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A Failure Rate Model for Reliability Assessment of Ibadan Distribution Systems

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Abstract

Failure rate is one of the parametric indices used for assessment of electrical power system. It is defined as the inability of the system to perform its designated function adequately without interruption over a period of time. The rate at which distribution systems fail depends on many factors some of which are lack of maintenance, ageing, inexperience nature of the technical expert and government policies.

This paper focuses on the development of a generalized failure rate model for assessment of reliability levels of Ibadan distribution system feeders. Ten selected feeders on Ibadan distribution systems were used to carry out the analysis. The outage data which included total no of faults on each of the distribution feeders and the corresponding time duration of faults for the two distribution systems were used as input parameters for computation of the failure rates. Curve fitting analysis was employed to develop a generalized model for the distribution system..The results of the model showed that Agodi feeder had the least failure rate of 0.1508 faults/sec because most of the faults on this feeder lasted for a short period of time. Onireke feeder recorded the highest failure rate of 0.2396 faults/sec because majority of the faults on this feeder persisted for a long period of time before being cleared.

The result of this work can be used to provide a comprehensive analysis for the causes of distribution system feeders' failure and the necessary policies to be formulated for enhancement of reliability improvement of Ibadan distribution system.

Keywords: Failure rate, Faults,, Normal repair, Up and Down times,, Distribution system, Reliability.

1. Introduction

Failure may be defined as the inability of a system and component to carry out its specific function. The cost of maintenance and consequences of failures can be significantly higher than the cost of the component. Maintenance actions are performed on the basis of components' degradation and potential failures probabilities, consequences and characteristics. The failures can be grouped into the following two categories (Abiad and James 2004, Bishnu and Vijay 2010, Calabrese 2003)

Re-occuring failures (i.e. to some extent possible to predict) and random failures. Failures can further be divided into the following two groups (Meliopoulos,Chao and George 2001). Failures with incubation time (possible to detect before they happen) and instant failures (without incubation time). Most of the time, relay operations are correct and satisfactory.

Maintenance policies play an important role in the reliability of repairable systems because maintenance actions can significantly affect the failure probability of the system(Arild and Arne 2006). For a complex system, i.e a unit with a large number of parts, the repair or the substitution of a failed part restores the system performance, but does not generally produce a significant reliability improvement because the conditions of the non-failed parts are left unchanged. In such a case, it is generally assumed that each repair brings the system to condition it was just before occurrence(Pereira and Pinto 1992, Roberts, Andrew and Brown 1999, Sakis, Fang and George 2004, Setreus, Wallnerstom and Bertling,2007, Singh and Miltra 2006, Singh and Billinton 2005, Takeshi, Nobuo and Kaora, 2010).

Two types of failures are used in distribution system reliability analysis. They are classified into sustained failures and temporary failures. Sustained failures require some kind of repair work to restore the function of the component into a normal position, while temporary failures will clear themselves if the component is de-energized (Endrenyi, Maenhaul and Payne,2005).

The quality of supply can considerably be improved by incorporating reliability considerations in the system design and in the system expansion planning, operation and maintenance (Vishai,Rohith and Indra 2010, Viadmiro ,,Leonel and Augusto, 2009).

According to (Oluseyi, Akinbulire and Awosope 2006, Morris,,Roberto and Enrico 2009, Gangel and Ringlee 2005). the following factors can cause component failure rates to vary with time and location: contamination, vegetations, animals, humans, excessive ambitient temperature, moistures, excessive load, lack of maintenance and ageing.. These factors cause the component failure rates to vary with time and location. Therefore, it is sometimes not accurate enough to assign identical average failure ratee values to all components of a particular type. Ideally, each component should be treated as an individual one with a unique failure rate. However, by considering information sources providing valid average failure rates for a variety of conditions within which it is reasonable to expect the average failure rates to vary, can be derived. It should be noted that the causes of incorrect behavior of protection and control systems and of circuit breakers are somewhat more complicated

1.1 Faults nn Distribution Feeders.

The faults that occur in distribution systems can be classified as temporary or permanent. A temporary fault will clear if deenergized and then re-energized, and a permanent fault will persist until repaired by human intervention (Meysam and Hasan,2009). An interruption is the loss of service (power supply) to one or more customers, and is classified as momentary or sustained. Despite the use of the term momentary interruption, in this work will be considered the concept of momentary interruption event. A momentary interruption event is one or more interruptions of total duration limited to the time period of 5 minutes. A sustained interruption is any interruption not classified as a part of a momentary event (Abiad and James 2004, Viadmiro, Leonel and Augusto 2009).

