Customer Reliability Indices Evaluation of Umudike 11Kv Distribution Feeder

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Abstract- Reliability analysis is the evaluation of customer supply interruption probability for a given network configuration. Reliability analysis simulates and examines systematically all single and multiple failures, for every failure, the unsupplied loads, the interruption durations and the possibilities of power restoration are determined. A Power system is set up basically to meet the demands of the customers. However, interruptions which are largely unavoidable contribute to the unavailability of power and thus prevent power system from achieving this. In most cases, it is the sustained interruptions that greatly affect both the utility company and its customers. The need for stable electricity supply in Nigeria cannot be overemphasized as it is a pre-requisite to economic, social and technical development. The consequence of interruption of supply in the transmission system is considerably high because an outage event in the transmission system can propagate and paralyze a widespread geographical area. The collected data were analyzed mathematically to estimate the reliability of the substation and the customer reliability indices computed for a twelve-month period. It was observed that the substation was available for an average 61.45% which is very low compared to IEEE standard. Thus, the overall system availability shows that the system performance is poor.

I. INTRODUCTION

The reliability of an electric power system is the probability that the system will continuously deliver electricity to its consumers without compromise on the quality of the power being delivered. It is also a measure of whether users have electricity when it is needed. Two different aspects of reliability receive attention in any type of power supply reliability analysis. These are frequency and duration. With respect to customer interruptions, frequency refers to the number of times a customer's service is interrupted during a period of analysis while Duration refers to the length of interruptions.

Frequency and duration are the two most important factors in reliability reporting. However, there is a third factor that is important to the electric utility because it is the one over which it has considerable control and which it can use to manage reliability on its system. This is the *extent* of an outage's impact on service. i.e how many customers or what portion of the plant's loads are interrupted by the outage of a particular unit of equipment.

The design of the electric power supply system i.e how its lines branch from one site to another and interconnect as they run up and down streets to deliver power to its customers greatly influences how much interruption occurs when an equipment outage occurs. A system designed with a certain type of circuit layout using an abundance of reclosers (a type of circuit breakers) and switches will have a low extent: outages may occur but each will interrupt service to only a relatively small number of customers. By contrast another system might have a higher extent; while no more equipment failures (outages) occur in the system, the average outage causes more customers to be affected. Thus, the average customer sees more interruptions because any outages in a bigger group of customers will affect his service.

Generally, reducing extent costs money, although clever design, attention to detail and good record-keeping for field operations can reduce it by as much as 15% in some systems without increasing cost. Beyond that, reliability-based planning methods optimize the cost spent to achieve systems that excel in this category of performance against other ways the utility can spend money.

II. RELIABILITY INDICES

Reliability indices measure the reliability performance of an entire utility or parts of its system. Usually, such indices are evaluated on a monthly and yearly basis. Their values and details behind them are used to manage reliability. They are used for measuring or evaluating the reliability of a power system distribution network based on observed outage data for a set of customer loads and feeders etc.

Failure Rate:

The failure rate is a measure of the frequency at which faults occur in the system. A high value of the failure rate indicates a low reliability.

$$\lambda = \frac{\text{Number of Outages on Component in a given Period}}{\text{Total Time Component is in Operation.}} \quad (1)$$

Mean Time Between Failures (MTBF)

This is the expected time between the occurrences of two consecutive failures for repairable system. MTBF is also the time that elapses before a component, or system fails. It describes the total time the component is in operation.

$$\text{MTBF} = \frac{\text{Total System Operating Hours}}{\text{Number of Failures}} \quad (2)$$

Mean Down Time (MDT) or Mean Time to Repair (MTTR):

This is the average time it takes to repair a failure and restore the system back to operation. It describes the average time the system a component is out of service due to fault before being restored to normal operation.

$$\text{MTTR} = \frac{\text{Total Duration of Outages}}{\text{Frequency of Outage}} \quad (3)$$

Availability:
This is the measure of the duration for which a component is in operation at any time and deals with the duration for which the system is fully operational for its specific function.

