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**Research Paper**

# Reliability Indices of Electric Distribution Network System Assessment

P.U.Okorie[1,a*], U.O Aliyu[2,b], B.Jimoh[3,c] and S.M.Sani[4,d]
[134] *Department of Electrical and Computer Engineering; Ahmadu Bello University, Zaria Nigeria.*
[2] *Electrical Engineering Program; ATB University Bauchi, Nigeria.*

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***ABSTRACT*:-** The electric utility industry is moving towards a deregulated, competitive environment where utilities must have accurate information about system performance to ensure that maintenance money are spent wisely and that customer expectation are met. To measure system performance, the electric utility industry has developed several performance measure of reliability. These reliability indices include measures of outage duration, frequency of outages, system availability, and response time. The continuous power outages and interruptions in the electrical parts distribution network always affect the health, safety and economic activity and low level of production in the industrial sector. The paper discusses the reliability of electric distribution network through the study of indicators of reliability analysis known as SAIDI, SAIFI, CAIDI , CAIFI, MAIFI, ASAI and CEMI5.

***Keywords:***- Reliability, distribution, network, customer, ASAI, SAIDI, CAIDI, SAIFI, CAIFI CEMI5 and MAIFI.

## I. INTRODUCTION

Over the past, distribution systems have received considerably less attention devoted to reliability modeling and evaluation than the generating and the transmission systems [1]. The reasons for this are that the generating stations and the transmission systems are capital intensive and the generation and the transmission inadequacy can have widespread catastrophic consequences for both society and the environment. A distribution system, however, is relatively cheap as compared to the other two as its effects are localized.

Therefore, less effort has been devoted to quantitative assessment of the adequacy of various alternatives and reinforcements. On the other hand, analysis of the customer failure statistics of most utilities shows that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer [1]. The distribution systems account for up to 90% of all customer reliability problems, improving distribution reliability is the key to improving customer reliability [2]. Therefore, the distribution reliability is one of the most important in the electric power industry due to its high impact on the cost of electricity and its high correlation with customer satisfaction.

Reliability Improvement Strategy has to be developed for each utilities depending upon their requirements. Outage mitigation technique in distribution system is require to be adopted in order to improve the reliability of the system and this can be classified into two categories namely; Electric and Non-electric. Electric mitigation techniques have a direct impact on the distribution system and affect the distribution system analysis and these techniques includes addition of protective devices (reclosers and fuses) and switching devices (manual and automated switches), system reconfiguration, feeder re-conductoring and integration of distributed generation. On the other hand, non electric mitigation techniques do not have any impact on other engineering analysis tools and can be evaluated solely with reliability studies and these techniques includes vegetation management, installation of lightning arresters and animal guards.

## II. PROBLEM FORMULATIONS

Electricity networks are, and will continue to be a critical part of our energy infrastructure, and we have the responsibility to ensure that they are developed consistently and in a manner that meets future demands of society and customers. The process of network development should be directed towards a long term vision aligned with the expectations of the present and future customers.

The main problem facing by electric power utilities in developing countries today is that the power demand is increasingly rapidly where supply growth is constrained by scarce resources, environmental problems and other societal concerns. This has resulted in a need for more extensive justifications of the new system facilities, and improvements in production and use of electricity. The analysis of the customer failure statistics reveal that the distribution system makes highest individual contribution to the unavailability of supply to the customer. With the vision of electricity deregulation to all within this period, will the interruptions be improve or may further deteriorate due to individual rapid expansion of the distribution systems? This is the question we should ask ourselves before embarking on deregulation. To the aim and objective of this research work, it is our esteem optimistic that the entire Disco to have high level of performances and to deliver power quality to the customer because of the market competition involve and to attract investors.

The reliability improvement should be based most probably upon the consideration of reliability worth and to find the reliability worth, formulation.

Intelligent placement of protection devices such as sectionalizers and switches in the distribution feeders has significant impact in reliability improvement and this will be further assessed along with the outage mitigation techniques for the distribution system network.