Faults occurring on distribution feeders cause protection system action that interrupt the power supplied to feeder customers. The faults are due to animals and tree that comes in contact with distribution equipment (Abiad and James,2004). System reliability can be improved by reducing the frequency of occurrence of faults and by reducing the repair time by means of various designs and maintenance strategies(Abiad and James 2004, Billinton 2004, Bizacott 2004).

Short circuits or faults occurring on distribution feeders cause protection system actions that interrupt the power Supplied to feeder customers. The faults are due to animals and trees that come in contact with distribution equipment, severe weather conditions such as lightning and wind storms, aging and infrequent maintenance of distribution equipment and traffic accidents, among other causes(Anderson and Bose 2003, Billinton 2004, Chang 1977)..

The reliability of a system can be improved by reducing the frequency of occurrence of faults and by reducing the repair time by means of various design and maintenance strategies(Wang,2003)..

Repair duration depends on a number of factors such as the nature of the fault, the time of day and day of the week at which the outage has occurred and the prevailing weather conditions. The total outage duration also depends on the distance the crew has to travel to reach the fault and accessibility of the fault location (Buzacott 2004, Endrenyi and Anders 2006, Olivera and Padilha 2009.

The number of faults occurring on a feeder and the repair duration vary randomly from year to year. Consequently the reliability indices of the system also vary randomly from year to year. While improvements in modeling the system behavior lead to more accurate estimates of the average values of reliability indices, the analytical methods used do not estimate the variability of these indices. Monte Carlo simulation method is used to obtain the probability distribution of load point and system indices for small sample distribution system (Oluseyi, Akinbulire and Awosope 2006, Singh, Fang and George 2004; Setreus, Wallnerstom and Bertling 2007, Takeshi, Nobuo and Kaora 2010)..

An adequate knowledge of the range over which the annual feeder reliability indices are expected to vary would be helpful to distribution engineers in making appropriate allocation of the available resources towards the upkeep of the distribution system. The assessment can be made using the probability distributions of the reliability indices (Abiad and James 2004, Billinton 1994, Billinton 2000,Chang 1977)..

1.2 Repairable Components – Normal Repair

The normal repair model allows for non-negligible repair durations. The repair time is treated as another random variable which, together with the one representing the operating times, describe the life process of a repairable component. This process, then consists of alternating ‘up’ and ‘down’ periods (T_u and T_D) as shown in Figure 1. below.

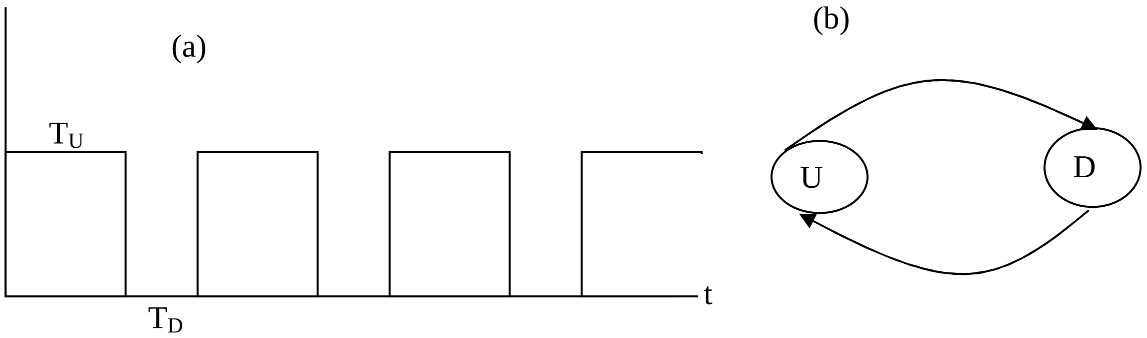

Figure 1.Component with normal repair:(a) Life history (b) state diagram

The process of up and down cycles can be illustrated by the state diagram in Figure 1 above showing the up state U, the down-state D, and the possible transition between them. In the two-state normal repair model, perfect repair is assured and the cycles are repeated endlessly(Wang,2003).

The reliability behaviour of repairable components. In the definitions, X_t indicates the state of the components can be described mathematically as below: In the definitions X_t indicates the state of the component (up or down) at time t.