$$\text{Availability} = \frac{\text{MTBF}}{\text{MTBF+MTTR}} \quad (4)$$

System Average Interruption Duration index (SAIDI):

This is defined as the average duration of all interruptions considered to have a duration, obtained by averaging the total time of customer interruptions experienced over all of the utility customers i.e. those who has outages and those who did not.

$$\text{SAIDI} = \frac{\text{Sum of the Durations of all Customer Interruptions}}{\text{Total Customers in the System.}} \quad (5)$$

System Average Interruption Frequency Index (SAIFI):

This is the average number of interruptions that are considered to have duration per utility customer during the period of analysis.

$$\text{SAIFI} = \frac{\text{Number of Customer Interruptions}}{\text{Total Number of Customers in the System}} \quad (6)$$

Customer Average Interruption Duration Index(CAIDI):

This is defined as the average length of an interruption weighted by the number of customers affected, for customers interrupted during a specific period of time.

$$\text{CAIDI} = \frac{\text{Sum of Customer Interruption Durations}}{\text{Total Number of Customers Interrupted}} = \frac{\text{SAIDI}}{\text{SAIFI}} \quad (7)$$

This index enables utilities to report the average duration of a customer outage for those customers affected. The ratio of CAIDI to SAIFI gives an idea of how “spotty” reliability problems are throughout the system.

Average Service Availability Index (ASAI):

This is a measure of the average availability of the distribution system that serves customers. It is usually expressed in percentages. It is expressed as

$$\text{ASAI} = \frac{\text{Customers Hours Service Availability}}{\textit{Customers Hours Service Demanded}} \quad (8)$$

Average Service Unavailability Index (ASUI):

This deals with the fraction of time customers are without electricity throughout the predefined interval of time. It is expressed as

$$ASUI = \frac{\text{Duration of Outages in Hours}}{\text{Total Hours Demanded}} \quad (9)$$

Reliability indices are used for a variety of purposes. Any of the reliability indices above can be tracked over time to identify trends that indicate developing problems. For one thing, utility regulatory commissions require that SAIDI and SAIFI be reported as a way of tracking and assuring the utility is performing well. Utilities also compare or benchmark themselves against one another to determine if and why they differ in reliability performance. The most useful application is to reveal trends and patterns expose problems and reveal how and where reliability can be improved.

III. RESULTS AND DISCUSSIONS

The data collected was for twelve-month outage duration. The substation system like other substations in Nigeria does not have intelligent device that can alert the distribution company whenever there is a failure of any equipment or any form of interruption to the delivery of electricity to the customer. Only forced outages and outages due to faults and failures were taken into consideration. For this paper to avoid extraneous circumstances, outages due to scheduled maintenance and load shedding were not taken into consideration. This is because scheduled outage or load shedding in the substation is intentional and cannot be attributed to any component failure which makes it hard for analysis to pin-point weak component if used. Rather it focuses on the substation's inability to deliver electricity as a result of its own deficiency when there is electricity available for distribution.

The table below shows the Customer reliability indices from January to December on Umudike 11KV feeder.

Table 1: Customer Reliability Indices January to December 2021 on Umudike 11Kv Feeder

Month	Frequency of interruption	Duration of Interruption	Total Hours	Failure Rate(F/yr)	MTBF	MTTR	Availability
January	83	326.40	744	0.1116	8.9639	3.9325	0.6951
February	99	428.55	696	0.1422	7.0303	4.3288	0.6189
March	116	452.87	744	0.1559	6.4138	3.9041	0.6216
April	127	483.40	720	0.1764	5.6693	3.8063	0.5983
May	124	462.67	744	0.1667	6.0000	3.7312	0.1667
June	125	488.06	720	0.1736	5.7600	3.9045	0.5960
July	119	521.25	744	0.1599	6.2521	4.3803	0.5880
August	94	482.72	744	0.1264	7.9149	5.1353	0.6065
September	92	384.89	720	0.1278	7.8261	4.1836	0.6516
October	116	513.87	744	0.1559	6.4138	4.4299	0.5915
November	99	375.27	720	0.1375	7.2727	3.7906	0.6574
December	105	591.50	744	0.1411	7.0857	5.6333	0.5571
TOTAL	1299	5,511.69	8784		6.7621	4.2430	0.6145

