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Analysis and Evaluation of Calabar Area Distribution Network Reliability for Effective Energy Delivery

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ABSTRACT
Electricity distribution in Calabar area of cross river state of Nigeria faced a serious challenges because of its topography. Due to the adopted technique in power distribution in the country. Electric power system is made to meet the demands of the users, a largely interruptions which are unavoidable contribute to the unavailability of power and thus prevent power system from achieving its goal. In most cases, it is the sustained interruptions that greatly affect both the utility company and its customers. Hence, it is necessary to find means of determining which component failure contributes most to the unavailability of the distribution system, and how this unavailability actually affects the customers. This is to enable system engineers to plan and develop a means of finding better solution of improving the reliability of a distribution substation network. By using analytical method and network reduction technique, the substation reliability was analyzed based on the outage data gotten from the utility company. The reliability analysis was done using Etap 16.0.The results from the simulation reveals that the most reliable on the network has an average interruption rate of 0.074 (f/yr) while the worst reliable has an average interruption rate of 3.6885(f/yr).The overall system availability shows poor system performance.

KEY WORDS: Reliability, Power System, Rate of Outages, System Interruption, Energy Availability.

I. INTRODUCTION

Power system reliability is the tendency of a system to provide a power that one can be assured of its continuity, availability at all time for the customer as this is the major parameters indices for measuring a sustainability. A network is said to be poor reliable, when there is much power outages, failures, excessive load scheduling, faults sustain for longer time [1, 2]. This alone can causes a migration of business in the area, low economy levels, and customers whose depends solely on the system a bound to run loss [1,4]. According to [2,5] the effect of unreliable systems are low infrastructure development, network collapses and environmental pollution since individuals are tend to satisfy his need electrically. [6,9] Maintained that reliability can be improved by considering the technical and organizational measures when planning on system operation and maintenances. According to [10,11] for system to be reliable it must be able to withstand a disturbances on the network, which may cause by the users and the system its self.

II. MODEL FORMULATIONS

The expected unit of time between the occurrences of two consecutive failures for repairable systems is Mean time between failures

$$\frac{\text{Total Up Time}}{\text{Number of Breakdown}} \quad (1)$$

Mean time to repairis given by

$$\frac{\text{Total Down Time}}{\text{Number of Breakdown}} \quad (2)$$

And equation (3) describe the availability

$$\frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \quad (3)$$

$$SAIFI = \frac{\sum \text{Total number of customer interruptions}}{\text{Total number of customer served}} \quad (4)$$

$$SAIFI = \frac{\sum N_i}{N_T} \quad (5)$$

$$SAIDI = \frac{\sum \text{customer interruption Durations}}{\text{Total number of customer served}} \quad (6)$$

$$SAIDI = \frac{\sum r_i N_i}{N_T} \quad (7)$$

$$CAIDI = \frac{\sum \text{customer interruption Durations}}{\text{Total number of customer interruptions}} \quad (8)$$

$$CAIDI = \frac{\sum r_i N_i}{\sum N_i} = \frac{SAIDI}{SAIFI} \quad (9)$$

$$CTAIDI = \frac{\sum \text{Customer Interruption Durations}}{\text{Total Number Customers Interrupted}} \quad (10)$$

$$CTAIDI = \frac{\sum r_i N_i}{C_N} \quad (11)$$

Where, C_N is the total number of customers facing an interruption during the reporting period.

$$CAIFI = \frac{\text{Total Number of Customer Interruptions}}{\text{Total Number Customers Interrupted}} \quad (12)$$

$$CAIFI = \frac{\sum N_i}{C_N} \quad (13)$$

$$ASAI = \frac{\text{Customer hours Service availability}}{\text{Customers hours service demand}} \quad (14)$$

$$ASAI = \frac{N_T * 8760 - \sum r_i N_i}{N_T * 8760} \quad (15)$$

$$ASIFI = \frac{\sum \text{Total connected KVA of Load Interrupted}}{\text{Total connected KVA served}} \quad (16)$$

$$ASIFI = \frac{\sum L_i}{L_T} \quad (17)$$

Where, Li is the load interrupted due to each outage while L_T is the total load connected to the system under consideration.

$$ASIDI = \frac{\sum \text{Connected KVA Duration of Load Interrupted}}{\text{Total connected KVA served}} \quad (18)$$

$$ASIFI = \frac{\sum r_i L_i}{L_T} \quad (19)$$

The average load La is given in Equations (20) and (21).