The probability of being in the up-state:

$$P_u(t) = P\,[\text{up at t}] = P\,[X_t = U] \tag{1}$$

The probability of being in the down-state

$$P_D(t) = P[\text{down at t}] = P\,[X_t = D] \tag{2}$$

Failure density

$$L(t) = l\lim_{\Delta t \to 0} \frac{1}{\Delta t} P[\,failure\ in(t, t+\Delta t)]$$

$$= \lim_{\Delta t \to 0} \frac{1}{\Delta t} P[(X_{t+\Delta t} = D) \cap (X_t = u)] \tag{3}$$

Intensity of transitions from U to D

$$q_{UD}(t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t} P[\,failure\ in(t, t+\Delta t)/\,working\ at\ t]$$

$$= \lim_{\Delta t \to 0} \frac{1}{\Delta t} P[X_{t+\Delta t} = D / X_t = u] \tag{4}$$

Mean up-time, or mean time to failure (MTTF)

$$Mu = \int_0^{\infty} t \frac{dFu(t)}{dt} dt \tag{5}$$

Mean down-time

$$M_D = \int_0^{\infty} t \frac{dF_D(t)}{dt} dt \tag{6}$$

Mean time between failure (MTBF), or mean cycle time

$$\text{MTBF} = M_u + M_D \tag{7}$$

Availability $$A = \frac{Mu}{Mu + M_D} \tag{8}$$

Unavailability $$\overline{A} = I - A = \frac{M_D}{M_u + M_D} \tag{9}$$

1.3 Exponential Up And Down Times

In the case of exponential up and down times, $F_u(t) = \lambda e^{-\lambda t}$ (10)

$F_D(t) = \mu e^{-\lambda t}$

with $M_u = \dfrac{1}{\lambda} \quad and \quad M_D = \dfrac{1}{\mu}$. The state probabilities $P_u(t)$ and $P_D(t)$ are obtained as

$$P_u(t) = \frac{\mu}{\lambda+\mu} + \frac{\lambda}{\lambda+\mu} e^{-(\lambda+\mu)t}$$
$$P_D(t) = \frac{\lambda}{\lambda+\mu} - \frac{\mu}{\lambda+\mu} \tag{11}$$

These functions are illustrated below in Figure 2.

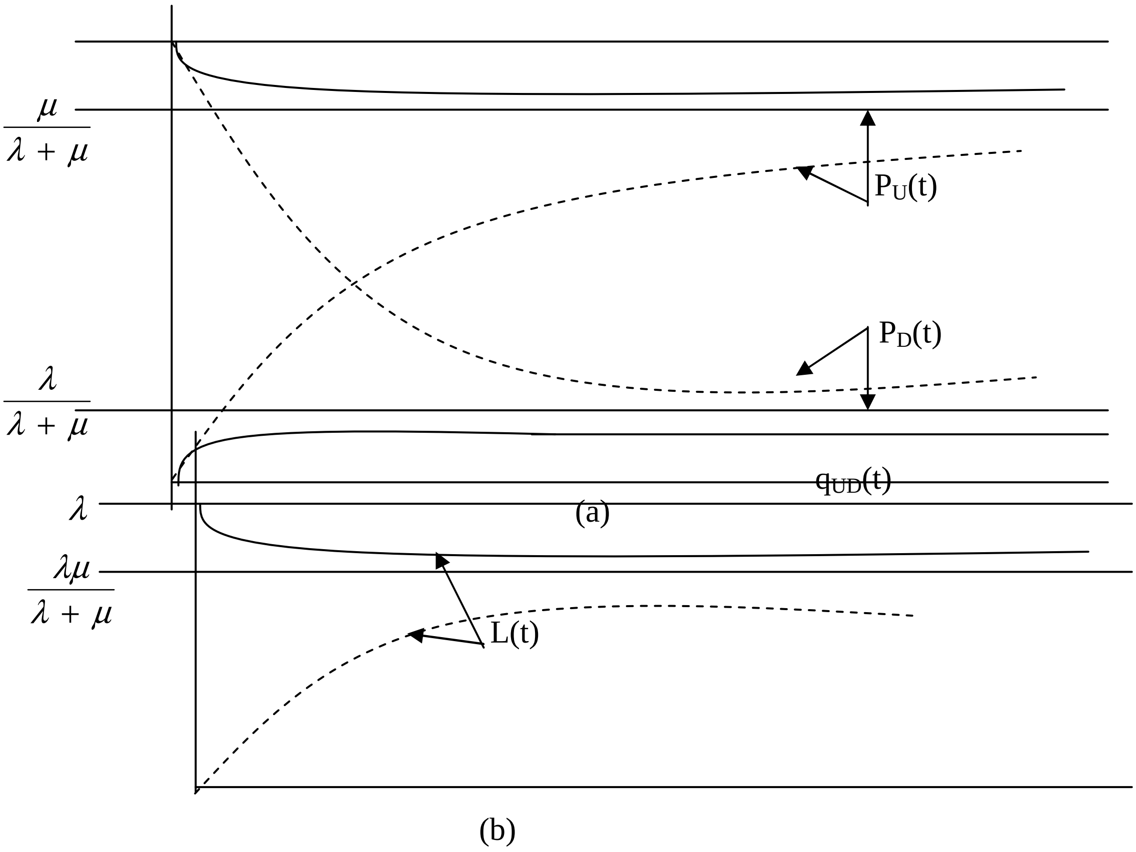

Figure.2: Characteristic functions for exponential up and down-time distributions full lines represents component up at t = 0: broken lines: component down at t = 0

