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Improved Reliability Analysis of Electricity Power Supply to Port Harcourt Distribution Network

[1]S. L. Braide, 2E. O. kenneth
[1]Department of Electrical/Computer EngineeringRivers State University, Port Harcourt, Rivers State Nigeria
[2]Faculty of Engineering Rivers State University, Port Harcourt, Rivers State Nigeria
Corresponding auther: S. L. Braide

Abstract:*This paper presents an analysis of reliability assessment for some area of electrical energy distribution system in Port Harcourt using analytical approach being supported by Electrical transient analyzer tool (ETAP) in order to run simulation on reliability assessment of the system. The investigation considered station-road, Amadi-North, floor-mail and Borikiri substation for purpose of analysis and verification. From the simulation results from system indices of ASAI: 0.9986pu, SAIFI: 0.7840 f/customer.yr, SAIDI: 12.66440hr/customer.yer, CAIDI: 16.128 hr/customer interruption in 2016 and ASAI: 0.9990pu, SAIFI: 0.78208/customer, yr. SAIDI:12.7740 hr/customer.yr, CAIDI: 16.108hr/customer interrupting in 2017. The reliability indices of the substations under study as obtained from the anlaysis, revealed that the reliability of the distribution system is below the set standard. Evidently improvement technique will be recommended in order to strengthen the activity of the system.*

Keywords: *reliability, distribution network, power supply, meantime to repair (MTTR), outage duration, meantime to between failure (MTBF)*

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I. Introduction

The reason for an electrical power system supply is for the provision of adequate supply of electrical power to all utilization point which also has to be at an economical rate for acceptance and reliability at reasonable level. Reliable power supply is of great importance in the electrical power system network for residential, commercial, industrial for purpose of economic growth for a given nation or place. Availability and reliability of a quality electric power supplied without interruption becomes extremely important. The importance of power system reliability is demonstrated when our electricity supply is disrupted, whether it decreases the comfort of our free time at home or causes the shutdown of our companies and results in huge economic deficits. The objective of Assessment of Power System Reliability is to contribute to the improvement of power system reliability [16].

Distribution of system reliability is an important measure of utility performance. In order to quantify the reliability of the distribution system, using system indices also known as reliability indices are used. The indices are statistical collections of reliability data. They are used as way to assess the effectiveness of the distribution system to supply power to the customer continually [2].

Amongst the three classof power system in Nigeria: Generation, Transmission and Distribution. Analysis and techniques of reliability and evaluation has shown the fact that the distribution network system at its level is less developed compared to generation and transmission, since it suffers lower outage than the others[4].

More so, based on analysis and statistics, it is known that the distribution power system accounts for 70% to 80% of the unavailability and reliability problems of the consumer, therefore, improving the distribution system is a vital step towards improving reliability and availability of electric power.

The fundamental purpose of Electrical power system is to provide an adequate electric power supply to all points of utilization at an economically acceptable rate with reasonable level of reliability.

Reliability of power supply has always been an important issue in the electric utility systems. Availability of high quality uninterrupted electric power system is essential to the industrial and economic growth of a nation.

Electricity supply involves a very complex and highly integrated system. Failures in any part of it can cause interruptions which range from inconveniencing a number of local residents, to major and widespread disruptions of supply. The economic impact of these outages is not restricted to loss of revenue by the utility or loss of energy utilization by the customer but include indirect costs imposed on the society and the environment due to the outage [11]

A power system consists of a generation, transmission and a distribution system. Traditionally, reliability analysis and evaluation techniques at the distribution level have been far less developed than at the generation or transmission levels since distribution outages are more localized and less costly than generation and transmission level outages.

However, analysis of the customer failure statistics of most utilities shows that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer [10]. The distribution systems account for 80% of all customer reliability problems. Hence, improving distribution reliability is the major element required to improve customer reliability [11].

Since the primary purpose of the system is to satisfy customer requirements and the proper functioning and longevity of the system are essential requisites for continued satisfaction, it is necessary that both demand and supply considerations are appropriately viewed and included in the systems. Therefore, the distribution reliability is one of the most important in the electric power industry due to its high impact on the cost of electricity and its high correlation with customer satisfaction[6].

II. Problem Statement

Reliable electric power supply is essential for modern society as it is one of the vitalelementdriving every economy.

The rapid increase in the population of people migrating from the rural areas to the urban areas, particularly Port Harcourt, Rivers State has caused an unprecedented increase in energy demand. However, the power system facilities, particularly the distribution network has not experienced a proportionate expansion adequate enough for maintenance thus leading to:

- Overloading of the system,
- System losses due to mismatches between the power generation and power received.
- unreliable power supply to consumers
- Transient behavior of the systems.
- Overloading of feeder (conductors, resulting to over-heating and insulation breakdown.
- Constant power outages leading to shutdown of production activities and eventual loss of revenue and gross profits.
- Overloading of substation
- Overloading of the system result to overheating of the system which has caused deficiency of the system to supply a reliable power to the consumer.

Therefore, there is a need to improve/upgrade and expand the distribution power system in Port Harcourt.

However considering the immense need for the improvement and the expansion of the distribution Network system in Port Harcourt will however not be achieved without a proper Reliability Assessment of the network.

Objectives of the Paper

- A reliability analysis of some substations from Port Harcourt Town distribution system shall be carried out using the Analytical Technique.
- To analyse the reliability indices of the distribution network of the area in view using performance data from Port Harcourt Electricity Distribution Company (PHEDC).
- To ascertain the Load Point Indices, System Indices and Cost Worth Indices of the distribution network which will thus reveal the reliability level of the network.

III. Materials And Methods

Materials

Electrical Transient Analyzer Program — ETAP

The Reliability Assessment software deployed to run the reliability assessment of the distribution network covered in this study is the Electrical Transient Analyzer Program (ETAP) software.

ETAP is a fully graphical electrical power system analysis program developed by Operation Technology Incorporated which has her headquarters in Irvine, California, USA. It is one of the most comprehensive tool for the design and analysis of power system reliability.

ETAP software capabilities and system analysis modules include but not limited toReliability Assessment Analysis, Load Flow Analysis, Short Circuit Analysis, OptimalPower Flow Analysis, Motor Acceleration Analysis, Transient Stability Analysis,Harmonics Analysis, Dc Load Flow Analysis, Dc Short Circuit Analysis, UnbalancedLoad Flow Analysis, Battery Discharge Sizing, Transformer MVA Sizing, Switching Sequence Management, etc.

The reliability assessment module of ETAP can calculate and produce output reports of reliability indices like load point Indices (i.e., Failure rate of the distribution network, Average outage duration, and annual outage duration),system indices (i.e., System Average Interruption Frequency Index – SAIFI, System Average interruption Duration index – SAIDI, Customer. Average Interruption duration index – CAIDI and Average Service Availability Index – ASAI) and cost worth indices (i.e, Expected Energy Not Supplied – EENS, Expected InterruptionCost – ECOST, Average Energy Not Supplied – AENS etc.). Hence, it is in no doubtadequate, suitable and has the required capabilities needed for this study.

