

RELIABILITY ASSESSMENT OF POWER GENERATING PLANT A CASE STUDY OF IKORODU GENERATING STATION

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Abstract

Reliability of power generating stations among others, has been one of the major factors that has contributed to unavailability of power supply in Nigeria. Thus, a lot of measure must be put in place to prevent occurrence of outages. In this regard, this study is carried out to determine the reliability of EGBIN power generating station which is important for technical decision making purposes. The total outage time of the generators, i.e. the number of time the generators at EGBIN power plant interrupts power supply for a six months period were collected and probabilistic approach was used to determine the reliability of the substation using indices such as availability, reliability, mean time to repair, the mean time before failure, and failure rate. Result obtained from the study during the period under investigation showed that the mean reliability of the supply system is 72.56%. For developing nation like Nigeria, the reliability is partly satisfactory. In addition, the reliability of Generator 1 was the highest (77.08%) while that of Generator 3 was the least (69.7%).

Keywords: Reliability, Availability, Mean-time-to-repair; Failure rate, Mean-time-before failure

1.0 Introduction

A power station is an industrial facility for the generation of electric power [1]. Most power stations contain generators, a rotating machine that converts mechanical power into electrical power. Electric current is thus created via the relative motion between a magnetic field and a conductor [1]. The energy source harnessed to turn the generator varies widely. Accordingly, most power stations in the world burn fossil fuels such as coal, oil, and natural gas to generate electricity while others use nuclear power. Recently, to generate electricity, there is an increasing use of cleaner renewable sources such as solar, wind, wave and hydroelectric [2]. Over the years, generation system has received less attention devoid to reliability studies compared to transmission and distribution network. This has been as a result of oversight, considering the amount spent on generating stations and the inadequacies can have widespread consequences for both consumers and suppliers. Hence, the reliability of power systems and their sub systems is a fundamental requirement towards achieving uninterrupted power supply. To determine the reliability of power systems and its subsystems, different probabilistic models have been employed [3]-[5]. Yet, the probabilistic models are not sufficiently general for reliability evaluation [5]. In a power system, the failures take place relatively seldom and the failure-repair cycle changes in very large limits. The questions when a failure occurs and how long it will take to repair are rather random than probabilistic cases hence, it does not give an accurate evaluation. Authors in [6] investigated the reliability analysis of distribution system based on Dynamic Bayesian Network. The drawback of this method is that it does not consider the impact of time factor to the variables, but reflect the probabilistic dependencies between variable and time varying of variables. On the other hand, work done in [7] employed the use of Artificial Neural Network method for reliability study. This method is not applicable for the reliability of generators hence, it needs further improvement. Since Electrical power is important to provide a cost effective way of tackling modern day challenges, the availability of a reliable power supply at reasonable cost is crucial for the economic growth and development of a country. Recently, it has been observed that around 90% of all transmission reliability problems are due to the problem in the generation system [7]. Thus, improving generating reliability is the key to improving transmission reliability. In contrast to existing result, using statistical analytical method, this work considers a

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detailed mathematical analysis on EGBIN power generating station in order to estimate the reliability of the generating station, and to proffer probable solutions to improve the reliability of the power supply for energy optimization in Nigeria.

2.0 Theoretical Analysis

This study focuses on the reliability analysis of EGBIN POWER GENERATORS. The parameter used to determine the reliability indices are failure rate, mean time between failure (MTBF), mean time to repair (MTTR), and availability. The research work concentrates on statistical analytical method since it has been the most adopted method over the years. In addition, statistical analytical methods provides high tolerance to uncertainties since they are more enhanced to provide useful and higher accuracy of reliability results.

2.1 Concept of Reliability

Reliability is defined as the probability that an item will be able to perform a required function in a specified period under stated conditions [8]. The reliability of an electric power system is therefore defined as the probability that the power system will perform the function of delivering electric energy to consumers on a continuous basis with acceptable service quality [8]. Since reliability is a measure of the probability of performance, its value lies between 1 and 0; (let reliability be R) when R= 1, the item will work as intended but when R=0, the item or equipment will absolutely not work as intended, i.e. the item or equipment has failed [8]. In order to assess the reliability of electric power generation at EGBIN power plant, Ikorodu, Lagos, the adopted approach is to obtain the estimate of the total outage time of the generators, i.e. the number of time the generator at EGBIN power plant interrupts power supply. In order to compute the reliability of the generators, the following reliability parameter are considered and used to determine the reliability of the system.

