International Journal of Engineering Research
Volume No.3, Issue No.11, pp : 640-644
ISSN:2319-6890)(online),2347-5013(print)
01 Nov. 2014

A Generalized Model for Electrical Power Distribution Feeders' Contributions to System Reliability Indices

Ganiyu A. Ajenikoko[1], Olawale .O. Olaluwoye[2]
[1,] Department of Electronic & Electrical Engineering, Ladoke Akintola University of Technology, P.M.B. 4000, Ogbomoso, Nigeria.
[2,] Department of Electrical and Computer Engineering, Olabisi Onabanjo University, Ibogun campus, Ago-Iwoye, Nigeria.
Corresponding Email: ajeedollar@gmail.com

Abstract

Reliability indices are parametric quantities used to assess the performance levels of electrical power distribution systems.

In this work, a generalized quadratic model is developed for electrical power distribution system contributions to system reliability indices using Ikeja, Port-Harcourt, Kaduna and Kano distribution system feeders as case studies.

The mean System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI) and Customer Average Interruption Duration Index (CAIDI) contributions to system reliability indices for Ikeja, Port-Harcourt, Kaduna and Kano distribution systems were 0.0033, 0.0026, 0.0033 and 0.0018 respectively due to the fact that a prolonged period of interruptions was recorded on most of the feeders attached to Port-Harcourt and Kano distribution systems making them to be less reliable compared to Ikeja and Kaduna distribution systems.

The generalized Quadratic model forms a basis for a good design, planning and maintenance of distribution systems at large.

Keywords:

Distribution, Feeders' contributions, SAIDI, SAIFI, CAIDI, Interruptions, Reliability Indices, Outage, Failure Rate, Load Point Indices.

I. Introduction.

Distribution networks are normally meshed in design but the operation is nearly always configured radially. Re-configuration consists of changing the network configurations by opening/closing feeders and tie switches so that the networks become radial in operation. The configuration of distribution networks may be modified manually or by automatic switching operations for supplying the loads aiming at minimizing the cost of active power losses. Re-configuration may increase system security and power quality (Khodr et al 2009, Meysam and Hasan 2009, Kovolev and Lebedeva 2000, Mahmud and saeed 2009)

Protective devices play a fundamental role in improving distribution system reliability (Chowdhurry et al 2003, Eissa et al 2010, Enrico and Gianfranco 2004) Automatic line sectionalizing devices such as line reclosers, interrupters, sectionalizers and fuses are often needed to reduce the total number of customers affected for a single outage by automatically isolating the faulted section. They also reduce the frequency of outage for customers on the source side of these devices and reduce the duration of outages by expediting the task of locating the faulted feeder section. The more the automatic devices installed on a distribution feeder, the better the service reliability. In addition, there are some application linitations such as co-ordination between devices and the cost of the installation, maintenance and operation **(**Allen and Bruce 2003, Guile and Peterson 2005 Hagkwen and chanan 2010, Meliopoulos et al 2001).

Two sets of reliability indices, customer load point indices and system indices, have been established to access the reliability performance of distribution systems. Load point indices measure the expected number of outages and their duration for individual customers (Geoge et al 2003).
System indices such as System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) measure the overall reliability of the system. These indices can be used to compare the effects of various design and maintenance strategies on system reliability (Ajenikoko et al 2010, Arild and Arne 2006, Chery et al 2003 Eduardo et al 2009, Allen and Bruce 2003, Khodr et al 2009).

Reliability indices can be calculated using historical outage data or predicted using stochastic methods (Chowdhurry et al 2003, George et al 2003, Eissen et al 2010).Various analytical methods are available for performing this predictive assessment. Distribution System protection equipment such as fuses, circuit breakers and reclosers fail to recognize and isolate fault conditions (Meysam and Hasan 2009) proposed a Markov modeling approach incorporating such realistic characteristics of protection equipment. Models for equipment aging are included in the reliability assessment by El-kady et al 2007, Endrenyi and Anders 2006).

Review of Related work.

