**Reliability and Maintenance of Assets in Electric Power Distribution network**


**Abstract**

Regular and stable supply of power to the consumers is very essential in the power system since reliability is one of the yardsticks that can be used to measure the performance of a service provider and reliability is ability of the system to function satisfactorily under stated condition at a particular period of time. Reliability and maintenance of assets in electric power distribution network was investigated using statistical analysis of outages data. Five years outages data caused by cables, transformers, breakers, line conductors and bursars & isolators were collected from Abule-Egba 33/11kV Injection substation in Ikeja Electricity Distribution Company, Lagos state and each year obtained data was represented in chart and also the comparison of the failures of different components within the observed years were represented in chart. Failure rate (λ), reliability ( $R_t$ ) and Mean Time between Failures (MTBF) were calculated and the obtained results were typified by chart .From the calculations and the data obtained from the station, it was observed that transformers had the lowest reliability(46.61%) and cables had the highest reliability (82.95%).



**Keywords: Reliability, Assets, Power, Distribution, Network and Outages**




**INTRODUCTION**

The electric power system is a very multifaceted infrastructure that is operated on a large- scale. Every human activity depends on it; hence it is expected to be reliable at all times. Reliability of power system is the probability that a power system will meet the consumers' load requirements at any time [1]. Power distribution system established mainly to provide adequate electricity supply to the customers as economically as possible with reasonable assurance of reliability. Nowadays, the power distribution networks have grown exponentially in term of size and technology over the past few years. As a result, The Utility Company must strive to ensure that the customers' reliability requirements are met with optimum strategic planning and lowest possible cost[3].Reliability of Power system can be explained as the ability of the system to function satisfactorily under stated planned actions for a certain time frame [10] and [13]. It can also be defined as the measure or the probability that a product or service will perform properly under normal operating condition for a specified period of time [4] and [13].

Asset management (AM) is a theory that is used for the operation and planning of the electrical power system. The purpose of AM is to handle physical assets in a most favorable/best way in order to fulfill goals of an organization and also considering time risk. In many situations, decisions regarding equipment maintenance, repair or replacement have been made in the heart of a crisis, usually at the time when critical equipment has failed and requires immediate attention [2]. AM in power industries plays a key role in the detection and evaluation of decisions leading to long term economical success and best possible earnings. For asset management to live up to these expectations, it has to meet a number of challenges. The four key challenges are: alignment of strategy and operations with stakeholder values and objectives; balancing of reliability, safety, and financial considerations; benefiting from performance-based rates; and living with the output based penalty regime. For this reason fundamental AM tasks cover aspects from technical issues like network maintenance scheduling or the definition of operational fundamentals to more economical themes like planning of investments and budgeting and end up in strategic planning issues [8]. Based on the activity aspect, asset management is categorized into technical, economical and societal asset managements and they are described below [7]:

- Technical asset management: Technical asset management refers to asset-related parameters such as physical condition of assets, inventory and maintenance. Ageing of components is of primary concern that links to the physical condition of assets. Other areas in this aspect are component condition, failure probability of assets, inventory or spare parts and maintenance history or future planning.
- Economical asset management: Economical asset management evolved when technical asset management at many instances proved to be financially unstable. As the name suggests economical asset management refers to financial aspect like maintenance costs

and other costs related to procurement of spare parts, maintaining the inventory and doing tests and assessment.

- Societal asset management: Societal asset management works closely with economical asset management. It refers to how the utilization of asset affects the society and environment. Any disturbances in other places like schools, government offices or convention centres will impact the status of distribution companies.

Maintenance management (MM) is therefore defined as an approach to handle decisions for these assets and to make precise and wise decisions on:

- What assets to apply actions to
- what actions to apply
- how to apply the actions
- when to apply the actions

The idea of maintenance is to increase the life span of the equipment or at least the mean time to the next failure whose repair may be costly. In addition, it is likely that effective maintenance policies will decrease the frequency of service interruptions and many unwanted consequences of such interruptions. Maintenance clearly affects system and component reliability. When much effort is not put to maintenance, a lot of catastrophe will be recorded and this will in turns cause too much number of costly failures and the performance of the system and will eventually reduce reliability of the system [5] and [2].