Methods

The Distribution Injection Substations covered in this study are fed from the Port Harcourt town 132/33kv injection transmission substation located at Nzirimo street by Port Harcourt - Aba express way, Port Harcourt which derives its power via two 132kv transmission lines from Afam power station locate at Afam, Oyigbo local government area of Rivers State.

The figure 1 illustrated in a tabular form as shown in table 1 below, AbonnemaWharf and Ikwerre Road 11kv outgoing feeders are supplied from Silver Bird 115MVA 33/11kv Injection Substation.Udi and Nsukka 11kv outgoing feeders and fed from Water Works 15MVA 33/11kv Injection Substation. State government secretariat 2xl5MVA 33/11kv Injection substation which is commonly referred to as Secretariat supplies Station Road, Amadi North, Flour Mill and Borokiri 11kv outgoing feeders.Ojoto, RSU, Federal and Wokoma 11kv outgoing feeders are fed from RSU 2xl5MVA 33/11kv Injection Substation which is domiciled at the Rivers State University, Nkpolu- Oroworukwor, Port Harcourt.

Finally, School of Nursing 15MVA 33/11kv Injection substation which is situated at the School of Nursing campus by Agip round-about, mile 4, Port Harcourt feeds Abacha Road, School of Nursing and Agip Road 11kv outgoing feeder.

Table 1: Injection Substation/Feeder Information and data

S/ N	Injection Substation	Installed Capacity	Source	Station Outgoing Feeders	Voltage Level
1.	Silver Bird 33/11kv Injection Substation	15MVA 33/11KV 100kva A.T	PH Town 132/33/11kv TS Injection Substation	1. Abonnema Wharf 2. Ikwerre Road	11kv 11kv
2.	Water Works 33/11kv Injection Substation	15MVA 33/11KV 100kva A.T	PH Town 132/33/11kv TS Injection Substation	1. Udi 2. Nsukka	11kv 11kv
3.		Substation / 200kva AT	PH Town 132/33/llkv TS Injection Substation	1. Station Road 2. Amadi North 3. Flour Mill 4. Borokiri	11kv 11Kv 11kv 11kv
4.	RSUST 33/11kv Injection Substation	2×l5MV A 33/11KV 100kva A.T	PH Town 132/33/11kv TS Injection Substation	1. Ojota 2. UST 3. Federal 4. Wokoma	11kv 11kv 11kv 11kv
5.	School of Nursing 133/11kv Injection Substation	15MVA 33/11KV 100kva A.T	PH Town 132/33/11kv TS Injection Substation	1. Abacha Road 2. School of Nursing 3. Agip Road	11kv 11kv 11kv

System Reliability

Every system is made up of component which determine and demonstrate the operations of the system weather it is working or not. This differentcomponents includes:

i. Parallel system,

ii. Series system. Etc.

The probability of the system to function adequately and properly the reliability is dependent on the type of system.

Parallel System

This type of system structure, the problem is that the rate of increase in reliability with an additional component decreases as number of component increases. "Law of diminishing returns" all the component must fail for the system to be down/stop functioning. Hence,overlapping outages is involved with failure modes of the load point. For the system to be interrupted, two or more components must be on outage state at the same time.

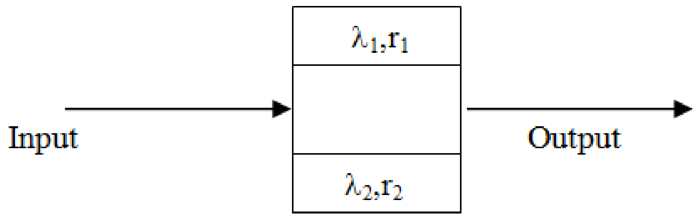


Figure 2: Parallel structural system of component.

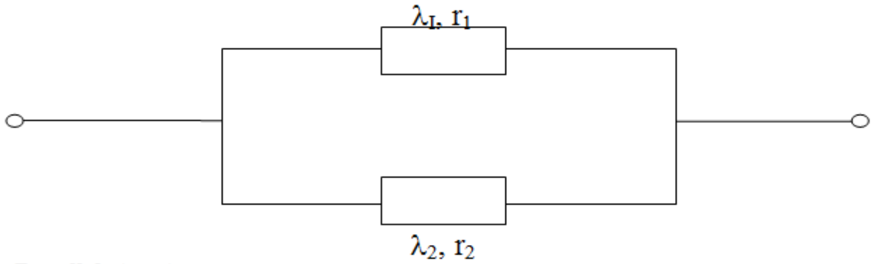


Figure 3: Parallel structure

In this case the failure modes of the load point involve overlapping outages, That is, two or more components must be on outage at the same time in order to interrupt a load point as shown in figure 3. The equations used to evaluate the indices of the overlapping outage are given as:

- Average Failure rate of the system;

$$\lambda_p = \frac{\lambda_1\lambda_2(r_2 + r_2)}{1 + \lambda_1 r_1 + \lambda_2 r_2} = \lambda_2\lambda_1\lambda_2(r_1 + r_2) \qquad (1)$$

Where, $\lambda_1 r_1$ and $\lambda_2 r_2$ usually << 1

- Average Outage time of the system;

$$r_p = \frac{r_1 r_2}{r_1 + r_2} \qquad (2)$$

Average Annual Outage time of the system;

$$\mu_p = \lambda_p r_p \qquad (3)$$

Series System

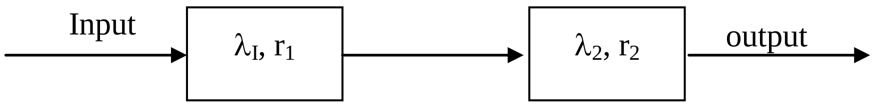


Figure 4: Series structural system of the components.

This type of system has the problem that reliability decreases quickly as the number of components increases.

It is known that when one component is down the system is entirely down for all state and the system is in functional state when all the components are up, that all the component been up and in functional state, then the probability product of the series system been in upstate are equal. This component includes: - the transformer, lines (transmission/distribution), switches and breakers etc. are all consisted in the series system. All component must be in functional state for this type of system structure to be in upstate.

Similarly, a radial system consists of set of series components like; circuit breakers, lines, switches, transformers and "consumers". In the series structure both components must be intact for the purpose of system to function normally while in the parallel structure both must fail for the system to stop functioning. In this case, all the components are connected in series as shown in figure 4 and these equations are formulated as follows:

Average failure rate of the system; $\lambda_s = \lambda_1\lambda_2 = \sum_{i=1}^{2} \lambda_i$ (4)

Average Outage time of the system; $r_s = \frac{\lambda_1 r_1 + \lambda_2 r_2 + \lambda_1 \lambda_2 + r_1 r_2}{\lambda_1 + \lambda_2} = \frac{\sum \lambda_i r_i}{\sum \lambda_i} = \frac{\mu_s}{\lambda_s}$ (5)

If $\lambda_1 \ \lambda_2 r_1 r_2 << \lambda_1 r_1 or \lambda_2 r_1 r_2$ (6)

Average Annual Outage time

$$\mu_s = f_s r_2 = \lambda_s . r_s \quad (7)$$

Where λ_i, is the failure rate at node i, r_i is the outage time at node i.

