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Impact of System Average Interruption Duration Index Threshold on the Reliability Assessment of Electrical Power Distribution Systems

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ABSTRACT: System Average Interruption Duration Index (SAIDI) is one of the parametric indices used for assessment of the performance of electrical power network. It is the ratio of customers' interruption duration to the total number of customers served. SAIDI threshold is used to determine the calendar days upon which either the system design limits or operational limits are exceeded. This research paper presents the impact of SAIDI threshold on the reliability assessment of electrical power distribution system. Data were collected from ten selected feeders of Ibadan distribution system for a period of five years. The daily SAIDI, natural logarithm of SAIDI, the log-average of SAIDI and the standard derivation of the logarithm of SAIDI were used as input parameters in the development of SAIDI threshold model. The result of the research paper shows that the SAIDI threshold values fluctuate over the years with the least and highest SAIDI threshold values as 2.11596 and 4.62518 respectively which were recorded in the months of September and April. The SAIDI thresholds in the months of January, February, March, April, May and June are 3.18318, 3.32458, 4.22242, 4.62518, 2.71360 and 3.27760 respectively suggesting an indefinite pattern in the SAIDI threshold as a result of unexpected interruptions experienced by customers attached to the distribution feeders. SAIDI threshold forms a basis for power system planning and maintenance strategies.

Keywords: SAIDI, Electrical power distribution systems, Threshold, SAIDI Threshold, Reliability, Interruption, Momentary interruptions.

1. INTRODUCTION

Electric power industries are moving towards a deregulated and competitive environment where utilities must have accurate information about system performance to ensure that maintenance cost are spent wisely and expectations of customers are met without compromising reliability. Reliability plays a significant role in assessing the performance of power network. As far as power system is concerned, the customer satisfaction is measured on the basis of parametric indices. It is necessary to supply high quality and adequate electric power at reasonable price to the customers. Reliability of a unit is the probability that the unit performs its intended function adequately for a given period of time under the stated operating conditions. The objective of a particular system or mission will determine its reliability requirements (Sindi and El-Saadany, 2016; Eminoglu U and Uyan, 2016; Rajaiah, Satyanarayana and Srinivas, 2015).

To measure system performance, the electric utility industry has developed several performance metrics of reliability. These performance indices include measures of outage duration, frequency outages, system availability and response of time. Measurement of actual system reliability provides feedback to the planners on the performance of executed plans. It gives feedback to operation personnel on reliability effects and maintenance practices. Reliability evaluation helps in system planning for long and short terms. System reliability indices are therefore a fundamental task in reliability evaluation (Okorie and Abdu, 2015; Mohan, Seetharam and Raju, 2015; Das and Deka, 2013).

The reliability of a network can be judged on the basis of reliability indices. System reliability indices are considered on the distribution side of the power network. These include: System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), System Average Interruption Frequency Index (SAIFI), Average Service Availability Index (ASAI), Average Service Unavailability Index (ASUI), Expected Energy Not Supplied (EENS) and Average Energy Not Supplied (AENS) (Elena and Vitaly, 2001; Wang, Billinton and Goel, 2000).

However, System Average Interruption Duration Index (SAIDI) implies how often an average customer experiences sustained interruption during a predefined given time period of a year. SAIDI is commonly used as a reliability indicator by electric power utilities and the most often used performance measurement for a sustained interruption. A sustained interruption is any interruption not classified as a momentary event. A momentary interruption event is an interruption of duration limited to the period required to restore services by an interrupting device. A momentary interruption is a single operation of an interrupting device that results in a voltage zero (Okorire *et al*., 2015; Elsalmawy *et al.,* 2011). SAIDI measures the duration of an interruption for the average customer during a given time period; it is normally calculated on either monthly or yearly basis. It can be calculated daily or for any other time period (El-Kady *et al*., 2007; Xiu-Ren *et al.,* 2005; Enrico and Gianfranco, 2004; Balijepalli, 2002; Kovalev and Lebedeva, 2000).

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When calculating daily SAIDI interruption durations that extends into subsequent days contribute to the day on which the interruption begins. Despite the fact that SAIDI is used to determine major event days, other reliability indices such as SAIFI and CAIDI can also be computed from the outage data. Customers on a given distribution system are usually out of service for some period of time during particular times of the year. Utilities analyze the collected data on a regular basis. This is on the basis that outage times for outages that occur on a given day accumulate to that day's reliability statistics. Major storms, hurricanes , ice storms, earthquakes and other disasters are some of the causes of interruptions. Many event day refers to a day on which a major event occurred.

2. MATERIALS AND METHOD

SAIDI threshold is used to determine the calendar days upon which either the system design limits or operational limits are exceeded.

Steps in the analysis;

i. Data collection over a period of 5 years
ii. Computation of the daily SAIDI
iii. Computation of the natural log (Ln) of each SAIDI value
iv. Computation of the log-average (α) of each SAIDI value
v. Computation of the standard deviation of the logarithm (β)
vi. Computation of the SAIDI threshold using;

$$SAIDI_{TH} = e^{(\alpha + 2.5\beta)}$$

Where;

e = Exponential function, 2.718

α = Log-average of the data (Ln SAIDI)

β = Log-standard deviation of the data (SD SAIDI)

3. DISCUSSION OF RESULTS

The values of SAIDI for January, February, March and April are 0.00166, 0.00056, 6.48326 and 0.00158 respectively indicating an irregular distribution of SAIDI within these four months. The same pattern is observed for the SAIDI distributions from May to December 2011 with SAIDI values of 0.01512, 0.41304, 0.03214, 0.33215, 0.41217, 0.63133, 0.05136 and 2.46121 respectively. A least SAIDI value of 0.00056 was recorded in 2011 with the highest SAIDI value of 6.48326 recorded in March 2011 as a result of a prolonged period of customers' interruption in March 2011 even though a fewer number of interruptions were experienced by the customers attached to the feeders in February 2011.

The natural logarithm of SAIDI distribution for year 2011 is illustrated in Figure 2. February 2011 is month of highest natural logarithm of SAIDI with a value of 7.4132 while June 2011 is a month associated with the least natural logarithm of SAIDI with a value of 2.5395. This is due to the fact that most of the faults experienced by the customers attached to the distributions feeders in February 2011 persisted for a longer period of time before the faults were cleared in June 2011, thus leaving the customers in period of complete darkness between February and early part of June 2011.

The standard derivation of the SAIDI for the year 2011 is illustrated in Figure 3. The SAIDI standard derivation is a measure of the occurrence of faults and the duration of the fault clearance. The standard derivation of the SAIDI distribution fluctuates appreciably over the year. The standard derivation of SAIDI for January, February, March, April, May and June 2011 are 2.2214, 1.6814, 1.5892, 2.6314, 3.2214 and 5.1214 respectively. The least SAIDI standard derivation is 1.5892 and was recorded in March 2011 while the highest SAIDI standard derivation was observed in the month of June 2011 with a value of 5.1214.

Figure 4 shows the SAIDI threshold for the year 2011. The month of April 2011 recorded the highest SAIDI threshold with a value of 3.8918 while the least SAIDI threshold was 1.5232 and it was recorded in May 2011. The SAIDI threshold for January, February, March, April, May and June 2011 are 2.4403, 2.4038, 3.1872, 3.8918, 1.5232 and 2.9314 respectively confirming the fluctuation nature of the SAIDI threshold as a result of intermittent interruption experienced by the customers attached to the concerned feeders.

Figure 5 shows the relationship between the natural logarithm of SAIDI values and the standard derivation of the SAIDI values for the year 2011. In the month of February, 2011, a natural logarithm value of 7.4132 was obtained which corresponds to the highest value in this range with the least value recorded as 2.5395 in the month of June, 2011. The least and highest values of the standard derivation of SAIDI were also recorded as 1.5892 and 5.1214 respectively as a result of variations in the number of customers served by the distribution feeders in this locality.

The SAIDI distribution for the year 2012 is illustrated in Figure 6. The SAIDI distribution for the year 2012 fluctuates over the years. The SAIDI distribution for January, February, March and April 2012 are 0.12569, 0.01368, 4.62167 and 0.83215 respectively. The least SAIDI value of 0.01368 was recorded in February 2012 with the highest SAIDI values of 4.62167recorded in March 2012. There were prolonged periods of interruptions in the month of March 2012. The interruptions lasted for a period of time before being cleared.

Figure 7 shows the natural logarithm of the system SAIDI for the year 2012. This logarithm of SAIDI fluctuates

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appreciably with the least value of 3.2456 recorded in the month of August, 2012 while the highest value of the natural logarithm of SAIDI is 8.5132 which was recorded in the month of February, 2012.

The standard derivation for SAIDI value for year 2012 is illustrated in Figure 8. In February 2012, the least standard derivation of SAIDI values was 1.5324 with the highest standard derivation of SAIDI value of 5.1352 due to the number of customers' interruptions and the duration of such interruptions.

Figure 9 shows the SAIDI threshold distribution over the period of one year for 2012. The least and highest values of SAIDI thresholds were 1.6324 and 4.6215 which were recorded in the months of May and April respectively as a result of the duration of the faults experienced by the distribution feeders.

The relationship between the logarithm average of SAIDI and the standard derivation of SAIDI for year 2012 is illustrated in Figure 10. A least standard derivation of 1.5324 corresponds to the highest natural logarithm SAIDI value of 8.513 which was recorded in February, 2012. In addition, the highest standard derivation of 5.1352 was recorded in June with the least natural logarithm of SAIDI values of 3.3456.

Figure 11 shows the SAIDI distribution for 2013. The SAIDI values for January, February, March, April, May and June are 0.26254, 0.02418, 4.52192, 0.93214, 0.06514 and 0.62143 respectively. February 2013 recorded the least SAIDI value of 0.02418 with the highest SAIDI value of 0.97318 which was recorded in the month of December.

Figure 12 illustrates the logarithm average of SAIDI value for the year 2013. The least logarithm average of SAIDI value was 2.8732 which was recorded in the month of October with a highest logarithm average of SAIDI value of 9.4208 recorded in the month of November.

The standard derivation for SAIDI for the year 2013 is depicted in Figure 13. The standard derivations vary over the year with the least value being 1.7546 in September and a highest value of 5.9326 which was recorded in June of the same year. The standard derivations of SAIDI for January, February, March and April are 2.0390, 2.1472, 1.3814 and 2.6319 respectively due to the level of interruption experienced by the customers attached to the distribution feeders.

Figure 14 shows the SAIDI threshold value for year 2013. The SAIDI threshold value varied between 1.9314 (least) in September to 5.3217 (highest) in April indicating that in April, 2013, many faults were experienced on the distribution feeders. Those faults persisted until they were eventually cleared in September, 2013. The SAIDI threshold for January, February, March, April, May and June are 2.6358, 3.6214, 4.1938, 5.3217, 2.6215 and 3.9216 respectively.

