The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 12 || December - 2014 || Pages || 68-79||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Reliability Prediction of Port Harcourt Electricity Distribution Network Using NEPLAN

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ABSTRACT

The reliability of Port Harcourt distribution network using Choba as a case study was assessed and analysed using various reliability indices in this paper. The network under study was modelled in NEPLAN (power system software) simulation environment using data obtained from Power Holding Company of Nigeria (PHCN) between June-November 2012. The overall system performance was then determined and possible ways of improving this were mentioned If this work is implemented in the power distribution network, it would stand out in its ability to evaluate and predict the reliability of an existing distribution system. It will also aid companies when planning to embark on a system that is reliable and efficient.

Reliability of Power Distribution System (RPDS)

Date of Submission: 07 November 2014 — Date of Accepted: 15 December 2014

I. INTRODUCTION

Electricity distribution is the final stage in electricity delivery to end users. The modern distribution system begins as the primary circuit leaves the sub-station and ends as the secondary service enters the customer's meter. Reliability is one of the major factors for planning, designing, operating and maintaining electrical power system (Billiton and Allan, 1996). Reliability of power systems is generally designated as a measure of the ability of the system to provide consumers with adequate supply. Consumers expect electric power tobe available twenty-four (24) hours a day without any interruption. Outage occurrences in power distribution system are almost unavoidable, the major challenges faced whenever this occurs are losses by Companies who are not only affected by the demanding norms but also by high financial lost due to energy non-sell and penalties. Also, weak points develop in systems which are either due to excess load demanded at that topology (configuration) or as a result of ageing factor. In predicting reliability of power distribution networks, certain factors are considered.

These include growth factor of residential power consumption among others. These when combined with commercial expansion and industrial construction makes the infrastructure that connects the generators with the consumers not to be very reliable. To this end, power distribution systems are as stressed as the generation and transmission systems. The residential demand could be the largest portion of the peak demand among all consumers (H.L Willis, 1997). The reliability of power distribution networks can be improved by two methods. The first method is to reduce the frequency of interruption and the second approach is to reduce outage duration when fault occurs. Installation of Fault Indicators (FIs) in the primary feeders of distribution network is one of ways to decrease outage duration (Y. Tang, H.F. Wang, A.T. Johns, and R.K. Aggarwal., 2000).Various methods have been used to tackle Reliability of Power Distribution Systems (RPDS) over the years among which are Voltage Stability Method (VSM), Artificial Intelligence (AI), Generic Algorithm (GA), Fuzzy Logic (FL), etc executed either in NEPLAN,ETAP, Power World Simulator, Matlab, visual basic C++ or C# environment.. It is vital that reliability analysis and prediction be carried out quickly for quick restoration of the system.A better approach to reliability evaluation and prediction is the use of NEPLAN.it is a power system simulation software used for analyzing power networks. One benefit of using NEPLAN reliability software is its ability to provide not only the reliability indices for both individual load points and the overall power system, but also it can be used to provide the cost of unreliability. NEPLAN uses the MARKOV process which is a stochastic and memory-less process in which the present state of the system is independent of all form of reliability states except the immediately preceding one (Wei Zhang, 1998).This paper will present a method for reliability evaluation and prediction of power distribution system using NEPLAN simulation software. The distribution network of Choba in Rivers State, was used as a case study as obtained fromRumuodomanya Business Unit, Port Harcourt. Rivers State and then modelled in NEPLAN environment.

Real time line parameters and data such as independent stochastic outage, determined outage, maintenance interruption duration and manual disconnection duration were obtained from Power Holding Company of Nigeria (PHCN) and used for predicting reliability of the network under study and various reliability indices were computed. This paper will proffer solution to the frequent breakdown of power system which causes interruption of power supplied in Choba distribution network under study and to minimize unnecessary expenditure in repairing failed systems.

II REVIEW OF DIFFERENT METHODS USED IN SOLVING RELIABILITY CALCULATION/PREDICTION PROBLEMS.

Voltage Stability Method : Voltage Stability Method (VSM) is an important performance index which defines the quality of supply. Voltage in a transformer is expected to be constant from the customer point of view. In most of the analysis, either voltage stability or reliability along with minimized cost has been considered as the basis of distribution system planning (Tang, 1996).Distribution system reliability incorporating the effect of voltage stability index often gives a better insight to the requirement from the customers'. (Bian et al, 1994). Voltage Stability Index (VSI) method maintain a stable voltage at all parts of the system so that with the increase of load, both power and voltage are controllable by using the VSI given in equations 1 2 and 3.