$$L_a = L_p * f \quad (20)$$

Where Lp = peak load demand, f = load factor, the average load La is also defined as follows:

$$L_a = \frac{\text{Total energy demanded in period of interest}}{\text{Period of Interest}} \quad (21)$$

$$L_a = \frac{E_d}{t} \quad (22)$$

Total energy not supplied by the system is estimated using Equation (20)

$$ENS = \sum L_{a(i)} * U_i \quad (23)$$

where, La(i) and Ui respectively are the average connected load and the average annual outage time at load point The average energy not supplied by the system is estimated using Equation (24) & (25).

$$AENS = \frac{\text{totalenergy not suplied}}{\text{total number of customers served}} \quad (24)$$

$$AENS = \frac{\sum L_{a(i)} * U_i}{\sum N_i} \quad (25)$$

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III. RESULT PRESENTATION

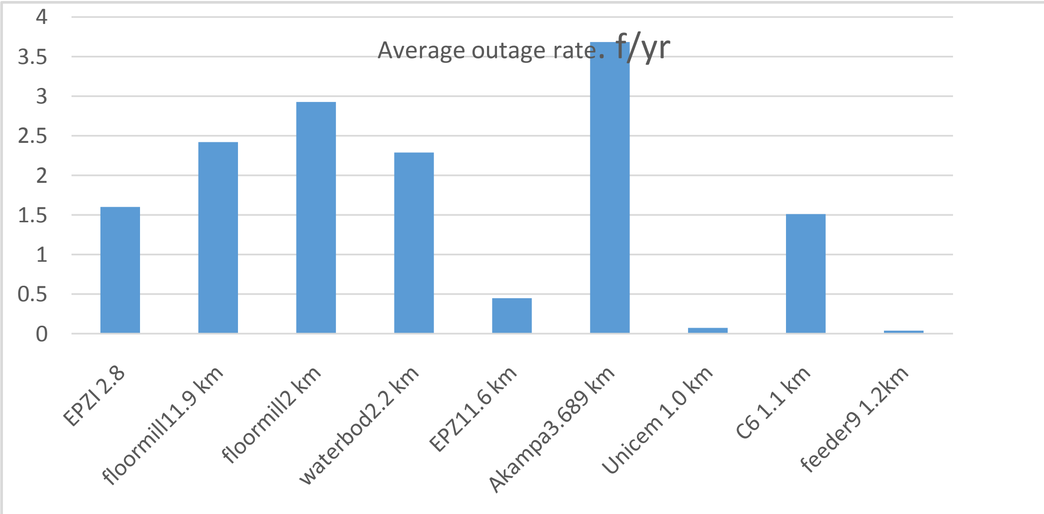
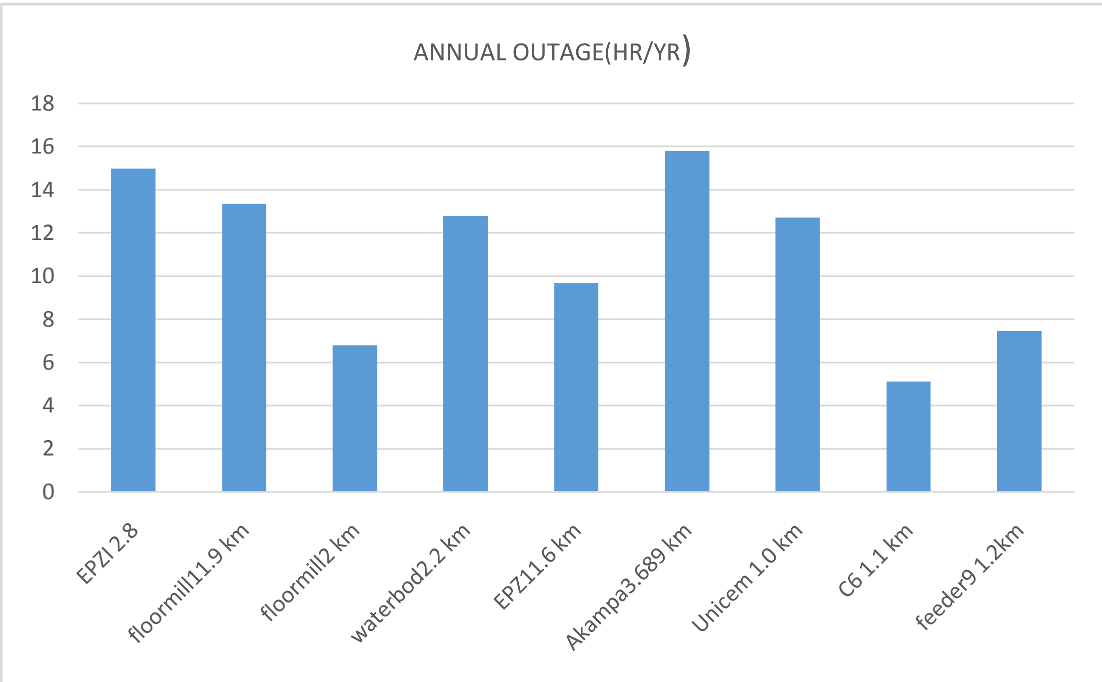