Figure 15 shows the variation of logarithm average of SAIDI values and the standard derivation of SAIDI values. The logarithm average of SAIDI values are 7.8325, 8.6215, 3.7328, 5.6387 and 6.3845 while the standard derivations for SAIDI values are 2.0390, 2.1472, 1.3814, 2.6119 and 5.2918 for the months of January, February, March, April and May respectively.

The distribution of SAIDI for year 2014 is illustrated in Figure 16. The distributions of SAIDI for year 2014 are 0.36431, 0.04639. 4.62414, 0.94214 and 0.07293 for the months of January, February, March, April and May. The least value of SAIDI was 0.04311 which was recorded in November while the highest value of SAIDI was 0.94214 and it was recorded in the month of April.

Figure 17 shows the natural logarithm of SAIDI distribution for 2014. The least and highest values of the natural logarithm of SAIDI distribution for the year 2014 are 3.6214 and 9.3061 respectively. Thus, the month of March recorded the least value of 3.6214 while November recorded the highest value of the natural logarithm of SAIDI distribution.

The standard derivation for SAIDI for the year 2014 is illustrated in Figure 18. The standard derivation measures the variation of the SAIDI values with the mean SAIDI for the year. Thus, the standard derivations for the SAIDI for the months of January, February, March and April are 3.0570, 2.9614, 1.6214 and 2.9315 respectively. For this year 2014, the least and highest standard derivation of the SAIDI values are 1.5421 which was recorded in the month of September and 5.2096 respectively in the month of November of the same year. This is due to fluctuation nature of the faults experienced by customers attached to the distribution feeder.

Figure 19 illustrates the SAIDI threshold for the year 2014. The SAIDI threshold for January, March, May, July and September are 3.1026, 5.2192, 3.9614, 2.9214 and 1.9051 respectively, thus indicating an irregular pattern in the SAIDI threshold distribution for the months. This is due to the unexpected interruptions experienced by the customers attached to the distribution feeders. The least and highest SAIDI threshold values are 1.9051 (in September) and 5.1413 (in November) of the same year.

The relationship between the natural logarithm of SAIDI values and the standard derivation is depicted in Figure 20. The month of March recorded the least natural logarithm of SAIDI values of 3.6214 with the month of November recording the highest value of 9.3061. The standard derivation of the SAIDI value was observed to be the least in September with a value of 1.5421 and the highest in the month of November with a value of 5.2096.
For the year 2015, the SAIDI distribution is show in Figure 21. In January, the SAIDI value was 0.26921. However, in February of the same year, the SAIDI values for March, April, May, June and July are 3.65214, 0.88418, 0.05632

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and 0.04913 respectively. The least SAIDI value is 0.04913 (recorded in July) while the highest SAIDI value is 5.33146 (recorded in December).

Figure 22 shows the natural logarithm of the SAIDI value for the year 2015. The least natural logarithm SAIDI value is 3.8250 which was recorded in the month of October. The highest natural logarithm of SAIDI value is 9.5038 recorded in the month of November of the same year.

The standard derivation of the SAIDI values for the year 2015 is show in Figure 23. The SAIDI standard derivation for January, February, March, April, May and June are 4.0372, 3.1056, 1.7219, 2.5396, 1.7621 and 3.5219 respectively suggesting an irregular pattern in the distribution. The least and highest SAIDI standard derivations are 1.6321 and 4.3214 respectively. However, these least and highest values were recorded in the month of September and November of year 2015.

Figure 24 shows the SAIDI threshold distribution for year 2015. The SAIDI threshold distribution fluctuates throughout the months for the year under study. The least and highest SAIDI threshold for the year 2015 are 1.9576 and 4.6428 respectively. These least and highest SAIDI threshold were recorded in the months of September and December respectively of the year 2015.

The correlation between the natural logarithm of SAIDI values and standard derivation of these SAIDI values are illustrated in Figure 25. The two quantities fluctuate over the year. Thus, the natural logarithm of SAIDI values for the months of February, April, June, August, October and December for the year 2015 are 8.4917, 5.2183, 5.8393, 4.6153, 3.8250 and 6.2596 respectively. In addition, the standard derivations for January, March, May and July for year 2015 are 4.0372, 1.7219, 1.7621 and 2.7219 respectively suggesting an irregular pattern in the SAIDI distribution as a result of unexpected interruptions experienced by many of the customers attached to the distribution feeder.

Figure 26 shows the average value of SAIDI for the five year duration. The average value of SAIDI fluctuates over the years. The average SAIDI values over the period of five years for the month of January, February, March, April, May and June are 6.75478, 8.31200, 3.68116, 5.42554, 5.87414 and 4.29296 respectively as a result of intermittent failures of some of the distribution line feeders. The least and highest SAIDI averages for the five year study period are 3.62106 and8.56022 respectively. These values were recorded in the month of August and November.

Figure 27 shows the variation of average values of the natural logarithm SAIDI values for the study period. The least and highest values recorded during this year are 2.1321 and 7.3142 respectively. These values were recorded in the month of March and July of the same year.

The average value of the standard derivation for SAIDI values are shown in Figure 28. Values of 2.8253, 2.2856, 1.58934, 2.66478 and 3.40194 were obtained for the months of January, February, March, April and May respectively for the study period. The least and highest values obtained for the average standard derivation of SAIDI were 1.8672 and 3.3241 respectively. These values were recorded in the month of June and October.

The variation of the daily SAIDI for the five years duration period is shown in Figure 29. The SAIDI threshold fluctuates over the year. The SAIDI threshold for the month of January, February, March, April, May and June are 3.18318, 3.32458, 4.22242, 4.62518, 4.73212 and 2.71360 respectively indicating an increase in the daily SAIDI between January and April and a decrease in the daily SAIDI from 4.62518 to 2.71360 during the month of April and May. The month of September recorded the least SAIDI threshold value of 2.11596 while a highest value of 4.62518 was recorded in the month of April of the same year.

The relationship between the average values for the natural logarithm of the SAIDI values and the standard derivation is illustrated in Figure 30. The average values of the natural logarithm and the standard derivation for SAIDI values for the five years study period is also illustrated. The average values of the natural logarithm for the month of July, August, September, October, November and December for the five years study period are 6.24372, 3.62106, 4.87878, 4.19966, 8.56022 and 5.93502 respectively. The average values of the standard deviations for the months of February, April, June, August and October of the same year are 2.2856, 2.66478, 4.8687, 2.28372 and 2.47882 respectively for the five years study period.

The variation of the mean value of the natural logarithm SAIDI value and the mean value of the standard derivation of the SAIDI values for the entire five years study period is illustrated in Figure 31. These two parameters fluctuate throughout the study periods with the least and highest values of the mean values of the natural logarithm of SAIDI values recorded as 1.6324 and 3.8324 respectively. These values were recorded in the months of March and July, indicating a prolonged level of interruptions in the month of March. These faults persisted for a long time until they were being cleared in July.

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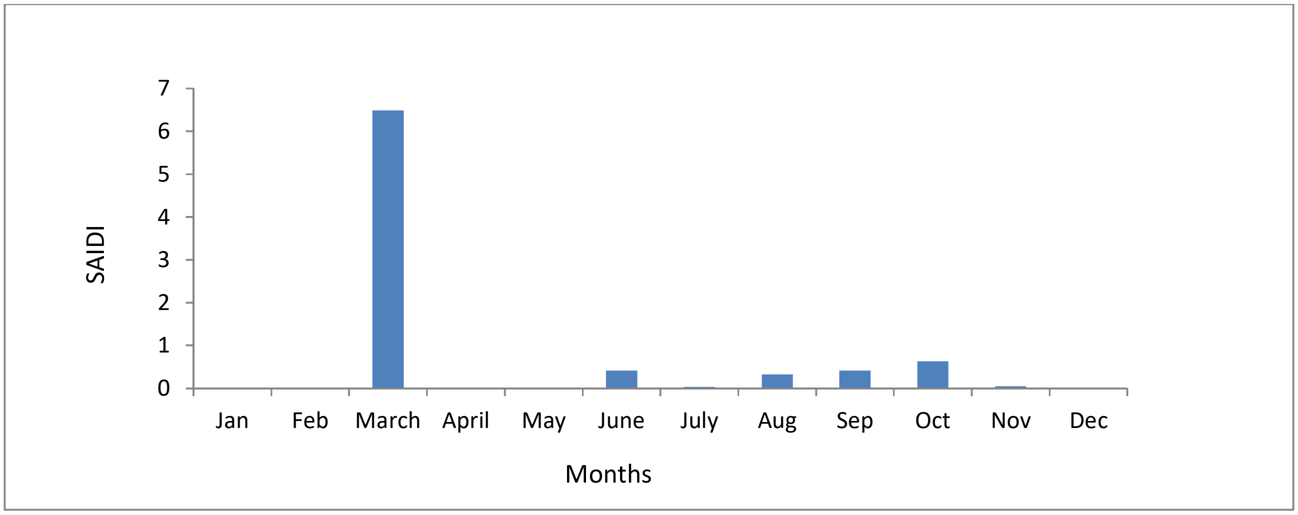