Reliability Indices

This is a necessary condition for having indices that expresses system failure event on probability and frequency basis. There are three basic indices: failure rate (λ), outage duration (r) and average annual outage time (U),which permits the measurement of reliability at each load point to be quantified and allow subsidiary indices such as the customer interruption indices to be determined.

In a similar manner, distribution system is the segment of the overall system which links the bulk system to the individual customers. The distribution system reliability performance evaluation is normally concerned with the electric power supply adequacy to the customer/consumer load point.

The basic analysis of distribution system reliability indices are the three level load point indices: Average Failure Rate, (λ), the Average Outage Duration, (r) and the Annual Outage Duration, (μ).

Load Point Indices Analysis

In this analysis of the study case the radial system of the distribution, the reliability indices basic equation for analysis are presented :

Failure rate average; $\lambda = \sum F/T \left(f / yr\right)$ (8)

Load point repair rate; $\mu = To / \left(\sum To / \sum F\right) \left(repair / yr\right)$ (9)

Annual outage duration; $\mu\lambda = \sum To/T \left(Hr / Yr\right)$ (10)

Outage duration average,

$$r_y = \mu_y / \lambda_y \left(Hr\right) \quad (11)$$

Mean time before failure,

MTBF = $\sum \frac{T}{F}$ (12)

Mean Time to Repair,

MTTR = $\sum \frac{T_O}{F}$ (13)

Where, F – failure frequency of load point.
T –Operating time (24hr × 365 = 8760/hrs)
T_O–Annual down time of load point

In the same manner, a radial system as it is the case in this paper, the basic equations for calculating the reliability indices at each load point, P are given as:

Average Failure Rate at load point, p,

$$\lambda_p = \frac{\Sigma_F}{T} \left(f / yr\right) \quad (14)$$

where;
F = Load point failure frequency
T = Operating Time (one year, i.e., 365×24hrs = 8,760hrs)

Annual Outage Duration at load point, p,

$$\lambda_p = \frac{\Sigma TdX}{T} \left(Hr/ yr\right) \quad (15)$$

Where;
T_{dx} = Load point annual Down time (in hours)
T = Operating Time

Average Outage Duration at Load Point, p

$$r_p = \frac{\mu_p}{\lambda_p}(Hr) \qquad (16)$$

Load Point Mean Time Before Failure,

$$MTBF = \sum \frac{T}{F} \qquad (17)$$

Where;
T = Operating Time and
F = failure frequency

Mean Time to Repair,

$$MTTR = \sum \frac{Tdx}{F} \qquad (18)$$

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

System Indices

The system indices commonly used by electricity supply utilities are SAIFI, SAID1, CAIDI, ASAI AND ASUI. These indices can be calculated using the basic load point indices. That is, Average Failure Rate, (A), the Average Outage Duration, (r) and the Annual Outage Duration, (μ).

System Average Interruption Frequency Index, SAIFI is designed to give information about the average of sustained interruptions per customer over a predefined zone. Given as:

$$SAIFI = \frac{\Sigma_{\lambda P.NP}}{\Sigma Np}\left(f / cust - yr\right) \qquad (19)$$

Where;
λ_p = Failure rate
Np = No of customers connected to load point, p

System Average Interruption Duration Index, SAIDI is commonly referred to as the customer minutes of interruption or customer hours. It is designed to give information about the average time the customers are interrupted.

$$SAIDI = \frac{\Sigma_{\mu p.Np}}{\Sigma Np}\left(Hr / cust - yr\right) \qquad (20)$$

Where;
μ_p= Annual Outage Duration at Load point, p
Np = No of customers connected to load point, p

Customer Average Interruption Index, CAIDI is the average time needed to restore service to the average customer per sustained interruption. Given as:

$$\text{CAIDI} = \frac{\Sigma \mu p.Np}{\Sigma \lambda p.Np}\left(hr / cust - Int.\right) \qquad (21)$$

Average Service Availability Index,

$$\text{ASAI} = \frac{\Sigma Np.8{,}760 - \Sigma \mu p.Np}{\Sigma Np.8{,}760}(\%) \qquad (22)$$

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

COST WORTH INDICES

Expected Energy Not Supplied, EENS

EENS= ΣEENSp (MWh/yr) (23)

EENSp= $X_P.\mu_P$ (24)

X_p= average load of load point, p
μ_p = annual outage duration at load point, p

Average Energy Not Supplied, AENS

AENS = $\frac{\Sigma EENSP}{\Sigma Np}\left(mwhr / cust - yr\right)$ (25)

Expected Interruption Cost, ECOST

ECOST = ΣECOSTp ($/yr)or (₦/hr) (26)

Where;
ECOSTp = Expected Interruption Cost at load point, p
ECOSTp = XpΣf(rij)λej (27)
Where;
X_p = Average Load of Load point, p
F(rij) = SCDF = Sector Customer Damage Function
The steps associated with the method of reliability (Analytical Method) deployed in this study are summarized as thus;

- Calculate the load point indices of each load point being serviced by a given distribution system configuration considering all interruption events and system constraints contributing to its unavailability for each year of the system. That is, **λ**, **μ**, and **r**.
- Calculate the system reliability indices using the calculated load point indices, load point average failure rate (**λ_p**), Average Outage Duration (**r_p**) and the Average Annual Outage Duration **(μ_p).**

Repeat both steps for all load points of the distribution system configuration under study to obtain all system and cost worth indices; SAIFI, SAIDI, CA1DI, ASAI, EENS, ECOST etc.

Table 2: Analysis and Calculations

Load Point	Failure Freq.	Annual Downtime(hrs)	Annual Uptime(hrs)	No.of Customer	Customer Type	Average Load(mw)	Peak Load(mw)
Station Rd	801	4413	3890	2120	Residential	3.9	4.8
Amadi N.	440	4530	4230	1308	Res/lnd.	4.2	5.3
Flour Mill	620	3881	4879	920	Comm./Res.	3.4	4.0
Borokiri	890	5475	3285	2,770	Residential	4.3	5.5

The source of the historical data utilized in this study is the daily operational report/log book of the substations which are all under the management of Port Harcourt Electricity Distribution Company. The data collected was for a period of two years (2014 - 2015) and the historical data relevant to this study were properly analyzed and presented in a suitable form this study.
Some of the load point details extracted from the daily operational log book of the substations include;

- Record of Failure frequency on the network
- Record of Forced and scheduled Outages
- Record of the Duration Forced and Scheduled Outages
- Number of Customers Connected to each Load point
- The average load and peak load connected to each load point