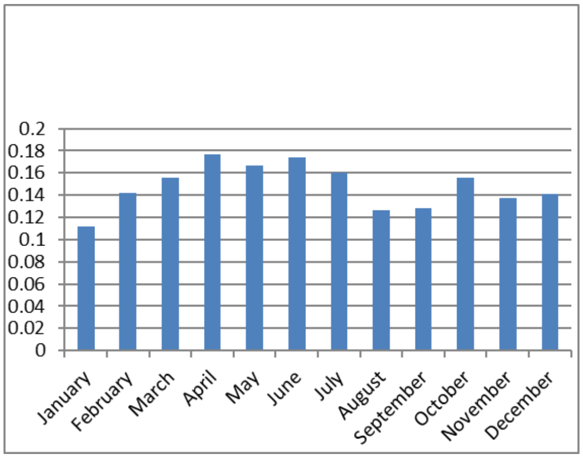

Figure 1: Bar chart showing Failure Rate of Umudike 11Kv Feeder Line

From table 1, it can be deduced that the substation availability for the year is 0.6145 which shows that the substation was available for an average of 61.45%. This value is very low compared to the IEEE standard for distribution substation. The table also depicts the failure rate of the substation. From the table, it is seen that the month of April has the highest failure rate of 0.1764. This is followed by the month of June and July which has failure rate of 0.1736 and 0.1599 respectively. The month of January witnessed the least value of failure rate of 0.1116

Table 2: Computed Customer Orientation Indices January to December 2021 on Umudike 11Kv Substation

Month	Frequency of interruption	Duration of Interruption	Total Hours	No of Customers	SAIDI	SAIFI	CAIDI	ASAI (pu)	ASUI (pu)
January	83	326.40	744	3156	0.1034	0.0263	3.9316	0.8884	0.1116
February	99	428.55	696	3156	0.1358	0.0314	4.3248	0.8578	0.1422
March	116	452.87	744	3156	0.1435	0.0368	3.8995	0.8441	0.1559
April	127	483.40	720	3156	0.1532	0.0402	3.8109	0.8236	0.1764
May	124	462.67	744	3156	0.1466	0.0393	3.7303	0.8333	0.1667
June	125	488.06	720	3156	0.1546	0.0396	3.9040	0.8264	0.1736
July	119	521.25	744	3156	0.1652	0.0377	4.3820	0.8401	0.1599
August	94	482.72	744	3156	0.1530	0.0298	5.1342	0.8737	0.1263
September	92	384.89	720	3156	0.1220	0.0292	4.1781	0.8722	0.1278
October	116	513.87	744	3156	0.1628	0.0368	4.4239	0.8441	0.1559
November	99	375.27	720	3156	0.1189	0.0314	3.7866	0.8625	0.1375
December	105	591.50	744	3156	0.1874	0.0333	5.6276	0.8589	0.1411
TOTAL	1299	5,511.69	8784		1.7464	0.4118	4.2409	0.8521	0.1479

