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ELECTRICAL LOAD RELIABILITY ASSESSMENT USING ANALYTICAL METHOD. CASE STUDY: FUPRE 1 X 2.5MVA INJECTION SUBSTATION

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Abstract: This paper presents the reliability assessment of electrical load distribution system in federal university of petroleum resources, Effurun (FUPRE), Warri using the Analytical Technique and ETAP software as the simulation tool to run the reliability assessment of the System. The analysis was carried out by using August 2018 – August 2019 historical data of Tetfund Classrooms Blocks, Hostels, Collage of Technology, Administration Block, Health Center, and College of Science Feeder obtained from the Benin Electricity Distribution Company [BEDC]. The results of the analysis revealed that Collage of Technology Injection Substation is the most reliable in the network when compared to the other five substations as it recorded system indices of ASAI: 99.30, SAIFI: 1.10, SAIDI: 55.35, CAIDI: 123.04 in August 2018 to August 2019. However, the overall reliability indices of the six substations under review as obtained from the analysis, revealed that availability of power to FUPRE distribution is very poor as compared with the benchmark of IEEE ASAI of 99.99 for distribution substation availability.

Keywords: Reliability Assessment, Availability of Power, Distribution System, Reliability Indices, Load Point Indices, System Indices and ETAP

1. INTRODUCTION

Reliable electric power supply is the bases for modern society. The fundamental capacity of a power system is to supply constant electricity to its customers at optimal operating costs with the affirmation of a reasonable quality and congruity consistently at all times. Power system reliability depicts the general capacity of the power system to perform its function adequately. Typically power system reliability discussions are divided into two separate perspectives, security and sufficiency. [1]

Power adequacy can be characterized as the presence of adequate facilities to fulfil the demand. Adequacy of a power system is identified to static conditions, and is normally analysed through power flow simulation studies. Security of power system reflects the capacity to respond to disturbances, henceforth, the security of a power system relates to the system dynamic response and can be analysed through unique studies. [2]

Electric power system is essentially set up to supply electric power with little or zero interruptions to its consumers. The number of interruptions that happen while the electric power system performs its intended function is part of what determines the general reliability of the system.

The other factor that determines its unwavering quality reliability is the quality of electrical power conveyed. Moreover, the ability of a power system to persistently convey quality electricity implies that the consumers are fulfilled and the power suppliers are having favorable returns on their investment as they continue their business of supplying electricity. As power utilization has become a significant factor that influences the drive needed for technology to grow and to encourage the development of modern society, it significant hence to pay attention to the issue of reliability of an electric power system. [3] Electric Generation, transmission and distribution are the three subsystems of an electric power system. Truth be told, a conventional electrical power system is centralized in terms of control and transmission of electrical power, the electrical energy produced by the generators in power plants flows over the grid from transmission and distribution system down to the consumers, as seen in figure 1.

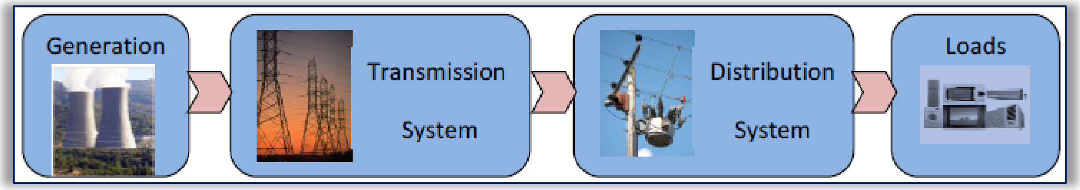

Figure 1. Power flow of a conventional power system

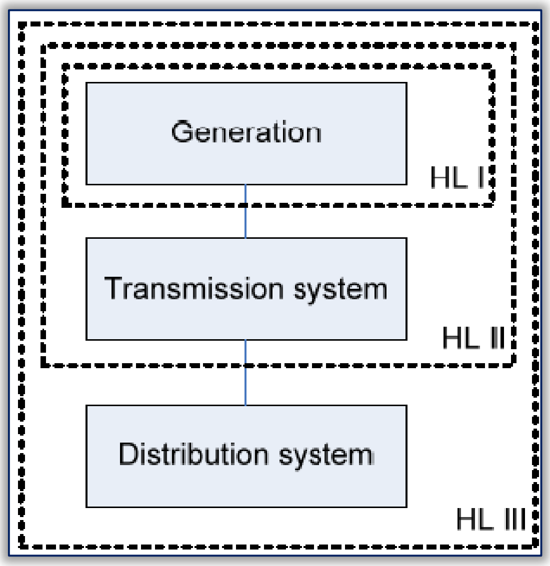

Figure 2. Power System Hierarchical Levels

In reliability analysis, electrical power systems are often divided into three parts to characterize the limits of the reliability assessment. These parts are alluded to as hierarchical levels, and can be portrayed as appeared in Figure 2.