2.2 Reliability Parameters

In other to access the performance of the feeders, the various reliability indices were computed using:

a. Failure Rate, λ : This is a basic index of reliability. It is a measure of the frequency at which fault occurs [9]. Two definitions of failure rate are available depending on whether it relates to repairable or non- repairable items. The definition which relates to non-repairable items expresses failure rate as a percentage and is given by [8]:

$$\lambda(\%) = \frac{\text{Cumulative frequency for each month}}{\text{Period of occurrence for the month}} \dots\dots\dots(1)$$

The other definition relates to repairable items or systems and expresses failure rate as the number of failures which occurs per unit-hour of operation. It is denoted by $\lambda(N)$ and given as [8]:

$$\lambda(N) = \frac{\text{Number of times that failure has occurred}}{\text{Number of units-hours of operation}} \dots\dots\dots(2)$$

The unit of $\lambda(N)$ is therefore failures per unit-hour but failures per thousand hours and failures per million hours are used [8]. Obviously, a high value of $\lambda(\%)$ or $\lambda(N)$ is an indication of low reliability [10].

b. Mean Time between Failures (MTBF)

This is another index of reliability. It expresses the average time which elapses between consecutive failures of a repairable system or equipment. Mathematically, MTBF is given by [8]:

$$\text{MTBF} = \frac{\text{Total system operating hours}}{\text{Number of failures}} \dots\dots\dots(3)$$

It is worth noting that MTBF is the reciprocal of failure rate [8]. Clearly, the longer MTBF is, the more reliable the system is.

c. Mean Time to Repair (MTTR)

This is the average time that is needed to restore a system or an item to operational effectiveness once it fails. MTTR is therefore an index of maintainability and hence refers only to repairable items. MTTR is a function of the equipment design, the expertise of the personnel and the tools available. Clearly, a low value of MTTR indicates good maintainability [8]. Mathematically, MTTR is given by [8]:

$$\text{Mean time to repair (MTTR)} = \frac{\text{Total system downtime}}{\text{Number of failures}} \dots\dots\dots(4)$$

d. Availability (A)

This is an important basic index of reliability. It is the probability that an equipment will be available to perform as required or that it will be in a state of operational effectiveness within a given period. Mathematically, availability (A) is given as [8]:

$$\text{Availability (A)} = \frac{\text{MTBF} - \text{MTTR}}{\text{MTBF}} \dots\dots\dots(5)$$

e. Reliability

$$(R) = e^{-\lambda t}.$$

Where λ = Failure rate

R= Reliability

T= time (1day)

Administrative and logistics are assumed to be negligible. Thus, availability integrates both the reliability and maintainability parameters of the system.

3.0 Experimental Work

The aim of this analysis is to determine the failure rate, operating time, availability and reliability of the substation for six months. Accordingly, for mathematical simplicity, a series of mathematical computation for the reliability study of Generators at EGBIN Power Plant was carried out in this study, and the results are presented both in tabular and graphical form.

4.0 Results and Discussions

4.1 Failure Rate Result Data and Analysis

Table 1 shows the failure rate of each of the respective generator for six months, and its graphical representation is shown in Figure 1.

Table 1: Summary of the generator Failure rate over six month

| GEN./DATE | JAN. | FEB. | MAR. | APR. | MAY | JUNE |
|-------------|--------|--------|-------|-------|-------|-------|
| GENERATOR 1 | 0.0430 | 0.036 | 0.036 | 0.047 | 0.030 | 0.021 |
| GENERATOR 2 | 0.0470 | 0.022 | 0.023 | 0.036 | 0.027 | 0.013 |
| GENERATOR 3 | 0.057 | 0.046 | 0.056 | 0.069 | 0.059 | 0.039 |
| GENERATOR 4 | 0.061 | 0.0632 | 0.071 | 0.068 | 0.071 | 0.055 |
| GENERATOR 5 | 0.039 | 0.0259 | 0.030 | 0.046 | 0.028 | 0.015 |
| GENERATOR 6 | 0.032 | 0.0201 | 0.022 | 0.033 | 0.044 | 0.028 |