Figure 1: SAIDI for 2011

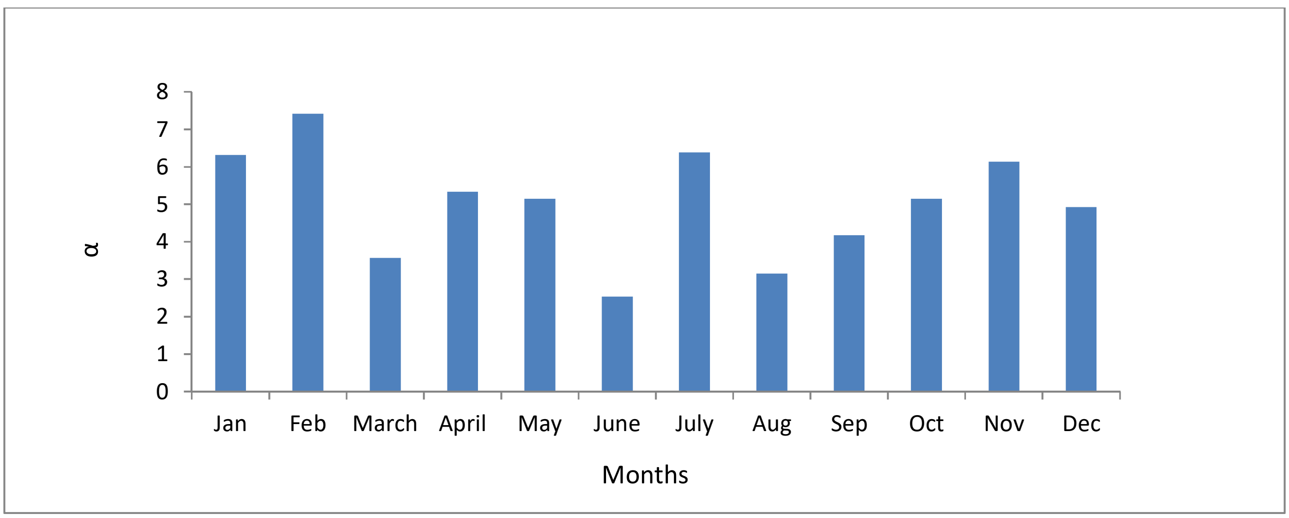

Figure 2: Log average (α) of SAIDI for 2011

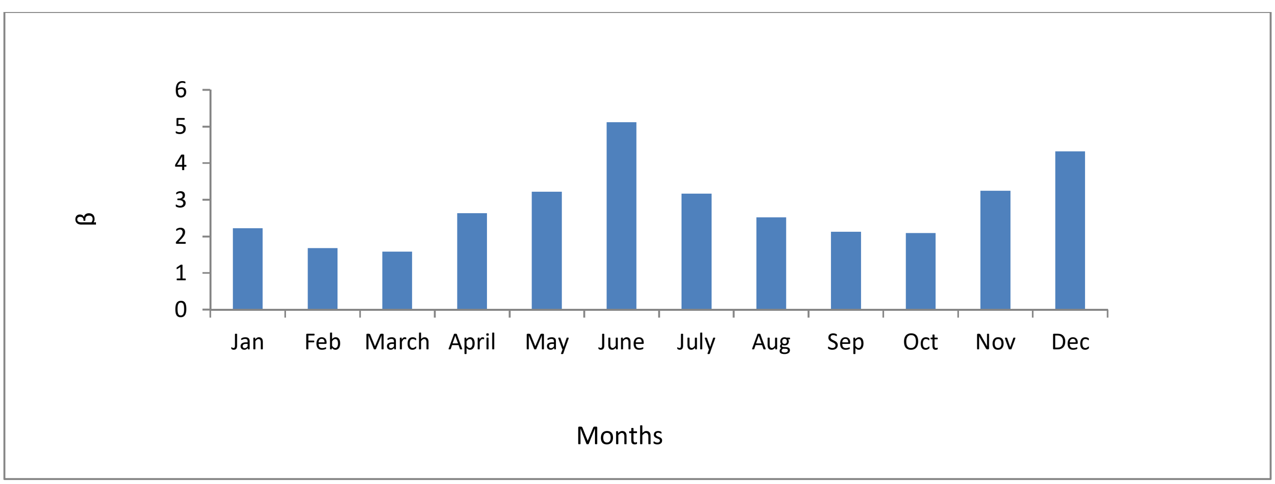

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Figure 3: Standard derivation (β) of the logarithm of SAIDI for 2011

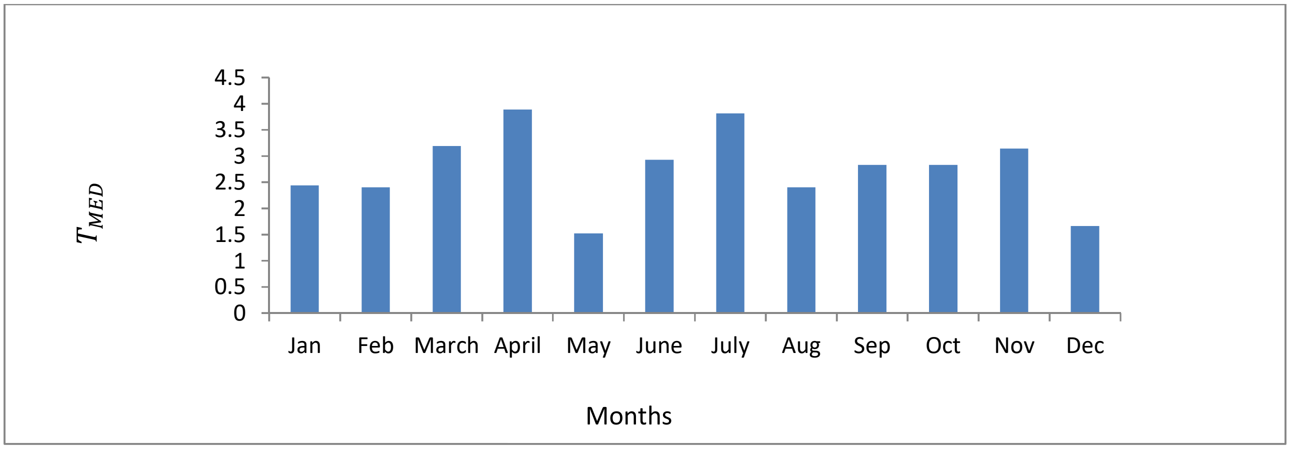

Figure 4: SAIDI threshold (T_{MED}) for 2011

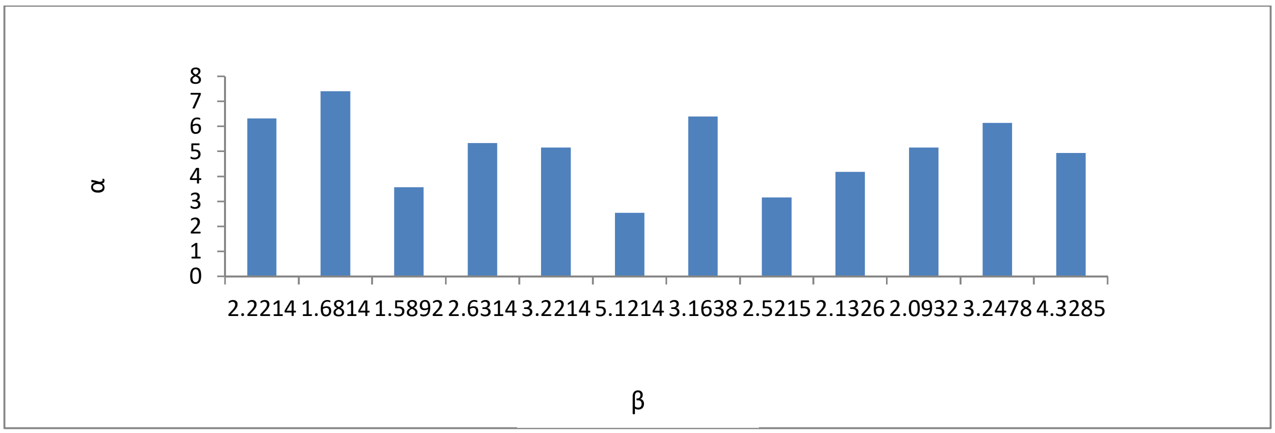

Figure 5: Log average (α) versus standard derivation (β) of the logarithm of SAIDI for 2011

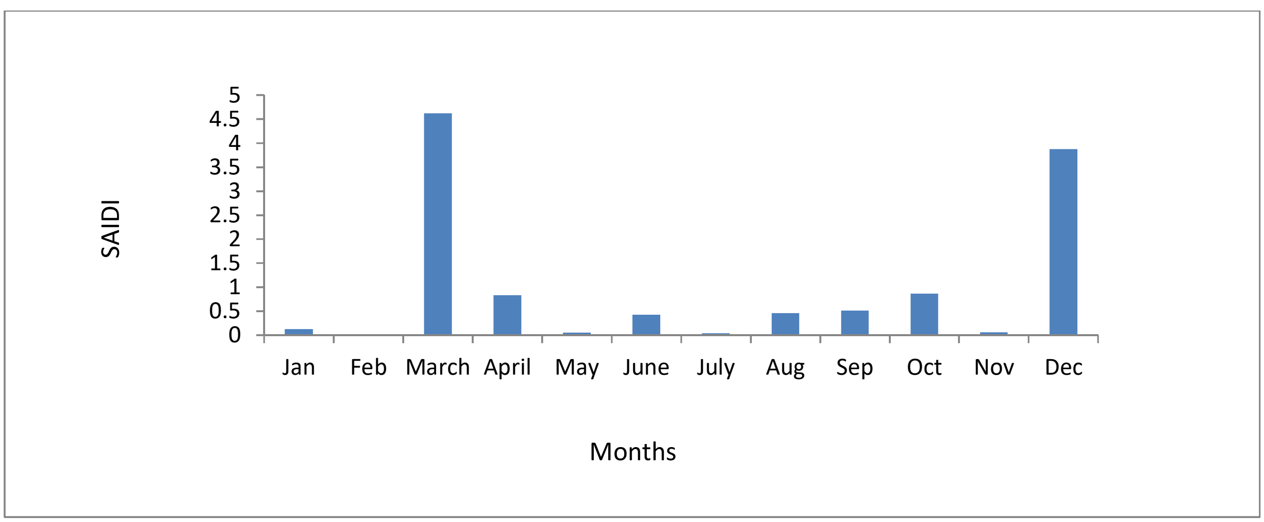

Figure 6: SAIDI for 2012

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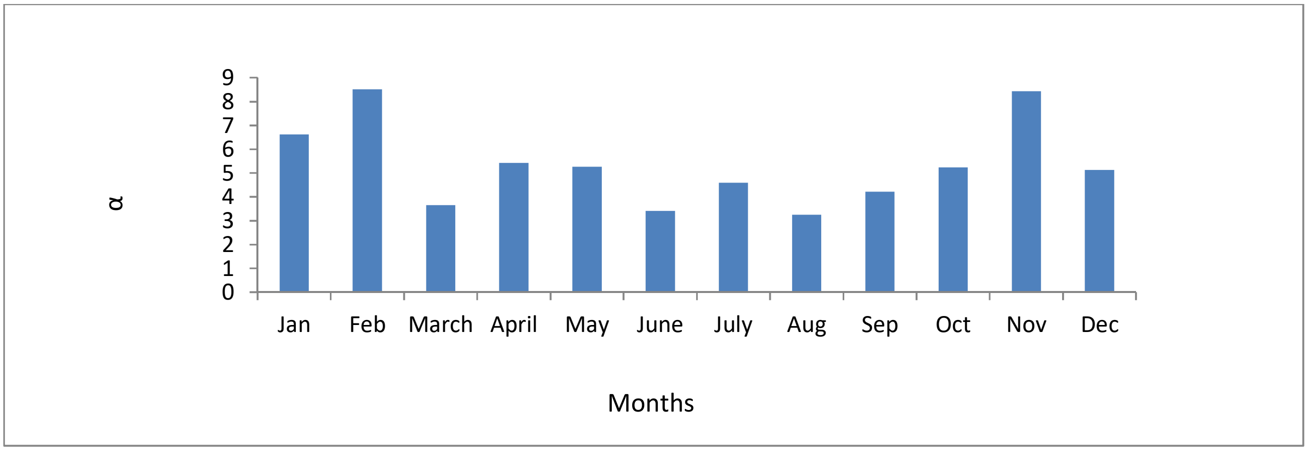