Hierarchical level I (HL I) incorporates only generation and load of the system. An unwavering reliability study of HL I is an assessment of the overall system generating capacity necessary so as to fulfil the normal system demand.

Hierarchical level II (HL II) is in the power system unwavering reliability field regularly referred to as the "bulk power system", including electrical generation and transmission. Henceforth, an unwavering reliability study of HL II assesses the generation and transmission ability to supply the system load (distributed in bulk load points).

Hierarchical level III (HL III) includes the whole power systems (generation, transmission and distribution). Because of the complexity and size of the power system, an unwavering reliability study of HL III is ordinarily reasonable for little systems. [5]

Sufficiency evaluation at HL1 is concerned about just the ampleness of generation to meet the system load requirements and the territory of activity is typically termed as generating capacity reliability assessment. Both generation and associated transmission equipment are considered at HLII adequacy evaluation is once in a while alluded to as composite system or bulk system adequacy assessment. HLIII adequacy evaluation includes the consideration of all three utilization areas in trying to assess customer load point sufficiency. In this manner, Assessment of HLIII is along these seen as overall power system adequacy evaluation. [6]

The principle function of an electrical power system is to supply electric power to its customers at optimal operating costs with the affirmation of a good quality and continuity consistently [7]. Reliability is the likelihood that a power system will perform its capacities sufficiently with no disappointment within a stipulated period of time when subjected to normal working conditions [8]. The reliability study can be used to survey the performance of the distribution system based on the accessibility of reasonable input information of component data and the setup of the system. The dependability evaluation can likewise be utilized to identify the malfunctioned components that need dire substitution in the distribution system as well as proposing the numbers of new components that ought to be incorporated in order as to improve the unwavering reliability of the networks [9].

The motivation behind this paper is to establish a comprehensive overview of the field of analytical power system reliability assessment of the FUPRE network.

2 MATERIALS AND METHODS

— Materials

The materials used in this paper are the historical data of the six (6) distribution injection substations within the university network under review. These data covered the period of one year (August 2018 – August 2019), were derived from the daily operational report of the six (6) substations owned by Benin Electricity Distribution Company (BEDC).

— Network Description

The network under review is the 2.5 MVA, 33 / 11kV situated at an institution (FUPRE). The institution is situated in Effurun, Delta State, Nigeria. It get its supply from Effurun Transmission

Substation 33kV feeder. The incoming goes into the 2.5MVA transformer situated in the university premises. Figure 3 shows the 2.5MVA substation and its accessories.

Figure 3. 2.5 MVA Transformer and its accessories

The 2.5MVA transformer feeds six (6) substations within the university premises. They are one (1) MVA transformer situated behind the administration block, five (5) numbers of 500kVA, 11 / 0.415V transformers situated at, hostels, health center, Tetfund Classroom Buildings, college of Science and college of Technology buildings. Figure 4 shows a 500kVA, 11/415V substation situated at the college of technology.