The maintenance tasks may be categorized into the following:

a) Routine inspection (RI) and visual and thermographic monitoring: This involves a visual inspection/investigation of the principle features of the substation facilities without requiring them to be taken out of service. Observations resulting from inspections may lead to the decision to carry out further maintenance activities.

b) Inspections on all Circuit Breakers (CB), transformers and isolators etc to check for abnormal conditions on the equipment. The conditions and meter readings of the equipment shall be recorded on the approved check sheets or feedback templates provided with job plans.

c) Minor maintenance: This involves the execution of scheduled or preventive maintenance work and may require the substation facilities to be taken out of service. Minor maintenance maybe time based and/or operational based. .

d) Major maintenance: This involves work performed with the objective of repairing, replacing or modifying parts/facilities as required. Major maintenance may involve the execution of specialized maintenance where specialized knowledge is required (live substation work)[8].

**Maintenance**

Maintenance is when the physical assets are continuously doing what their operators want them to perform. This will depend on how and where the asset is being employed (the operating context). Maintenance procedures are an integrated part of the planning, construction and operation of a system. Moreover they are crucial and central to the effective use of available equipment. The purpose of maintenance activities is to continuously meet reliability, performance and economic requirements, while also conforming to the constraints set by system and customer necessities [11]. The maintenance concept means all actions undertaken to keep or restore equipment to a desired state [9]. The cost of maintenance must be taken into consideration when handling system assets to minimize the lifetime costs of the system. However, some maintenance activities must be undertaken even if when they are not profitable, such as earth – plate – metering inspections stipulated in the IEE regulations for power system [6].

**Methodology**

In some cases, the distribution network will contain the following: Transformers, fuses, lines conductors (lines, poles and related items), cables (cables, junctions and related items), breakers, bus coupler, isolators and bus bars.

But five years outages caused by Cables, Breakers, Transformers, Bus bars &Isolators, Line conductors would be analyzed. Five years power outages that occurred as a result of improper planning, equipment failures and scheduled maintenance will be collected and outages due to insufficient power generation would be excluded. The data will be collected from Abule-Egba 33/11kV Injection substation in Ikeja Electricity Distribution Company, Lagos state. Equipment Maintenance is very important part of power systems. The power industry is highly demanding and competitive. Adequate planning and preparation towards maintenance will amount to a crucial part of reliability and asset management in distribution sector of power system because, in this part of the world only breakdown maintenance is been practiced. The outcomes of this will be regular and unannounced power failures and interruptions. The major challenge in the power industries today, especially the developing countries is that the demand for power is increasing speedily and the supply growth is forced by ageing generating stations/ plants and ageing distribution facilities and resources to construct new ones are not readily available

**Basic Theory of reliability**

R ($t$): is the reliability function: this is the probability of finding a healthy component in a healthy state after a time t.,

f (t ) : Failure density distribution: This is the rate at which a component will fail at time t.

h (t ):Hazard rate: The rate at which a component fails at time t given that it is healthy until time t .

λ = failure rate

t = time

μ = Repair Rate

Power equipment and power systems are vulnerable to failures that occurred due to internal or external sources. The failure of a component is the inability of a component to perform its intended /planned function at a particular time under specified operating conditions.

A failure is specified by its failure rate and repair rate.

Further reliability parameters given are also given as follows:

• **MTTF** (**Mean Time to Failure):** The average time it takes for a healthy component before it fails.

• **MTTR** (**Mean Time to Repair)** or **Repair Time:** This is the average time it takes to repair a failed component.

$$MTTR = \frac{Total\ duration\ of\ outages}{Frequency\ of\ outages} \quad (1)$$

• **MTBF**: **Mean Time between Failures:** This is the average time between two failures of the components. i.e.

$$MTBF = \frac{Total\ System\ operating\ hours}{Number\ of\ failures} \quad (2)$$

$$MTBF = MTTF + MTTR = \frac{1}{Frequecy} \quad (3)$$

$$Availability\ (A) = \frac{MTBF - MTTR}{MTBF} \quad (4)$$

From these parameters, some other parameters can be derived (when assuming the negative exponential distribution) [12]:

- $\lambda$= 1/MTTF: Failure rate: The rate at which a healthy component fails.
- $\mu$= 1/MTTR: Repair rate: The rate at which a failed component is repaired.
- $f$ = 1/MTBF: Failure frequency: The average frequency at which a component fails.