Figure 7: Log average (α) of SAIDI for 2012

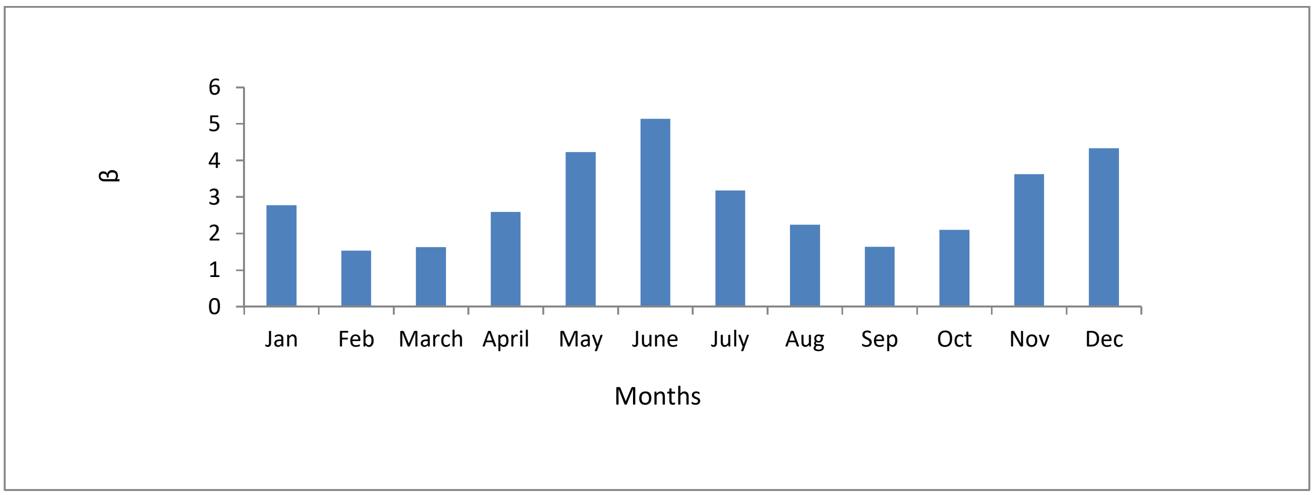

Figure 8: Standard derivation (β) of the logarithm of SAIDI for 2012

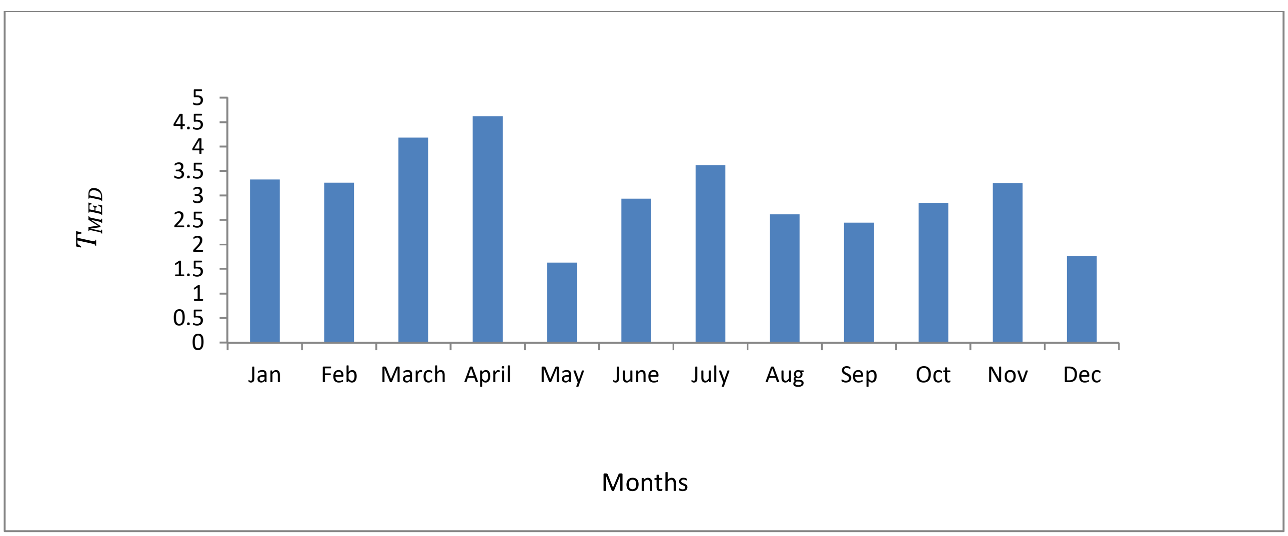

Figure 9: SAIDI threshold (T_{MED}) for 2012

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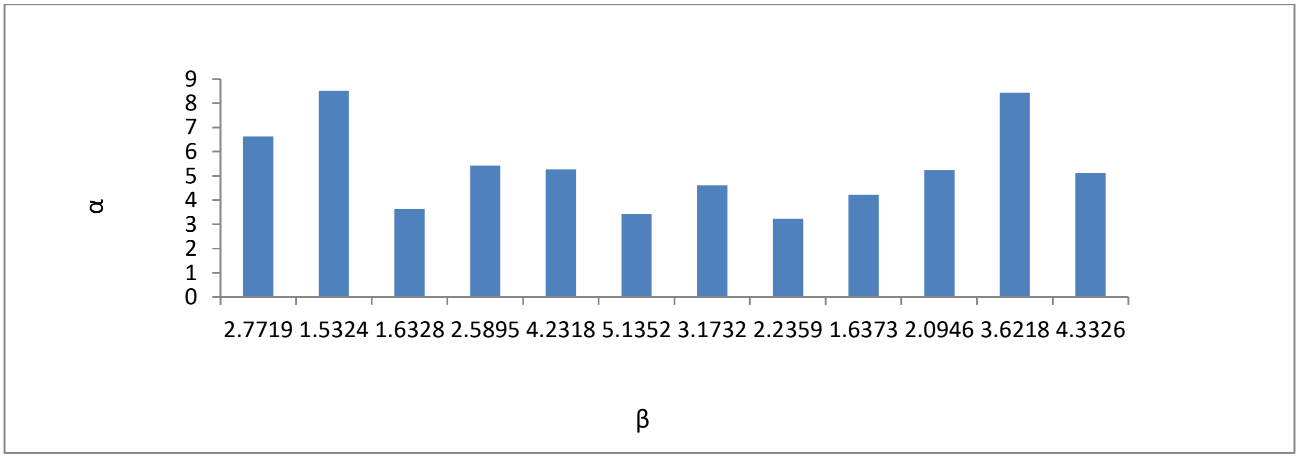

Figure 10: Log average (α) of SAIDI versus standard derivation (β) of the logarithm of SAIDI for 2013