Figure 4. 500kVA, 11/415V Transformer situated at College of Technology

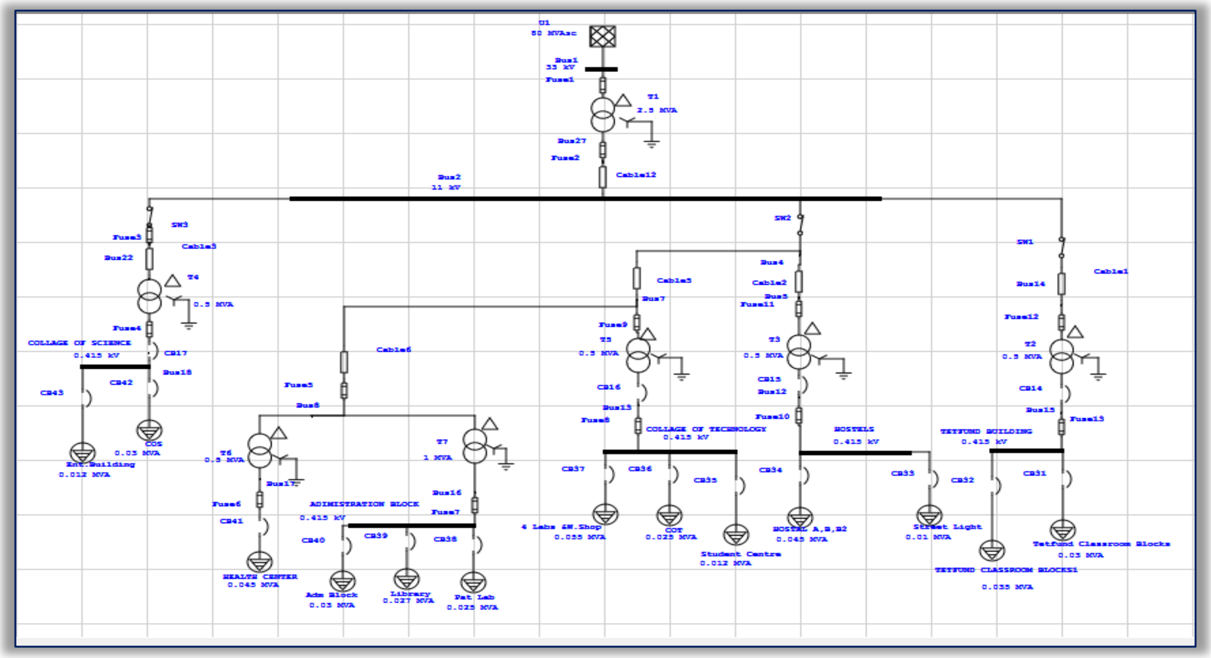

Figure 5. Single line diagram of the entire FUPRE Network in Electrical Transient Analyzer Programme (ETAP).

3. METHOD

In general, reliability assessment analysis can be performed either analytically or numerically, while this paper only treats analytical methods.

In analytical methods, the system is represented by mathematical models, which are typically based on Markov models. The expectation values of reliability indices are calculated by solving an equation system.

The most common numerical method is the Monte Carlo simulation method. In this method, the random behavior of the system is analyzed through simulation of physical relationships. The outcome of a Monte Carlo simulation is the expectation value probability distributions of reliability indices, i.e. not only the average values as in analytical methods. The method offers the possibility to apply more sophisticated component models, e.g. including effects of component aging. However this leads to increased computation time.

The Analytical Technique represents the system by a simplified mathematical model and evaluates the reliability indices from this model using direct mathematical solutions. The analytical technique is however used in this paper and the Electrical Transient Analyzer Program (ETAP) was utilized for the system analysis.

— Reliability Indices

A distribution system is that part of the power system which connects the bulk system to the individual customers. The distribution system reliability indices analysis is normally concerned with adequate electric power supply at the customer load point. The elementary distribution system reliability indices are the three load point indices, Average Failure Rate, (λ), the Average Outage Duration, (r) and the Annual Outage Duration, (μ).

— Load Point Indices

The basic equations for calculating the reliability indices at each load point, P are:

Average Failure Rate at load point, p,

$$\lambda_P = \frac{\Sigma F}{T} \text{ (f/yr.)} \tag{1}$$

where: F = load point failure frequency, T = Operating Time (a calendar year. i.e., 365×24hrs = 8,760hrs)

Annual Outage Duration at load point, p,

$$\mu_P = \frac{\Sigma T dx}{T} \text{ (hr / yr.)} \tag{2}$$

where: Tdx = Load point annual Down time (in hours), T = Operating Time

Average Outage Duration at Load Point, p

$$r_P = \frac{\mu_P}{\lambda_P} \text{ (hr.)} \tag{3}$$

Load Point Mean Time before Failure,

$$\text{MTBF} = \Sigma \frac{T}{F} \tag{4}$$

where: T = Operating Time and F = failure frequency

Mean Time to Repair,

$$\text{MTTR} = \Sigma \frac{T dx}{F} \tag{5}$$

where, Tdx = Load point annual Down time (in hours), F = Load point failure frequency

— System Indices

The system indices commonly used by utilities are SAIFI, SAIDI, CAIDI and ASAI. These indices can be calculated using the basic load point indices. I.e., Average Failure Rate, (λ), the Average Outage Duration, (r) and the Annual Outage Duration, (μ).

System Average Interruption Frequency Index,

$$\text{SAIFI} = \frac{\Sigma \lambda_T . N_T}{\Sigma N_T} \text{ (f/cust – yr.)} \tag{6}$$

where: λ_T = Failure rate; N_T = No of customers connected to load point, p

System Average Interruption Duration Index,

$$\text{SAIDI} = \frac{\Sigma \mu_T . N_T}{\Sigma N_T} \text{ (hr/cust – yr)} \tag{7}$$

where: μ_T= Annual Outage Duration at Load point, p, N_T = No of customers connected to load point, p

Customer Average Interruption Index,

$$CAIDI = \frac{\Sigma\, \mu_T\,.\,N_T}{\Sigma\lambda T\,.\,N_T}\ (hr/cust - int) \quad (8)$$

Average Service Availability Index,

$$ASAI = \frac{\Sigma\, N_T\,.8760 - \Sigma\, \mu_T\,.\,N_T}{\Sigma\, N_T\,.8760}\ (\%) \quad (9)$$

where 8,760 is the operating time, (i.e., the No of hours in a calendar year, 365 x 24hrs)

4. CASE STUDY

The substation under review consist of one (1) Transformer which have capacity of 2.5MVA and has six (6) distribution substation connected to it namely Collage of Science, Health Centre, Administration Block, College of Technology, Hostels and TETFUND Classroom Blocks.

