RELIABILITY ANALYSIS OF POWER DISTRIBUTION NETWORK IN LAFIA METROPOLIS

BY

ALHASSAN I ALLO

(2000/10646EE)

SUBMITTED TO

THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE

IN PARTIAL FULFILMENT OF THE REQUIREMENT OF THE AWARD OF BACHELOR OF ENGINEERING (B. ENG) DEGREE IN ELECTRICAL AND COMPUTER ENGINEERING.

NOVEMBER 2005.

DECLERATION

I, Allo I. Alhassan hereby declare that this project has been carried out by me, and that it is a record of my own research work. It has not been presented in any previous application for a first degree award.

....

Allo I. Alhassan

2000/10646EE

CERTIFICATION

This is to certify that this thesis "Reliability Analysis of Power Distribution Network in Lafia Metropolis" is the original work of Allo I. Alhassan carried out under the supervision of Dr Y. A. Adediran for the award of Bachelor of Engineering (B. Eng) degree in Electrical and Computer Engineering of F U T., Minna.

Dr. Y. A. Adediran (Project Supervisor)	Date
Engr. M. D. Abdullahi (Head of Department)	Date
Engr. Dr. J. D. Jiya (External Examiner)	Date

DEDICATION

This project is dedicated to God the Almighty and to Mr. Adamu Obagu, Rtd Chief Vehicle Inspection Officer (V. I. O.), Nasarawa State.

ABSTRACT

The increasing complexity of industrial systems, the prominent part they play in economic and social life, the need for design and operation cost reduction in highly competitive market are as many reasons for carefully attending to reliability and dependability of industrial systems such as power transmission and distribution network.

Consequently, measures, methods and models of evaluating reliability were developed. One of the methods is the equation for calculating the probability of an undesirable event from causes or combinations of elementary causes. Measures in current use include: probability, mean time between failures MTBF, failure rate, fault number e. t. c. Models include exponential model of systems. The use of MBTF failure rate and exponential model for reliability analysis were employed in the course of determining the reliability of power distribution network in Lafia metropolis in Nasarawa State. The reliability of the power distribution was found to be 0.46. It was recommended that an additional 33kV line be added to Lafia distribution system, so as to reduce the frequency of power outages in the metropolis.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION

The aim of any electric power utility company is to supply reliable power of acceptable quality and at minimal cost. Such power system will consist of generating transmission, and distribution aspects. The whole system efficiency is therefore dependent on the reliabilities of each aspect involved since they are all interconnected.

Reliability is the probability that a system or component of a system will carry out their prescribed duty without failure for a given time when operated correctly in a specified environment. In a layman's language, reliability of service is ultimately the continuity of service provision or uninterruption of service availability.

For any system to overcome service interruptions there must be adequate measures put in place to guard against such interruptions. In power distribution systems, the measures include:

- Adequate earthing of all metallic bodies in distribution substations
- Provisions of automatic circuit breakers and line isolators
- Use of fast operating relays
- Installing lightning arrestors to safeguard distribution equipments from lightning
- Maintenance of equipment and most significantly replacement of out-use components or parts.

All these protective measures help in safeguarding the distribution network by actually indicating the occurrence of fault. This makes it easier for the authority concerned to investigate and correct such fault on time.

The frequency at which faults occur, the causes of such faults, the time taken to amend faults, maintenance work being carried out, the efficiency of the distribution network as well as the availability of power supply: are the indices on which the reliability analysis of power distribution network in Lafia, the Nasarawa state capital is actually based upon.

Data available for the reliability evaluation are as obtain from the record office of Power House Company of Nigeria (PHCN), Lafia business unit, over a period of twenty-four months; specifically from June 2003 to May 2005.

The analysis covers Lafia metropolis only.

1.1 GENERAL CONCEPTS OF RELIABILITY ANALYSIS

Reliability analysis becomes an emphasis in present day design and construction due to the fact that equipments and systems are bound to fail under certain unfavourable conditions. The failure of a system as complex as a distribution network of course depends on a number of influences. First of all, what does failure really mean? It is the termination of the ability of a system to perform its required function.

A system is considered to have failed under any of the following three conditions;

- When it becomes completely inoperative.
- When it is still operative but with low efficiency.
- When it becomes too risky for its continued use.

Failure may be classified due to:

i. Causes of failure: This involves excessive stress on a system or inherent weakness of the system born from design or manufacturing error.

ii. Timing of failures: This involves sudden failure and or gradual failure over time.

iii. Degree of failure: This involves partial failure which gives rise to deviations in the working state of a system beyond the limit generally acceptable.

iv. Combination of failures: This involves catastrophic failure in which both sudden and complete failure occurs. Degrading failure where both gradual and potential failure occurs is also one form of combination of failures.

In all these factors, it is paramount to devise a means of relating all the failure factors as they affect the operation of a system, and then examine their individual effects as well as the cumulative effect such failure have on a system when they occur. The final outcome is what can be termed the assessment of system reliability.

Reliability analysis procedure consists of the following steps:

- Identify the component parts of the system.
- State the basic failure rate for each part.
- Multiply the failure rate by the number of similar parts.
- Multiply all available weighing factors.
- Add up all the products obtained from previous steps the give the overall failure rate for the system.

$$\lambda = \frac{1}{MTBF}$$ -------------for repairable items

where $\lambda = \sum_{i}^{n} \lambda_i$

MTBF= mean time between failure.

Or

$$\lambda = \frac{1}{MTTF}$$ -------------for non repairable items

MTTF= mean time to failure

- Determine the system reliability R for a given operating time t, using the expression:

$$R = e^{-\lambda t}$$

(R= for exponential models with constant failure rate λ)

Or

$$R = e^{-\lambda \int t dt}$$ .... (for non constant failure rate)

For non exponential models, the failure probability formula can be used. This is given as:

F=1-R

Where

F= the probability of failure

R= probability of survival (reliability)

R=1-F

$= 1 - [(1-R_1)(1-R_2)(1-R_3) \text{--------} (1-R_n)]$

$$R = 1 - \prod_{i=1}^{n} (1 - R_i)$$ ---------------- Parallel connection

$R_{(t)} = R_{1(t)} \times R_{2(t)} \times R_{3(t)} \times \text{---------} R_{n(t)}$ ------Series connection

1.2 THE NEED FOR SYSTEM RELIABILITY ANALYSIS

Modern day equipment or systems are mostly complex in nature. Due to their multivariate functions, they are expected to perform, it becomes necessary for equipment / system to have very high reliability values so as to avoid frequent failure.

Reliability analysis is the method by which such reliability values are ascertained.

In production organizations, the knowledge of reliability analysis goes a long way in influencing management decisions. This is because it brings out a concise outlook as to what the organization is running at. It also makes it possible for maintenance engineers to easily identify and accord priorities to failure methods thereby planning ahead, ways to avoid such failures by embarking on preventive, routine or even corrective maintenance.