The failure rate $(f_t)$ can be calculated as shown below in equation (5)

$$f_t = \frac{n_f}{n_s} \text{ Or } \frac{n_f}{n_O} = \lambda \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (5)$$

$$f_{t=}\ \lambda$$

Where, $n_f$ = number of failures per year

$n_{O=Total\ number\ of\ obervation\ per\ year}$

$$n_s = total\ number\ of\ sucesses\ per\ year$$

The failure rate for the total numbers of the observed n consecutive years can be expressed as

$$\lambda_t = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \ldots\ldots + \lambda_n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ (6)$$

And n = number of the observed years

Reliability is given as,

$$R_t = e^{-\lambda t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (7)$$

$$R_t = P(T > t) = 1 - f_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..\ (8)$$

$$R_t = 1 - f_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (9)$$

Therefore Reliability of the system would be evaluated by using equation (9).

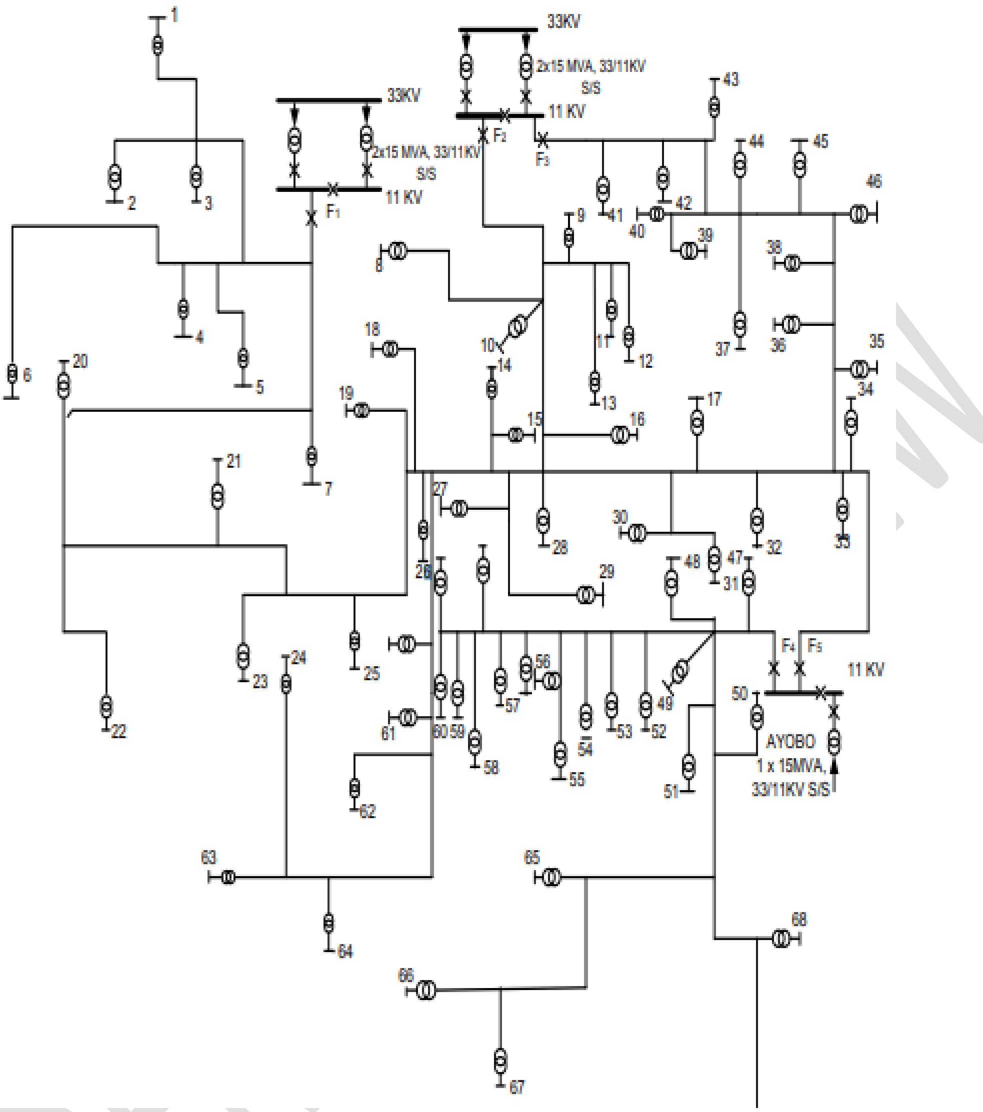


Figure1: A cross-section of the Abule Egba distribution business unit [2].