The system is a 33/11kV Distribution substations which has a total number of 6,813 customers connected to 6 x 11/0.415V outgoing transformers or feeder, and it has been simulated by using the reliability assessment model of ETAP 16.00 software. The circuit was constructed using all required data and parameters as shown in the single line diagram in the figure 6.

5. RELIABILITY INDICES CALCULATION

The reliability indices for the system is manually calculated to show how the reliability module of ETAP software calculate the indices. This could be achieved in using the historical data of the network system is shown in table 1 by using reliability equation (1) to (9).

— **Average failure rate at load point T (Administration Block)**

$$\lambda_T = \frac{\Sigma f}{T} = \frac{804}{8760} = 0.1032 f/yr$$

Annual outage duration

$$\mu_T = \frac{\Sigma Tdx}{T} = \frac{6475}{8760} = 0.7393\ hrs/yr$$

Average outage duration

$$\gamma_T = \frac{\mu_T}{\lambda_T} = \frac{0.7392}{0.1032} = 7.1627\ hrs$$

Mean Time before Failure

$$MTBF = \frac{T}{\Sigma f} = \frac{8760}{904} = 9.69\ hrs$$

Mean Time to Repair

$$MTTR = \Sigma\frac{Tdx}{F} = \frac{6475}{904} = 7.163 hrs$$

— **Average failure rate at Load Point T (College of Science)**

$$\lambda_T = \frac{\Sigma f}{T} = \frac{882}{8760} = 0.1007\ f/yr.$$

Annual outage duration

$$\mu_T = \frac{\Sigma Tdx}{T} = \frac{4414}{8760} = 0.5039\ hr./yr.$$

Average outage duration at load point

$$\gamma = \frac{\mu_T}{\lambda}\ (hr) = \frac{0.5039}{0.1007} = 4.850\ hr/yr$$

Mean Time before Failure

$$MTBF = \frac{T}{\Sigma f} = \frac{8760}{882} = 9.932\ hrs$$

Mean Time to Repair

$$MTTR = \Sigma\frac{Tdx}{F} = \frac{4.414}{882} = 5.005 hrs$$

— **Average Failure rate at load point T (College of Technology)**

$$\lambda_T = \frac{\Sigma f}{T} = \frac{965}{8760} = 0.1102\ f/yr.$$

Annual outage duration

$$\mu_T = \frac{\Sigma Tdx}{T} = \frac{5951}{8760} = 0.6793\ hrs./yr.$$

Average outage duration

$$\gamma = \frac{\mu_T}{\lambda_T} = \frac{0.6793}{0.1102} = 6.1643 hrs$$

Mean Time before Failure

$$MTBF = \frac{T}{\Sigma f} = \frac{8760}{965} = 9.078\ hrs$$

Mean Time to Repair

$$\mathrm{MTTR} = \Sigma\frac{\mathrm{Tdx}}{\mathrm{F}} = \frac{5951}{965} = 6.167\mathrm{hrs}$$

— **Average Failure rate at load point T (Hostel)**

$$\lambda_{\mathrm{T}} = \frac{\Sigma \mathrm{f}}{\mathrm{T}} = \frac{588}{8760} = 0.0671\ \mathrm{f/yr.}$$

Annual outage duration

$$\mu_{\mathrm{T}} = \frac{\Sigma \mathrm{Tdx}}{\mathrm{T}} = \frac{4819}{8760} = 0.5501\ \mathrm{hrs.\ /yr.}$$

Average outage duration

$$\gamma = \frac{\mu_{\mathrm{T}}}{\lambda_{\mathrm{T}}} = \frac{0.5501}{0.0671} = 8.198\mathrm{hrs}$$

Mean Time before Failure

$$\mathrm{MTBF} = \frac{\mathrm{T}}{\Sigma \mathrm{f}} = \frac{8760}{588} = 14.898\ \mathrm{hrs}$$

Mean Time to Repair

$$\mathrm{MTTR} = \Sigma\frac{\mathrm{Tdx}}{\mathrm{F}} = \frac{4819}{588} = 8.196\mathrm{hrs}$$

— **Average Failure rate at load point T (Tetfund Classroom Block I)**

$$\lambda_{\mathrm{T}} = \frac{\Sigma \mathrm{f}}{\mathrm{T}} = \frac{589}{8760} = 0.0672\ \mathrm{f/yrs.}$$

Annual outage duration

$$\mu_{\mathrm{T}} = \frac{\Sigma \mathrm{Tdx}}{\mathrm{T}} = \frac{1985}{8760} = 0.2266\ \mathrm{hrs.\ /yr.}$$