VSI=

$$4\left[(X_{eq}P_{leq} - R_{req}Q_{leq})^2 + (X_{eq}Q_{leq} - R_{req}Q_{leq}\right] \quad 1$$

Where,

$$R_{eq} = \sum P_{loss} / \{(P_{leq} + \sum P_{loss})^2 + (Q_{leq} + \sum Q_{loss})^2\} \; 2$$

$$X_{eq} = \sum Q_{loss} / \{(P_{leq} + \sum P_{loss})^2 + (Q_{leq} + \sum Q_{loss})^2\} \; 3$$

Where $P_{leq}$and $Q_{leq}$are the total real and reactive loads respectively.One of the limitations of the VSM is the variability of voltages in the system configuration at different hours of the day.

Artificial Intelligence Method : The model proposes the concepts of "Intelligence Matrix" and "Agent". A very remarkable aspect of the conjunction matrix-agent is the facility with which it deals with the elements of protection and switching devices to value the importance of the strategic location of these elements. Furthermore the "Intelligence Matrix" gathers a condition so that the "Agent" works in an efficient way within the topological search. This connection makes the run in an efficient and rapid way to complete the layout of the routes that involves the distribution reliability's calculus. This point is the clue of success in the search tree-failure modes.From a more general perspective, the use of this model presents important economic measures, in which the electric companies could commit or incur when not having a suitable control.Finally, the investigation's development resulted in the necessity to deepen in ordaining the switching and protection devices that can lead to obtain the best reliability of the system (Lopez et al, 2006).

Genetic Algorithm : Genetic Algorithm (GA) is a search technique which is conceptually based on the mechanism of natural genetic and evolution (Holland, 2000). GA uses genetic-like operation which is similar to the neurons of the Artificial Neural Network (ANN) for searching the global optimum. GA starts with a population of candidate solutions chosen randomly within the feasible range, encoded in a binary string that forms chromosomes.Each member of the population is then decoded to pass through an evaluation process. The initial population undergoes three main genetic operations: selection, crossover, and mutation. The main drawbacks of GA are the long computation time and the premature convergence unlike the artificial neural network.

Fuzzy Logic : Fuzzy Logic (FL) is a form of many-valued logic which deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued-logic true or false, fuzzy logic variables may have a truth-value that ranges in degree between 0 and 1. FL has been extended to handle the concept of partial truth where the truth-value may range between completely true and completely false.Fuzzy logic began with the 1965 proposal of fuzzy set theory by Lotfizadeh. FL has been applied to many fields, from control theory to artificial intelligence. The AND, OR and NOT operators of Boolean logic exist in fuzzy logic, usually defined as the minimum, maximum and complement; when they are defined this way, they are called the Zadeh operators. Fuzzy sets theory defines fuzzy operators on fuzzy sets. The problem in applying this is that the appropriate fuzzy operator may not be known, for this reason, fuzzy logic usually uses IF-THEN rules.

C Sharp (C#) : C Sharp which is represented by the symbol C#, is a general-purpose computer programming language developed between 1969 and 1973 by Dennis Ritchie at the Bell Telephone laboratories for use with the UNIX operating system. C# is one the most widely used programming languages of all times and there are very few computer architectures for which a C# compiler does not exist. C# is often chosen over other interpreted language because of its speed, stability and near universal availability (Wikipedia.org, 2008).

Artificial Neural Network (ANN) : ANNis composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the connections between elements largely determine the network function. You can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements.Typically, neural networks are adjusted, or trained, so that a particular input leads to a specific target output. The network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically, many such input/target pairs are needed to train a network.

III MARKOV MODELING METHOD

This method classifies electric power distribution reliability under two categories: Simulation and analytical techniques. In the simulation technique, such as Monte Carlo simulation (NEPLAN Reliability analysis, 2000), it is highly time consuming and expensive because it has to simulate a huge number of failures. Also, since the simulation of probabilistic events generates variable results, in effect simulating the variability of real life, it is usually necessary to perform a number of runs in order to obtain estimates of means and variance of the output parameters of interest, such as availability, number of repairs arising and repair facility utilization (O'Connor, 2002). Analytical technique is sub-divided into network and Markov modeling. A discrete parameter stochastic process, $\{x(t); t = 0, 1, 2 \dots\}$, or a continuous parameter stochastic process, $\{x(t); t \geq 0\}$, is a Markov process if it satisfies Markovian property (Gonen, 1986). This proposed method, uses the IEEE Std. 1366^{TM}, 2003, as a guide for Electric Power Distribution Reliability Indices for the purpose of uniformity and consistency in reporting practices in the electric power distribution industry and also serve as a useful tool employed by personnel for the comparison of various distribution companies (Medwell, 2007).Considering the fact that distribution networks are largely radial, Markov methods are simple to understand and implement but lack prediction ability. Markov modeling is a well define approach with fast computer run time when all the states are defined. This method is a stochastic system for which the occurrence of a future state depends only on the immediately preceding state (Zhang, 1998). Because of the aforementioned, the Markovian process is characterized by a lack of memory (Vincentini et al, 2004).