$q_{uD}(t) \quad = \quad \lambda$

The failure density becomes

$$L(t) = \frac{\lambda\mu}{\lambda+\mu} + \frac{\lambda^2}{\lambda+\mu} e^{-(\lambda+\mu)t} \tag{12}$$

Figure 2 (b) shows the corresponding plots of $q_{uD}(t)$ and L(t)

The availability and unavailability indices are given by the expressions

$$A = \frac{\mu}{\lambda+\mu} \quad and \quad \overline{A} = \frac{\lambda}{\lambda+\mu}. \tag{13}$$

Also, forced Outage Rate (FOR)

$$FOR = \overline{A} = \frac{\lambda}{\lambda+\mu} \tag{14}$$

Components can be repairable or non-repairable. The reliability of a non-repairable component can be described by a single index, such as the reliability R, indicating the probability that the component performs its function for an intended duration of time, or the mean time to failure MTTF. It can also be described by a single function, such as hazard function h(t) or the reliability function R(t), in which case the indices above can be calculated(Maurizio and Gianpolo, 2009)..

The reliability of repairable components must be described by at least two functions, such as the time functions of the up-state and down state probabilities. In the long run, component with any type of up-and down time distributions tend to behave like components with exponential distributions(Pereira and Pinto1992, Sakis, Fang and George 2004, Singh and Miltra 2006, Takeshi,Nobuo and Kaora 2010...

If only the long term behaviour is of interest, then, two indices such as the availability A and the mean down-time M_D are sufficient measures of reliability.

There are several criteria by which a system state must be tested before it is judged successful or failed.

A bulk power system is considered failed if the service at the load busses is interrupted or its quality become, unacceptable. Such a condition arises if any of the following events occur(Singh and Miltra 2006,Takeshi,Nobuo and Kaora 2010, Vishai,Rohitth and Indra 2010, Viadmiro,Leonel and Augusto 2010). .

(i) There is not enough generation available in the system to meet the load demand.
(ii) The continuity of supply to a load point is interrupted.
(iii) Transmission lines are overloaded.
(iv) Bus voltages are outside tolerance.

A failure by any of the above criteria does not generally mean the collapse of the entire system, while it is conceivable that, for example, an overload condition could develop into a cascading sequence of events, finally resulting in a break-up of the system, it is much move likely that such a catastrophe would be averted by switching, generation rescheduling or load shedding (Oluseyi, Akinbulire and Awosope,2006)..

The system failures are merely undesirable events which form a basis for the calculation of the reliability indices. In certain contingencies, the system may become unstable and fail even if no system failure occurs by any of the criteria..

Accurate reliability analysis of power sytems helps to predict future failure behaviour and make appropriate maintenance plans (Endrenyi and Anders, 2006; Endrenyi et al, 2001; Endrenyi et al, 1998). Reliability performance of distribution utilities has received considerable attention in recent years(Endrenyi,Maenhaul and Payne 2005).

The reliability of power distribution systems is greatly affected by outages caused by different environmental factors on overhead lines. Since animals cause significant number of outages on overhead distribution systems, it is important to investigate these outages(Setreus,Walllnerstom and Bertling,2007)

The main function of protective relays on power system is to detect and remove the faulted parts as fast and selectively as possible (Abbas et al, 2009).

Accurate fault location is required by operators and utility staff in order to expedite service restoration and thus to reduce outage time, operating costs and customer complaints(Endrenyi, Maenhaul and Payne 2005, Maurizio and Gianpolo 2009).

Maintenance policies play an important role in the reliability of repairable systems because maintenance actions can significantly affect the failure probability of the system. For a complex system, i.e a unit with a large number of parts, the repair or the substitution of a failed part restores the system performance, but does not generally produce a significant reliability improvement because the conditions of the non-failed parts are left unchanged. In such a case, it is generally assumed that each repair brings the system to condition it was just before occurrence(Vishai, Rohith and Indra 2010).

2. Review of Related work.

Reliability analysis in electrical distribution system considering preventive maintenance applications on circuit breakers was presented by Mahmud and Saeed {2009). The paper presented the results of the preventive maintenance application based study and modeling of failure rates in breakers of electrical distribution system which is a critical issue in the reliability assessment of a system. In the analysis considered in this paper, the impacts of failure rate variations caused by a preventive maintenance were examined. This is considered as a part of a Reliabilty Centred Maintenance (RCM) application program. A number of load point reliability indices is derived using the mathematical model of the failure rate which is established using the observesd data in a distribution system.