Fig. 1.0: Graph of average outage rate against distance

Fig.2.0: Graph of annual outage rate against distance



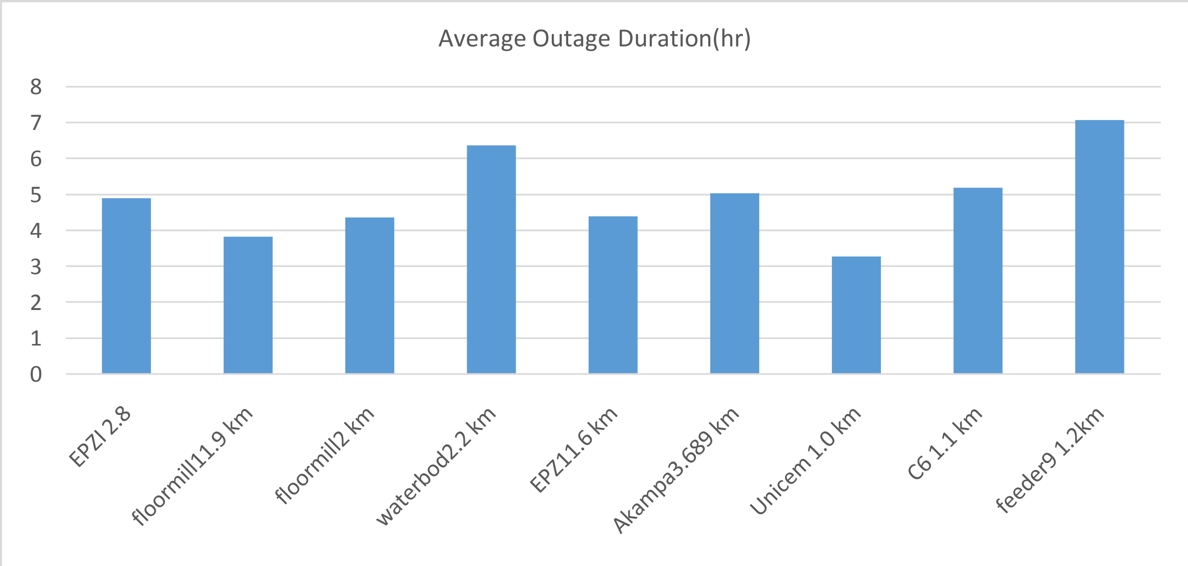


Fig. 3.0: Graph of average outage (hr) against distance

TABLE:2.0 Load point indexes analysis

Feeder	Distance Km	Average interruption (f/yr)	Annual Outage (hr/yr)	Average Outage duration (hr)
Akamkpa	2.8	3.6885	5.030	15.800
Floormill 1	1.9	2.4207	3.821	3.30
Floormill 2	1.6	2.9314	4.36	6.70
Waterboard	2.2	2.2900	6.36	12.786
EPZ 1	1.6	0.4520	4.02	9.68
EPZ 2	1.32	0.110	4.89	6.128
UNICEM	1.0	0.0145	3.27	12.712
C6	1.1	1.5128	5.18	5.108
FEEDER 9	1.2	0.039	7.06	7.451

TABLE: 1.0: RELIABILITY DATA OF EACH COMPONENTS

COMPONENTS	Failure Rate (f/yr)	Repair Time	Switching Time (hr)
TRANSFORMER	0.015	18	2.0
330KV/132KV	0.015	16	2.0
BREAKER	0.003	6.0	2.0
330KV/132 KV	0.003	6.0	2.0
BUSBAR	0.002	4.0	2.0
330KV/1320KV	0.001	4.0	2.0
FEEDERS	0.02	7.0	2.0
330KV/132KV	0.02	7.0	2.0

TABLE: 3.0: SYSTEM INDICES

SYSTEM INDICES	RESULTS
AENS	0.0426 MW hr / customer.yr
ASAI	0.9870 pu
ASUI	0.01304 pu
CAIDI	71.574 hr / customer interruption
ECOST	281.420 $ / yr