ANALYTICAL APPROACH : Analytical approach is the most common methods used for reliability assessment of power systems. Results obtained from applying this approach provide an appropriate benchmark for evaluating system performance and its reliability.In analytical approach, the system is represented by its mathematical equivalent model. Direct numerical solutions are applied to provide reliability indices. Generally, there are five main procedures in analytical approach; State Space Diagram Generation **(SSDG)**, System State Enumeration**(SSE)**, System State Analysis **(SSA)**, Remedial Action **(RA)** and Reliability indices **(RI)**.

State Space Diagram Generation : An important and basic stage in performing the reliability investigation is to generate the appropriate reliability model. In this level the physical system is transferred to the simple model which is convenient for reliability studies. The system model can be generated by applying the Markov process.In Markov process, the transition rates are assumed to be constant.

System State Enumeration : Among the significant drawbacks of applying the Markov technique to achieve the reliability model is the extremely large number of generated states which assigns a large computational effort to reliability evaluation. Due of these drawbacks, several methods of reducing the number of states have been proposed. The method used here is the contingency and ranking technique. In this approach, only the credible events are considered. The credible events are the failure events which have the most significant impact on the system performance. In order to choose the appropriate contingencies, it is necessary to obtain a deep understanding over the system under study and the factors that may cause a failure.

System State Analysis : One of the main parts in reliability assessment is to analyze the impact of the possible failures that may occur in a practical system on the performance of the overall distribution system. Network solutions can be applied to perform such analysis. In case of any violation in system characteristics, the system state is defined as an abnormal state and requires the remedial action in form of corrective action or load curtailment to clear the abnormality.

Remedial Action : After identifying the violation in the system, remedial actions are applied. Remedial action is applied to alleviate the system abnormal conditions (Zhang, 1998). Therefore the main emphasis is on clearing the abnormality of the system due to the special contingency. This can be performed by applying corrective action such as removing the failed component or rescheduling the generation unit and re-supplying the loads after performing the corrective action to re-supply the load if the violation still exists, then load curtailment will be required. The contingency which led to load curtailment contributes to provide the reliability indices.

IV RELIABILITY INDICES

This section presents analytical approach applied to assess reliability of power systems using reliability indices. It begins by explaining reliability formula used for calculating and predicting distribution systems. The essence is to minimize consumers 'outage duration at reduced cost. Reliability indices are numerical parameters that reflect the capability of the system to provide its customers an acceptable level of supply. These indices estimate system reliability by providing quantitative measures at each individual load point and for the whole system. The main reliability indices in power system evaluation are frequency of interruption and the associated duration. These two indices are important as they indicate the expected frequency and duration of load supply interruption. The system reliability indices such as; system average interruption duration index (SAIDI), system average interruption frequency index (SAIFI), customer average interruption duration index (CAIDI) were used to predict the system reliability. Other reliability indices used include; customer average interruption frequency index (CAIFI), customer interrupted per interruption index (CII), momentary average interruption frequency index (MAIFI) and average service availability index (ASAI).Load point indices used to predict reliability of distribution system and includes load point average failure rate, λ_s average outage duration, r_s, and annual unavailability, U_s. Component failure rates and repair times are obtained by observation of a population. NEPLAN simulation software is used to obtain the overall system indices. This investigation covers period of six months data(February 2012-Nov 2012).Data used for this work was obtained from the Choba injection sub-station of Power Holding Company of Nigeria (PHCN)

The procedure involves the following:

- ❖ Set up Choba power distribution system simulation using NEPLAN Simulation Software.
- ❖ Calculate system indices using NEPLAN Simulation Software.

Mathematical/reliability formula and modelling in NEPLAN environment

The average annual failure rate, λ, is calculated as.

$$\lambda = \frac{f}{n \times m} \qquad 4$$

Where; $f = the\ number\ of\ failures, n = the\ number\ of\ components\ considered$

$m = number\ of\ years\ of\ recorded\ data$

For radial systems that will be considered in this project, the following equations are applicable;

$$\lambda_s = \sum_i \lambda_i \ldots \qquad 5$$

$$U_s = \sum_i \lambda_i r_i \qquad 6$$

$$r_s = \frac{U_s}{\lambda_s} = \frac{\sum_i \lambda_i r_i}{\sum_i \lambda_i} \qquad 7$$

To reflect more actual system severity, additional reliability indices called system indices are used. The most common of these additional indices are;