A linear contribution factor model of distribution reliability indices and its application in Monte Carlo simulation and sensitivity analysis was reported by (Fangxing et al, 2003). A mathematical model for improvement in reliability indices was developed. This linear model can be applied to risk analysis and sensitivity analysis. Traditional approaches for both analysis require many repetitions of reliability index assessment. The model failed to appreciably improve the reliability indices of

International Journal of Engineering Research ISSN:2319-6890)(online),2347-5013(print)
Volume No.3, Issue No.11, pp : 640-644 01 Nov. 2014

most system indices in an electrical distribution system of the National grid.

Ajenikoko et al, 2009 presented a Modified Linear Contribution Factor Model (MLCFM) for improvement of reliability indices of electrical distribution system. Data collection and data analysis were carried out to develop the MLCF model used on the three selected distribution systems on the Nigerian National Grid. With the use of the modified LCF model, the average percentage improvement in the system reliability indices were 97.72%, 98.55% and 98.63% for Ibadan, Ilorin and Ikeja distribution systems respectively as against an average percentage improvement of 36.08%, 11.36% and 24.36% in the system reliability indices for Ibadan, Ilorin and Ikeja distribution system respectively with the use of Conventional Linear Contribution Factor Model (CLCFM).

II. Materials and Methodology

The following steps were taken in analyzing the method used.

i. The system reliability indices for the distribution system under study were identified

ii.The contributions to each of the system reliability indices from the feeders were computed.

$$SAIFI^{C} = \frac{\lambda_i I_i}{n_i} \qquad (1)$$

$$SAIDI^{C} = \frac{\lambda_i \left(\sum_{i=1}^{I_i} d_{ij} \right)}{n_i} = \frac{\lambda_i D_i}{n_i} \qquad (2)$$

$$CAIDI^{C} = \lambda_i \left(\frac{D_i}{I_i} \right)$$

where:

$SAIFI^c$ = Contribution to SAIFI from the feeders

$SAIDI^c$ = Contribution to SAIDI from the feeders

$CAIDI^c$ = Contribution to CAIDI from the feeders

λ_i = Failure rates of feeders i.

I_i = Number of customers experiencing sustained interruptions.

due to a failure of feeders i

d_{ij} = Interruption duration for customer *j* due to a failure of feeder *i*.

n_i = Total number of customers on a feeder i.

D_i = Sum of customers interruption duration due to a failure of feeder *i*

iii. Compute Mean sum of reliability indices .

iv. Plot a graph of Mean sum of reliability indices Versus Distribution feeders.

v. Obtain a generalized model using curve fitting approach.

4.Results and Discussions.

Olowu feeder of Ikeja distribution system experienced a prolonged period of customers' interruption. 7-Up feeder had the least mean SAIDI of 0.0693 with a standard deviation of 0.0371 from the mean. The SAIDI contribution of this feeder is 0.0013 as shown in Figure 1..A shorter period of time interruption was experienced by customers served by this feeder.

Alagbole feeder recorded the highest mean SAIFI of 0.2481 with a standard deviation 0.0279 even though its SAIFI contribution is 0.0054 which appears to be the highest in that range as shown in Figure 2 . Fewer of the many customers interrupted on this feeder were served adequately. The least mean SAIFI of 0.1887 was recorded on Opebi feeder with a standard deviation of 0.0168 and a SAIFI contribution of 0.0030 because many of the customers attached to this feeder were adequately served. (1)

Opebi feeder has the highest mean CAIDI of 0.5394 with a standard deviation of 0.2846 even though, its contribution to CAIDI index is 0.0085 which appeared to be the highest in that range. The number of customers' interruptions had reduced appreciably. (2)

The least mean CAIDI of 0.3825 and a standard deviation of 0.1891 were recorded on Alagbole feeder (3) with a CAIDI contribution of 0.0061 as shown in Figure 3.

The graphical illustrations for the contributions to total system reliability indices and the mean total system reliability indices for Ikeja distribution systems are shown in Figures 4 and 5.

Michelin feeder of Portharcourt distribution system had the least mean SAIDI of 0.0695 with a standard deviation of 0.0342 while the SAIDI contribution is 0.0007 as shown in Figure 6. A shorter period of interruptions is experienced by many customers served by this feeder. A highest mean SAIFI of 0.1931 with a standard deviation of 0.0686 and a SAIFI contribution of 0.0007 were recorded on Shell 3 feeder of this distribution system.