Average outage duration

$$\gamma = \frac{\mu_{\mathrm{T}}}{\lambda_{\mathrm{T}}} = \frac{0.2266}{0.0672} = 3.372\mathrm{hrs}$$

Mean Time before Failure

$$\mathrm{MTBF} = \frac{\mathrm{T}}{\Sigma \mathrm{f}} = \frac{8760}{589} = 14.873\ \mathrm{hrs}$$

Mean Time to Repair

$$\mathrm{MTTR} = \Sigma\frac{\mathrm{Tdx}}{\mathrm{F}} = \frac{1985}{589} = 3.37\mathrm{hrs}$$

— **Average Failure rate at load point T (Health Centre)**

$$\lambda_{\mathrm{T}} = \frac{\Sigma \mathrm{f}}{\mathrm{T}} = \frac{620}{8760} = 0.0708\ \mathrm{f/yrs.}$$

Annual outage duration

$$\mu_{\mathrm{T}} = \frac{\Sigma \mathrm{Tdx}}{\mathrm{T}} = \frac{4892}{8760} = 0.559\ \mathrm{hr.\ /yr.}$$

Average outage duration

$$\gamma = \frac{\mu_{\mathrm{T}}}{\lambda_{\mathrm{T}}} = \frac{0.559}{0.0708} = 7.896\mathrm{hrs}$$

Mean Time before Failure

$$\mathrm{MTBF} = \frac{\mathrm{T}}{\Sigma \mathrm{f}} = \frac{8760}{620} = 14.129\ \mathrm{hrs.}$$

Mean Time to Repair

$$\mathrm{MTTR} = \Sigma\frac{\mathrm{Tdx}}{\mathrm{F}} = \frac{4892}{620} = 7.89\mathrm{hrs}$$

6. SYSTEM INDICES

The reliability assessment indices of the Institution system are calculated using equations (6) to (9) Applying these equations yields

— System Average Interruption Frequency Index (SAIFI)

College of Science (COS)

$$\mathrm{SAIFI} = \frac{\Sigma\lambda_T.\mathrm{N}_T}{\Sigma \mathrm{N}_T} = \frac{(1.1025\ X\ 2299)+(1.1105\ X\ 869)}{2299+869} = 1.105\mathrm{f/Cust} - \mathrm{yr.}$$

— System Average Interruption Duration Index (SAIDI)

$$\mathrm{SAIDI} = \frac{\Sigma\mu_T.\mathrm{N}_P}{\Sigma \mathrm{N}_T} = \frac{(135{,}6851\ x\ 2299)+(136.5651\ x\ 869)}{2299+869} = 135.93\ \mathrm{hrs/Cust\text{-}yr.}$$

— Customer Average Interruption Index (CAIDI)

$$\mathrm{CAIDI} = \frac{\Sigma\mu_T.\mathrm{N}_T}{\Sigma\lambda_T \mathrm{N}_T} = \frac{(135.6851\ x\ 229)+(136{,}5651\ x\ 869)}{(1.1025\ x\ 2299)+(1.1105\ x\ 869)} = 123.04\mathrm{hrs/Cust.\ Int}$$

— Average Service Availability Index (ASAI)

$$\text{ASAI} = \frac{\Sigma N_T.8760 - \Sigma \mu_T.N_T}{\Sigma N_T.8760} = \frac{(3{,}169\ x\ 8760) - (135.6851\ x\ 2299) + (136.5651\ x 869)}{3{,}169\ x\ 8760}$$

$$= 0.98449 \text{ x } 100 = 98.45\%.$$

where 8760 is the operational time (i.e. the no of hours in a calendar year 365 x 24hrs)

7. RESULTS

The distribution network under review has modelled and simulated using Reliability Assessment model of ETAP as shown in figure 6. The historical data used for modelling of this substation under review is shown in table 1 which were used to run the simulator and different results were obtained are shown in table below.

Table 1: Historical Data of the Distribution System

Load point	Failure Frequency	Annual Downtime (hrs.)	Annual Uptime (hrs.)	No of Customers	Customer Type
Collage of Science Building	882	4,414	3,134	2,299	Offices/Labs
Collage of Technology Building	965	5,951	6,886	85	Offices
Health Centre	620	4592	4,206	57	Commercial
Hostels	588	4,819	5,507	528	Residential
TETFUND Classroom Block 1	589	1,985	2952	146	Offices/Labs
Administration Block	904	6,475	5,180	92	Offices
Entrepreneurship Building	492	2,802	3,521	869	Offices/Labs
Library	648	5208	4801	180	Offices
Petroleum Lab	538	3935	2,890	828	Offices/Labs
4 Labs &Workshop	9,818	9,670	7,904	1,380	Offices/Labs
Student Centre	3,956	4,718	3,902	47	Offices
Street Light	2,984	1,869	2,957	192	Lights
Tetfund Classroom Block 2	6,792	4,891	3,619	110	Offices