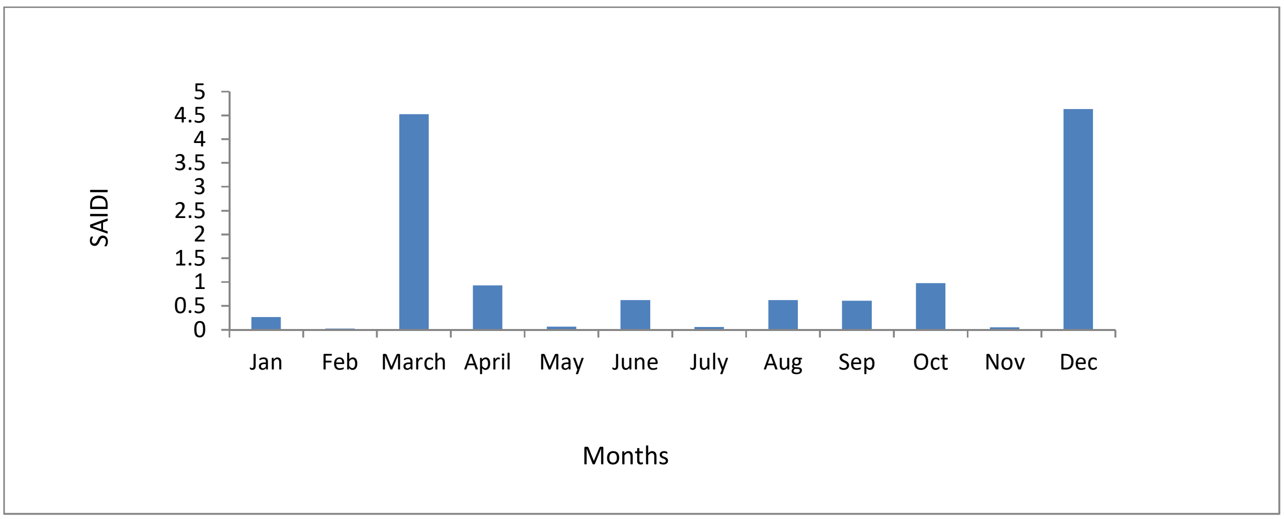

Figure 11: SAIDI for 2013

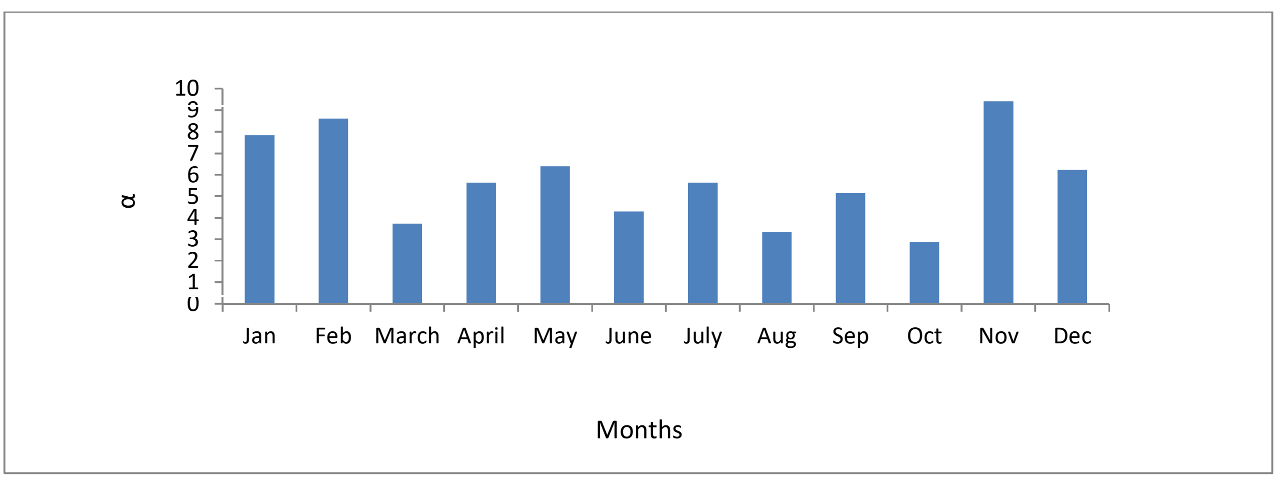

Figure 12: Log average (α) of SAIDI for 2013

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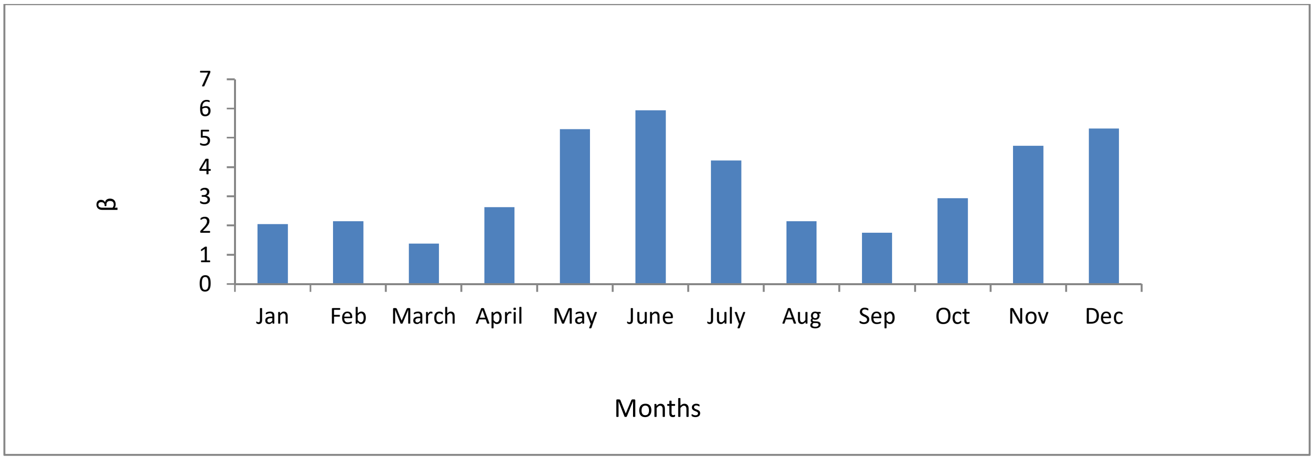

Figure 13: Standard derivation (β) of the logarithm of SAIDI for 2013

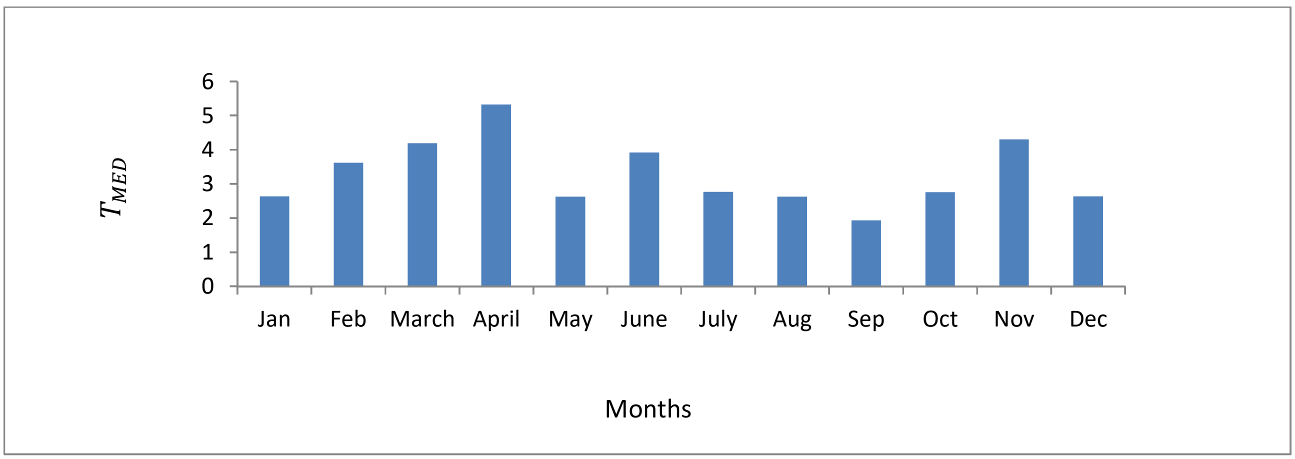

Figure 14: SAIDI threshold (T_{MED}) for 2013

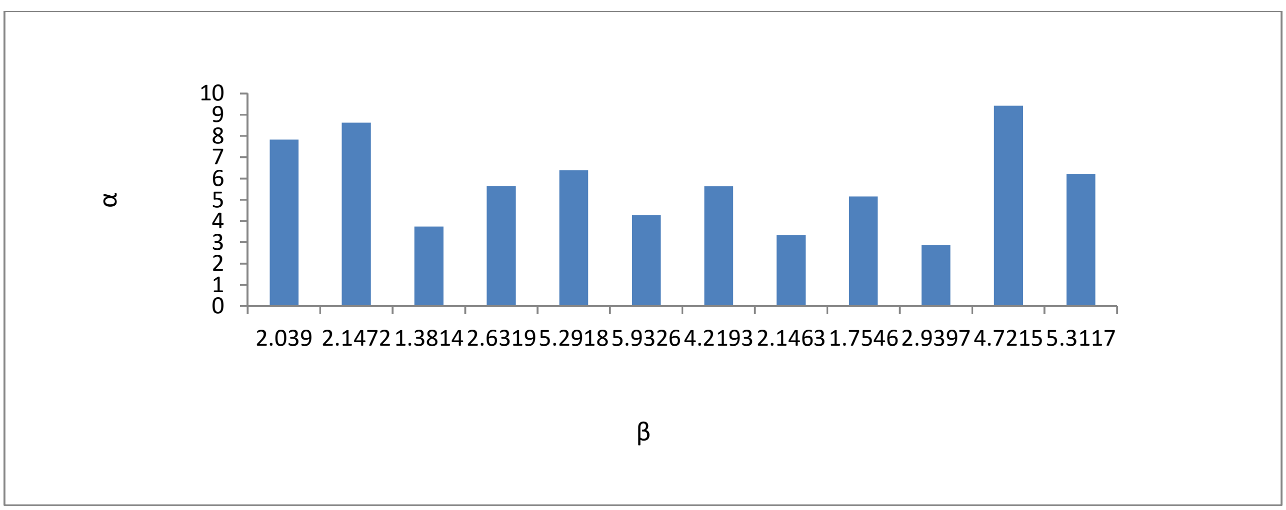

Figure 15: Log average (α) of SAIDI versus standard derivation (β) of the logarithm of SAIDI for 2013

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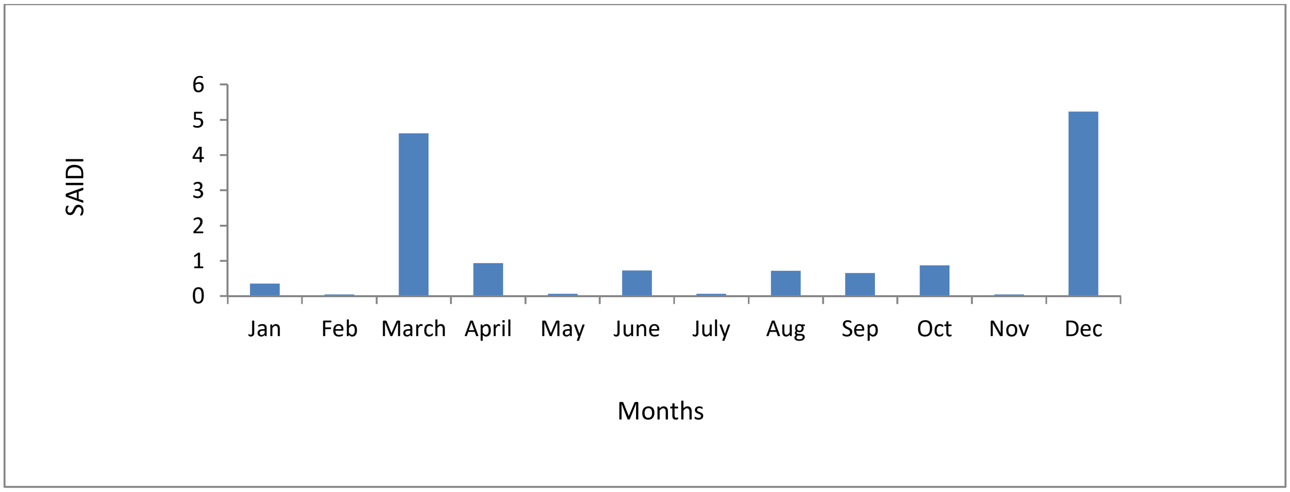