Many of the customers were interrupted on this feeder while few of them were adequately served. The least mean SAIFI of 0.1392, and a standard deviation of 0.0198 with a SAIFI contribution of 0.0017 were recorded on Airport feeder as displayed in Figure 7. Many of the customers attached to this feeder were adequately served. Airport feeder also recorded the highest mean CAIDI of 0.7651 and a standard deviation of

International Journal of Engineering Research
Volume No.3, Issue No.11, pp : 640-644

ISSN:2319-6890)(online),2347-5013(print)
01 Nov. 2014

0.3989 with a CAIDI contribution of 0.0094. This is because customers on this feeder were interrupted for a long time even though, the number of customer interruption had reduced accordingly.

Michelin feeder has the least mean CAIDI of 0.3813 with a standard deviation of 0.2636 and a CAIDI contribution of 0.0038 as illustrated in Figure 8. This is because fewer of the customers attached to this feeder were interrupted for a short time.

The graphical illustrations for the contributions to total system reliability indices and the mean total system reliability indices for Portharcourt distribution systems are shown in Figures 9 and 10.

Generalized model.

The model for Ikeja distribution system contribution to system reliability indices is:

$$y = 0.00003x^2 - 0.000x^2 + 0.002x \quad (4)$$

$$R^2 = 0.992 \quad (5)$$

The model for Port-Harcourt distribution system contribution to system reliability indices is:

$$y = 0.00006x^2 - 0.000x + 0.007$$

$$R^2 = 0.997$$

where:

y= Contribution to system reliability indices for the distribution system.

x = Number of feeders

R^2 = Coefficient of determination.