Eduardo et al (2009) presented a novel nonlinear binary programming model designed to improve the reliability indices of a distribution network. This model identifies the type and location of protection devices that should be installed in a distribution feeder and is a generalization of the classical optimization models. This new approach is more flexible and leads to better placement solutions. Numerical results of the tests performed on real feeders are presented for analysis.

Allan and Da Silva (1995) described an approach for evaluating the probability distributions associated with the reliability indices in meshed networks. A procedure for combining these indices with the costs of interruption duration and of customer's average interruption duration index (CAIDI), to assess the costs of interruptions in such networks has been reported by them. The proposed approaches are based on a combination of analytical technique and Monte Carlo-Carlo simulation. The results from this study demonstrated that greatly increased information can be obtained from using the distribution of the reliability indices. These include:

(a) The ability of predicting the proportion of customers having interruptions greater than a certain number or outage duration greater than a particular value.This is of vital concern in demonstrating whether a specified reinforcement meets specified target standards.

(b) The benefits of using alternative system designs is emphasized by comparing distributions and the tail regions rather than simply average values.

(c) The distribution permits more accurate values of interruption costs to be evaluated.

Ajenikoko, Fakolujo and Raji (2010) presented a generalized model for a quantitative evaluation of reliability indices of the National Grid system. The work formulated a generalized model for a new measure of reliability index called the Relative Customer Average Interruption Duration Index (CAIDI) for the National Grid System. The generalized model is a polynomial function whose order depends majorly on the level of industrialization of the distribution system and invariably, on the coefficients of the distribution feeders.

3 Materials and Method

3.1 Development of mathematical model

The electric power system belongs to the discrete state, continuous time class. This is because each distribution system feeder can operate either in fully up-state or down-state and inter-state transition can occur randomly at any time. The probability that each unit moves independently to a new state is a function of the rate of departure from its present state.

The Markov transition rates needs to be estimated accurately from the available outage database for the distribution system. The mathematical model for a discrete state continuous time process is derived as follows:

Let $\phi_i(t)$ = probability that the system is in state i at time t.

λ_{ij} = rate of departure from state i to another state j.

$\lambda_{ij}\Delta t$ = probability of moving from state i to another state j in time Δt where Δt is made sufficiently small that the probability of two or more transitions occurring during Δt is negligible.

The probability of an 'n' state system being in any state i at time (t + Δt) is $\phi_i(t + \Delta t)$ = probability of being in state i at time t and not leaving it in time t or probability of being in another state j at time t and moving to state i during the time interval.

That is: $$\phi_i(t+\Delta t) = \phi_j(t)[1-\sum_{j=1}^{n}\lambda_{ij}\Delta t] + \sum_{j=1}^{n}\phi_j(t)\lambda_{ij}\Delta t \qquad (1)$$

j = 1, i = 1,2, . . . n.

Rearranging and taking limit as t tends to zero, equation (1) can be written in matrix form as

$$\phi(t) = A\phi(t)$$

where:

$$A = \begin{bmatrix} \alpha_{1,1}\lambda_{2.1}\ldots\lambda_{i.1}\ldots\lambda_{n.1} \\ \lambda_{1.2}\alpha_{2.2}\ldots\lambda_{i.2}\ldots\lambda_{n.2} \\ . \\ . \\ . \\ \lambda_{1.n}\lambda_{2.n}\ldots\lambda_{i.n}\ldots\alpha_{n.n} \end{bmatrix}$$

$$\phi(t) = [\phi_1(t), \phi_2(t)\ldots\phi_n(t)]^T$$

$$\alpha_{ii} = -\sum_{j=1}^{n} \lambda_{ij} \qquad (2)$$

where

A = n x n stochastic transitional rate matrix

λ_{ij} = the rate of departure from state i to state j, i = j

$\phi_i(t)$ = the time dependent probability of state i

$$\phi_i(t) = \frac{d\phi_i(t)}{dt} \qquad (3)$$

T = transpose

Given the appropriate initial conditions,

$\phi(0)$ = [$\phi_1(0)$, $\phi_2(0)$, … $\phi_n(0)$]

$$\phi(t) = e^{\lambda t}\phi(0) \qquad (4)$$

Of prime importance and interest are the reliabilities of distribution system for which the limiting steady state probabilities are to be computed (Aliyu and Musa, 1992).

One way of obtaining the limiting steady state probabilities from the equation involves taking

$$\underset{t\to\infty}{Lim}\,\phi(t) = \psi \qquad (5)$$

where

ψ = [ψ_1 , ψ_2 ,… ψ_n]^T is the desired steady state probability vector such that:

$$\sum_{i=1}^{n} \psi_i = 1 \qquad (6)$$

Equation 6 can be reduced to its steady state value so that the time rate of change of $\phi(t)$ equals zero.