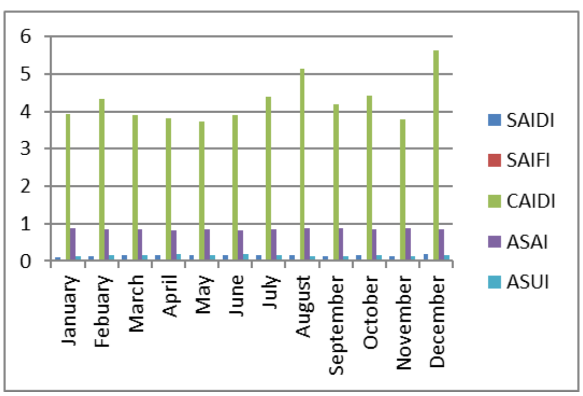

Figure 2: Annual SAIDI, ASAI, SAIFI, CAIDI, ASUI bar Chart

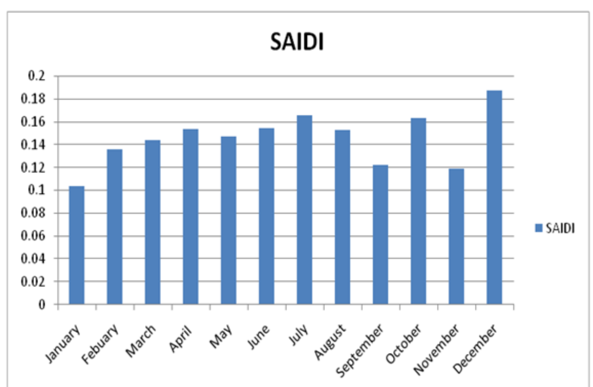

Figure 3: Bar Chart of SAIDI for Twelve Months

The average outage duration, SAIDI for each customer served is 1.7464 hours for the whole year. This is slightly above the IEEE standard 1366-2003 which gives a value of 1.5 hours for North American utility. Therefore the performance of this distribution substation is slightly low. The month of December had the highest SAIDI value having a SAIDI value of 0.1874.This implies that there were much interruptions in the month of December. This is followed by July having a SAIDI value of 0.1652 and October having a SAIDI value of 0.1628. However the month of January had the least value of SAIDI having a SAIDI value of 0.1.034. This is followed by the month of November having a SAIDI value of 0.1189.

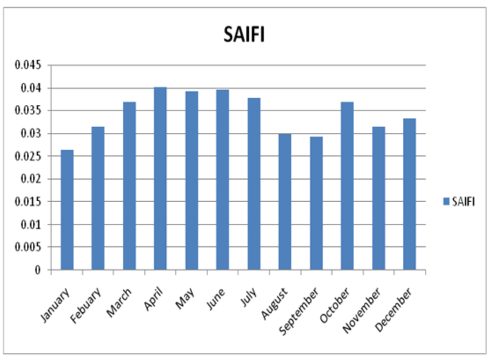

Figure 4: Bar chart of SAIFI for twelve months

This substation has a very low value of SAIFI for the year (0.4118). This means that the frequency of interruptions spread across the year is actually low. The month of April had the highest value of SAIFI (0.0402). This is followed by the months of June and may which have a SAIFI value of 0.0396 and 0.0393 respectively. While the month of January has the least value of SAIFI (0.0263). This followed by the month of September and August which have a SAIFI value of 0.0292 and 0.0298 respectively.

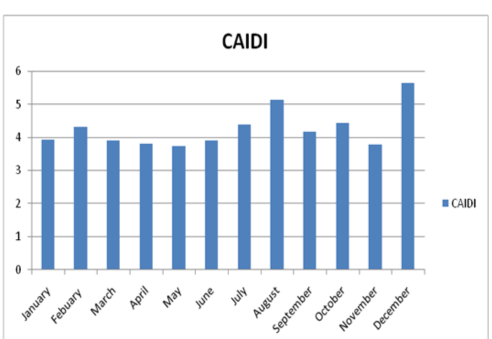

Figure 5: Bar chart of CAIDI for twelve month

The substation has a CAIDI value of 4.2409 for the year. This implies that from the customer end, there was no supply of electricity for 4.2409 hours every day for the whole year. This means that it takes4.2409 hours to restore the power supply whenever there is an interruption. In other words, any interruption lasts for an average of 4.2409 hours throughout the year.

The month of December has the highest monthly CAIDI (5.6276). This is followed by the months of August and October which have CAIDI values of 5.1342 and 4.4239 respectively. This implies that in the month of August it takes 5.1342 hours to restore power supply and 4.4239 hours to restore power supply in the month of October. The month of November has the least value of CAIDI (3.7866). This followed by the month of May and April which have a CAIDI value of 3.7303 and 3.8109 respectively.