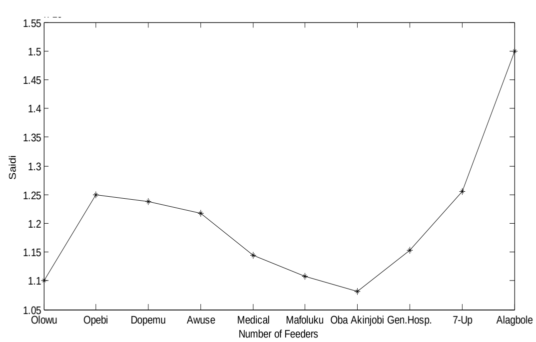

Figure1: Contributions to SAIDI for Ikeja distribution system

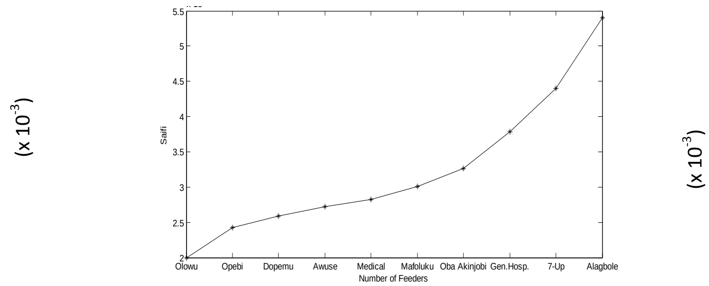

Figure 2: Contributions to SAIFI for Ikeja distribution system

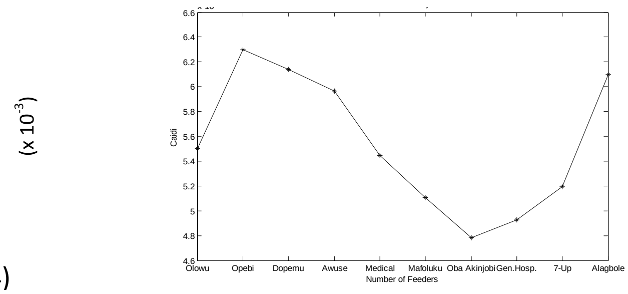

Figure 3: Contributions to CAIDI for Ikeja distribution system

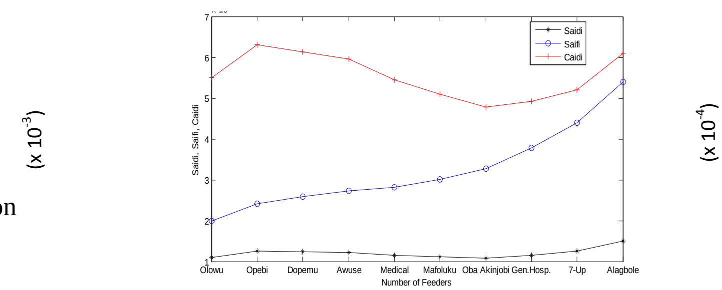

Figure 4: Contributions to Total system reliability indices for Ikeja distribution system

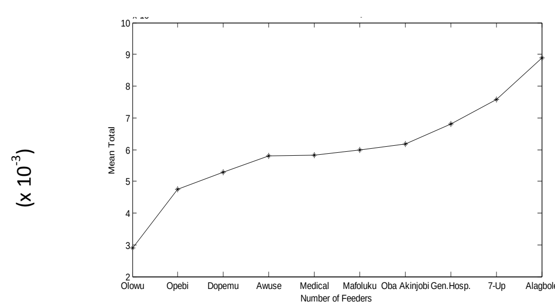

Figure 5: Contributions to Mean Total system reliability indices for Ikeja distribution system

ISSN:2319-6890)(online),2347-5013(print)
01 Nov. 2014

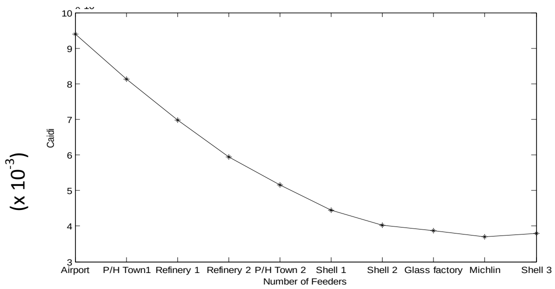

Figure 6: Contributions to SAIDI for Port-Harcourt distribution system

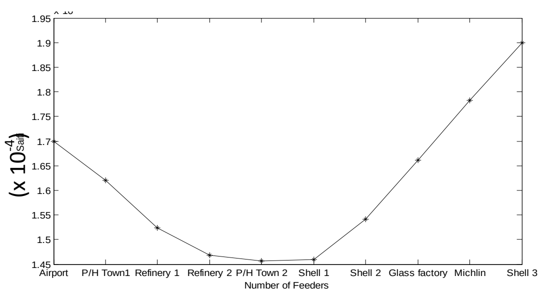

Figure 7: Contributions to SAIFI for Port-Harcourt distribution system

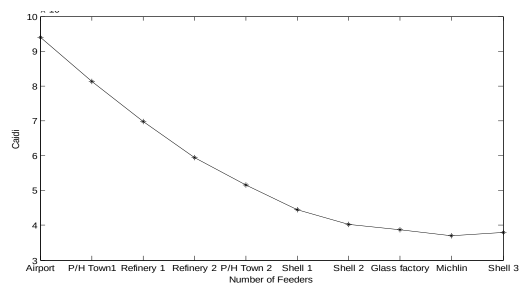

Figure 8: Contributions to CAIDI for Port-Harcourt distribution system

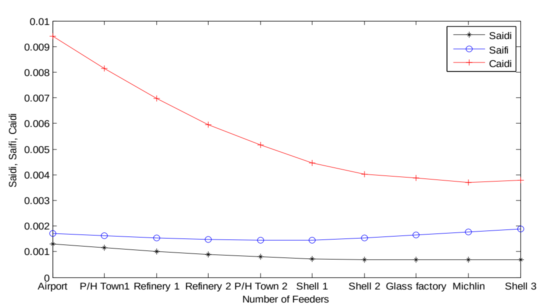

Figure 9: Contributions to Total system reliability indices

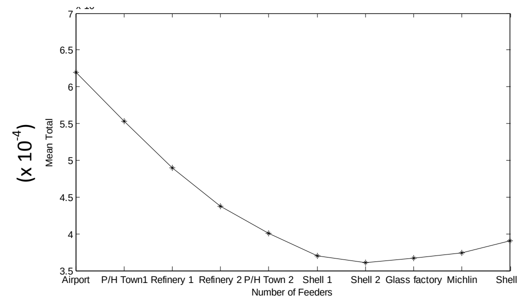

Figure 10: Contribution to Mean Total reliability indices for Port-Harcourt distribution system