## III. OVERVIEW ON RELIABILITY

Electric power is a vital element in any modern economy. The availability of a reliable power supply at a reasonable cost is crucial for the economic growth and development of a country.

Electric power utilities throughout the world therefore endeavor to meet customer demands as economically as possible at a reasonable service of reliability. To meet customer demands, the power utility has to evolve and the distribution system have to be upgraded, operated and maintained accordingly. An analysis throughout the world shows that around 90% of all customer reliability problems are due to the problem in distribution system, hence, improving distribution reliability is the key to improving customer reliability [2].

Increasingly, the utilities are being squeezed between the conflicting demands of customer who require higher quality of service and to adopts or roll on the economic of reliability approach which is generally known as Value Base Reliability Planning (VBRP). The Value Based Reliability Planning directly takes account of the value of reliability and power quality to customers in assessing the cost effective of the proposed investment alternatives [3]. In general, VBRP follows the process as shown in the figure 1.

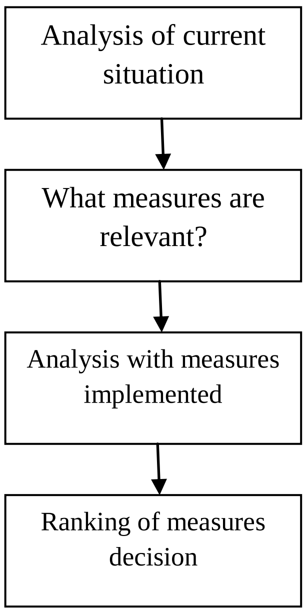


**Figure 1: Identification of problems and analysis of measures**

Due to its localized effect and minimal cost on the outages while comparing with the generation and transmission system, less effort have been devoted to distribution system in quantitative assessment of the adequacy of the various alternative designs and reinforcements in distribution system. However, analysis of the customer failure statistics reveals that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer. Statistics such as these reinforce the need to be concerned with the reliability evaluation of distribution system, to evaluate quantitatively the merits of various reinforcement schemes available to the planner and to ensure that the limited capital resources are used to achieve the greatest possible incremental reliability and improvement in the system. Therefore, it is necessary to ensure a reasonable balance in the reliability of the various constituent parts of a power system, i.e generation, transmission and distribution [1].

Once the distribution systems are planned, designed and built, they must be continually monitored, adjusted, expanded and repaired. These distributions operation plays an important role in distribution reliability.

The Mitigation Techniques like electric or non electric methods could be used to improve the reliability in the system. Modern automation technologies can reduce contingency margins, improve utilization and economy of operation and even provide improved scheduling and effectiveness of maintenance and service [4]. However, they must be applied well, with the technologies selected to be compatible with systems need and targeted effectively. On the other hand, non-electric method such as vegetation management, system improvements, crew placement and management, maintenance practices plays an important role in improving reliability in the system.

## IV. RELIABILITY EVALUATIONS

The ultimate goal of reliability analysis is to help answer questions like “is the system reliable enough?” “which scheme will fail less?” and “where can the next resources (Naira) be best spent in order to improve the system?” [5]. Reliability in power system can be divided in two basic aspects; System adequacy and System security. Adequacy relates to the capacity of the system in relation to energy demand and security relates to the dynamic response of the system to disturbances (such as faults). Since distribution systems are seldom loaded near their limits, system adequacy is of relatively small concern and reliability emphasis in on system security.

The two main approaches applied to reliability evaluation of distribution systems are [6].

- Simulation methods based on drawings from statistical distributions (Monte Carlo).
- Analytical methods based on solution of mathematical models

The Monte Carlo techniques are normally “time” consuming due to large number of drawings necessary in order to obtain accurate results. The fault contribution from each component is given by a statistical distribution of failure rates and outage times.

The analytical approach is based on assumptions concerning the statistical distributions of failure rate and repair times. The analytical approach to reliability evaluation of radial distribution system shall be used. The approach is called RELRAD (Reliability in Radial systems) and is complimentary to the minimum cut set approach.