Through reliability analysis, the transition from the useful life of equipment or a system, to the out used phase, can be monitored over time. This will help an organization to minimize or cut off its expenses on recurrent repairs and go for replacement once an equipment has attained the out-used phase.

Safety is a very important factor that is highly regarded in any working environment, most especially, where automotive machines are involved. The engineers working in such environment will not feel safe unless he is guaranteed some degree of reliability, on the machine he is working with. Reliability analysis is a guide to ensuring safe working environment if only the engineers will adhere to the specifications on reliable and safe working parameters on any equipment.

1.3 METHODS OF ANALYSING SYSTEM RELIABILITY

With the increasing complexity of power system configuration, the analysis of reliability becomes more tedious when one has to deal with a complex system. There has been a continuing and increasing interest in methods of power system reliability evaluation in the reliability of complex systems, a usual approach is to describe the physical system by means of some logic diagram which expresses all functional relations between components or events considered to be elemental

Many methods are available for evaluating power system reliability. Some of these methods are:

i. *The Mean Time Between Failures (MTBF) method*: This is a measure which does not involve the period of observation. It is measured by testing a system for X number of times during which Y number of failures occur. Each failure is independent of another. The time taken in repairs is not included in the total test time.

$$MEBF = \frac{Total\ test\ number\ \ (X)}{Number\ of\ \ failure\ that\ occur\ (Y)}$$

ii. *The Failure Rate method*: Failure rate is the number of failures that occur per unit time. The failure rate for most electrical system is assumes to be approximately constant for most part of their working life.

Mathematically, failure rate λ is expressed as reciprocal of mean time between failures (MTBF) – for repairable components, or the reciprocal of mean time to failure (MTTF) for non-repairable components.

$$\lambda = \frac{1}{MTBF} \quad \text{or } \lambda = \frac{1}{MTTF}$$

MTBF and MTTF are both expressed in hours hence their units are in faults per hour.

iii. *Loss of Load Probability (LDLP) index* : LDLP index is employed in reliability studies of electric power systems to evaluate the probability that the system load might exceed the available generating capacity [3]

LDLP can be defined as the probability of the system load exceeding the available generating capacity under the assumption that the peak load of each day lasts all day. When the reliability of an electric power system is evaluated by LDLP method, it is necessary to take into account the uncertainty in the load forecast by associating a peak load distribution with the assumed daily peak load duration curve

iv. *Loss of Energy Index*: This can be used for a generating system. It is the ratio of the expected amount of energy not applied during some long period of observation, to the total energy required during the same period.

The loss energy index is an in-depth measure reliability in that, it will assume higher values for more serious events then for marginal failures even if their probabilities and frequencies are the same [3]

However, a setback to this method is that, true loss of energy cannot be accurately computed on the basis of the cumulative of daily peaks. This is why the method is seldom used.

v. *Fault Tree Analysis*: a comparatively new approach to system reliability evaluation is the fault tree analysis (FTA). This technique has rapidly gained favour because of it's versatility in degree of detail of complex systems. Fault tree is one of the most commonly used in representation of system logic.

The FTA starts by identifying an undesirable event called the TOP EVENT that is associated with a system, in the case of system availability and reliability studies, the fault provides a diagrammatic representation of event combination resulting in the occurrence of this undesirable event.

The basic steps involved in fault tree analysis include:

- Alpha –numeric identification of gates and primary events.

- Representation of the Boolean relationship (AND / OR) present at each gate, and
- Ordering of these gates appropriate to the subsequent analysis.

A fault tree is made up successive levels such that each event is generated out of lower level events through various logic operators (AND/OR gates). This deductive process goes on until it gets to a basic event which can be failures, human errors, external conditions etc.

1.4 AIMS AND OBJECTIVES OF THE PROJECT

The ultimate goal of any service provider is to give its subscriber maximum satisfaction in exchange for what they are paying for what they are paying for and to make good returns out of the services being rendered. Maximum satisfaction to the electricity users translate to constant, adequate and reliable supply of power.

In Nigeria, the organization is saddled with the responsibility of providing the much needed power is the defunct National Electric Power Authority (NEPA), now known as Power Holding Company of Nigeria (PHCN). Although the organization is making efforts towards ensuring availability of power, various factors exist which undermine such efforts. These factors are the various failure modes that are regularly encountered in both transmission and distribution systems in the country. In some places around the country, the organization is rendered almost useless as electricity users are forced to look form alter native source of supply to do their businesses.

The aim of this project work is to take a closer look at the failure modes of as they affect the operation and availability of power in the distribution network in Lafia town, the capital of Nasarawa State. The performance of the 33kV line, 11kV feeder supplying the town, the efficiency of the distribution lines at consumer premises as well as the efficiency of the distribution transformers in the town will be carefully evaluated. Finally, the reliability and availability of power supply in the entire distribution network will be obtained. Useful suggestion will be made on how to improve the availability of power supply in the town.

CHAPTER TWO

LITERATURE REVIEW

2.1 EVOLUTION OF RELIABILITY STUDY

The concept of designing equipment and studying its performance for a given time dates back more than a hundred years [1]

Originally, the attention was mostly focused on mechanical systems. However, with the advent of electricity, engineers work hard to improve reliability of power sources; improvement was to be seen in the area of parallel wiring of transformers as well as interconnection of high voltage lines [1]. Progress was made in reliability as redundant designs were avoided, and enhanced equipment quality was ensured.

In engineering practice, the emphasis on reliability has grown out of necessity. In electrical engineering, the need for improved reliability has always been in focus. At the initial stage of electrical development, faults were corrected manually. With development, this became unacceptable; hence fuse was introduced [2]. Fuses were again found wanting as they take long time to operate. Moreover, fuses have poor discrimination and one has to physically replace a ruptured fuse in order to restore power supply. Consequently, a more reliable system was introduced – the circuit breakers.

Nowadays, the operation of circuit breakers is being made more effective by the use of relays which provide / ensure fast automatic operation of circuit breakers. The development of fast operating relays has reduced significantly equipment damage, and system instability. Power outages are also reduced and quality of service is sustained to a great extent.

2.2 RELIABILITY STUDY IN THE 1930s

The interest in reliability does not stop at mechanical and electrical engineering alone. In the 1930s, a new facet of reliability was born. Thus statistical data on failure rates of various aircraft components were collected. The collected figures form the basis for choice of future improvements and objectives. For the first time, probabilistic concept concerning the safety and reliability levels of air craft came into being [2]. Consequently, the London Aeronautical Research Council, in 1939 and 1942, published Pugsley research work which asked that the accident rate of an air craft, considering all the failure causes, should not exceed 10^{-5} per hour and 10^{-7} per hour for structural causes [1]. This was one of the first risk objectives defined for aircraft safety.