IV. Conclusion.

A generalized Quadratic model for electrical power distribution feeders' contributions to system reliability indices has been developed. Notable reliability indices were identified and computed on the distribution systems. The computed mean and standard deviation of the system reliability indices were used as input parameters for the developed model. The relationship between the mean sum of the reliability indices and the distribution feeders was used with the aid of curve fitting tools in MATLAB computer programming language for the development of the model.

The model developed can be used to find the statistical distribution of the reliability indices which will form a basis for system planning and maintenance strategies.

REFERENCES

i. *Ajenikoko G. A, Fakolujo O. A and Raji T.I (2009): "A Modified Linear Contribution Factor Model for improvement of reliability indices of electrical distribution systems", Journal of Research in Engineering, Vol. 6, No. 2, Pp. 61-69.*

ii. *Ajenikoko G. A, Fakolujo O. A and Raji T.I (2010): "A Generalized model for quantitative evaluation of reliability indices of the National grid system", In proceedings of the 1st International Conference on 'The Role of Engineering and Technology Research in the Realization of the MDG's', LAUTECH, Pp 183-193.*

iii. *Allen W. J. and Bruce W. F. (2003): "Power Generation, Operation and Control", John Wiley and Sons Inc, Fourth Edition,Pp 204 – 219.*

iv. *Arild H and Arne T.H (2006): "Reliability modeling of gas and electric power distribution systems; similarities and differences;", 9th International Conference on Probabilistic Methods Applied to Power Systems, KTH, Stockholm, Sweden. Pp. 327-341.*

v. *Chery, A. W, Dan J. P and Michael T. J. (2003): "A Nationwide survey of recorded information used for calculating distributions reliability indices". IEEE Transactions on power delivery Vol. 18, No. 2. Pp 449-453.*

vi. *Chowdhurry A. A, Sudhir K. A and Don O. K (2003): "Reliability modeling of distributed generation in conventional distribution systems planning and analysis", IEEE Transactions on industry applications, Vol. 19, No. 5, Pp 1493-1498.*

vii. *Eduardo Z, Debora Z. B, Berilhes B. G and Elias F. A (2009): "A novel nonlinear programming model for distribution protection optimization", IEEE transactions on power delivery, Vol. 24, No. 4, Pp 1951-1958.*

viii. *Eissa M. M, Masoud M. E. and Elanwar M. M. (2010): "A Novel back-up wide area protection technique for power grids using phasor measurement unit", IEEE transactions on power delivery, Vol. 25, No. 1, Pp 270-278.*

ix. *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, Vol. 11, No. 5, Pp 328-336.*

x. *Endrenyi J. and Anders G. J. (2006): "Aging maintenance and reliability", IEEE Power energy magazine, Vol. 4, No. 3, pp 59-67.*

xi. *Fangxing L, Richard E. B. and Lavelle A. A. F. (2003):" A linear contribution factor model of distribution reliability indices and its applications in Monte Carlo simulation and sensitivity analysis" IEEE Transaction on power systems, Vol 18, No 3, Pp 93-98.*

xii. *George S. K, Meliopoulos A.P. and George C. J. (2003): "Probabilistic Power Flow with Non-Conforming Electric Loads", In Proceedings of the 8th International Conference on Probability Methods Applied to Power Systems PMAPS), Ames, Iowa, Pp. 525-531.*

xiii. *Khodr H.M, Martinez-Crespo J, Matos M. A and Pereira J. (2009): "Distribution Systems reconfiguration based on OPF using Benders decomposition", IEEE Transactions on power delivery, Vol. 24, No. 4, Pp. 2166-2176.*

xiv. *Meysam J and Hasan M (2009): "Scheduling of spinning reserve considering customer choice on reliability", IEEE transactions on power system, Vol. 24, No. 4, Pp 476-489.*