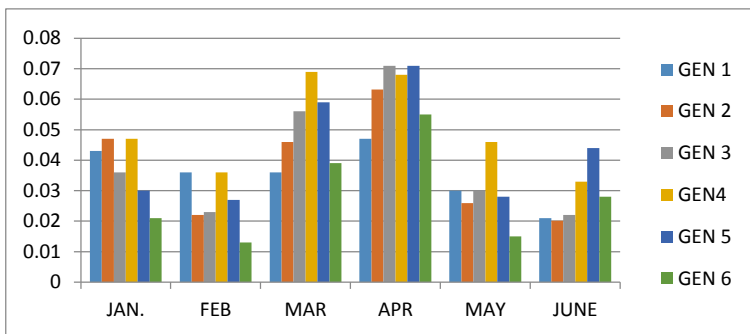


Figure 1: Bar chart representation of generator failure rate for six months

4.2 Mean Time Between Failure Result Data and Analysis

Table 2 shows the mean time between failure of each of the respective generator for six months, and its graphical representation is shown in Figure 2.

Table 2: Summary of the generator MTBF over six month.

| GEN./DATE | JAN. | FEB. | MAR. | APR. | MAY | JUNE |
|-------------|-------|-------|-------|-------|-------|-------|
| GENERATOR 1 | 23.25 | 27.82 | 27.55 | 21.18 | 33.82 | 48.00 |
| GENERATOR 2 | 21.26 | 46.40 | 42.76 | 27.69 | 37.20 | 80.00 |
| GENERATOR 3 | 17.71 | 21.75 | 17.71 | 14.40 | 16.90 | 25.71 |
| GENERATOR 4 | 16.53 | 15.82 | 14.08 | 14.69 | 14.04 | 18.00 |
| GENERATOR 5 | 25.69 | 38.67 | 33.82 | 21.82 | 35.43 | 65.45 |
| GENERATOR 6 | 23.1 | 49.71 | 46.50 | 30.00 | 22.50 | 36.00 |

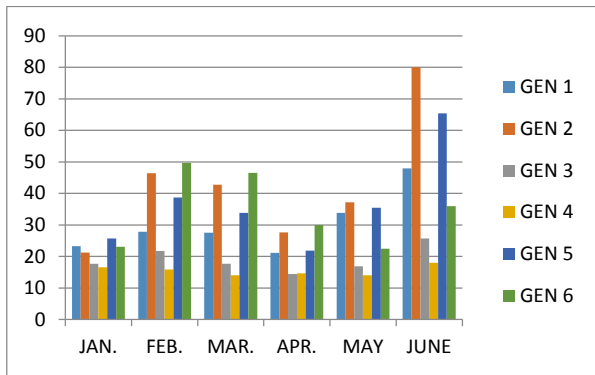


Figure 2: Bar Chart representation of generator MTBF for six month

4.3 Mean –Time- To - Repair Result Data and Analysis

Table 3 shows the mean time to repair of each of the respective generator for six months, and its graphical representation is shown in Figure 3.

Table 3: Summary of the generator MTTR for six month.

| GEN./DATE | JAN. | FEB. | MAR. | APR. | MAY | JUNE |
|-------------|-------|------|------|------|-------|-------|
| GENERATOR 1 | 5.37 | 4.01 | 5.86 | 3.89 | 3.20 | 8.50 |
| GENERATOR 2 | 12.28 | 3.09 | 5.05 | 4.14 | 3.24 | 9.68 |
| GENERATOR 3 | 9.66 | 6.37 | 8.16 | 8.04 | 7.92 | 9.98 |
| GENERATOR 4 | 5.88 | 3.23 | 3.86 | 3.49 | 3.17 | 4.73 |
| GENERATOR 5 | 3.96 | 3.07 | 7.60 | 8.00 | 11.09 | 12.27 |
| GENERATOR 6 | 3.34 | 2.68 | 6.20 | 4.51 | 8.94 | 7.96 |