Table1: Power outages obtained from the Injection Substations.

| S/N | Names of the failed components | 2015 power outages | 2016 power outages | 2017 power outages | 2018 power outages | 2019 power outages |
|---|---|---|---|---|---|---|
| 1 | Cables | 10 | 15 | 12 | 15 | 10 |
| 2 | Breakers | 25 | 40 | 20 | 29 | 30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 3 | Transformers | 40 | 50 | 35 | 30 | 40 |
| 4 | Bursbars &Isolators | 15 | 20 | 20 | 25 | 27 |
| 5 | Line Conductors | 10 | 15 | 11 | 15 | 20 |
| **Total observed outages per year** | | 100 | 140 | 98 | 114 | 127 |

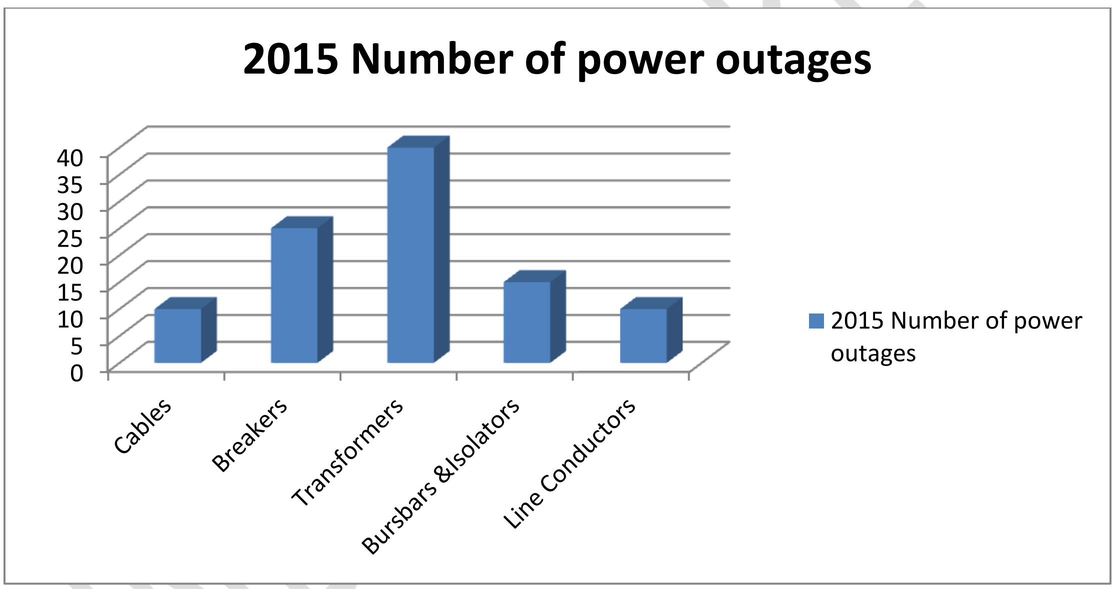


Figure2: 2015 distribution components power outages.