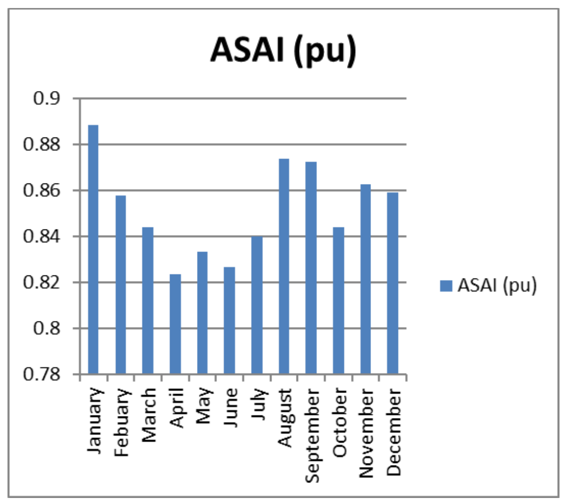

Figure 6: Bar chart of ASAI for twelve months

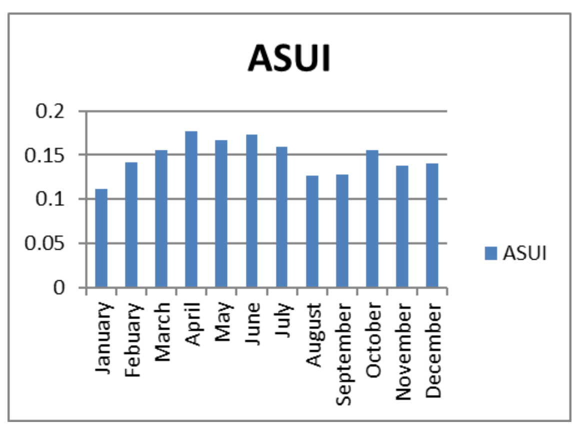

Figure 7: Bar chart of ASUI for twelve months

From the results in table 2 the distribution substation has a system reliability index, an ASAI value of 0.8521 which represents an ASAI value of 85.21%. This value calculated for the substation is very poor compared with most utilities in the world which may have ASAI values of up to 99.99%. The highest value recorded for the year was in January (0.8884) while the least value was in April (0.8236).

The ASUI value is a complement of ASAI because it provides the substation unavailability value. This substation has an ASAI value of 0.1479.

CONCLUSION

The reliability of a power system acts as a method of ranking the performance of the power system design. Having presented the reliability analysis of Umudike 11Kv substation from January 2021 to December 2021. From the analysis carried out, it was observed that the failure rate was highest in the month of April which had a failure rate of 0.1764 followed by the months of June and July which had a failure rate of 0.1736 and 0.1599 respectively while the month of January witnessed the lowest failure rate of 0.1116.

The substation availability for the year was 61.45%. This value was observed to be low compared to the IEEE standard. The average outage duration SAIDI for each customer was 1.7464 which is slightly higher above the IEEE standard hence the substation performance is said to be slightly low. Also CAIDI value was 4.2409 which imply that any interruption lasts for an average of 4.2409 hours throughout the year. The SAIFI value for the substation was observed to be 0.4118. This implies that the frequency of interruptions spread across the year for the substation is very low. However this does not imply that the substation is reliable as there other indices that are used to quantify the reliability of the system.

RECOMMENDATIONS

Reliability as normally applied by power distribution-utilities means continuity of service to their electric customers and this has always been a concern of electric utilities and their employees. Therefore to ensure reliability the following recommendations are made.

- Efforts should be geared towards reducing system overloading. Hence utility companies should have accurate data of their customers.
- Utility facilities should be inspected regularly to prevent vandalization.
- Utility companies should make concise efforts in ensuring that the outage duration is greatly reduced or minimized as this will improve the reliability of the substation.

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