## V. RELIABILITY INDICES

Quantitative reliability evaluation of a distribution system can be divided into two basic segments; measuring of the past performance and predicting the future performance [7].

Some of the basic indices that have been used to assess the past performance are;

- System Average Interruption Frequency Index (SAIFI)
- System Average Interruption Duration Index (SAIDI)
- Customer Average Interruption Duration Index (CAIDI)
- The Average Service Availability Index {Unavailability} ( ASAI) {ASUI}
- Energy not supplied (ENS)

Past performance statistics provide valuable reliability profile of the existing system. However, distribution planning involves the analysis of future systems and evaluation of system reliability on the existing structures; configuration, operation conditions or in protection schemes. The basic indices associated with system load points are; failure rate, average outage duration and annual unavailability.

SAIFI indicates how often an average customer is subjected to sustained interruption over a predefine time interval where as SAIDI indicates the total duration of interruption an average customer is subjected for a predefined time interval. CAIDI indicates the average time required to restore the service. ASAI specifies the fraction of time that a customer has received the power during the predefine interval of time and is vice versa for ASUI. ENS specifies the average energy the customer has not received in the predefined time.

## VI. RELIABILITY ASSESSMENT, METRICS AND INDICES

Distribution reliability is the ability of the distribution system to perform its function under stated conditions for a stated period of time without failure (Baggini, 2008). Distribution reliability is becoming significantly important in the current competitive climate because the distribution system feeds the customer directly. The distribution system is the face of the utility to the customer. Its assessment is to determine the system reliability and customer satisfaction.

Rigorous analytical treatment of distribution reliability requires well defined units of measurement, referred to as metrics. Many utilities across the world today use reliability indices to track the performance of the utility or a region or a circuit. Regulators require most investor owned utilities to report their reliability indices. The regulatory trend is moving to performance based rates where performance is penalized or rewarded based as quantified by reliability indices. Most of the utilities also pay bonuses to managers or others based in part on reliability achievements. Even some of the commercial and industrial customer ask utilities for their reliability indices when planning to find a location for their establishments.

## VII. RELIABILITY ANALYSES

Reliability analysis of electrical distribution system is considered as a tool for the planning engineer to ensure a reasonable quality of service and to choose between different system expansion plans that cost wise were comparable considering system investment and cost of losses (Kjolle and Sand, 1991).

As earlier mentioned there are two main approaches applied for reliability evaluation of distribution system, namely Simulation method based on drawings from statistical distributions (Monte Carlo) and Analytical methods based on solutions of mathematical models. The usual method of evaluating the reliability indexes is an analytical approach based on failure modes assessment and the use of equations for series and parallel networks. The common indices used for evaluation: the expected failure rate ($\lambda$), the average outage time(r), and the expected annual outage time(U) which are adequate to the simple radial system. In distribution system whether the networks are radial or meshed, the radial are most simple to assess, while the parallel or meshed networks process are more complex.

## VIII. THE ALGORITHM FLOW CHART FOR CALCULATION OF RELIABILITY INDICES

The logic describing the relation between the components and their fault contribution to different load points-the reliability topology is generated before starting the reliability calculations. The figure 2 shows a flow chart of the algorithm.

The next step is to generate expected values from the statistical distribution of failure rates, repair times and sectioning times for all components in the system. The algorithm then accumulates reliability indices for each load point from each component giving outages to the load point. Finally, when all the fault contribution is found, the total accumulated indices are available.