Figure 16: SAIDI for 2014

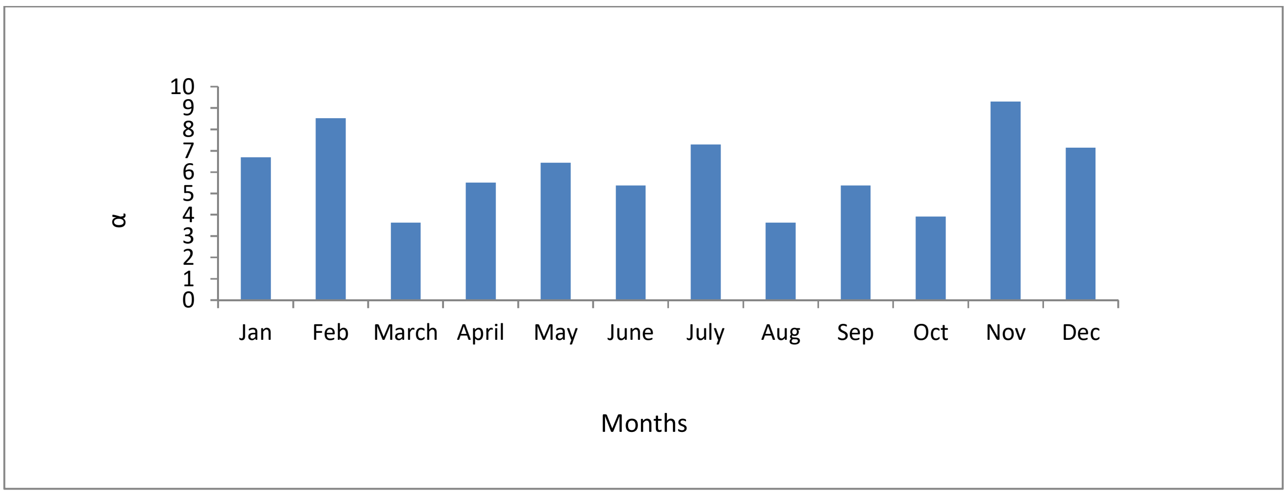

Figure 17: Log average (α) of SAIDI for 2014

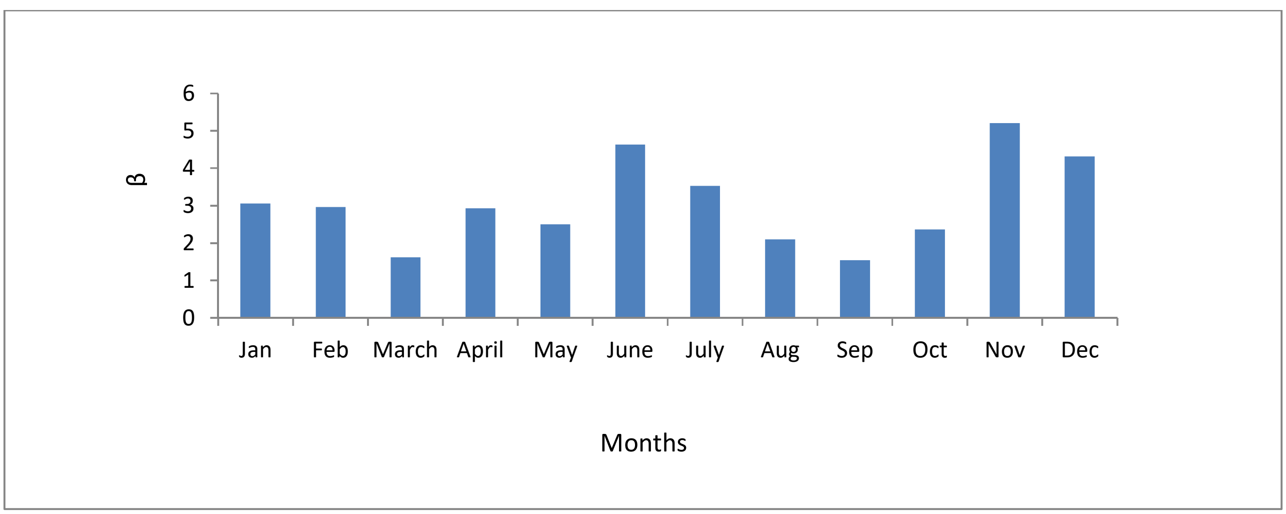

Figure 18: Standard derivation (β) of the logarithm of SAIDI for 2014

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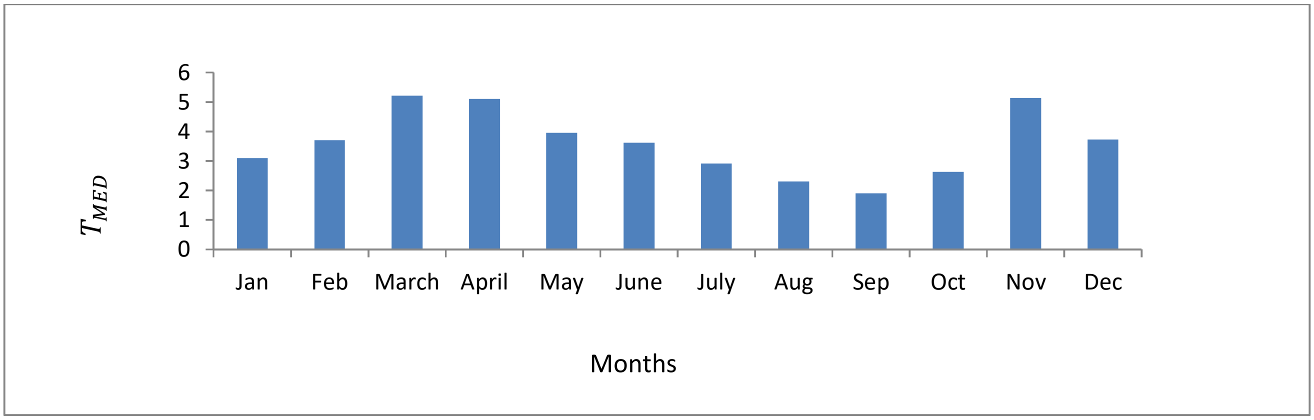

Figure 19 SAIDI threshold (T_{MED}) for 2014

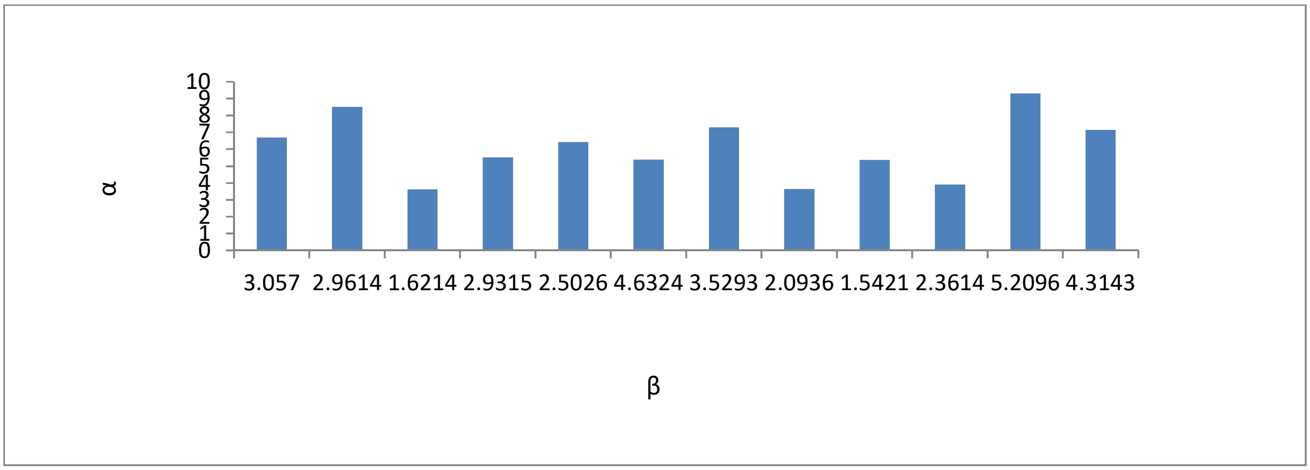

Figure 20: Log average (α) of SAIDI versus standard derivation (β) of the logarithm of SAIDI for 2014

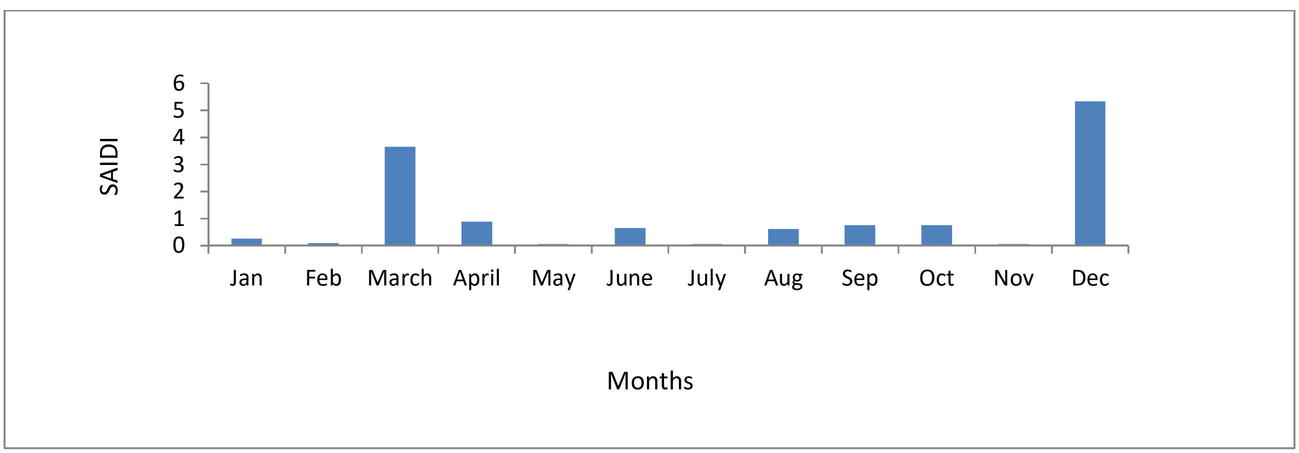

Figure 21: SAIDI for 2015

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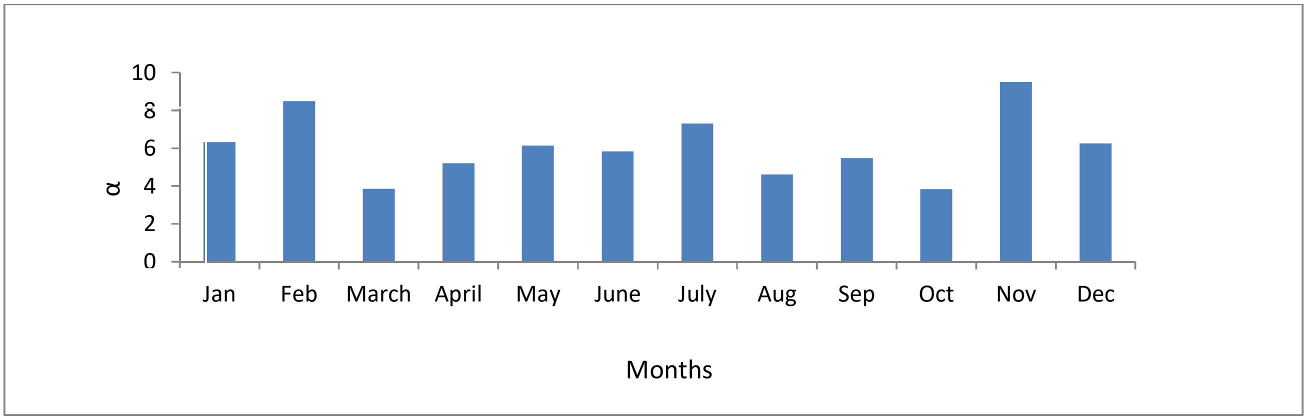