Outage: Describes the state of a component or the system when it is not available to perform its intended function due to some event directly associated with the component or the system
Forced Outage: An outage caused by emergency condition directly associated with a component that requires the component to be taken out of service immediately, either automatically or as soon as switching operations can be performed.
Scheduled Outage: An outage that results when a component is deliberately taken out of service at a selected time, usually for the purpose of construction, preventive maintenance or repair. The key test to determine if an outage should be classified as forced or scheduled outage is as follows; if it is possible to defer the outage when such deferment is desirable, the outage is a scheduled outage otherwise, the outage is a forced outage.
Forced Outage Duration: It is the period from the initiation of an outage until the component is replaced or repaired.
Scheduled Outage Duration: It is the period from the initiation of the outage until construction, preventive maintenance or repairs are completed.
The substations historical data collected were on monthly basis but since the analysis in this study is annualized, the data were however cumulated and tabulated in an annualized form and classified mainly as thus;
Annual Outage Hours (Annual Downtime): The number of hours in a calendar year that the system was out of service by reason of forced or scheduled outage. This is a summation of the monthly downtime time hours.
Case 1: Station Road
Failure frequency, F = 791
Annual outage duration, is equivalent to down time = $\sum Tdx = 4413$

Operating Time, T = 365×24hrs= 8,760

$$\mu_p = \frac{\sum Tdx}{T}$$

$$\mu_p = \frac{4413}{8760} = 0.5037671$$

Meantime to repair;

$$MTTR = \sum \frac{Tdx}{F} = \frac{4413}{791} = 5.58hrs$$

Applying the reliability equation, above we can determine our load point failure rate given as:

$$\lambda_p = \frac{\sum F}{T} = \frac{791}{8760} = 0.0902\, f\,/\,yrs$$

Annual outage duration,

$$\mu_p = \frac{\sum Tdx}{T} = \frac{4413}{8760} = 0.504hrs\,/\,yrs$$

Average Outage Duration,

$$r_p = \frac{\mu p}{\lambda p} = \frac{0.504}{0.0902} = 5.59hrs$$

Mean Time Before Failure (MTBF),

$$MTBF = T/EF = \frac{8760}{791} = 11.074589hrs$$

Mean Time To Repair (MTTR),

$$MTTR = \frac{\sum Tdx}{F} = \frac{4413}{791} = 5.58hrs$$

Similarly, we can effect the same equation and procedure to the other load point analysis

Case 2: Amadi North

$\lambda_p =$ $0.0502\, f\,/\,yr$

$\mu_p = 0.517hrs\,/\,yrs$

$r_p = 10.30hrs$

MTBF = 19.91hrs

MTTR = 10.29hrs

Case 3: Flour Mill

$\lambda_p =$ $0.0708\, f\,/\,yr$

$\mu_p = 0.4430hrs\,/\,yr$

$r_p = 10.30hrs$

MTBF = 19.91hrs

MTTR = 10.29hrs

r_p = 6.28hrs

MTBF = 14.13hrs

MTTR = 10.29hrs

Borokiri;

λp = 0.0934f/yr

μp = 0.511hrs/yr

rp = 5.47hrs

MTBF = 10.71hrs

MTTR = 5.47hrs

Other component failure rates are;

Transformer;

132/33kv = 0.002

33/11kv = 0.003

Circuit Breaker;

132kv = 0.001
33kv = 0.015
11kv = 0.006
Bus Bar;
132kv = 0.001
33 kv = 0.001
11kv = 0.015

Table 3:Shows the total load point indices of the system case

Load Point	λ_T(f/hr)	r_T(hours)	μ_T(hr/yr)
Station Rd –Lpl	0.8787	9.29	8.1661
Amadi N. –Lp2	0.8387	9.70	8.1391
Flour Mill –Lp3	0.8593	9.38	8.0631
Borokiri–Lp4	0.8900	9.14	8.1325

System Indices
The system indices of the system case are calculated using equation (19), (20), (21) and (22). Applying these equations yields;
System Average Interruption Frequency Index,

$$SAIFI = \frac{\sum \lambda p.Np}{\sum Np} =$$

$$\frac{\{(0.8787 \times 2{,}120) + (0.8387 \times 1{,}308) + (0.8593 \times 920) + (0.8900 \times 2{,}770) + \}}{2{,}120 + 1{,}308 + 920 + 2{,}770}$$

SAIFI = 0.873f/cust-yr.
System Average Interruption Duration Index,

$$SAIDI = \frac{\sum \mu p.Np}{\sum Np} =$$

$$\frac{\{(8.166 \times 2{,}120) + (8.139 \times 1{,}308) + (8.063 \times 920) + (8.132 \times 2{,}770) + \}}{2{,}120 + 1{,}308 + 920 + 2{,}770}$$

SAIDI = 8.134hrs/cust-yr.
Customer Average Interruption Index, CAIDI

$$CAIDI = \frac{\sum \mu p.Np}{\sum \lambda p.Np} =$$

$$\frac{\{(8.166 \times 2{,}120) + (8.139 \times 1{,}308) + (8.063 \times 920) + (8.132 \times 2{,}770) + \}}{\{(0.8787 \times 2{,}120) + (0.8387 \times 1{,}308) + (0.8593 \times 920) + (0.8900 \times 2{,}770)\}}$$

CAIDI = 9.317hrs/cust-lnt.
Average Service Availability Index,

$$ASAI = \frac{\sum Np.8{,}760 - \sum \mu p.Np}{\sum Np.8{,}760}$$

$$ASAI = \frac{(7{,}1186 \times 8{,}760) + (8.166 \times 2{,}120) + (8.139 \times 1{,}308) + (8.063 \times 920) + (8.132 \times 2{,}770)}{7{,}118 \times 8{,}760}$$

ASAI = 0.99901 × 100

ASAI = 99.91%

Table 4:Shows the system indices for the sample system

Index	Values	Unit
SAIFI	0.873	Int./yr
SAIDI	8.134	Hrs/yr
CAIDI	9.137	Hrs/cust-int.
ASAI	99.91	%

Cost Worth Indices
The cost worth indices of the system case are calculated using equations (28) to (29) as follows;

EENS = ΣEENSp (mwh/yr) (28)

EENSp = Xp.μp (29)

Where;
Xp = average load of load point, p
μp = annual outage duration at load point, p

Expected Energy Not Supplied, EENS
EENS = {(3.9 x 8.166) + (4.2 x 8.139) + (3.2 x 8.063) + (4.3 x 8.132)}

EENS = 128.41mwh/yr
Expected Interruption Cost, ECOST
ECOST = ΣECOSTp
= 70,598.46 + 256,913.30 + 318,183 +77,128.95
ECOST = $722,823.71 (for ₦250 for $1 = ₦180,705,927.5

Table 5: Shows the cost worth indices of the system case.