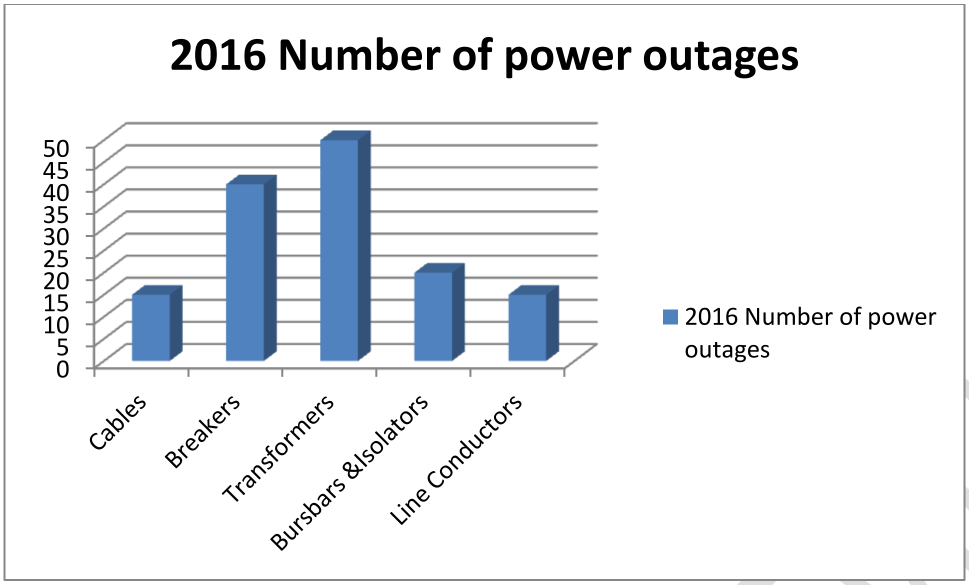


Figure 3: 2016 distribution components power outages.

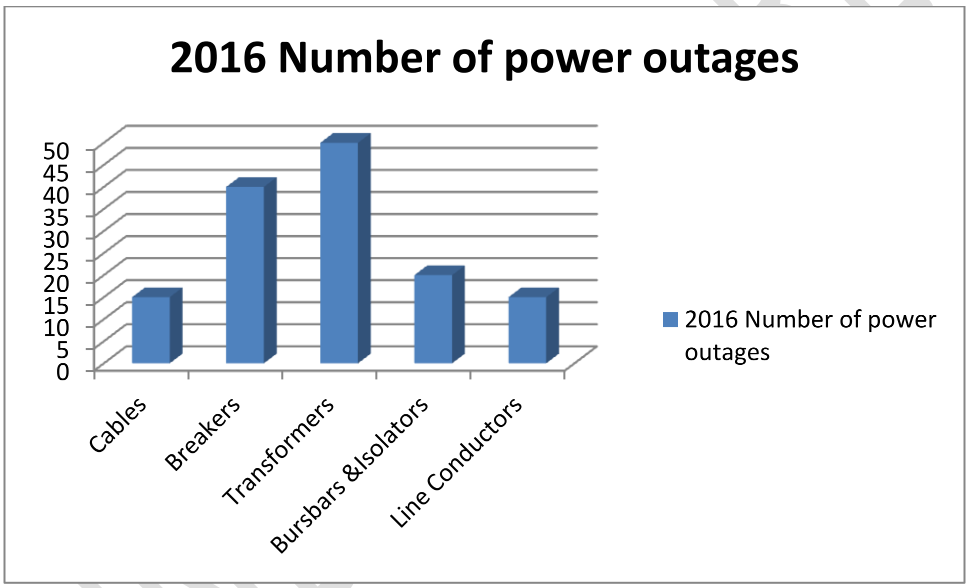


Figure 4: 2017 distribution components power outages.

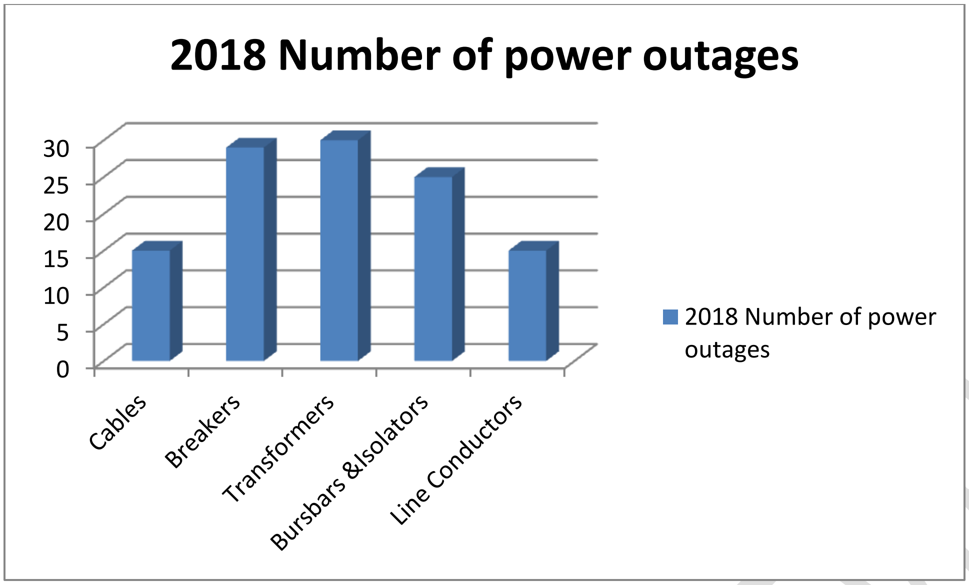


Figure 5: 2018 distribution components power outages.