2.3 RELIABILITY GROWTH IN THE 1940s

During the Second World War, precision in reliability forecast became serious as regards engineering tools. There were failures in some important projects embarked on by engineers. For instance, the original series of about ten rockets made by Von Braun, who was working on a project called "V1 missile project" detonated on their launching pads. In attempt to resolve this problem, Wernher Von Braun's team began their analogy from the theory first produced in 1926 by Pierce which states "a chain is no stronger than its weakest link"

This theory was later seen to be obviously wrong because it means that the missile had to be as strong, as reliable as its weakest part. It also implies that each time a component gave out, the team is doomed. The team then progressed to the idea that all components had to be taken into account, since sometimes good components regarded as strong links had failed in some tests causing mission failure.

Eric Peiruschka, a mathematician established that if a survival probability of an element is $\frac{1}{X}$, the survival probability of a set of identical elements will be $\frac{1}{X^n}$ [1]. It was on this that the formula for the reliability of a series system which is often called Lusser's law on product of reliabilities was derived, thus:

$$R_s = R_1 \times R_2 \times R_3 \times \text{-----------------------} R_n$$

2.4 RELIABILITY AS A BRANCH OF ENGINEERING

Reliability as a branch of engineering was born in the United States of America in the 1950s, particularly in electronics. In 1952, the Department of Defence and all the electronic industries decided to create the Advisory Group on Reliability of Electronic Equipment (AGREE) [1]. This body studied life span of electronic equipment.

Gradually, the body found that there is more in designing reliable equipment than waiting for failures and having to repair them.

AGREE came to the conclusion that breaking the maintenance cost produced by the lack of reliability should become an integral part of the development cycle of electronic equipment. It insisted on new equipment being tested for several thousand hours in a severe environment in order to spot as many weak points as possible at a sufficiently early stage to be able to correct these defects before mass production is embarked upon.

The group also advised that reliability should be demonstrated and that the mean time between failures be computed as well as its dependable interval; and also that the actual mean time between failures should be shown to exceed the required mean time failures. This was the first reliability criteria that were applied to mass produced components [1].

2.5 RELIABILITY GROWTH IN 1960s TO 1980s

The 1960s saw the emergence of new reliability techniques with wide variety of application. The first detailed analysis of components failure and their effect on the system performance and on the safety of the person were performed [1]. During this period the failure mode and effect analysis (FMEA) method was devised. Concern for safety also grew to a subject matter; hence in 1962, the air force in the U.S.A called for separate safety studies. Consequently, the Department of Defence adopted standard, requested safety studies to be performed at all the product development stages in 1966.This standard systems safety programs for systems and associated subsystems and equipments has been in use by the Department of Defence from 1964 onwards. Distinguished mathematicians like Binbaum Barlow, Esary and Weibull contributed to the development of mathematics of reliability during this period.

In the 1970s. new methods of reliability analysis were employed, prominent among which is the event tree method which was used to evaluate accident scenario in nuclear industry. Software reliability studies also began during this period.

In the 1980s, extensive and costly risk assessments were carried out. This technique became widely adopted in such areas as oil industry, chemical industry, car industry and industrial waste treatment [1].

Today, the initial attention which was focussed on reliability and safety has now broadened to eleven where maintainability, dependability and availability serve as useful measures in reality evaluation. One major aim of this project is to obtain the availability of power supply after all the analysis.

2.6 RELIABILITY OF POWER DISTRIBUION SYSTEM

Every system is generally defined by one or several functions (or missions) it must fulfil, with given components, under given conditions and in a given environment. A power distribution system is a means of bringing electricity to the door- steps of users. Distribution system itself consists of many components. The distribution transformers, the poles, conductors, etc. The state of functionality of all these will determine how reliable a distribution system will be. A power distribution system can therefore be said to be reliable if it can deliver the required power to be used by consumers within the distribution network at any time.

2.7 DISTRIBUTION NETWORK WITHIN LAFIA METROPOLIS

Lafia, the state capital of Nasarawa State, is connected to the national grid via a 33kV line which originates from Akwanga transmission station. At the injection substation in Lafia, two branches were made from the 33kV incomer. Each of the branches is connected to a line breaker, then to a power transformer.

The first branch, which is protected by oil-operated line breaker and connected to a 7.5 MVA, 33kV / 11kV power transformer is known as feeder 1.The other branch is protected by a gas-operated line breaker which is connected to another 7.5 MVA, 33 /11 kV power transformer known as feeder 2.

The 11kV line from feeder 1 covers a distance of about 9km, it serves abut 60% of electricity users in Lafia.

Notable areas like Emir's palace, Rice mill, UAC road, Doma road and Markurdi road are taking their electricity supply from feeder 1.

Feeder 1 has a total of 28 distribution substations. This number is made up of the following:

- 18 no 500kVA, 11/ 0.415 kV
- 5 no 300kVA, 11/ 0.415 kV
- 3 no 200kVA, 11 / 0.415kV
- 2 no 100kVA, 11/ 0.415 kV

There are 21 distribution substations in feeder 2, which covers a distance of about 12 km. Areas that take supply from feeder 2 includes Government House, Jos road, Specialist Hospital and National Supply. The distribution substations are of the following categories:

- 10 no 500kVA, 11/ 0.415 kV
- 1 no 315kVA, 11/ 0.415 kV
- 6 no 300kVA, 11 / 0.415kV
- 1 no 200kVA, 11/ 0.415 kV
- 3 no 10kVA, 11/ 0.415 kV

Radial connection is used in both feeders. Both feeders function independent of each other.

2.8 POWER DEMAND CAPACITYOF LAFIA METROPOLIS

The maximum peak load in feeder 1 ever recorded in Lafia is 345A [4].

This current value can be converted to megawatt value by dividing by 60 (which is a scale conversion factor), thus:

345 / 60 = 5.8MW

Feeder 2 recorded a peak load, the highest ever of 240A

This gives 240 / 60 = 4MW

Therefore the demand of power in Lafia metropolis as at date can be estimated to be 10MW.

2.9 CAUSES OF POWER FAIURE IN DISTRIBUTION NETWORK

The causes of power failure in distribution systems are quite enormous. The most commonly occurred are:

i. H.T line faults caused by 33kV and 11kV lines, broken and leaning poles, discs and pin insulators, cross- arms, cables.
ii. Substation faults caused by distribution transformers.
iii. H.T cables (from D- fittings to transformer), L.T cables (incomer and up riser cables), feeder pillars – fittings.
iv. L.T line faults caused by broken poles, shackle insulators, wire cut (causing lives to bridge or fall on the ground)
v. Rupturing of fuses in feeder pillar due to over loading.
vi. Twisting of service conductors.
vii. Transformer failure
viii. Tripping of 11kV feeders due to over current or earth fault.
ix. Power equipment vandalization.
x. Poor maintenance culture
xi. Illegal electrical connections, etc.