System Average Interruption Duration Index (SAIFI) [int/yr, cust]:

$$SAIFI = \frac{Total\ Number\ of\ Customers\ Interruption}{Total\ Numbers\ of\ Customers\ Served} \qquad 8$$

$$SAIFI = \frac{\sum \lambda_i N_i}{\sum N_i} \qquad 9$$

System Average Interruption Duration Index (SAIDI) [h/yr, cust.]:

$$SAIDI = \frac{Sum\ of\ Customers\ Duration\ Interruption}{Total\ Number\ of\ Customer\ Service} \qquad 10$$

$$SAIDI = \frac{\sum U_i N_i}{\sum N_i} \qquad 11$$

Customers Average Interruption Duration Index (CAIDI) [h/int.]:

$$CAIDI = \frac{Sum\ of\ Customers\ Duration\ Interruption}{Total\ Number\ of\ Customer\ Interruption} \quad 12$$

$$CAIDI = \frac{\sum U_i . N_i}{\sum \lambda_i . N_i} \quad 13$$

Average Service Availability Index (ASAI) [%]:

$$ASAI = \frac{Customer\ Hours\ of\ Available\ Service}{Customers\ Hours\ Service\ Demands} \quad 14$$

$$ASAI = \frac{\sum (N_i . 8760 - U_i . N_i)}{\sum N_i . 8760} \quad 15$$

Where;

$N_i = Number\ of\ customers\ at\ load\ point\ i.$

$\lambda_i[{}^1/_{yr}] = Expected\ failure\ rate\ per\ year\ at\ load\ point\ i$ 16

$U_i = Unavailability\ of\ load\ point\ i.$

I. DATA COLLECTION

Data was collected from log book of Choba injection Substation in Rivers State, Nigeria. The data collected consist of the outage time, the incoming energy, the outgoing three-phase current and the outgoing kV rating for the three feeders serving Choba, Aluu and Rumuekini respectively as shown in table 1.0

Table 1: Sample of Data Taken From Choba Injection Substation

	FEEDER (FRIDAY, 01/06/2012)																		
	RUMUEKINI				CHOBA				ALUU				INCOMER	KV	MW	OT	WT	DC	ENERGY
S/N	OUTGOING CURRENT			AVG	OUTGOING CURRENT			AVG	OUTGOING CURRENT			AVG							
1	E/F			0	53	60	69	1	108	103	94	1.7							
2	"			0	53	60	69	1	102	103	94	1.7							
3	"			0	53	60	69	1	102	103	94	1.7							
4	"			0	53	60	69	1	102	103	94	1.7							
5	"			0	70	75	75	1.2	110	111	100	1.8							
6	"			0	80	88	84	1.4	121	125	120	2							
7	"			0	82	90	90	1.5	134	135	130	2.2							
8	"			0	84	86	88	1.4	123	123	118	2							
9	"			0	84	86	88	1.4	123	123	118	2							
10	"			0	80	84	83	1.4	121	116	111	1.9							
11	"			0	79	84	82	1.4	136	113	101	1.9							
12	"			0	79	84	82	1.4	136	113	101	1.9							
13	NO SUPPLY			0	NO SUPPLY			0	NO SUPPLY			0							
14	"			0	"			0	"			0							
15	"			0	82	85	84	1.4	98	102	116	1.8							
16	NO SUPPLY			0	NO SUPPLY			0	NO SUPPLY			0							
17	"			0	"			0	"			0							
18	174	163	162	166	L/S			0	L/S			0							
19	185	175	163	174	"			0	"			0							
20	185	186	185	185	"			0	"			0							
21	NO SUPPLY			0	NO SUPPLY			0	NO SUPPLY			0							
22	"			0	"			0	"			0							
23	L/S			0	82	82	84	1.4	L/S			0							
24	L/S			0	78	78	79	1.3	"			0							
KEY																			
E/F=EARTH FAULT																			
L/S=LOAD SHEDDING																			
N/S=NO SUPPLY																			

Each of the feeders is controlled and regulated during an outage (such as; earth fault (E/F), load shedding (L/S), and during any maintenance work on any of the areas served by specific feeder). Figures2.0and 3.0 shows a typical outgoing feeder serving Choba injection substation breaker and Aluu feeder respectively.

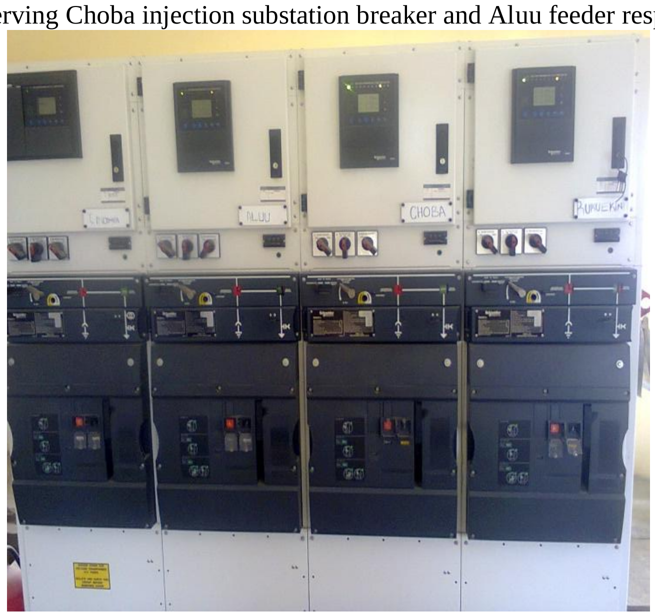

Fig 2:Choba injection substation breaker

Fig3: Aluu Outgoing Feeder

The data covers a period of six months spanning June to November 2012.