Load Point	EENSp (mwh/Cust-Yr)	ECOSTp ($/Yr)	AENS
Station Rd - 1	31.8478	70,598,46	0.015
Amadi N.-2	34.1841	256,913.30	0.026
Flour Mill -3	27.4145	318,183.00	0.029
Borokiri-4	34.9699	77,128.95	0.013
TOTAL	**128.413**	**722,823.71**	**0.018**

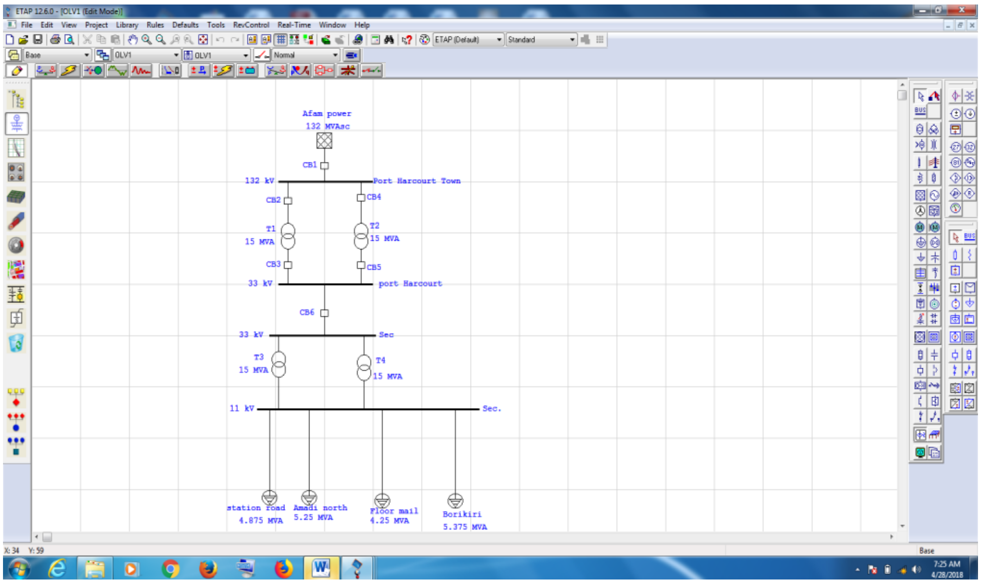


Figure 1: Distribution feeders: station road, Amadi north, floor mail and Borikiri (before simulation)

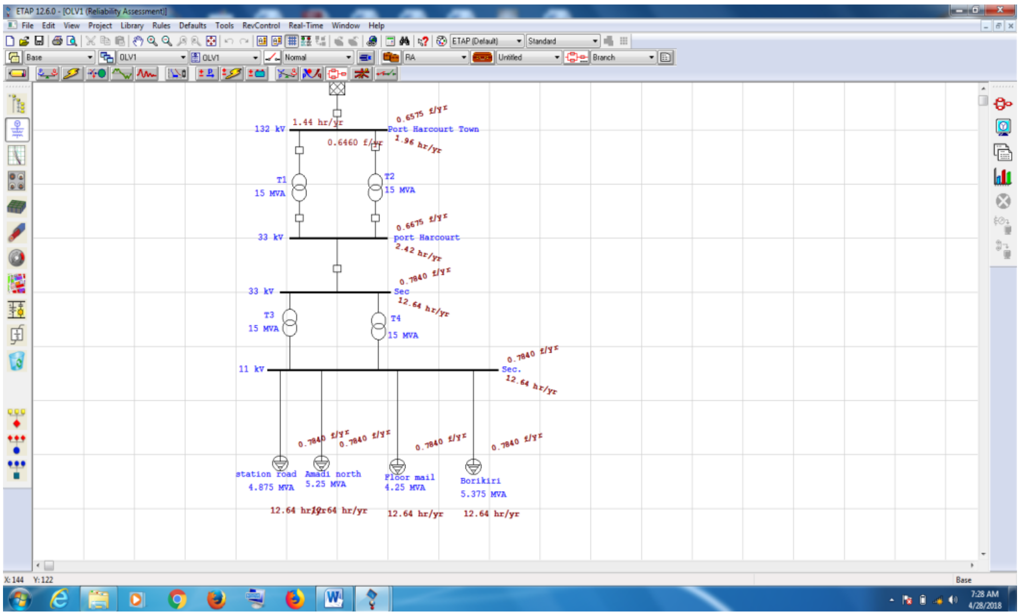
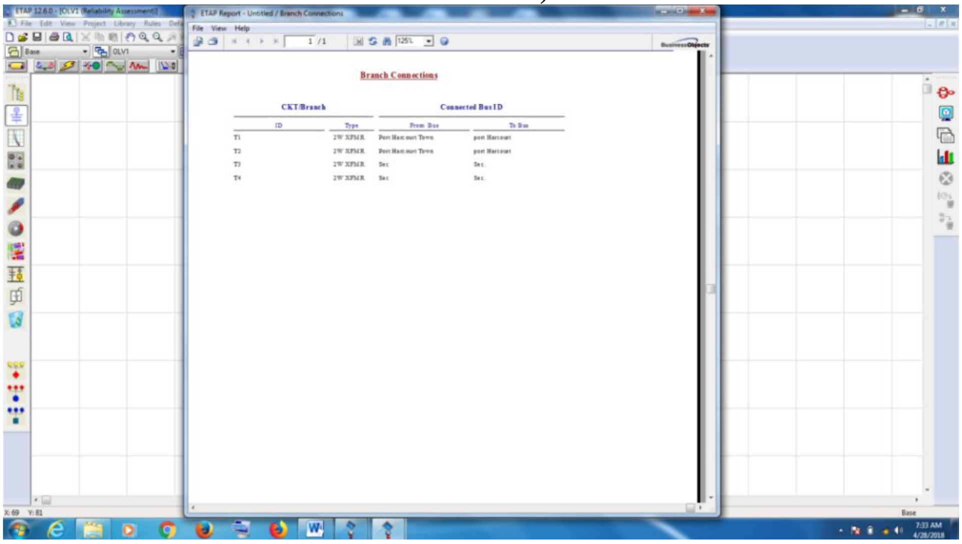


Figure 2: Distribution feeders: station road, Amadi north, floor mail and Borikiri (after simulation)

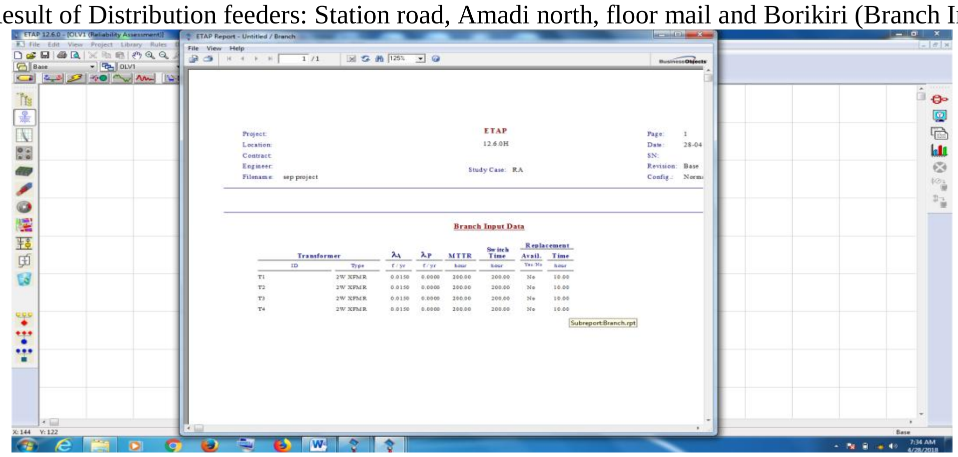
Table 6: Result of Distribution feeders: Station road, Amadi north, floor mail and Borikiri (Branch Connections)



Branch Connections

CKT/Branch		Connected Bus ID	
ID	Type	From Bus	To Bus
T1	2W XFMR	Port Harcourt Town	port Harcourt
T2	2W XFMR	Port Harcourt Town	port Harcourt
T3	2W XFMR	Sec	Sec.
T4	2W XFMR	Sec	Sec.