Since the rank of the resulting set of n algebraic equations is n – 1, it can be shown that replacing anyone of them enable a unique solution to be obtained. If the nth algebraic equation is replaced the following matrix equation results.

$$\bar{b} = A'\psi \qquad (7)$$

where

$$A_{nxn} = \begin{bmatrix} \frac{A_{n-1xn}}{u_{1xn}} \end{bmatrix} \qquad (8)$$

$$\bar{b}_{nx1} = [0,0,0,\ldots0,1]^T$$

$$u_{nx1} = [0,0,0,\ldots1,1]^{T^{-}}$$

$$\bar{A}(i,j) = A(i,j) : [i \in (i, n-1) : j \in (1,n)]$$

The resulting algebraic matrix equation 8 is easily solved for ψ.

Generally, the rate of transition from state i to any other state j is estimated from the following:

$$\lambda_{ij} = \frac{1}{T_i} \tag{9}$$

where:

T_i is the average time spent in state i as given by the following relation:

$$T_i = \frac{t_i}{N_{ij}} \tag{10}$$

where:

T_i is the total time spent in state and N_{ij} is the number of transitions from state i to any other state j.

In the special case of a unit with two state model (ups and down) it can move from up to down state and vice versa with failure rate (λ) and repair rate (μ) being their corresponding transition rates.

The Raw data needed were collected from the national control center (NCC), Osogbo which formed a basis for this analysis.

Ten years of outage information from Ibadan distribution systems were collected from NCC Osogbo. The relevant information includes: Recorded faults on Ibadan distribution system for the study period and the recorded outage times on the selected distribution systems..

The failure rate graph was plotted from which a Failure Rate Model is developed.

4. Results and Discussion.

Agodi feeder recorded a least value of 920 faults within the first 6100 seconds. The fault progresses along the feeders of the distribution system as the time increases thus making the failure rates to fluctuate as well..This distribution feeder has a failure rate of 0.1508 faults/second which happens to be the least in this case. Most of the faults recorded on this feeder lasted for a very short period of time making it possible to serve most of the numerous customers attached to it. The relationship between the Failure rate and the duration of faults for Ibadan distribution system is shown in Figure 1. It is observed that the failure rate fluctuates as the faults duration progresses. This is due to the fact that most of the faults occurred at random and lasted for a short period of time before being cleared.

Figure 2 shows the relationship between the failure rate and the feeders. It shows how often the feeders vary with time during the study period. Eruwa feeder recorded a low failure rate of 0.1512 because fewer faults were recorded on this feeder even though, those faults were cleared promptly so as to serve the numerous customers attached to the feeder. Onireke feeder had a failure rate of 0.2396 and emerged as having the highest failure rate because majority of the faults recorded on this feeder persisted for a long period of time thus putting most of the numerous customers attached to this feeder in a complete darkness.

The number of faults recorded on Eruwa distribution feeder increases to 1320 within the next 300 seconds making the feeder to fail at the rate of 0.206 faults/second. This is because more faults were experienced on this distribution feeder, majority of which persisted for a very long time and consequently, putting most of the customers attached to it in complete darkness thus paralyzing their commercial activities.

Figure 3 shows the relationship between the faults and the duration of faults. It expresses how the two parameters vary. It is observed that the faults increase as the duration of faults increases.

Eleyele feeder fails at the of 0.1875 faults per second within the next 800 seconds because most of the numerous faults recorded on this feeder were cleared promptly thus providing adequate services to the numerous customers attached to the feeder.

A high level of maintenance practice was noticed on Moniya feeder of Ibadan distribution system. It recorded a total of 1600 faults in 7800 seconds making it to fail at the rate of 0.205 faults/seconds.. On this feeder, most of the faults lasted for just a few seconds and were cleared promptly so as to serve the customers attached to it without any further interruptions.

Figure 4 expresses the correlation between the fault duration and the feeders. It shows the time duration for each of the feeders.

Secretariat feeder of this distribution system has a failure rate of 0.206 faults/second because the same maintenance strategy adopted on Moniya feeder was also introduced to the feeder in order to clear most of the faults on the feeder so as to provide adequate services without interruptions to the numerous customers attached to it.

Figure 5 describes the variation of the faults with respect to the feeders. It shows at a glance, how the faults vary from feeder to feeder.

Lack of adequate maintenance culture on Bashorun, Premier, Ijokodo and Cocoa feeders was responsible for appreciable failure rates of 0.2174 faults/second, 0.2263 faults/second, 0.2280 faults/second and 0.2349 faults/second respectively. Most of the faults recorded on these feeders persisted for a very long period of time without them being cleared thus putting most of the customers attached to them in a prolonged darkness.