Figure 22: Log average (α) of SAIDI for 2015

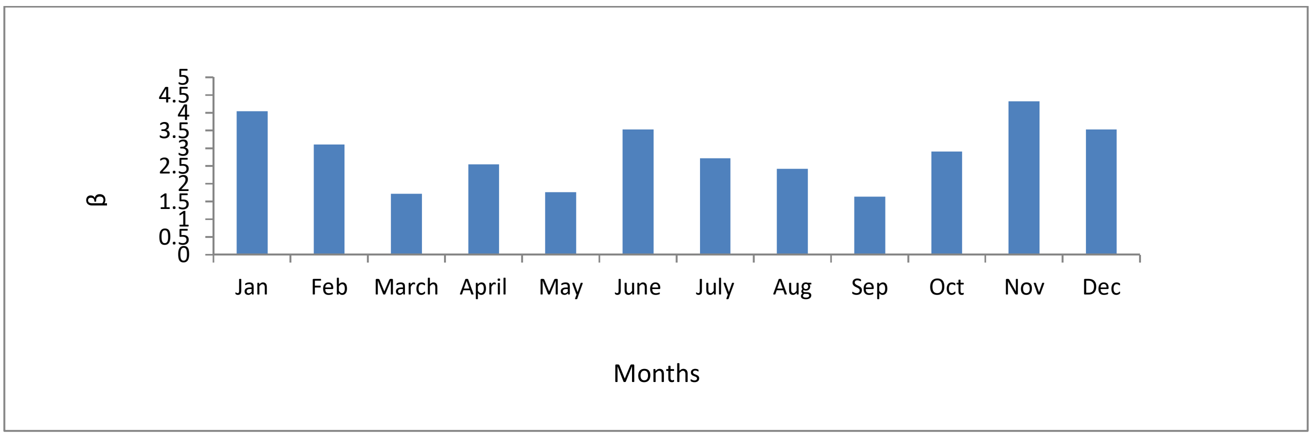

Figure 23: Standard derivation (β) of the logarithm of SAIDI for 2015

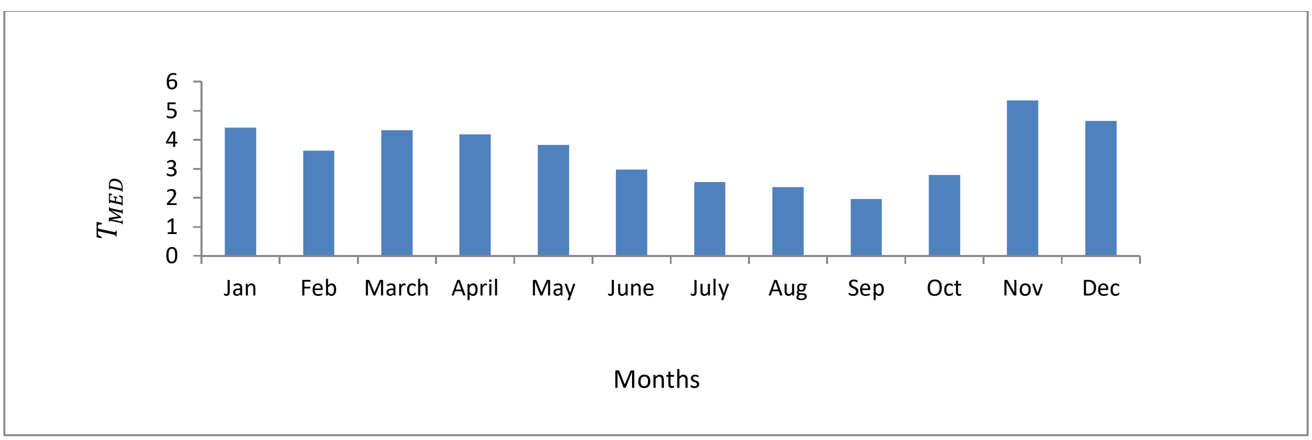

Figure 24: SAIDI threshold (T_{MED}) for 2015

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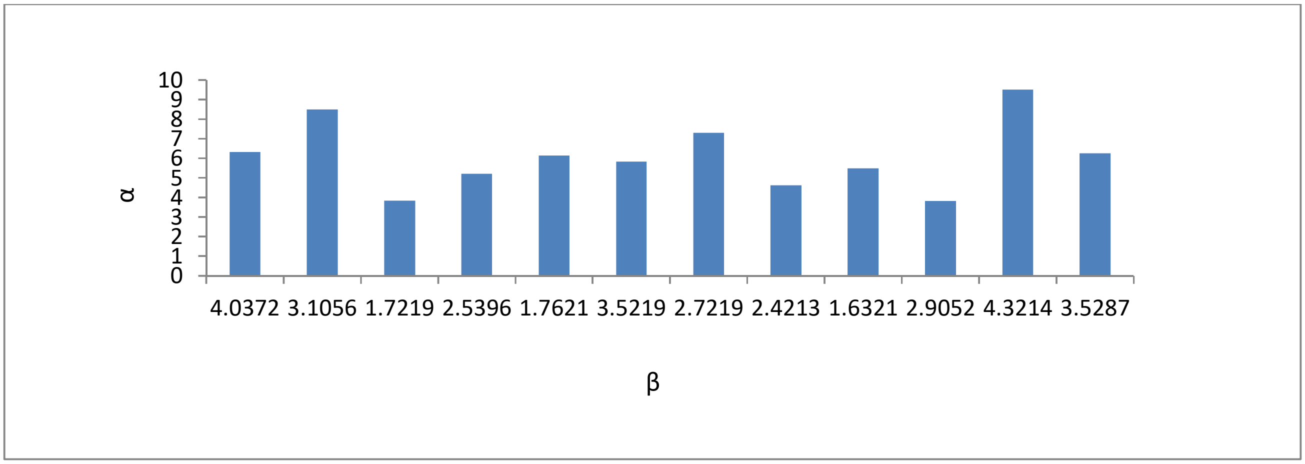

Figure 25: Log average (α) of SAIDI versus standard derivation (β) of the logarithm of SAIDI for 2015

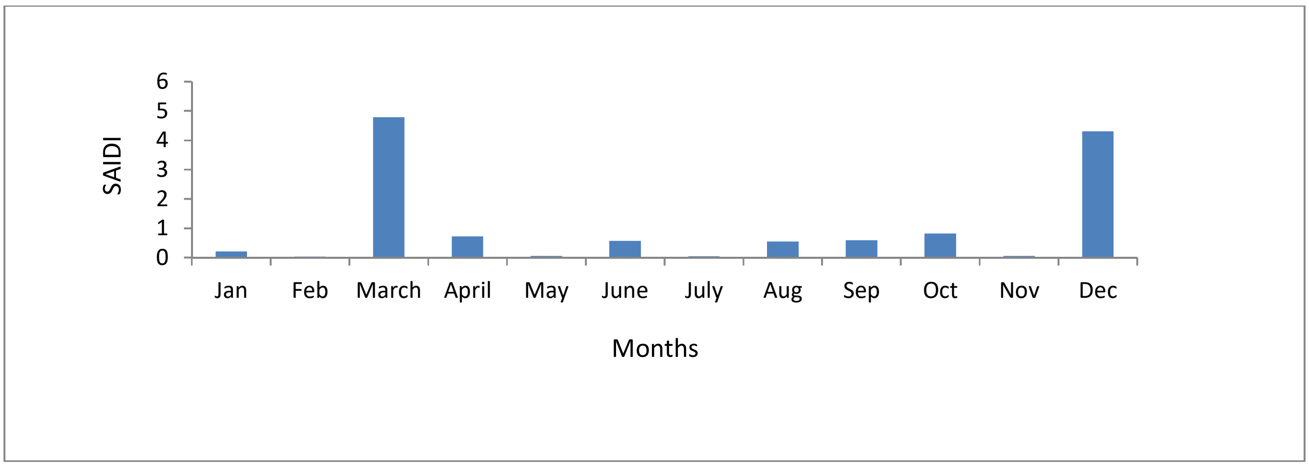

Figure 26: $SAIDI_{Average}$ for 2011-2015

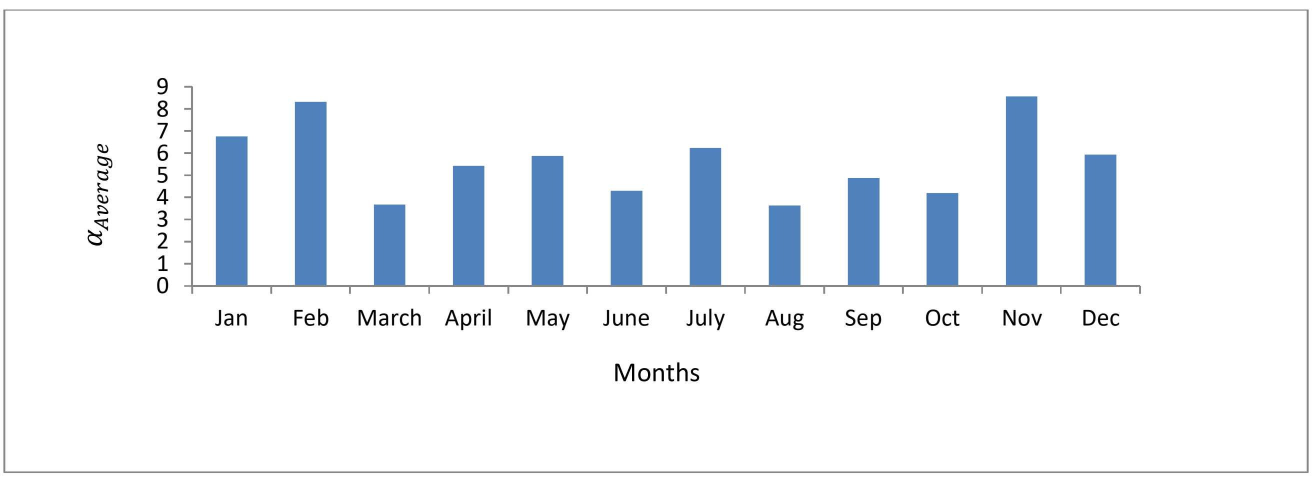

Figure 27: Log average ($\alpha_{Average}$) of SAIDI for 2011- 2015

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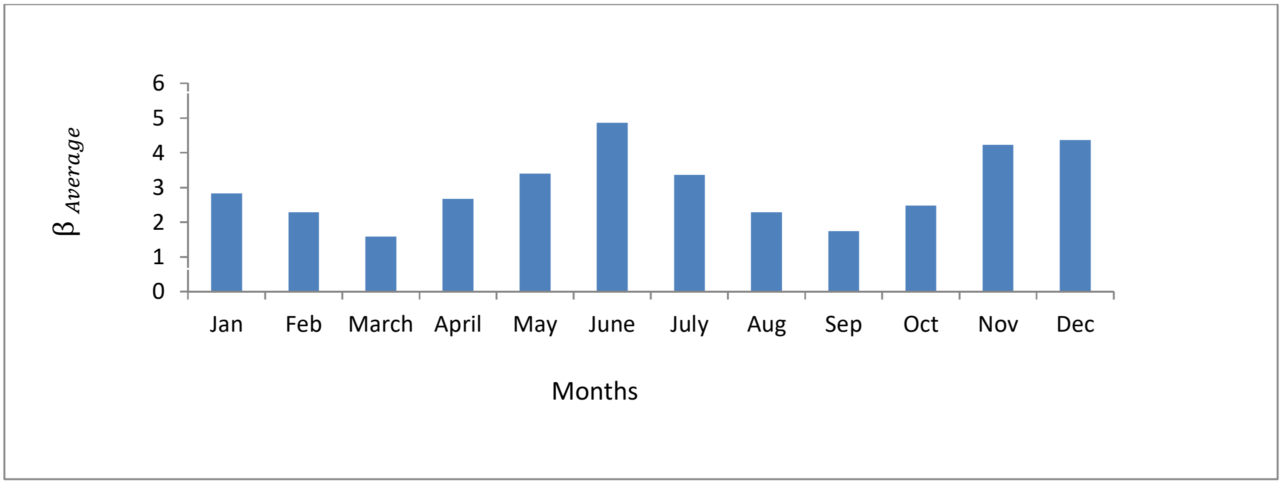