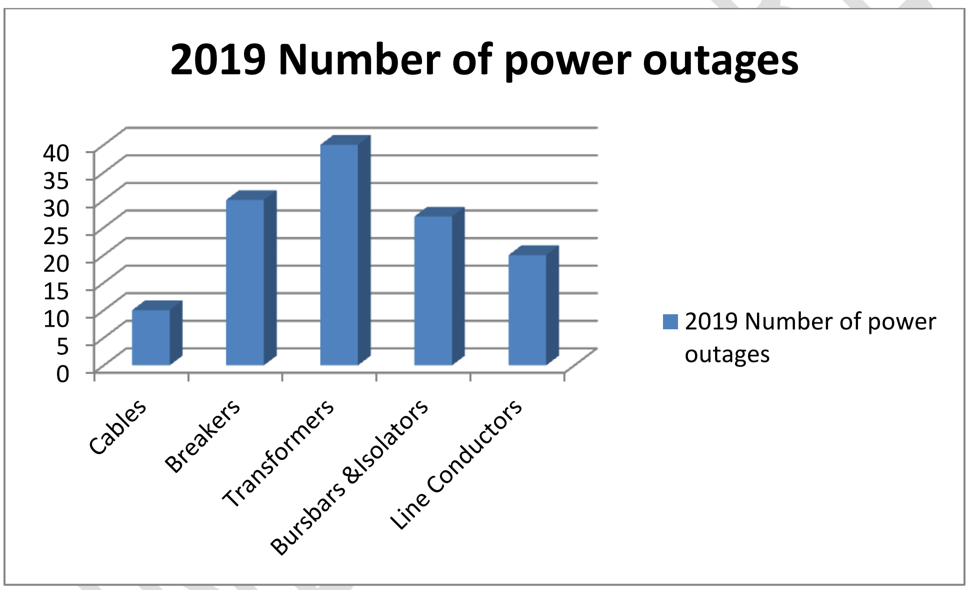


Figure 6:2019 distribution components power outages.

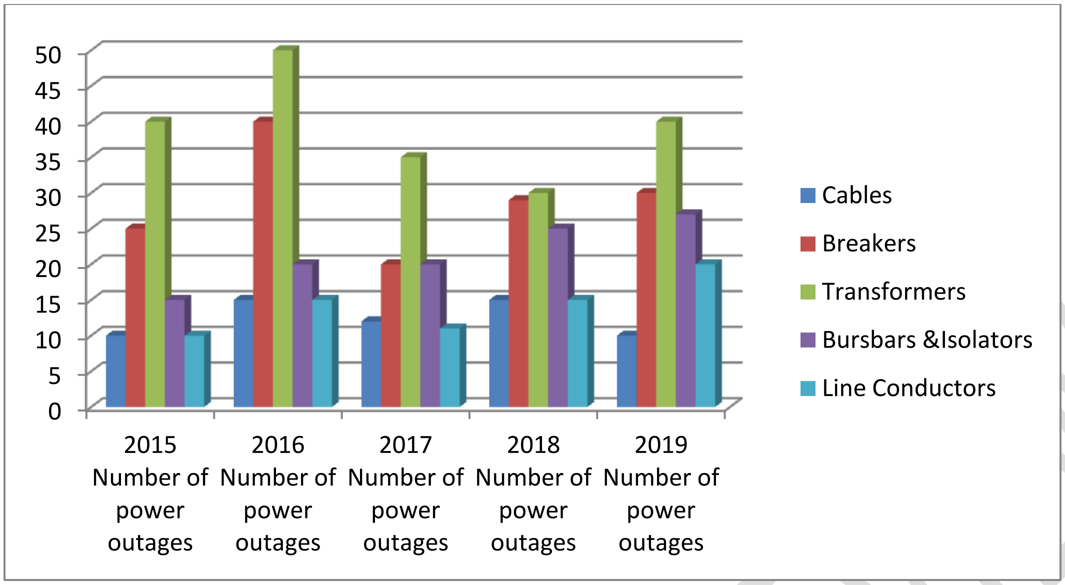


Figure 7: Comparison of the failures of different components within the observed years (2015 to 2019).