Table 7: Result of Distribution feeders: Station road, Amadi north, floor mail and Borikiri (Branch Input Data)

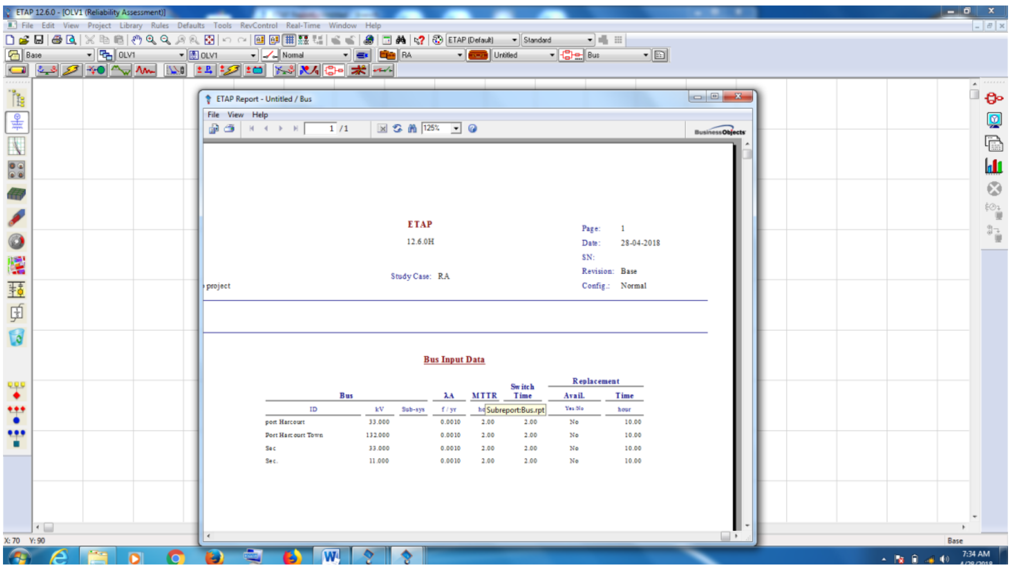


ETAP
12.6.0H
Project:
Location:
Contract:
Engineer:
Filename: sep project
Study Case: RA
Page: 1
Date: 28-04
SN:
Revision: Base
Config.: Norm

Branch Input Data

Transformer		λA	λP	MTTR	Switch Time	Replacement	
						Avail.	Time
ID	Type	f / yr	f / yr	hour	hour	Yes/No	hour
T1	2W XFMR	0.0150	0.0000	200.00	200.00	No	10.00
T2	2W XFMR	0.0150	0.0000	200.00	200.00	No	10.00
T3	2W XFMR	0.0150	0.0000	200.00	200.00	No	10.00
T4	2W XFMR	0.0150	0.0000	200.00	200.00	No	10.00

Table 8: Result of Distribution feeders: Station road, Amadi north, floor mail and Borikiri (Bus Input Data) data



ETAP
12.6.0H
Study Case: RA
project
Page: 1
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SN:
Revision: Base
Config.: Normal

Bus Input Data

Bus			λA	MTTR	Switch Time	Replacement	
						Avail.	Time
ID	kV	Sub-sys	f / yr	hour		Yes/No	hour
port Harcourt	33.000		0.0010	2.00	2.00	No	10.00
Port Harcourt Town	132.000		0.0010	2.00	2.00	No	10.00
Sec	33.000		0.0010	2.00	2.00	No	10.00
Sec.	11.000		0.0010	2.00	2.00	No	10.00

Table 9: Result of Distribution feeders: Station road, Amadi north, floor mail and Borikiri (Reliability Analysis)

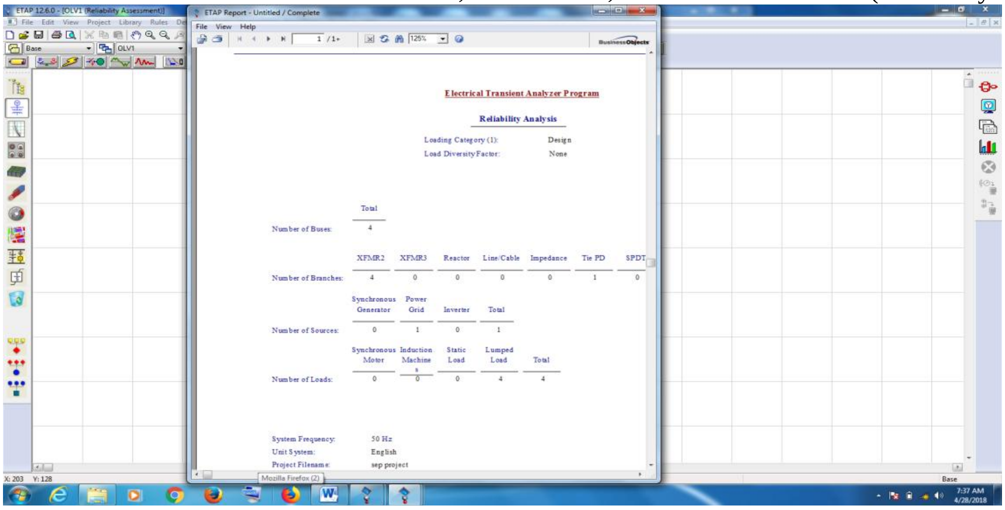
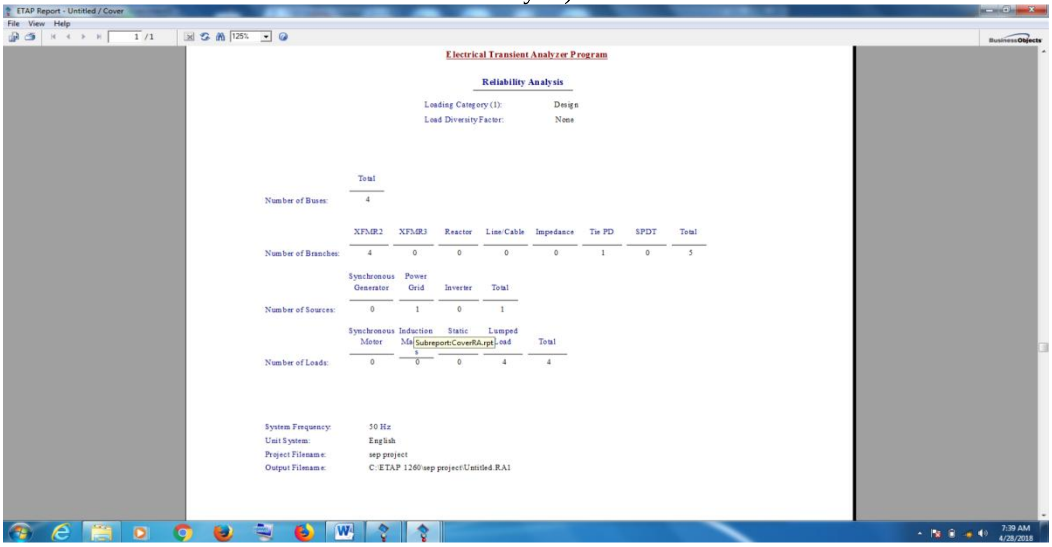