2.10 WAYS OF IMPROVING RELIABILITY OF POWER DISTRIBUTION NETWORK

The availability of electricity can be enhanced when certain measures are employed. In some instances, prior warnings are indicated before the occurrence of a fault, but in most cases it usually a sudden occurrence, since most fault occurrences are unforeseen, it then requires that fault clearing personnel will always be at alert to handle any fault as soon as it occurs, prompt response to fault clearance will lessen the outage duration.

Transformer failures can be minimized by adequate services and replacement of transformer oil as at when due. Persistent fuse rupturing in feeder pillars can be checked by carrying out load balancing. Where the capacity of a distribution transformer cannot carry the load demand, such transformers should be replaced by one that can carry the load to avoid fire outbreak.

Routine line patrol will identify places where conductors twist together by the action of tree branches, the tree branches can be trimmed off the conductors. This will prevent unnecessary rupturing of fuses in feeder pillar.

Adequate security should be put in place to arrest and prosecute vandals, and electricity users who are fond of making illegal connection.

Maintenance schedules should be properly and strictly adhered to. This is the only way to ensure that all the breakers, relays and other protective devices are in order and can rise up to the task should a fault come up. This will go long way in reducing unnecessary power outages hence improving the reliability of the entire distribution network.

CHAPTER THREE

ASSESSMENT OF THE POWER SUPPLY STATUS ON THE 33Kv INCOMER TO LAFIA AND ENVIRONS

Lafia metropolis and its neighbouring villages can only enjoy electricity supply when the 33kV incomer is in circuit, and delivering power. The conditions that can guarantee uninterrupted power delivery in the 33kV incomer are that:

- There must be no system failure from the national grid.
- The 33kV line must not be isolated from the transmission station in Akwanga.
- There must be no fault occurrences that could cause the 132 / 33kV feeder to trip.

Apart from these, there must not be any fault occurrence on the 33kV line itself. Unfortunately, it is not possible to achieve these conditions anywhere in the country at the moment, given the deplorable state of power transmission and distribution facilities in Nigeria.

In determining the power supply status on the 33kV line, two categories of factors that hinder steady delivery of power supply on this line are considered. The first category consists of power outages that are notified before they occur. They are:

i. Outages granted for maintenance purposes.

ii. Outages granted on request (to execute an urgent work)

iii. Load shedding.

The second category involves the outages that occur suddenly. These are actually fault conditions, they are:

i. Over current fault

ii. Earth fault

iii. System failure from grid

For easy evaluation, the occurrence of all the factors mentioned, and durations are taken cumulatively on monthly basis.

3.1 CAUSES OF POWER OUTAGES ON 33KV INCOMER AND THEIR CUMULATIVE PEROD OF OCCURRENCE PER MONTH

Table 3.1 gives a breakdown of the factors that are responsible for power interruption on the 33kv line as well as their respective cumulative time of occurrence for each month from June 2003 to May 2005

Table 3.1: Breakdown of causes of power interruptions for a period of 24 months

onth	Factors						Total time hrs:min	Number of faults occurred
	Earth fault hrs:min	System failure hrs:min	Overcurrent hrs:min	Request hrs:min	Load shedding hrs:min	Maintenance permit hrs:min		
2003	08:57	-	-	18:08	15:06	-	42:11	16
”	13:17	-	03:23	03:30	09:31	-	29:41	13
G ”	09:10	14:38	-	05:05	09:30	14:00	52:23	09
PT ”	01:30	11:50	-	01:18	05:04	212:23	41:05	08
T ”	-	-	00:15	00:06	14:23	-	14:44	06
V ”	00:08	-	08:15	00:04	27:44	08:20	54:31	07
C ”	-	05:20	00:49	00:16	20:41	-	27:06	08
N2004	00:15	10:43	-	02:40	43:03	-	47:41	08
B ”	09:21	-	00:07	00:56	00:03	-	10:27	09
AR ”	01:57	02:00	00:15	22:18	08:10	04:49	39:29	06
PL ”	13:05	-	04:13	03:23	-	-	20:50	07
AY ”	03:09	09:24	-	11:54	-	-	24:27	08
N ”	-	-	-	07:00	-	-	07:00	02
”	03:39	02:20	18:41	04:36	-	05:51	35:07	12
JG ”	05:59	-	00:28	07:03	-	-	17:30	06
PT ”	05:58	00:23	01:09	06:08	02:01	-	15:39	03
CT ”	00:23	03:30	00:41	-	-	-	04:34	05
OV ”	-	02:59	01:02	07:21	01:24	-	12:46	08
EC ”	-	-	00:10	-	36:16	-	36:26	02
N2005	-	97:51	-	-	08:59	-	106:50	07
EB ”	08:11	72:00	05:00	-	-	-	45:11	09
AR ”	13:15	-	02:40	-	-	-	15:55	03
PL ”	04:42	00:42	09:16	-	18:48	-	33:28	07
AY ”	02:25	01:08	-	04:46	06:31	-	14:50	08
OTAL	109:21	234:48	56:24	106:41	228:14	54:23	789:51	177

Source: Operation / Maintenance record section PHCN, Lafia business unit.

3.2 PERFORMANCE STATUS OF 11KV FEEDRS IN LAFIA.

The performance of the two 33 / 11kV feeders are based on the following outage conditions as they occur:

i. Earth fault
ii. Over current
iii. Load shedding
iv. Requested outages
v. Maintenance permit.

The occurrences of these conditions and their cumulative outage duration for each month, and for each feeder are given in table 3.3.

3.3 PERFORMANCE OF FEEDER 1

Table 3.2: Feeder 1 power outage records

Month	Factors					Total time hrs:min	Number of faults occurred
	Earth fault hrs:min	Overcurrent hrs:min	Request hrs:min	Load shedding hrs:min	Maintenance permit hrs:min		
JN 2003	113:47	07:00	03:37	104:31	08:00	236:55	32
JLY "	137:40	05:37	24:25	131:2	-	298:44	33
AUG "	134:31	-	46:16	164:37	12:30	243:54	28
SEPT "	81:20	03:00	32:28	78:15	22:10	219:13	15
OCT "	63:50	14:25	41:20	92:10	-	211:52	17
NOV "	-	-	15:30	115:12	-	130:42	04
DEC "	18:01	-	23:51	66:47	05:30	114:09	07
JAN2004	44:12	-	41:18	62:30	-	148:00	07
. FEB "	21:27	-	34:24	76:24	07:25	139:40	24
MAR "	-	-	23:02	52:33	-	75:35	22
APL "	-	04:18	14:22	78:59	-	97:39	07
MAY "	58:10	-	22:28	48:58	09:20	138:56	14
JN "	12:08	-	16:18	32:14	-	60:40	15
JLY "	05:17	01:40	09:33	68:34	-	85:04	16
AUG "	06:00	07:06	04:00	36:08	-	53:14	10
SEPT "	-	-	02:30	14:15	14:53	31:38	03
OCT "	-	-	-	08:20	-	08:20	02
NOV "	01:05	-	-	04:47	-	05:52	02
DEC "	-	-	-	02:25	-	02:25	02
JAN2005	-	-	-	15:45	-	15:45	02
FEB "	-	-	-	04:12	03:30	07:42	03
MAR "	-	01:20	-	-	-	01:20	02
APL "	-	-	-	-	-	-	-
MAY "	-	-	-	06:00	-	06:00	01
TOTAL	687:35	44:26	355:22	1264:38	83:18	2435:19	268

Source: Operation / Maintenance record section PHCN, Lafia business unit.