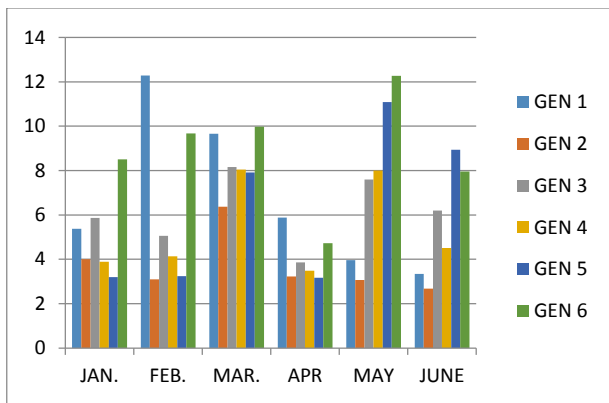


Figure 3: Bar Chart representation of generator MTTR for six month

4.4 Availability Result Data and Analysis

Table 4 shows the availability of each of the respective generator for six months, and its graphical representation is shown in Figure 4.

Table 4: Summary of the generator availability for six month

| GEN./DATE | JAN. | FEB. | MAR. | APR. | MAY | JUNE |
|-------------|------|------|------|------|-----|------|
| GENERATOR 1 | 17% | 85% | 78% | 81% | 90% | 82% |
| GENERATOR 2 | 42% | 93% | 88% | 85% | 91% | 87% |
| GENERATOR 3 | 45% | 70% | 54% | 44% | 93% | 61% |
| GENERATOR 4 | 64% | 79% | 72% | 76% | 77% | 73% |
| GENERATOR 5 | 84% | 92% | 77% | 63% | 68% | 81% |
| GENERATOR 6 | 89% | 94% | 86% | 85% | 60% | 73% |

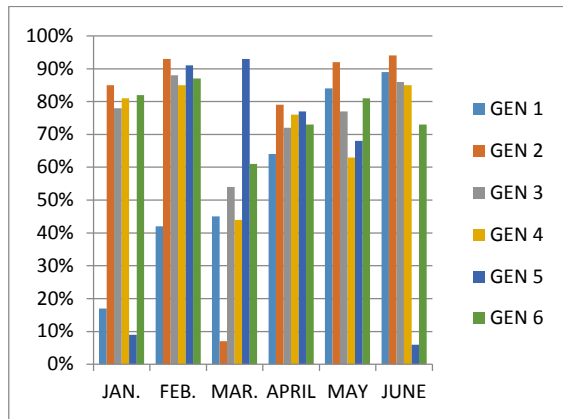


Figure 4: Bar Chart of the Generators Availability

5.0 Conclusion

Power system reliability assures an increased quality electricity supply which invariably improves the living standard of electricity consumers. Accordingly, accurate monitoring of power system is necessary to detect dangerous conditions that might damage or cause loss of service. From the results obtained, it is evident that the mean reliability of the supply system is 72.56%. For a developing country like Nigeria, the reliability is partly satisfactory. Suffice to say here that the reliability of **Generator 1** was the highest (77.08%) while that of **Generator 3** was the least (69.7%). Also, reliability of power being available at the distribution station is very poor because the power generated is smaller, when compared to the power demand. Further research in this and other related field is thus encouraged.

5.1 Recommendation

To improve power system reliability at EGBIN power generating station, this study recommends the following:

1., Redundancy in the System

System redundancy, which provides for “installed spares” that ensures the availability of excess capacity at all times should be included in power generating system design. In this regard, any unit needing repairs may be taken out of use without interrupting consumers’ supply, thus, mitigating the effects of faults.

2., Increased Repair Facilities

Sufficient repair facilities to carry out corrective maintenance should be made readily available, so that system downtime (MTTR) would be substantially reduced thereby ensuring a minimal loss of revenue.

3., Planned Maintenance and Regular Training of Personnel

To reduce the incidence of equipment failure, system or equipment parts should be replaced before the occurrence of faults. Also, training and re-training of technical staffs should be encouraged.

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