V PROCEDURE

Data collected from the logbook of Choba Injection Substation were used to evaluate the Various Reliability Indices which include: System Average Interruption Duration Index (SAIDI), Customers Average Interruption Duration Index (CAIDI), System Average Interruption Frequency Index (SAIFI), Customer Average Interruption Frequency Index (CAIFI), Customer Interruption per Interruption Index (CIII), Momentary Average Interruption Frequency Index (MAIFI) and the Average Service Availability Index (ASAI).

Design of Choba Distribution Network Using NEPLAN Analyzer : Choba distribution network is designed using NEPLAN analyzer.NEPLAN is an electric power analyzer which has been developed by the BCP group in Switzerland. This software package is used mainly for transmission and distribution systems analysis. It includes optimal power flow, transient stability and reliability analyses. NEPLAN reliability software can be used to provide not only the reliability indices for both the individual load points and the overall power system, but also it can be used to provide the cost of unreliability. The approach in NEPLAN follows the same procedure that has been explained previously in this paper.

Startup of the Design Procedure : The NEPLAN analyzer software is an interactive package that enables users to design and evaluate a power system network using one-line diagrams. This is possible by the interconnection and arrangement of the various power elements such as generators, buses, transformers, transmission lines, etc. that make up a practical system network.Figure 4.0 shows complete model of Choba distribution network while Figure 5.0 Shows the Run Mode Reliability Option

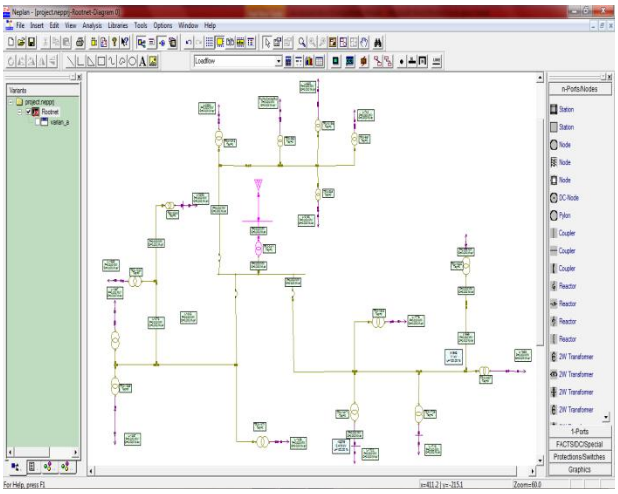

Fig4: Complete Model of Choba Distribution Network

In other to calculate the reliability of the load point and the complete system, the following process was followed:

- ❖ On the menu option bar, click on "Analysis".
- ❖ Go to "Reliability".
- ❖ Select the "Evaluation" option as shown below.

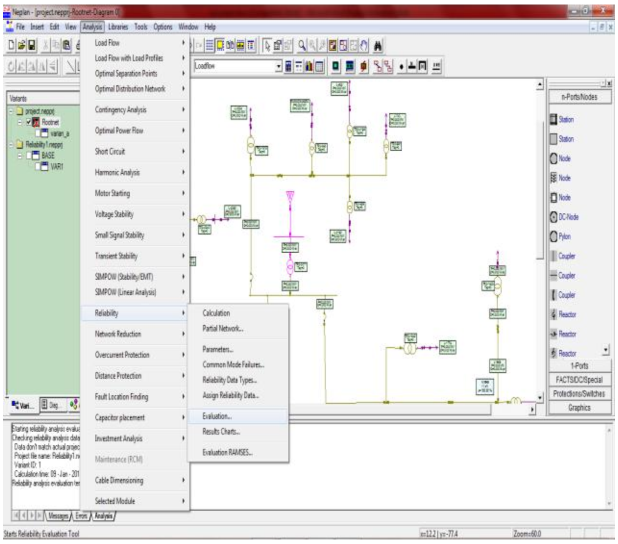

Fig 5: Showing the Run Mode Reliability Option

VI RESULTS AND ANALYSIS

In order to calculate the system indices, Choba distribution system consisting of Ten (10) transformers and a single 11kV distribution line that extends from the substation down to areas where it was stepped down to their respective 0.415kV voltage was considered. A constant load demand of 4MVA was assumed. For the purpose of obtaining the various reliability indices (load indices and system indices) from the already modeled Choba distribution system in NEPLAN analyzer, the variant manager that exclusively defines only Choba topology (configuration) and loading was activated. The results obtained from the simulation of NEPLAN analyzer, are shown in Table 2.0, 3.0, 4.0, 5.0, 6.0 and 7.0 respectively which is in accordance with that obtained manually by calculation. The system indices for the various days of July were calculated where the average values for the week was taken. The same procedure was followed for the remaining months.