Table 10: Result of Distribution feeders: Station road, Amadi north, floor mail and Borikiri (Reliability Analysis)



Electrical Transient Analyzer Program

Reliability Analysis

Loading Category (1): Design
Load Diversity Factor: None

	Total
Number of Buses:	4

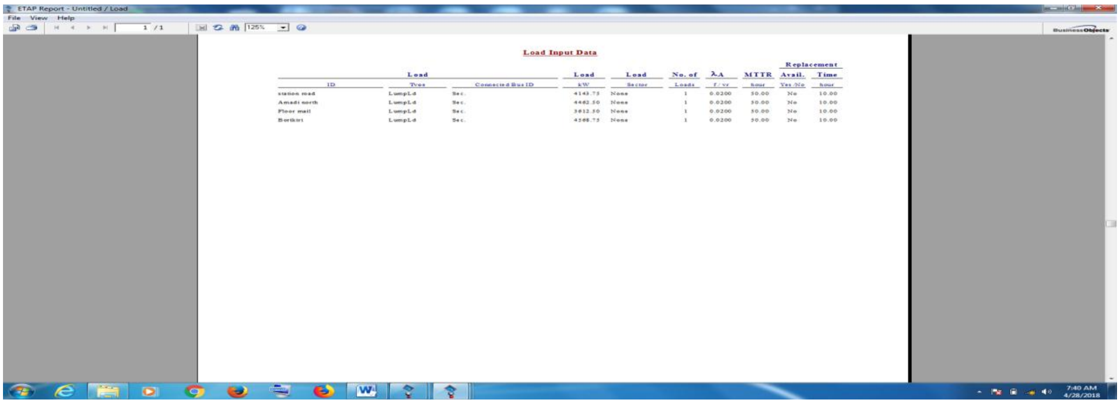
	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	SPDT	Total
Number of Branches:	4	0	0	0	0	1	0	5

	Synchronous Generator	Power Grid	Inverter	Total
Number of Sources:	0	1	0	1

	Synchronous Motor	Induction Machines	Static Load	Lumped Load	Total
Number of Loads:	0	0	0	4	4

System Frequency: 50 Hz
Unit System: English
Project Filename: sep project
Output Filename: C:\ETAP 1260\sep project\Untitled.RA1

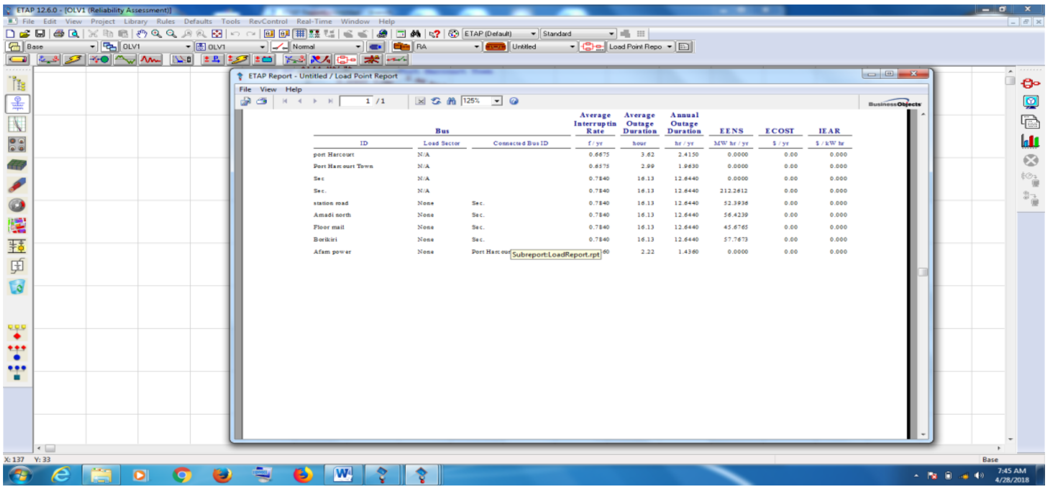
Table 11: Result of Distribution feeders: Station road, Amadi north, floor mail and Borikiri (Load Input Data)



Load Input Data

Load ID	Load Type	Connected Bus ID	Load kW	Load Sector	No. of Loads	λA f/yr	MTTR hour	Avail. Yes/No	Replacement Time hour
station road	LumpLd	Sec.	4143.75	None	1	0.0200	30.00	No	10.00
Amadi north	LumpLd	Sec.	4462.50	None	1	0.0200	30.00	No	10.00
Floor mail	LumpLd	Sec.	3612.50	None	1	0.0200	30.00	No	10.00
Borikiri	LumpLd	Sec.	4568.75	None	1	0.0200	30.00	No	10.00