Table 2: failure rate (λ), reliability ( $R_t$ ) and Mean Time between Failures Mean Time (MTBF) between Failures

| **S/N** | **Components** | **Failure rate (λ)** | **Reliability ( $R_t$)** | MTBF = $\frac{1}{\lambda}$ |
|---|---|---|---|---|
| 1 | Cables | **0.1705** | **82.95%** | **5.865** |
| 2 | Breakers | **0.2958** | **70.42%** | **3.381** |
| 3 | Transformers | **0.5338** | **46.61%** | **1.873** |
| 4 | Bursbars &Isolators | **0.2938** | **70.62%** | **3.4037** |
| 5 | Line Conductors | **0.1951** | **80.49%** | **5.1256** |

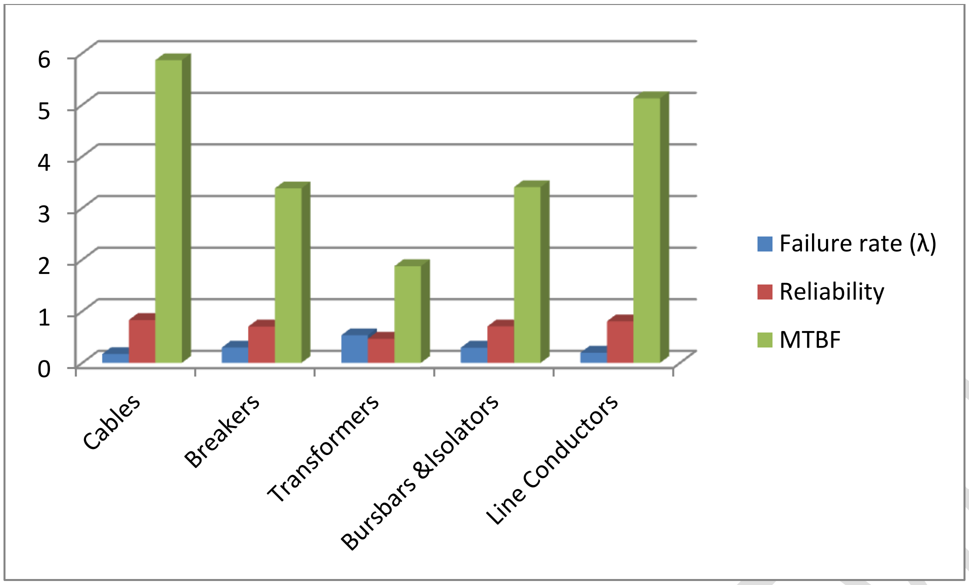


Figure8: Chart representing the failure rate (λ), reliability ( $R_t$ ) and Mean Time between Failures (MTBF).

**Conclusion**

Reliability and Maintenance of Assets in Electric Power Distribution network using Statistical Analysis of outages data was investigated from 2015 to 2019 using Abule Egba Business unit as a case study. The data was collected from the data log book of 33/11kV of Abule Egba injection Substation. This injection substation is been fed by 4x60MVA, 132/33kV, this injection substation in turn feed Thirty-three 11kV different customer feeders with 700 different loads – points. The obtained data were analysed by equations (1-9) and Table1 was used to represent the power outages obtained from all the assets under investigation and also, Table 2 represented the failure rate (λ), reliability ( $R_t$ ) and Mean Time between Failures (MTBF). Similarly, Figures 2-6 signified the distribution components of power outages from 2015 to 2019, Figure 7 indicated the comparison of the failures of different components within the observed years (2015 to 2019) and Figure8 displayed the failure rate (λ), reliability ( $R_t$ ) and Mean Time between Failures Mean Time (MTBF). From the calculations and obtained data it was observed that transformers had the lowest reliability (46.61%) ,it may be due to the fact that it  very vital in power system and most of the faults on power system do happen on transformers and cables had the highest reliability (82.95%).

**COMPETING INTERESTS DISCLAIMER:**

**Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.**

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