From table 3.2, it can be deduced that out of the 17520 hours in 24 months,2435 hours 19 minutes were lost to power outages.

3.4 PERFORMANCE OF FEEDER 2

Table 3.3: Feeder 2 power outage records

Month	Factors					Total time hrs:min	Number of faults occurred
	Earth fault hrs:min	Overcurrent hrs:min	Request hrs:min	Load shedding hrs:min	Maintenance permit hrs:min		
JN 2003	05:25	05:00	04:51	63:28	-	78:44	29
JLY "	28:25	-	05:21	111:00	-	144:46	27
AUG "	-	-	19:49	139:47	04:00	163:36	28
SEPT "	18:40	-	28:28	82:04	-	129:12	16
OCT "	24:25	-	17:36	93:14	-	135:15	19
NOV "	04:18	-	22:00	51:13	-	77:31	11
DEC "	-	-	18:06	26:08	03:20	47:34	06
JAN2004	09:45	01:43	11:12	27:28	-	50:08	05
FEB "	-	-	02:21	42:52	-	45:13	20
MAR "	-	-	02:32	50:49	-	54:21	20
APL "	-	-	03:32	38:06	-	41:38	09
MAY "	08:00	-	13:01	47:13	01:20	69:34	06
JN "	-	-	02:45	24:52	-	27:37	06
JLY "	13:10	-	-	19:22	-	32:32	10
AUG "	03:12	-	-	08:51	-	12:03	06
SEPT "	09:41	-	04:22	25:41	-	39:44	08
OCT "	-	-	-	-	-	-	-
NOV "	-	-	-	10:52	04:30	15:20	04
DEC "	-	-	08:10	05:22	-	13:32	02
JAN2005	-	-	-	35:50	-	35:50	05
FEB "	02:38	-	-	14:52	-	17:30	02
MAR "	-	-	-	17:32	-	17:32	02
APL "	-	-	-	14:30	-	14:30	02
MAY "	-	-	-	13:32	-	13:32	02
TOTAL	129:39	06:43	164:06	964:36	13:10	1277:14	245

Source: Operation / Maintenance record section PHCN, Lafia business unit.

Total outage duration on feeder 2 = 1277.14 hours

Total outage duration on the 33kV line = 789.85 hours

Number of hours that feeder 2 delivers power = 17520 – (1277.14 + 789.85)

= 15,452.92 hours.

3.5 RELIABILITY OF THE FEEDERS

Reliability of the two feeders – feeders 1 and 2, is calculated by considering the total outage duration for each month as a failure distribution. The mean of the failure distribution is then found; hence the failure rate. Exponential rate formula is used to calculate the reliability value.

3.6 RELIABILITY OF FEEDER ONE

With reference to Table 3.2, the failure distribution in hours of feeder 1 and that of the 33kV line gives 3225.17 hours in 24 months.

Mean time between failures (MTBF) for the failure distribution is thus:

$$MTBF= \frac{3225.17}{24}$$

$$=134.38 \text{ hours}$$

$$\text{Failure rate } \lambda = \frac{1}{MTBF} = \frac{1}{134.38}$$

$$=0.00744/\text{hr}$$

Using the exponential formula for reliability:

$$R = e^{-\lambda t}$$

Therefore $R= e^{-(0.00744 \times 24)}$

$= e^{-(0.179)}$

$=0.836$

3.7 RELIABILITY OF FEEDER 2

From table 3.3, total hours for the failure distribution is found by adding the total failure hours for the 33kV incomer. This gives:

1277.14 + 789.85 = 2067.08 hrs

MTBF = 2067.08/24 =86.13hrs

$$\text{Failure rate } \lambda = \frac{1}{MTBF}$$

$$= \frac{1}{86.13}$$

$=0.0116/hr$

$$\text{Reliability, } R = e^{-\lambda t}$$

$$= e^{-(0.116 \times 24)}$$

$=0.757$

3.8 EFFICIENCY OF 415V DISTRIBUTION NETWORK IN LAFIA.

The efficiency of 415V distribution network in the whole of Lafia town is calculated based on the number of faults reported by electricity users and the number of such faults cleared within 8 hours. Again, for the simplicity the daily records are summed up together and presented on monthly bases. The table 3.4 shows the breakdown for the period under review.

Table 3.4: L V Fault records

Month	Number of faults reported	Number of faults cleared within 8 hours	Number of faults not cleared
JN 2003	435	337	98
JLY "	570	559	11
AUG "	480	480	-
SEPT "	520	514	6
OCT "	398	384	14
NOV "	545	502	3
DEC "	306	296	9
JAN2004	432	428	4
FEB "	425	412	13
MAR "	486	465	21
APL "	541	460	41
MAY "	406	476	30
JN "	358	355	3
JLY "	334	324	11
AUG "	465	446	19
SEPT "	519	507	11
OCT "	410	403	7
NOV "	370	366	4
DEC "	508	586	22
JAN2005	511	469	42
FEB "	301	285	16
MAR "	472	454	18
APL "	458	416	42
MAY "	659	630	29
TOTAL	10928	10454	474

Source: Fault record section PHCN, Lafia business unit.

From table 3.4

Total number of faults reported in 24 months= 10,928

Total number of faults cleared within 8 hours= 10,454

Total number of faults not cleared within 8 hours= 474

$$Efficiency\ of\ the\ network = \frac{(number\ of\ faults\ reported - number\ of\ fault\ not\ cleared)}{(number\ of\ fault\ reported)}$$

= [(10928-474)/10928)] x 100%

= 95.7%

3.9 RELIABILITY OF THE DISTRIBUTION NETWORK

Reliability of the entire distribution network may be determined by taken the combine performance of the two feeders and the 33kV incomer supplying these feeders into consideration. It is therefore necessary to find the reliability of the 33kV line itself.