Onireke feeder has a failure rate of 0.2337 faults/second which is a slight fall in failure rate recorded on Cocoa feeder .Most of the faults recorded on this feeder were cleared immediately after the adoption of an appropriate maintenance scheme. Most of the customers attached to this feeder were adequately served..

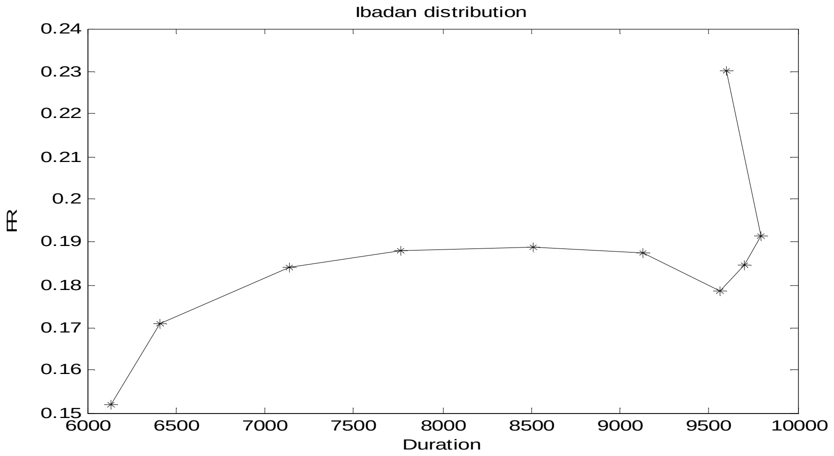

Figure 1: Variation of Failure rate with time for Ibadan distribution system.

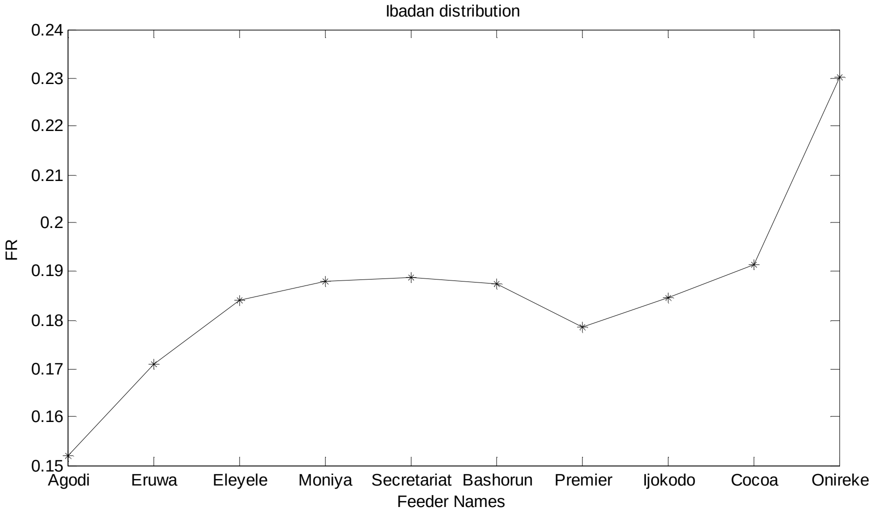

Figure 2: Variation of Failure rate with feeder names for Ibadan distribution system.

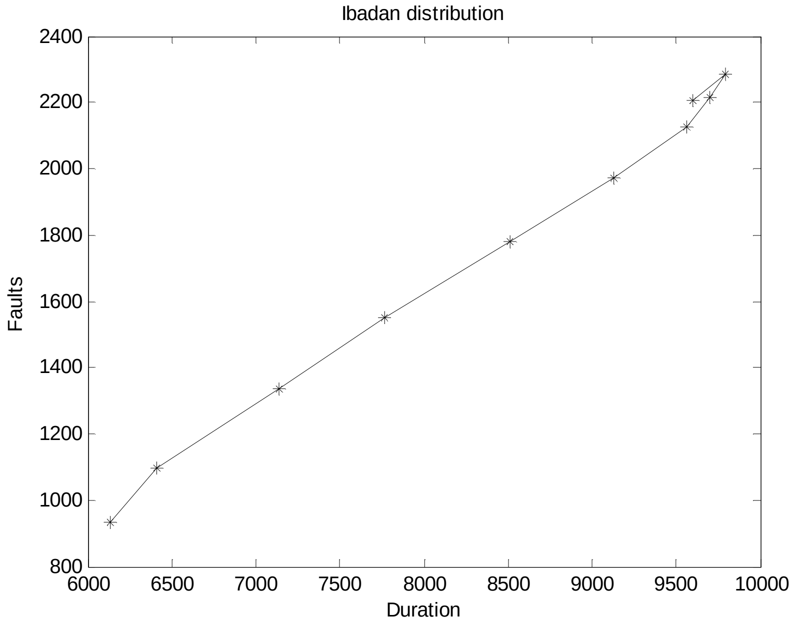

Figure 3: Variation of faults with duration for Ibadan distribution system.