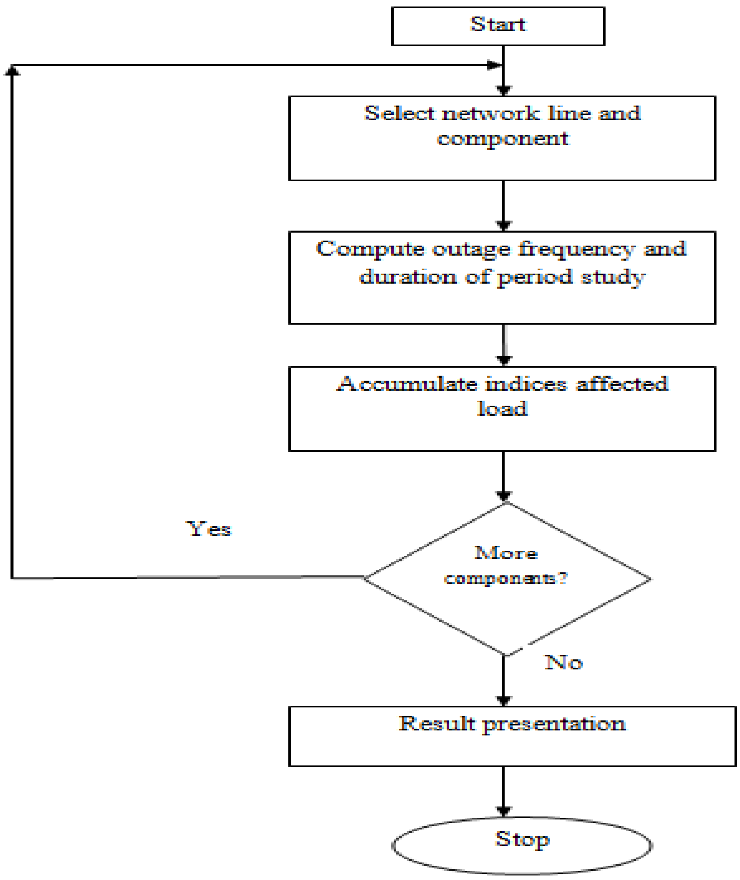


**Figure 2: Flow chart for calculation of reliability indices**

## IX. RELIABILITY INDICES

Reliability indices are statistical aggregations of reliability data for a well defined set of loads, components or customers. Most reliability indices are average values of a particular reliability characteristic for an entire system, operating region, substation service territory, or feeder.
Comprehensive treatment is not practicable, but the following sections discuss the most important reliability indices used around the world. The utility indices have traditionally only included long duration interruption (usually defined as interruptions longer than 5 minutes). A common way of defining reliability is in terms of customer and load based indices.

## X. CUSTOMER BASED INDICES

The Utilities commonly use the following reliability indices for frequency and duration to quantify the performance of their systems [8].
(i) System Average Interruption Frequency Index (SAIFI) is designed to give information about the average frequency of sustained interruptions per customer over a predefined area.

$$SAIFI_{ik} = \frac{Total\ number\ of\ customer's\ interruption\ (CI_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})}$$

$$= \sum(N_i)/N_T \quad (/yr)$$

(ii) System Average Interruption Duration Index, (SAIDI) is commonly referred to as customer minutes of interruption or customer hours, and is designed to provide information about the average time that the customers are interrupted:

$$SAIDI_{ik} = \frac{Sum\ of\ all\ customers\ minutes\ interrupted\ (CMI_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})}$$

$$= \sum(r_i * N_i)/N_T\, hr/yr)$$

(iii) Customer Average Interruption Duration Index (CAIDI) is the average time needed to restore service to the average customer per sustained interruption:

$$CAIDI_{ik} = \frac{Sum\ of\ all\ customers\ minutes\ interrupted\ (CMI_{ik})}{Total\ number\ of\ customers\ interruptions\ (CI_{ik})}$$

$$= \sum(r_i * N_i)/\sum(N_T)\ (hr)$$

(iv) Customer Average Interruption Frequency Index (CAIFI) is designed to show trends in customers interrupted and helps to show the number of customers affected out of whole customer base.

$$CAIFI = \frac{Total\ number\ of\ customer\ interrupted}{Number\ of\ customer\ affected}$$

$$= \sum(N_0)/\Sigma(N_i)$$

(v) Customer Interrupted per Interruption Index (CIII), gives the average number of customers interrupted during an outage. It is the reciprocal of the CAIFI.