From table 3.1 where the failure distribution of the line in hours is shown for each month. A total of 789.85hours of failure were recorded in a period of 24months in 177 faults instances. Thus:

MTBF = 789.85/24 =32.91hrs

$$\text{Failure rate } \lambda = \frac{1}{MTBF}$$

$$= \frac{1}{32.91}$$

=0.03038 / hr

Reliability of the line $R = e^{-\lambda t}$

$= e^{-(0.03038 \times 24)}$

=0.48

Considering the mode of connection, Feeders 1 and 2 take their supply from the same 33kV line. However, both feeders function independently. This arrangement may be likened to a series-parallel representation of components whose individual reliabilities are already known.

Hence the entire network may be represented as shown in fig 3.1.

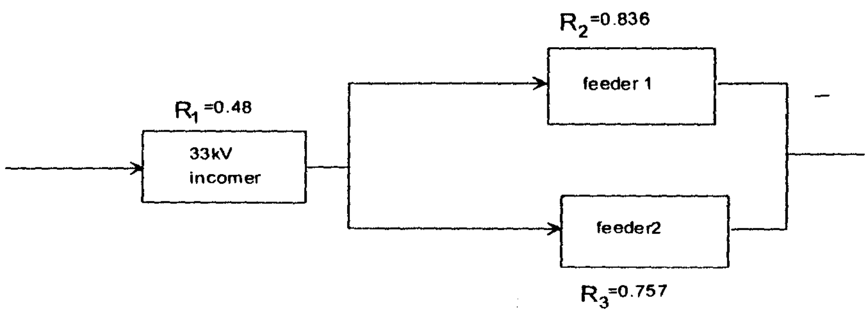


Fig 3.1 Block diagram representation of the distribution network

Applying the formula for reliability of components in parallel:

$$R = 1 - \prod_{i=1}^{n}(1 - e^{-\lambda t})$$

The parallel combination of R_2 and R_3, which represents reliability of feeder 1 and 2 respectively, gives:

$R_{(t)p} = 1 - (1-0.836)(1-0.757)$

$= 1-0.0398$

$= 0.96$

The equivalent block diagram for figure 3.1 becomes like one shown in figure 3.2

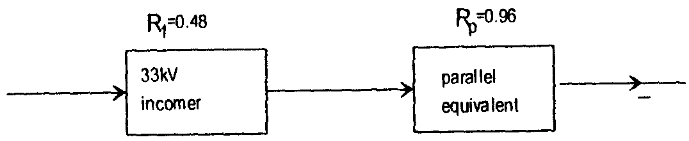


Fig 3.2 Series equivalent of figure 3.1

Applying the series connection formula for reliability;

$$R_{(t)} = \prod_{i=1}^{n} R_i$$

The total reliability of the system is thus:

R_{Total}= [(0.48)(0.96)]

=0.46

3.10 AVAILABILITY OF THE DISTRIBUTION NETWORK

Availability of the distribution network is a function of the availability of feeder 1, feeder 2 and the 33kV line. Individual availability of these three items may be determined in the following way:

i. Availability of the 33kV line.

With reference to table 3.1;

Total hours of failure = 789.85hours

Total number of failure within 24 months = 177

$$\text{Mean Time to Repair (MTTR)} = \frac{\text{Total hours of failure}}{\text{Total failure event}}$$

$$= \frac{789.85}{177}$$

$= 4.46$ hours/fault

Mean time between failures for the 33kV line was found earlier to be 32.91 hrs

$$\text{Availability, } A_1 = \frac{MTBF}{(MTBF + MTTR)} \text{ x } 100\%$$

$$= \frac{32.91}{(32.91 + 4.46)} \text{ x } 100\%$$

$=88.0\%$

ii. Availability of feeder 1

Referring to table 3.2,

Total hours of failure =2435.2 hours

Total failure events = 268

$$MTTR = \frac{2435.2}{268}$$

$= 9$ hrs / fault

MTTR for feeder 1 = 134.38 hrs/month

$$A_2 = \frac{MTBF}{(MTBF + MTTR)} \text{ x } 100\%$$

$$= \frac{134.38}{(134.38 + 9)} \text{ x } 100\%$$

$= 93.7\%$

This value is the self availability of feeder 1. The actual availability of feeder 1 is it's self availability minus unavailability of the 33kV line, thus;

Actual availability of feeder 1 $A_{actual} = A_2 - (100-88)$

$A_{actual} = A_2 - 12$

$=93.7-12$

$=81.7\%$

iii. Availability of feeder 2

From table 3.3

Total hours of failure in 24 months = 1277.23 hrs

Total failure events = 245

$$MTTR = \frac{1277.23}{245}$$

$$= 5.2 \text{ hrs / fault}$$

MTBF for feeder 2 was found to be 86.13 hrs.

$$\text{Availability of feeder 2, } A_3 = \frac{MTBF}{(MTBF + MTTR)} \times 100\%$$

$$= \frac{86.13}{86.13 + 5.2}$$

$$= 94.3\%$$

Actual availability of feeder 2, $A_{3actual} = A_3 - 12$

$$A_{3actual} = 94.3 - 12$$

$$= 82.3\%$$

System availability can be obtained by using the associated formula below

$$A_{(t)} = \prod_{i=1}^{n} a_{i(t)} \text{ ------------------------series}$$

$$A_{(t)} = 1 - \prod_{i=1}^{n} (1 - a_{i(t)}) \text{ --------------parallel}$$

Again, representing availabilities in block form gives:

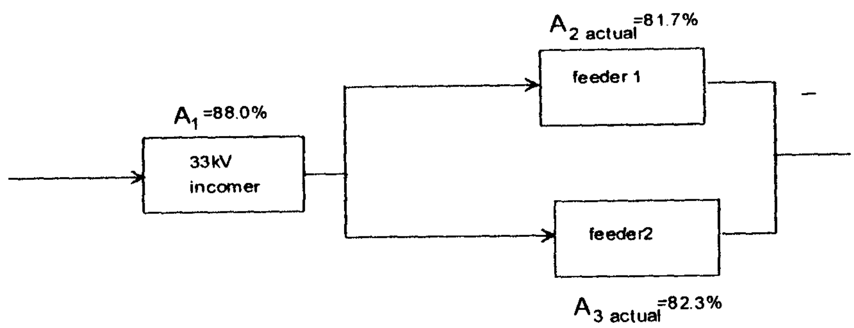


Fig 3.3 Block diagram representation of availabilities of the system

For the parallel combination A_2 and A_3

A_p=1 – [(1-0.817)(1-0.023)]

=0.964

=96.4%

The equivalent of figure 3.3 is shown below

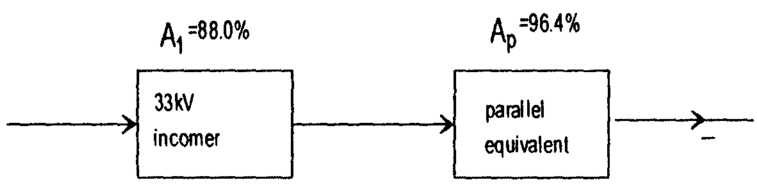


Fig 3.4 Series equivalent of figure 3.3

Therefore, Total availability of distribution network may be found by applying the series formula above:

A_{total}= [(0.88) x (0.964)]

= 0.84832

= 84.8%

CHAPTER FOUR

4.1 DISCUSSION OF RESULTS

Reliability values for the two feeders and the 33kV line, on separate consideration were found to be 0.836, 0.757, 0.48 for feeder 1, feeder 2, and the 33kV line respectively.