Figure 28: Standard derivation ($\beta_{Average}$) average of the logarithm of SAIDI for 2011-2015

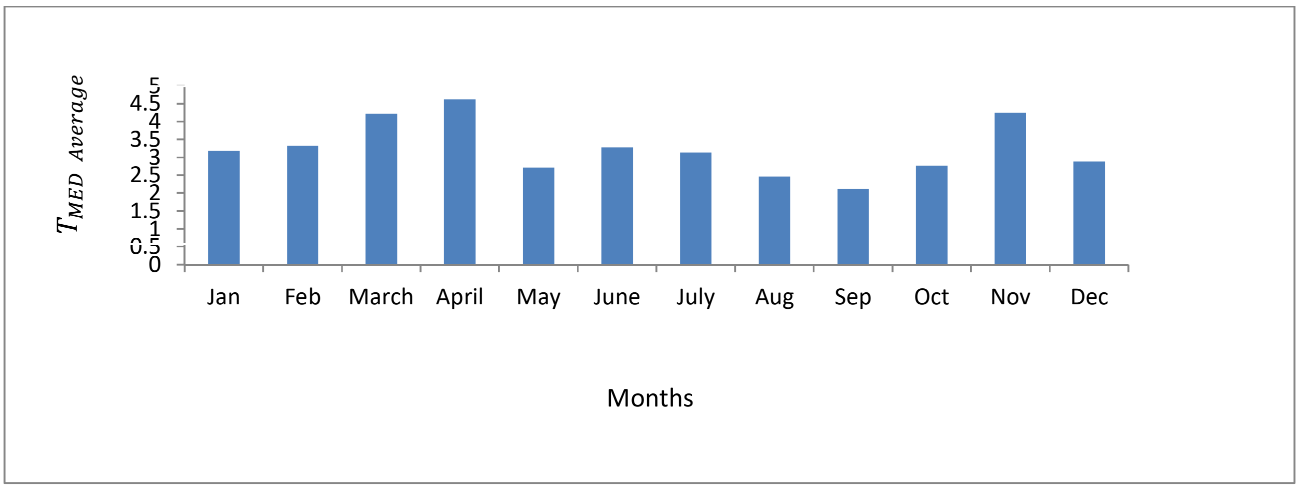

Figure 29: SAIDI threshold ($T_{MED\ Average}$) average for 2011-2015

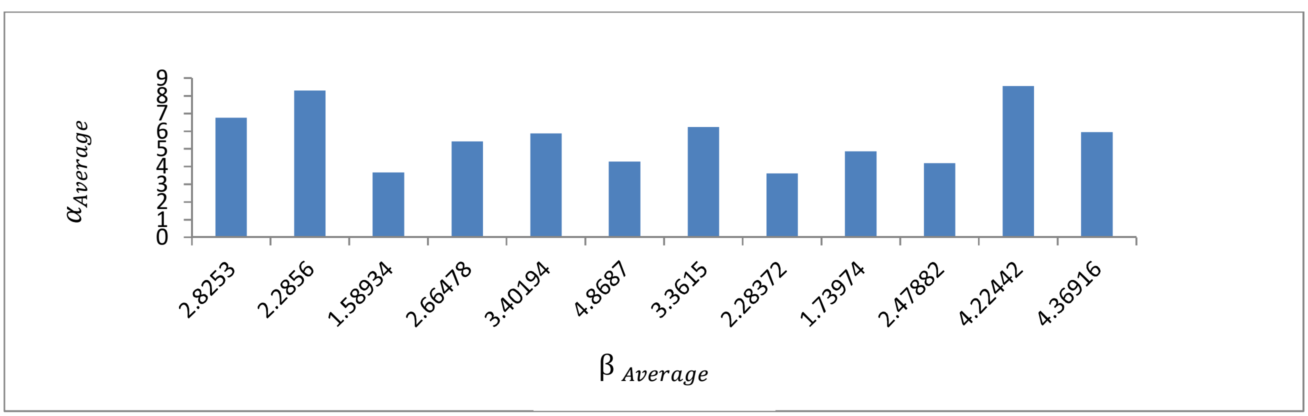

Figure 30: Log average ($\alpha_{Average}$) of SAIDI versus standard derivation average ($\beta_{Average}$) of the logarithm of SAIDI for 2011-2015

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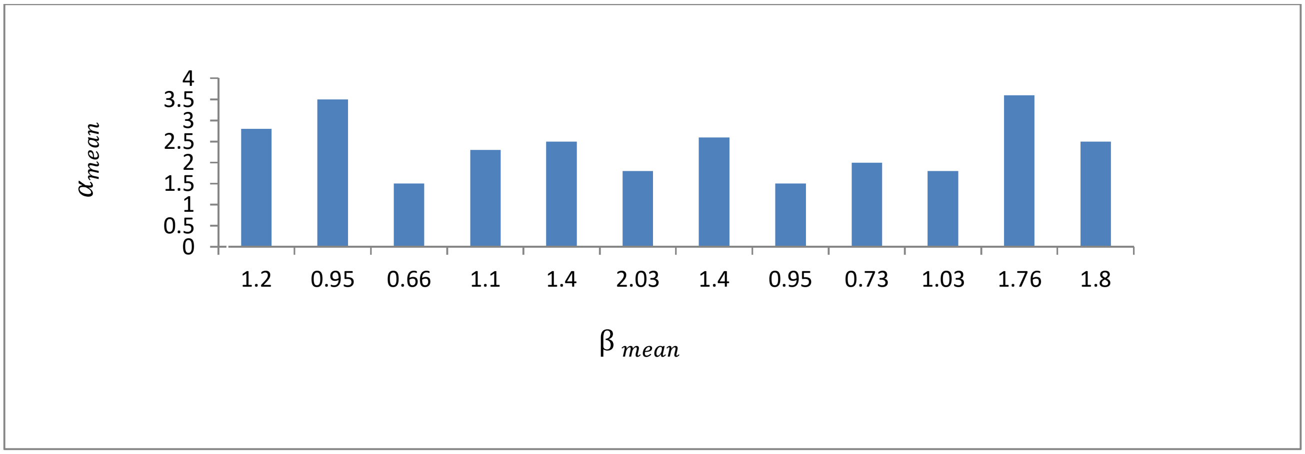

Figure 31: Log average mean (α_{mean}) versus standard derivation mean (β_{mean}) of the logarithm of SAIDI

4. CONCLUSION

The impact of SAIDI threshold on the reliability assessment of electrical power distribution system has been presented. The fault data collected from ten selected feeders of Ibadan distribution system served as the input parameters for the computation of the threshold SAIDI using appropriate mathematical analysis. The result of the research paper shows that the SAIDI threshold fluctuates over the years. The SAIDI thresholds for the months of July, August, September, October, November and December are 3.13314, 2.46298, 2.11596, 2.77344, 4.24186 and 2.88492 respectively suggesting a fluctuation in the distribution pattern of SAIDI threshold as a result of frequent interruptions experienced by customers attached to the distribution feeders.

REFERENCES

[1] Sindi H and El-Saadany E. (2016). Unified reliability index development for utility performance assessment developing a novel normalization-based index and comparing it with a fuzzy inference unified index. Intell Journal of Industrial System, 2(3), 149–161.

[2] Eminoglu U and Uyan R. (2016). Reliability analyses of electrical distribution system: a case study. International Refereed Journal of Engineering and Science, 5(12), 94-102.

[3] Rajaiah S, Satyanarayana V.S and Srinivas K. (2015). Evaluation and analysis of customer specific distribution reliability indices. Control Theory and Informatics, 5(1), 16-23.

[4] Okorire P.U, Aliyu U.O, Jimoh B and Sani S.M. (2015). Reliability indices of electric distribution network system assessment. Quest Journals Journal of Electronics and Communication Engineering Research, 3(1), 1-6.

[5] Okorie P.U and Abdu A.I. (2015). Reliability evaluation of power distribution network system in Kano metropolis of Nigeria. International Journal of Electrical and Electronic Science, 2(1), 1-5.

[6] Mohan C.V, Seetharam K and Raju H.B. P. (2015). Reliability Indices of Distribution system by Fuzzy Method. International Journal of Science, Engineering and Technology Research (IJSETR), 4(7), 2444-2446.

[7] Das B and Deka B. (2013). Impact of distributed generation on reliability of distribution system. IOSR Journal of Electrical and Electronics Engineering, 8(1), 42-50.

[8] Elsalmawy H, Youssef K, Abdulla S and Hussein S. (2011). Elementary evaluation of reliability indices for power system in Egypt. 21st International Conference on Electricity Distribution, 1(9), 1-4.

[9] El-Kady M. A, Alaskar B. A, Shaalan A. M and Al-Shammri B.M. (2007). Composite reliability and quality assessment of interconnected power systems. IEEE Transactions on Power Systems, 11(5), 328-396.

[10] Xiu-Ren L, Zhen R, Wen-Ying H and Bi-Yun C. (2005). Fussy reliability analysis of distribution systems accounting parameters uncertainty. In proceedings of the fourth international conference on machine learning cybernetics. 5(6), 90-109.

[11] Enrico C and Gianfranco C. (2004). Evaluation of the probability density functions of distribution system reliability indices with a characteristic function-based approach. IEEE Transaction on power systems, 19(2), 31-57.

[12] Balijepalli N. (2002). Advances in distribution system reliability assessment. Retrospective Theses Dissertation, Iowa State University, 6(8), 357-386.

[13] Elena N. Z and Vitaly G. L. (2001). Design of dynamic reliability indices. IEEE Transactions on power systems, 18(5), 39-51

[14] Wang P, Billinton R and Goel L. (2000). Probability distribution evaluation of distribution system reliability indices using a time sequential simulation technique. John Wiley and Sons, Inc. 4(6), 65-71.

[15] Kovalev G. F and Lebedeva L. M. (2000). A model for evaluating the reliability of electric power system for long-term operational planning. IEEE Transactions on Power Systems, 7(3), 118-134.