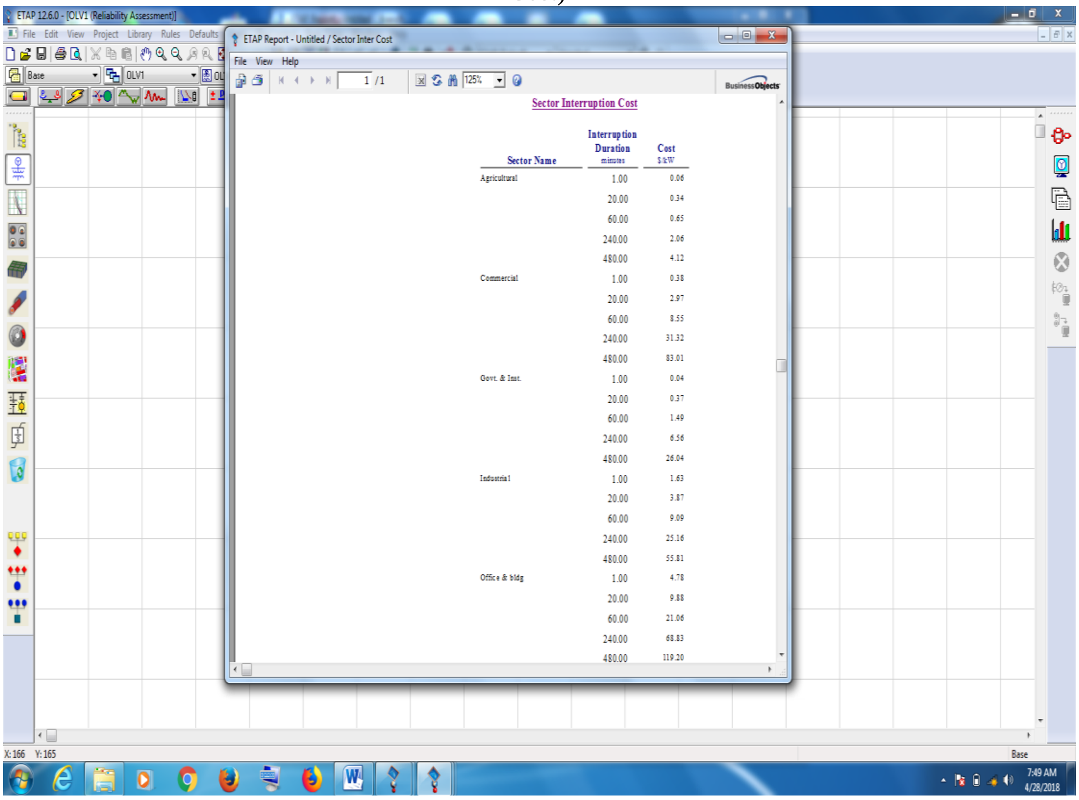
Table 12: Result of distribution feeders: Station road, Amadi north, floor mail and Borikiri (Buses)



ETAP Report - Untitled / Load Point Report

Bus ID	Bus Load Sector	Connected Bus ID	Average Interruptin Rate (f / yr)	Average Outage Duration (hour)	Annual Outage Duration (hr / yr)	EENS (MW hr / yr)	ECOST ($ / yr)	IEAR ($ / kW hr)
port Harcourt	N/A		0.6675	3.62	2.4150	0.0000	0.00	0.000
Port Harcourt Town	N/A		0.6575	2.99	1.9630	0.0000	0.00	0.000
Sec	N/A		0.7840	16.13	12.6440	0.0000	0.00	0.000
Sec.	N/A		0.7840	16.13	12.6440	212.2612	0.00	0.000
station road	None	Sec.	0.7840	16.13	12.6440	52.3936	0.00	0.000
Amadi north	None	Sec.	0.7840	16.13	12.6440	56.4239	0.00	0.000
Floor mail	None	Sec.	0.7840	16.13	12.6440	45.6765	0.00	0.000
Borikiri	None	Sec.	0.7840	16.13	12.6440	57.7673	0.00	0.000
Afam power	None	Port Harcour[illegible]	[illegible]	2.22	1.4360	0.0000	0.00	0.000

Table 13: Result of distribution feeders: Station road, Amadi north, floor mail and Borikiri (Sector Interruption Cost)

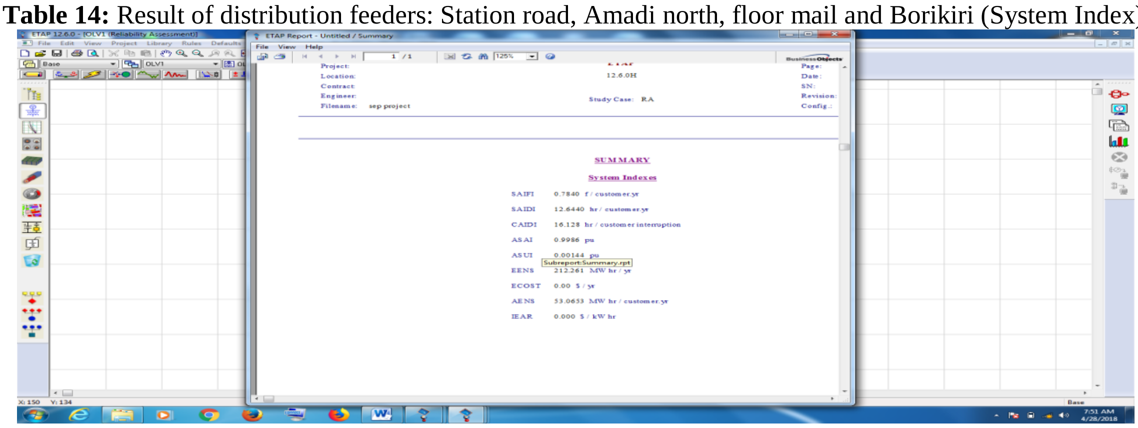


ETAP Report - Untitled / Sector Inter Cost

Sector Interruption Cost

Sector Name	Interruption Duration (minutes)	Cost ($/kW)
Agricultural	1.00	0.06
	20.00	0.34
	60.00	0.65
	240.00	2.06
	480.00	4.12
Commercial	1.00	0.38
	20.00	2.97
	60.00	8.55
	240.00	31.32
	480.00	83.01
Govt. & Inst.	1.00	0.04
	20.00	0.37
	60.00	1.49
	240.00	6.56
	480.00	26.04
Industrial	1.00	1.63
	20.00	3.87
	60.00	9.09
	240.00	25.16
	480.00	55.81
Office & bldg	1.00	4.78
	20.00	9.88
	60.00	21.06
	240.00	68.83
	480.00	119.20

Table 14: Result of distribution feeders: Station road, Amadi north, floor mail and Borikiri (System Index)



ETAP Report - Untitled / Summary

Project:
Location: 12.6.0H
Contract:
Engineer: Study Case: RA
Filename: sep project

Page:
Date:
SN:
Revision:
Config.:

SUMMARY

System Indexes

SAIFI	0.7840 f / customer.yr
SAIDI	12.6440 hr / customer.yr
CAIDI	16.128 hr / customer interruption
ASAI	0.9986 pu
ASUI	0.00144 pu
EENS	212.261 MW hr / yr
ECOST	0.00 $ / yr
AENS	53.0653 MW hr / customer.yr
IEAR	0.000 $ / kW hr

IV. Conclusion And Recommendation

Conclusion

The reliability assessment for substations for some Port Harcourt town distribution network are presented using analytical approach and being supported by ETAP simulation tool.

The result presented in the study case using the reliability system indices: SAIFI, SAIDI, CAIDI, ASAI etc, this shows quantitatively that the entire system is below or declared international set standards, hence the system behaviour is unreliable. Essentially, improving techniques configuration will be recommended for purpose of improving system stability.

Recommendation

Considering the analysis of this study case, the following recommendation for purpose of improving the system reliability of the distribution networkarestated:

i. Expansion of the network by the electric utilities: PHEDC, etc in order to take care of the overload problem on the system.
ii. System reconfiguration is considered in order to reduce the number of customer connected to already over stressed distribution network.
iii. Immediate replacement of faulty or aged system component with quality or new ones.

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