The total reliability of the distribution network was found to be 0.46 This value is less that all three individual reliabilities earlier mentioned due to the mode of distribution employed in the network.

The connection to the two feeders from the 33kV line at the injection sub-station is in a series-parallel. One major characteristic of a series parallel system is that the reliability of the overall system can not be greater than the least reliability value of the circuit elements making up the system. This explains why the reliability of the entire distribution network is smaller than the 33kv line, which is the least among the three individual reliability values of feeder 1, feeder 2, and the 33kV line.

Results also show that the availability of the 33kV line, unlike in the case of reliability has the highest value of 0.88 compared to the availability value of feeder 1 and feeder 2 which were found to be 0.817 and 0.823 respectively. The series-parallel connection of the distribution network also affects the total of the network. It can be observed that the total availability of the distribution network yielded a value of 0.84 which is again less than 0.88 being the availability value for the33kV line.

In comparison, the total availability value of the distribution network is higher than the reliability value. The reason for this is not far-fetched; availability depends on the value mean time to repair (MTTR), the lower the MTTR, the higher the availability of the system. From the results obtained in chapter 3, the MTTRs for the 33kV line and the two feeders are:

4.46 hours/fault, 9 hours/fault and 5.2 hours/fault respectively. Since availability is given by

$$A = \frac{MTBF}{(MTBF + MTTR)}$$

It is obvious that the least value of MTTR will yield the highest availability value just as obtained in this analysis.

Reliability in an exponential model, is a function of the failure rate (λ) of a component or system. The exponential formula is given by:

$$R = e^{-\lambda t}$$

Since the time of evaluation is the same, it means that the system with the highest failure rate will have the least reliability value. This explains why the 33kV line which has the highest failure rate (0.03038) compares those of feeder 1 and feeder 2, which have 0.00744/hour and 0.0116/hour, ends up with the least reliability value of 0.401 compared to 0.836 and 0.757 of feeder 1 and feeder two respectively.

4.2 CONCLUSION

Any system that operates on a reliability of 0.46 is obviously not viable economically, socially and otherwise. A power distribution system is not an exception. The result of the reliability analysis therefore signifies one thing; that is – there is the need for improvement of the system's performance, a close look at the failure distribution table shows that the major factor responsible for high values of outage durations is load shedding.

Load shedding accounts for 29% of the total outage duration in the 33kV line, 52% in feeder 1 and 75.4% in feeder 2, the cumulative effects of all these failure hours contribute a lot to the low reliability value so obtained.

A considerable percentage of outages recorded within the 24 months is actually not as a result of failure within the distribution system itself, but due to the fact that there is not enough power to meet the demand of distribution system. Therefore the reliability of the distribution network maybe enhance to a great extent if there is an increase in reliability expansion of the generating stations such as to meet the ever increasing power demand. In other words, this is an issue that is beyond only distribution.

A lot of socio-economical activities have suffered due to the menace of load shedding and other factors causing power outages. Generally, a lot of businesses have folded up because the entrepreneurs cannot afford the cost of operating generating sets. Even those that could use generators are compelled to review the charges for their services upward. This makes it difficult for the general public to enjoy their services as it should be.

Going by the results of the reliability analysis obtained, it can be concluded that the distribution network in Lafia metropolis is supplying electricity to the costumers slightly above average. However, it could have being better if only the supply of power to the metropolis could be made more regular and sustainable.

4.3 RECOMMENDATIONS

In view of the factors militating against improved reliability and availability of the power distribution in Lafia metropolis, two things are recommended. These two recommendations have to do with the short run and the long run benefit as it affects the distribution network. For the short run solution, it would be good to get the authority concerned with public power distribution to update the equipment that are used in the distribution process. Example of such equipment include transformers, line breakers and other accessories such as broken or cracked insulators, poles e t c. the authority should also build up a formidable team that respond swiftly to fault occurrences and equip them with the necessary tools to work with. One other important area that needs improved attention is the area of maintenance. Maintenance / supervision of power distribution facilities on routine basis will greatly reduce the chances of sudden fault occurrences in the distribution network because ailing components may be easily identified and replaced as appropriate.

As a long term solution, it is recommended that Government should provide an additional 33kV source of power supply into the Lafia metropolis such that the town can be supplied via two interconnected buses that will form a ring connection. Once this is done, the number of power outages will reduce tremendously because a fault on one of the 33kVA line will no longer affect the whole distribution network as the other 33kVA line will take care of the situation.

Finally, the Government could work out an effective security check that could safeguard the transmission lines from the activities of vandals which could put a whole region in blackout.