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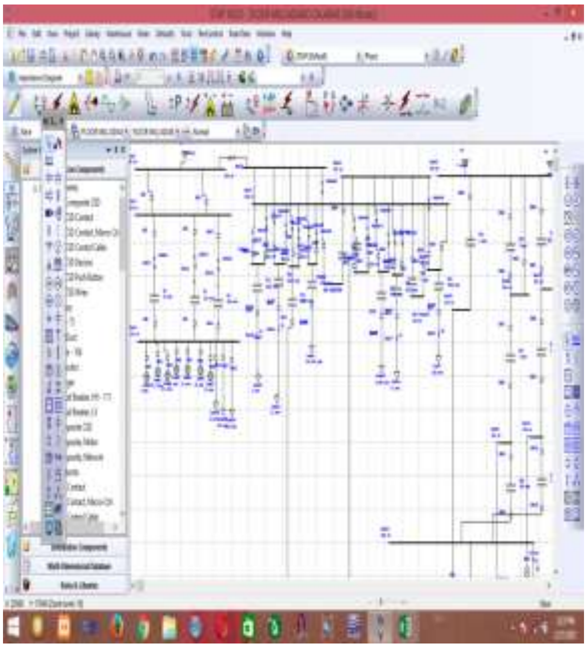
EENS	281.00 MW hr / yr
SAIDI	114.2735 hr / customer.yr
SAIFI	1.5966 f / customer.yr

ACCI System Average Customer Curtailment Index
AENS Average Energy Not Supplied
ALII System Average Connected kVA Interrupted per kVA of Connected Load Served
ASAI Average service Availability Index
ASUI Average Service Unavailability Index
CAIDI Customer Average Interruption Duration Index
ECOST Expected Interruption Cost
EENS Expected Energy Not Supplied
SAIDI System Average Interruption Duration Index
SAIFI System Average Interruption Frequency Index



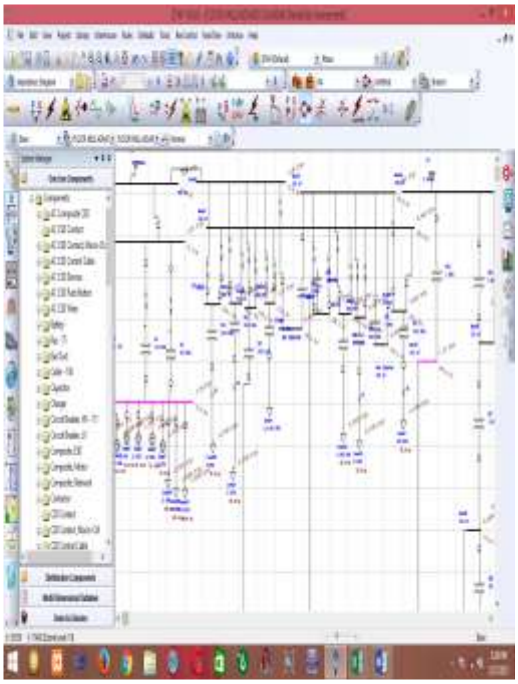


Figure 4.0: Etap model of the distribution Figure 5.0 Etap model of the distribution network not simulated simulatednetwork

IV. DISCUSSION OF RESULTS

The simulation was done on ETAP 16.0 on the model of Calabar distribution network. This model is presented in figure 1 and figure 2. Fig.1 is the network model not simulated and fig. 2 is the model after simulation. And the results from the simulations are presented in tables below.

Table 1 is shows the reliabilities of each components on the model (this includes switching time, repair time and failure rate). Table 2.0 shows the results of load point indices analysis of the network. This involves average interruptions (f/yr), annual outages (hr/yr) and annual outage durations (hr). But reliability study is not complete with this three factors mentioned only, it also includes the items shown in Table 3.0 for complete reliability studies. The results from table 2 is presented graphically in figures 3.0, figure 4.0 and figure 5.0 for easily understanding.

V. CONCLUSION

The reliability of the system in Calabar network under investigation has been carried out using ETAP 16.0. It reveals that the most reliable on the network has an average interruption rate of 0.074 (f/yr) while the worst reliable has an average interruption rate of 3.6885(f/yr). This values is caused by the long distance f the area. Power system planning and evaluations has to be taken a good measure to maintain the area that is reliable and improve on the area that's not reliable in order to meet the consumers demand. The must be adequate investments towards the direction where the system is not reliable and ensure prompt payments of utility charges in order to maintain reliability in the entire system.

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