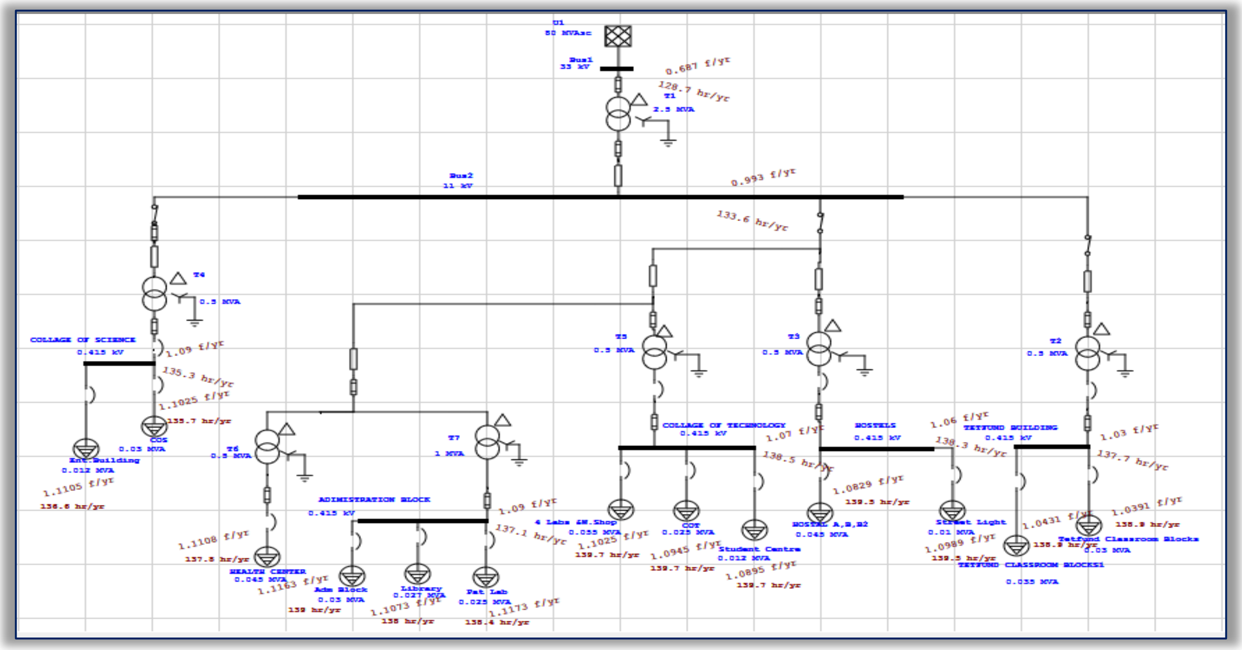

Figure 6. Fupre Distribution Network in ETAP 16.00 Simulation Environment

Table 2: Load Point Indices of the Distribution Network

Load Point	λ_T (f/yr)	γ_T (Hours)	μ_T (f/yr)
Hostels	1.0829	128.83	139.5043
Street Light	1.0989	126.95	139.5046
Collage of Science Building	1.1025	123.08	135.6851
Entrepreneurship Building	1.105	122.98	136.5651
4Labs & W.Shop	1.1025	126.71	139.6933
Collage of Technology	1.0945	127.62	139.6789
Students Centre	1.0895	128.22	139.6943
Administration Block	1.1163	124.50	138.9746
Library	1.1073	124.65	138.0197
Petroleum lab	1.1173	123.84	138,3607
Health Centre	1.1108	124.02	137.7600
Tetfund Classroom Block 1	1.0431	133.19	138.9302
Tetfund Classroom Block II	1.0391	133.70	138.9306

Table 3: System Indices of the Substation under Review

Substation	SAIFI (Int/yr.)	SAIDI (Hrs. /yr.)	CAIDI (Hrs./Cust.Int)	ASAI (%)
College of Science	1.11	135.93	123.04	98.45
College of Technology	1.10	60.98	55.35	99.30
Hostels	1..09	139.50	128.32	98.41
Tetfund Classroom Blocks	1.04	138.93	133.41	98.41
Health Centre	1.11	137.76	124.02	98.43
Administration Blocks	1.12	138.54	124.19	98.42