Table 2: Average System Indices for June

AVERAGE SYSTEM INDICES FOR THE MONTH OF JUNE					
	week 1	**week 2**	**week 3**	**week 4**	**MONTHLY AVERAGE**
SAIDI	28.345	27.77	26.564	29.334	112.013
CAIDI	10.127	11.235	8.347	10.282	9.99775
SAIFI	0.577	0.545	0.556	0.742	0.605
CAIFI	0.0006	0.0006	0.0006	0.0006	0.0006
CIII	1695	1695	1695	1695	1695
MAIFI	0.365	0.344	0.323	0.563	0.39875
ASAI	96.764	95.455	97.847	96.688	96.6885

Table 3: Average System Indices for July

AVERAGE SYSTEM INDICES FOR THE MONTH OF JULY					MONTHLY AVERAGE
	week 1	week 2	week 3	week 4	
SAIDI	27.454	27.77	22.45	29.707	107.381
CAIDI	8.678	11.244	12.684	10.486	10.773
SAIFI	0.565	0.677	0.553	0.742	0.63425
CAIFI	0.0006	0.0006	0.0006	0.0006	0.0006
CIII	1695	1695	1695	1695	1695
MAIFI	0.453	0.333	0.323	0.442	0.38775
ASAI	96.808	95.455	95.445	95.401	95.77725

Table 4: Average system Indices for August

AVERAGE SYSTEM INDICES FOR THE MONTH OF AUGUST					MONTHLY AVERAGE
	WEEK 1	WEEK 2	WEEK 3	WEEK 4	
SAIDI	28.345	28.756	29.342	29.334	115.777
CAIDI	13.55	10.238	10.235	10.282	11.07625
SAIFI	0.577	0.545	0.775	0.742	0.65975
CAIFI	0.0006	0.0006	0.0006	0.0006	0.0006
CIII	1695	1695	1695	1695	1695
MAIFI	0.448	0.443	0.442	0.563	0.474
ASAI	95.562	96.672	95.552	95.43	95.804

Table 5: Average system Indices of September

AVERAGE SYSTEM INDICES FOR THE MONTH OF SEPTEMBER					MONTHLY AVERAGE
	WEEK 1	WEEK 2	WEEK 3	WEEK 4	
SAIDI	27.98	27.77	26.564	29.334	111.648
CAIDI	11.74	9.67	10.45	10.383	10.56075
SAIFI	0.567	0.545	0.742	0.553	0.60175
CAIFI	0.0006	0.0006	0.0006	0.0006	0.0006
CIII	1695	1695	1695	1695	1695
MAIFI	0.453	0.553	0.563	0.563	0.533
ASAI	95.553	97.821	96.764	95.43	96.392

Table 6: Average System Indices for October

AVERAGE SYSTEM INDICES FOR THE MONTH OF OCTOBER					MONTHLY AVERAGE
	WEEK 1	WEEK 2	WEEK 3	WEEK 4	
SAIDI	22.458	28.56	19.45	29.707	100.175
CAIDI	8.678	11.244	12.684	10.486	10.773
SAIFI	0.565	0.677	0.553	0.742	0.63425
CAIFI	0.0006	0.0006	0.0006	0.0006	0.0006
CIII	1695	1695	1695	1695	1695
MAIFI	0.453	0.333	0.323	0.442	0.38775
ASAI	96.808	95.455	95.445	95.401	95.77725

Table 7: Average System Indices for November

AVERAGE SYSTEM INDICES FOR THE MONTH OF NOVEMBER					
	WEEK 1	WEEK 2	WEEK 3	WEEK 4	MONTHLY AVERAGE
SAIDI	24.454	23.89	22.45	29.707	100.501
CAIDI	8.678	10.468	12.684	10.486	10.579
SAIFI	0.565	0.742	0.247	0.742	0.574
CAIFI	0.0006	0.0006	0.0006	0.0006	0.0006
CIII	1695	1695	1695	1695	1695
MAIFI	0.365	0.363	0.365	0.365	0.3645
ASAI	97.324	95.985	95.932	96.81	96.51275

Table 8: average system indices for six months

MONTH	SAIDI (hr/yr)	CAIDI (hr)	SAIFI (1/yr)	CAI FI	CIII	MAIFI	ASAI (%)
JUNE	112.013	9.998	0.605	0.00 06	1695	0.399	96.689
JULY	107.381	10.773	0.634	0.00 06	1695	0.388	95.777
AUG	115.777	11.076	0.66	0.00 06	1695	0.474	95.804
SEPT	111.648	10.56	0.602	0.00 06	1695	0.533	96.392
OCT	100.175	10.773	0.634	0.00 06	1695	0.388	95.777
NOV	100.501	10.579	0.574	0.00 06	1695	0.365	96.513

Figure 6.0, 7.0, 8.0, 9.0, 10.0, 11.0 and 12.0 shows the graphical comparison of the various system indices from the month of June to November.