$CIII_{ik} = \sum(N_i)/\sum(N_0)$

(vi) Momentary Average Interruption Frequency Index (MAIFI) is the momentary average interruption frequency index and measures the average number of momentary interruptions that a customer experiences during a given time period.

$$MAIFIE_{ik} = \frac{Sum\ of\ all\ customers\ momentary\ interruption\ events\ (CME_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})}$$

$$= \sum(IDi_i * N_i)/N_T$$

(vii) $$CEMI5_{ik} = \frac{Customers\ experienced\ more\ than\ 5\ interruptions\ (CEM5_{ik})}{Total\ number\ of\ customers\ served\ (C_{ik})}\ x\ 100\%$$

(viii) Average Service Availability Index (ASAI)

$$ASAI_{ik} = \frac{Total\ number\ of\ customer's\ hours\ available\ (CHA_{ik})}{Total\ customers\ hours\ demanded\ (CHD_{ik})}$$

$$= [1-(\square(r_i * N_i)/(N_T * T))]*100$$

(ie $ASAI = \frac{\sum Ni\ x\ 8760 - \sum ri\ Ni}{\sum NI\ x\ 8760}$); where 87660 is the number of hours in a calendar year.

Where ,
$r_i$ = Restoration time, hours.
$N_i$ =Total number of customers interrupted.
$N_T$ = Total number of customers served.

T= Time period under study, hours.

ID= Number of interrupting device operations.

No = Number of interruptions.

i = 1, 2, 3 ………………………… m

k = 1, 2, 3 ………………………… n

where i denotes year and

k denotes $k^{th}$ district

## XI. CONCLUSIONS

This paper has presented fairly comprehensive reliability assessment of distribution infrastructure based reliability metrics to be computed in line with the field data gathered for a study period. Both narrative and quantitative reliability characterizations of distribution infrastructural outlays should be employed in order to proffer sound operational philosophies aimed at insuring efficient, secure, reliable and high quality electricity delivery to consumers. We therefore reiterate the profound significance of a reliable distribution network anchored onsound planning philosophy and implementation strategy as well as adoption of modern distribution automation system.

## REFERENCE

[1]. Billinton Roy and Allan Ronald N. Reliability Evaluation of Power System, SecondEdition, 1996.
[2]. Brown Richard E.Electric Power Distribution Reliability, Second Edition, 2008.
[3]. Sullivan, M. J.; Suddeth, B. N.;Vardell, T.;Vojdani, A.; InterruptionCosts, Customer Satisfaction and Expectations for Service Reliability, IEEETransactions on Power Systems, Vol. 11, No. 2, May 1996.
[4]. Northcote-GreenJames and Wilson Robert, Control and Automation of Electrical PowerDistribution Systems, CRC, Taylor and Francis Group, 2006.
[5]. Brown, R.E; Gupta,S.; Christie,R.D;Venkata, S.S and Fletcher, R.; Distribution SystemReliability Assessment Using Hierarchical Markov Modeling, IEEE Transactions onPower Delivery, Vol. 11, No. 4, October 1996.
[6]. KjolleGerd and Sand Kjell, RELRAD-An Analytical approach for Distribution SystemReliability Assessment, IEEE Transactions on Power Delivery, Vol. 7, No. 2, April1991.
[7]. Da Silva, M.G.; Rodrigues, A. B.; de Castro, C. L.C.;.Neto, A.C;Moutinho, E.A.; Neto, N.S.A.; Cavalcante.A.B.; Reliability Assessment of Distribution Networks in Brazil'sNortheast, 8th International Conference on Probabilistic Methods Applied to PowerSystems, Iowa State University, September 12-16, 2004.
[8]. Baggini Angelo, Handbook of Power Quality, Edited by Angelo Baggini, John Wiley and Sons, Ltd, 2008.