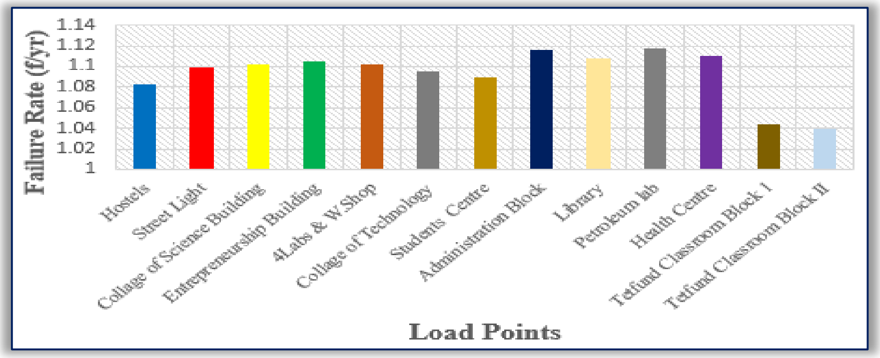

Figure 7. Bar Chart of Failure Rate with Respect to Load Points

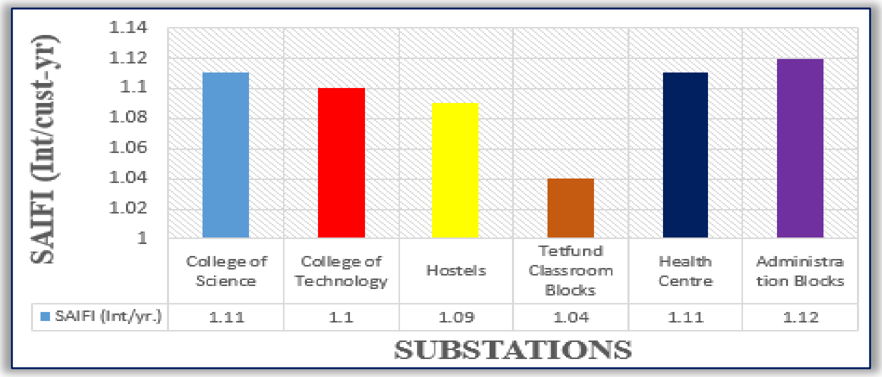

Figure 8. Bar chart of SAIFI with Respect to Substation.

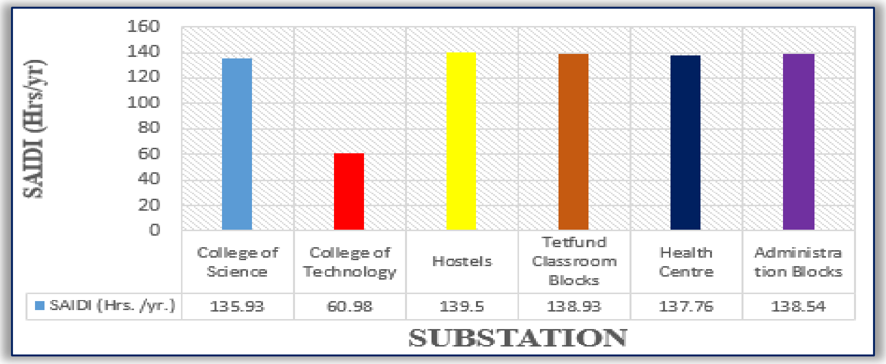

Figure 9. Bar chart of SAIDI with Respect to Substation.

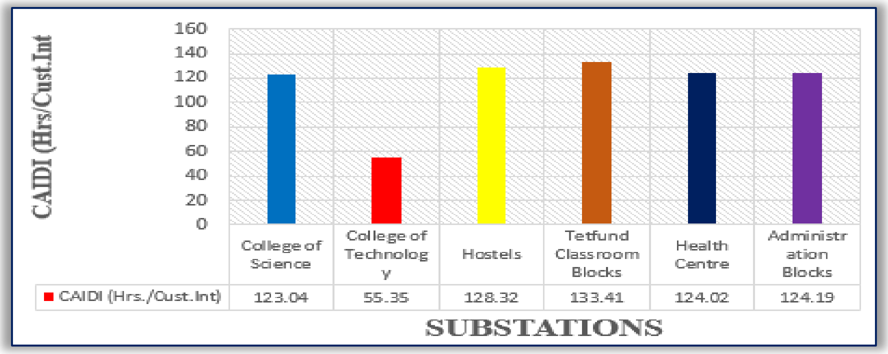

Figure 10. Bar chart of CAIDI with Respect to Substation

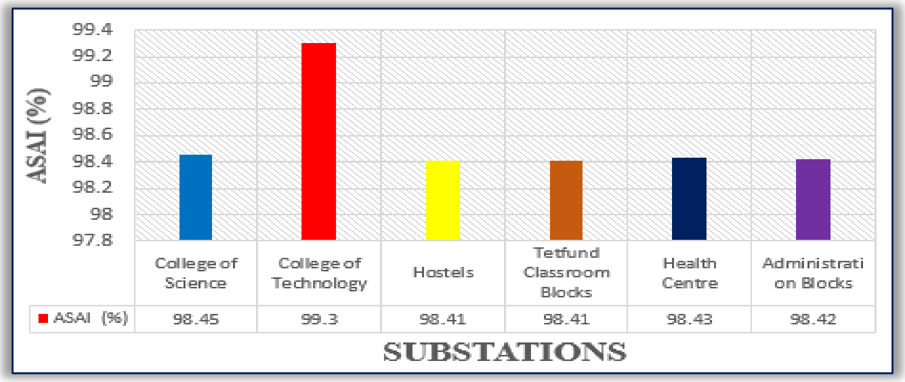

Figure 11. Bar chart of ASAI with Respect to Substations.