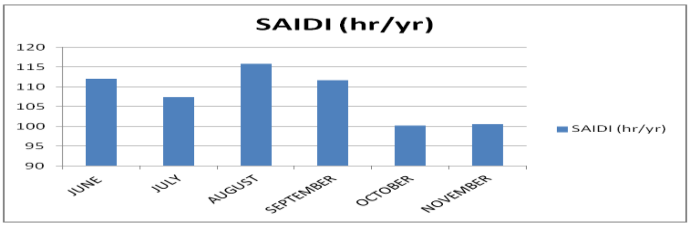

Fig6:Chart Showing SAIDI For Six Months

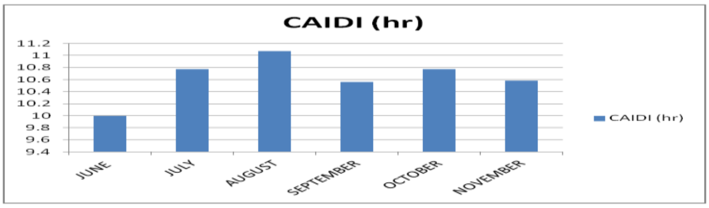

Fig7:Chart Showing CAIDI For Six Months

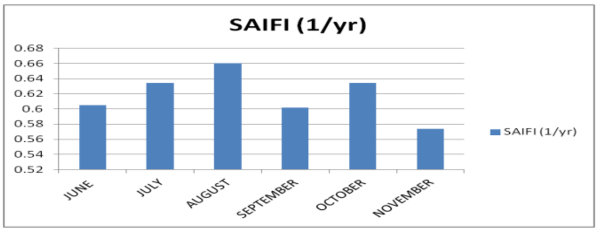

Fig8:Chart Showing SAIFI For Six Months

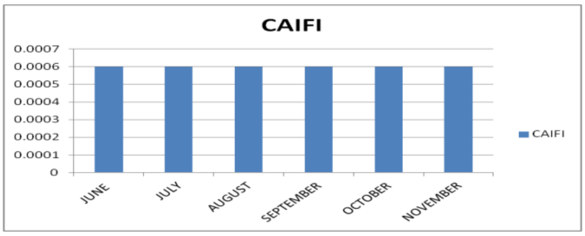

Fig9:Chart Showing SAIFI For Six Months

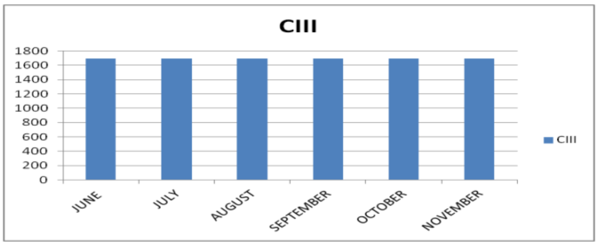

Fig10: Chart Showing CIII For Six Months

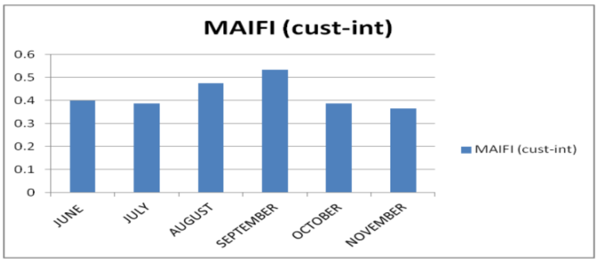

Fig11: Chart Showing MAIFI For Six Months

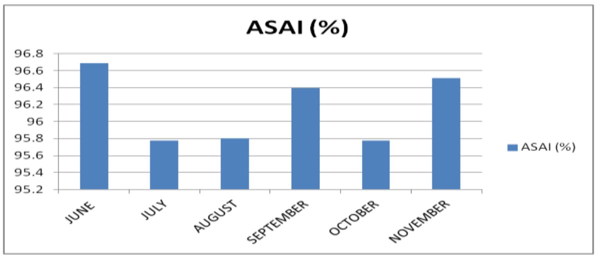

Fig12: Chart Showing ASAIFor Six Months

VII DISCUSSION OF RESULTS

Considering the formula used for SAIDI,

$$SAIDI = \sum (r_i . N_i) / N_T$$

r_i *is the outage duration, where* $i = 1,2,3 \ldots n.$ $r_1 = 1.20hrs, r_2 = 5.30hrs,\ N_i = 1695\ N_T = 6850$.