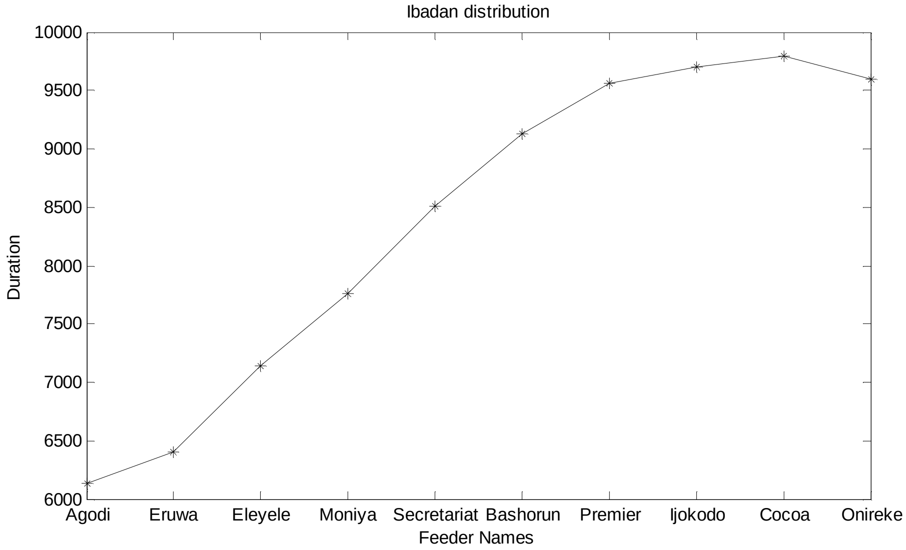

Figure 4: Variation of Duration of faults with feeder names for Ibadan distribution system.

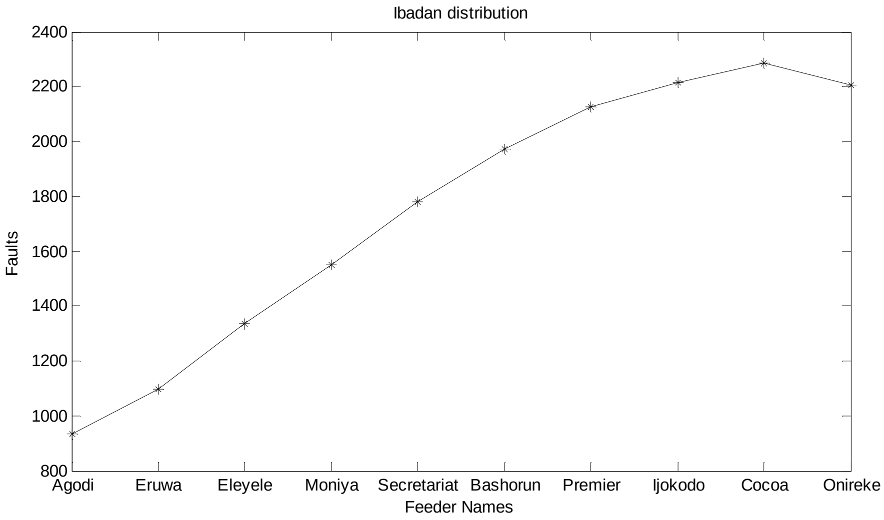

Figure 5: Variation of faults with feeder names for Ibadan distribution system.

In order to fit the data to a standard function and due to the approximation of the data, some degrees of polynomial were used in the developed model. The functional relationship between failure rate and time, using a 4-degree polynomial is expressed as follow:

The Failure rate model developed for Ibadan distribution system is:

:
$$y = 0.00007x^4 - 0.001x^3 + 0.001x^2 + 0.019x + 0.132$$

$$R^2 = 0.989$$

where:

y = Failure rate which is a 4-degree polynomial function.
x= Number of feeders.
R^2 = Coefficient of determination

The Failure rate model developed is a polynomial of order 4 . The order of the polynomial is as a result of the level of industrialization of the city compared to any other civilized city in the world..

5. Conclusion

A Polynomial Failure rate model has been developed for Ibadan distribution system.. The development of the model started with identification of system feeders and estimating the contributions of the system indices to the failure rate of selected feeders on the distribution system.

The mean and standard deviation of the system reliability indices were computed using statistical analysis. The computed system reliability indices were used as input parameters for the model.

The best curve that fitted the relationship between the failure rate and the number of feeders were obtained for the distribution systems and empirical equation for this curve was obtained for the distribution system. The generalized model is a polynomial whose order depends on the level of industrialization of the distribution system.

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