In table 3 and fig 8 - 11 shows the system indices of the substation results. From the results represented in the table 3 and fig 10 shows that Tetfund Classroom Blocks has highest CAIDI of 133.41hours which means on average, customers on this network will experienced power outage more than 133hours and fig 9 indicate the system SAIDI for the period of one year under review and it was observed that Hostels recorded the highest hours for which the customers were out of power of above 138.50 hours as compared to other substations. In the same vein fig 8 shows that Administration Block substation customers has highest SAIFI of 1.12Int/yr., which means it has 1.12 probability of experiencing power outage for the period of one year, with next high exhibited be the College of Science, Health Centre, College of Technology and Hostels respectively with the lowest displayed is Tetfund Classroom Blocks. Finally taking a look at fig 11 shows the highest ASAI of Collage of Technology network with a value of 99.30%, SAIDI of 60.98hours per year, CAIDI of 55.35hour per outage and SAIFI of 1.10 interruption per year. The average system availability index (ASAI) IEEE standard of utility have been recorded to have a value of 99.99% or four-nines. Therefore with the results presented have shown that the system is unreliable and very poor.

4. CONCLUSION

Electric power system is essentially set up to supply electric power with little or zero interruptions to its consumers. The number of interruptions that happen while the electric power system performs its intended function is part of what determines the general reliability of the system, moreover power utilization has become a significant factor that influences the drive needed for technology to grow and to encourage the development of modern society, it is significant hence to pay attention to the issue of reliability of an electric power system. From the analysis carried out so far, it has been verified that however the frequency of outage affect the reliability, but the outage duration has more influence on the system and on reliability. Administration Block, Petroleum Lab has the highest number of failure rates and Hostels, Tetfund Classroom Blocks had the highest duration of outages. However it was the Hostels and Tetfund Classroom Blocks that had highest value for system unavailability throughout the year. This means that even if there are failures or faults in the network, it is the duration for which the outage is certified that critically influence the overall system.

Furthermore the results also shown that Collage of Technology is the most reliable in the network. Equally, reliability indices of the system as presented above shows that the availability of power in FUPRE distribution network is below internationally set benchmark for utilities. Hence, the system can be characterised as unreliable or poor. In future the effect of photovoltaic system at the different load point of the distribution network can be used to improve reliability.

References

[1] R. Billiton, R. N. Allan, "Power-system reliability in perspective", IEE Electronics and Power, Vol. 30, No. 3, March 1993.
[2] M. Zima, "Contributions to Security of Electric Power Systems", ETH, 2006.
[3] A.A. Adebisi, "Reliability Evaluation of Secondary Distribution System in Nigeria: A Case Study of Ayetoro 1 Substation, Aguda, Lagos State" A Dissertation Submitted To The Department of Electrical and Information Engineering, College of Engineering, Covenant University, Ota, Ogun State, Nigeria. July, 2017.
[4] T. K. Vrana, E. Johansson "Overview of Power System Reliability Assessment Techniques" Norwegian University of Science and Technology, Norway.
[5] Billinton, R. and Allan, R.N., "Reliability Evaluation of Power Systems" 1st Edition, Plenum Press, New York, 1996.

[6] Aprajita Tripathi & Shilpi Sisodia "Comparative Study of Reliability Assessment Techniques for Composite Power System Planning & Applications". International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 International Conference on Emerging Trends in Mechanical and Electrical Engineering (ICETMEE- 13th-14th March 2014)
[7] D'Annunzio C., "Generation Adequacy Assessment of Power Systems with Significant Wind Generation: A System Planning and Operations Perspective", Unpublished Thesis, the University of Texas at Austin, 2009.
[8] X. Wang and J. Lin, "Reliability evaluation based on network simplification for the distribution system with distributed generation," *Automation of Electric Power Systems*, vol. 34, no. 4, pp. 38–43, 2010.
[9] A.E.Airiboma, E.A.Ogujor and I.K. Okakwu, "Reliability analysis of power system network; case study of transmission Company of Nigeria, Benin City", Conference paper – June 2017; DOI 10.1109/Power Africa.2017.7991206.

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