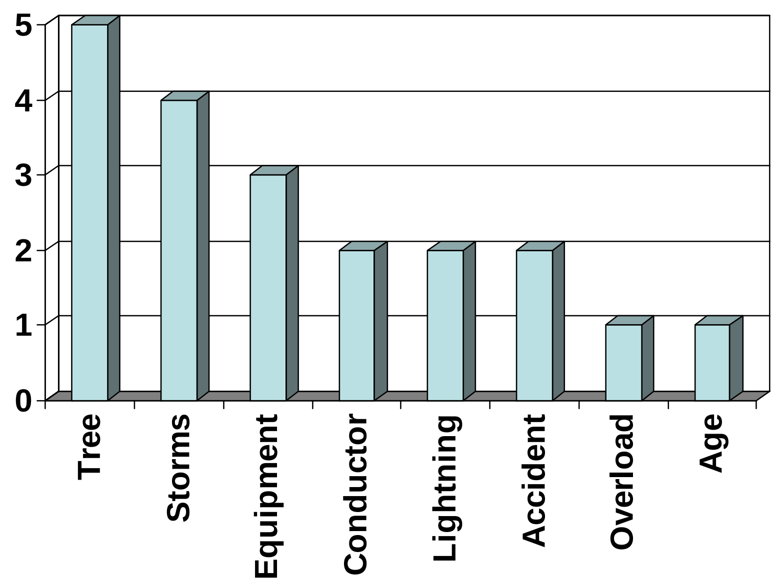

Figure 21: 2007 Top two reported causes of outage duration

Figure 21 illustrates the top two outage cause categories listed by utilities for causing outage duration minutes in 2007. Trees were listed as one of the top two categories by five of the ten utilities reporting. Storms were listed as one of the top two categories by four of the ten utilities.