Substituting these values into SAIDI defined above gives; $SAIDI = (1.20 * 1695 + 5.30 * 1695)/6850$

$SAIDI = 1.608\ hr$ Or $96.504\ min$

This says that the average customers were out for 1.608 hours on the 1st of July 2012. The monthly SAIDI values are calculated by summing the average weekly values.

Similarly, CAIDI is calculated using the formula given below. Thus;

$$CAIDI = \sum (r_i . N_i) / \sum (N_i)$$

$$CAIDI = (1.20 * 1695 + 5.30 * 1695)/1695$$

$CAIDI = 3.25$ Hours

This shows that on average, any customer who experienced an outage on the 1st of June 2012 was out of service for 3.25 hours. The monthly CAIDI are calculated by taken the average values of the weekly values as shown in figure:

In the same vein, the SAIFI, CAIFI, CIII, ASAI, etc. were calculated using their respective indices formula.

$$SAIFI = \frac{SAIDI}{CAIDI} = \frac{\sum(N_i)}{N_T}$$

$$SAIFI = (3390/6850)$$

$$SAIFI = 0.485\ 1/yr$$

Meaning that on the 1st of June 2012, the customers at this utility had a 0.485 probability of experiencing a power outage. SAIDI can also be found by dividing SAIDI value by the CAIDI value.

$$CAIFI = \frac{\sum(N_0)}{\sum N_i}$$

Where;

$N_0 = \textit{the numbers of interruptions.}$

$$CAIFI = (1+1)/(1695+1695)$$

$$CAIFI = 0.00059 \cong 0.0006.$$

This says that the average number of interruptions for a customer who was interrupted is 0.0006 times.

$$CIII = \frac{\sum N_i}{\sum N_o}$$

$$CIII = 1695\ \textit{customers.}$$

This says that, on average, 1695 customers were interrupted on the day under consideration. Of course, on the detailed look at the outages on the 1st of June 2012, it is clear that any outage contributed to the entire customer outages. And finally, taking a look at the Average Service Availability Index (ASAI),

$$ASAI = [(8{,}760 - SAIDI)/8{,}760] * 100$$

Where;

$8{,}760 = \textit{yearly hours of data collected}$

$$ASAI = [(8{,}760 - 1.608)/8{,}760] * 100$$

$ASAI = 99.98\%$.From the ASAI, the system has an average availability of 99.98%.Figure 6.0 shows the monthly SAIDI for a period of six months. It is observed that the month of August recorded the highest average hour for which the customers were out (i.e. above 115 hours) as compared with the other months. In similar vein, figure7.0 shows that on average in the month of August, any customers who experienced outage, where out for more than eleven hours. This period therefore shows a very critical period which should be considered when planning or carrying out any operations during this month. With these under consideration, it becomes evident why the probability of obtaining an outage in the month of August is high as described by the SAIFI of figure 8.0 which shows a relative higher probability of experiencing an outage, with the next higher probability exhibited be the month of July, October, June respectively with the lowest displayed in November.A different picture is portrayed both by CAIFI and CIII. In this analysis, the average number of interruptions for a customer who was interrupted and the average customers interrupted on the various months under consideration possess a constant value of 0.0006 and 1,695 respectively. This is due to the fact that a radial distribution system was considered in this paper as found in the network under study and whenever there is an outage at the substation, all the consumers are affected at the same time.Finally, taking a look at figure 12.0, the highest ASAI of Choba Distribution System shows a value of 96.69%. Some utilities have set an ASAI goal of "four-nines" or 99.99% reliability. A "four-nines" reliability value translates into a SAIDI of 52 minutes per year. Therefore, the reliability of this typical distribution system is very poor.

VIII CONCLUSION AND RECOMMENDATIONS

The test results indicate the effectiveness of the technique and accuracy in estimating system strength and weakness. Although the simulation was done off-line, the project can be adapted for a real power system and the algorithm used for reliability calculation on an energized system. Thus, the use of NEPLAN will provide an insight into the system performance and this will help predict any possible outage in any system. During the cause of this work some challenges were encountered such as getting access to the data necessary for the successful completion of this research work.It is recommended that PHCN should ensure that a detailed account of data and records of each station and sub-station with reference to the outage time, failure rate of components (switches, breakers, lines, etc.), and total energy consumed be well documented to ensure the addition of other predictive reliability indices such as Energy Not Supplied.Also, it will be of tremendous help if PHCN can ensure a means of isolating only the faulted areas from the substation during any fault, instead of shutting down the entire area served by that particular feeder.

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