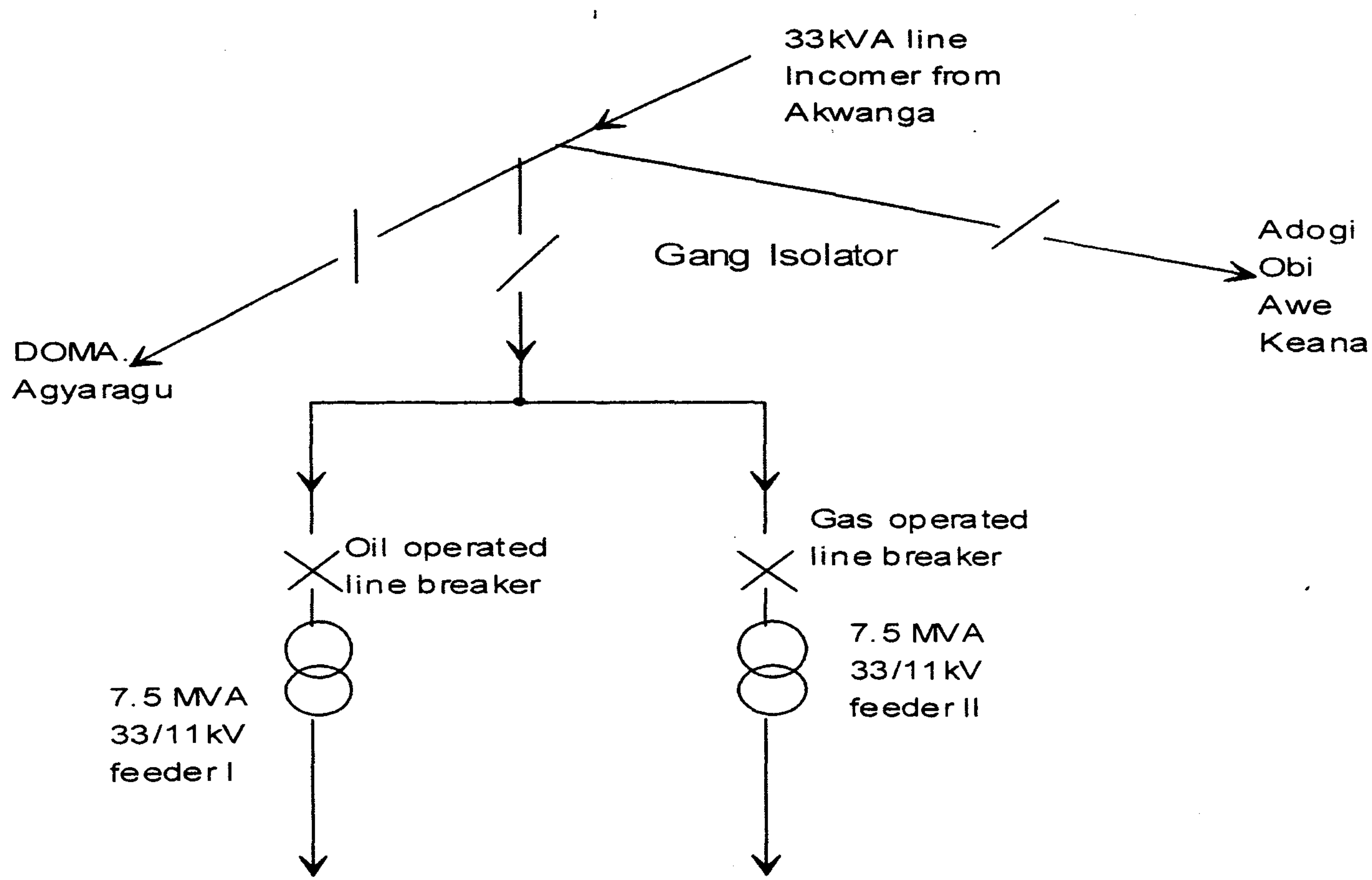
REFERENCES

[1] Alain Villmeur "Reliability, Availability, Maintainability and Safety Assessment" Volume 1, 1991 p 5-13,142-143

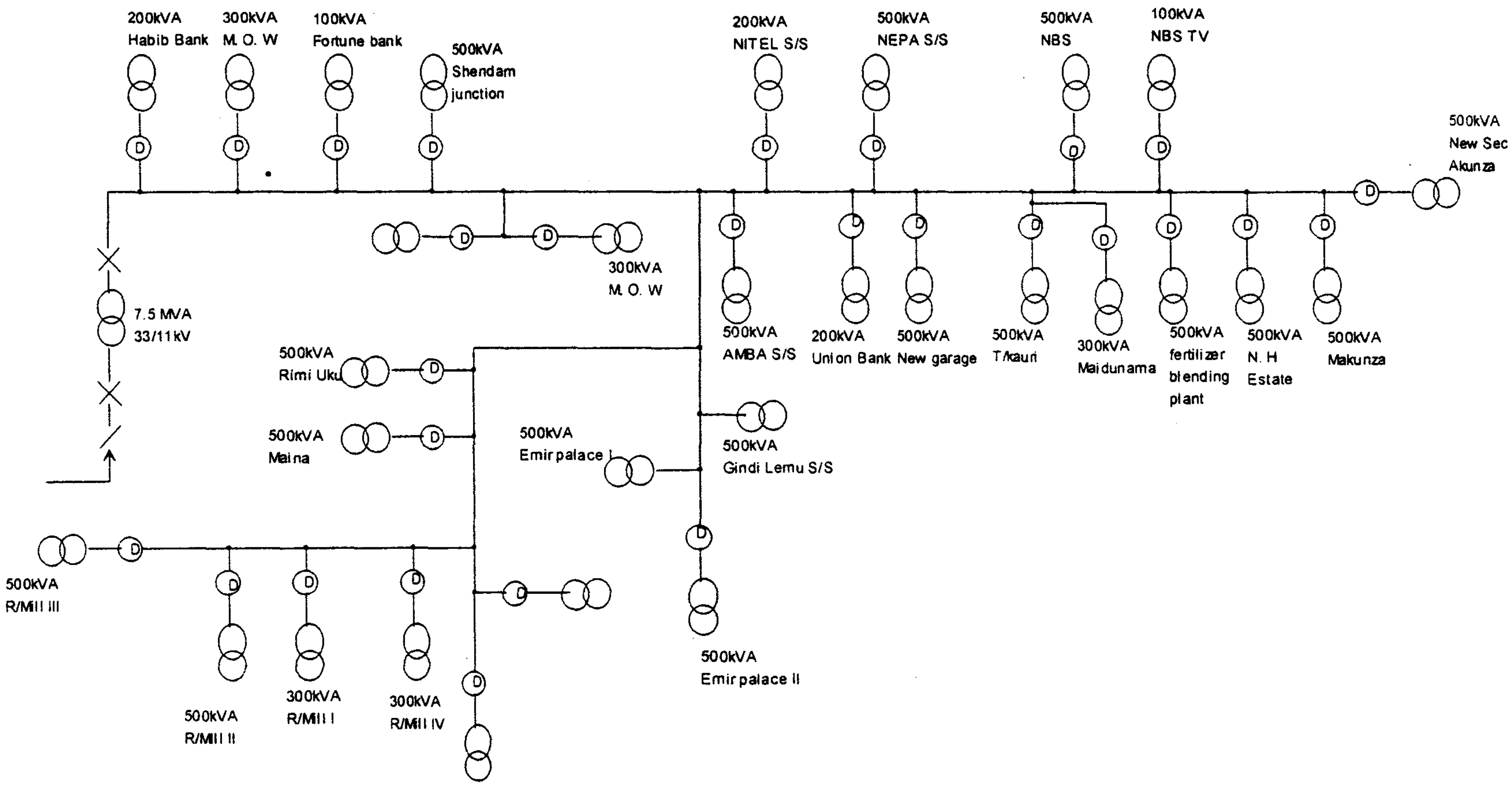
[2] M.A Adio "Basic Protection course for technicians" Kainji Professional Training Centre, 1998

[3] Stella Morris and Morris A.G. Ezra "Data Structure in Power System Reliability Estimation; Journal of Applied Sciences 4(2)322-329, 2004.

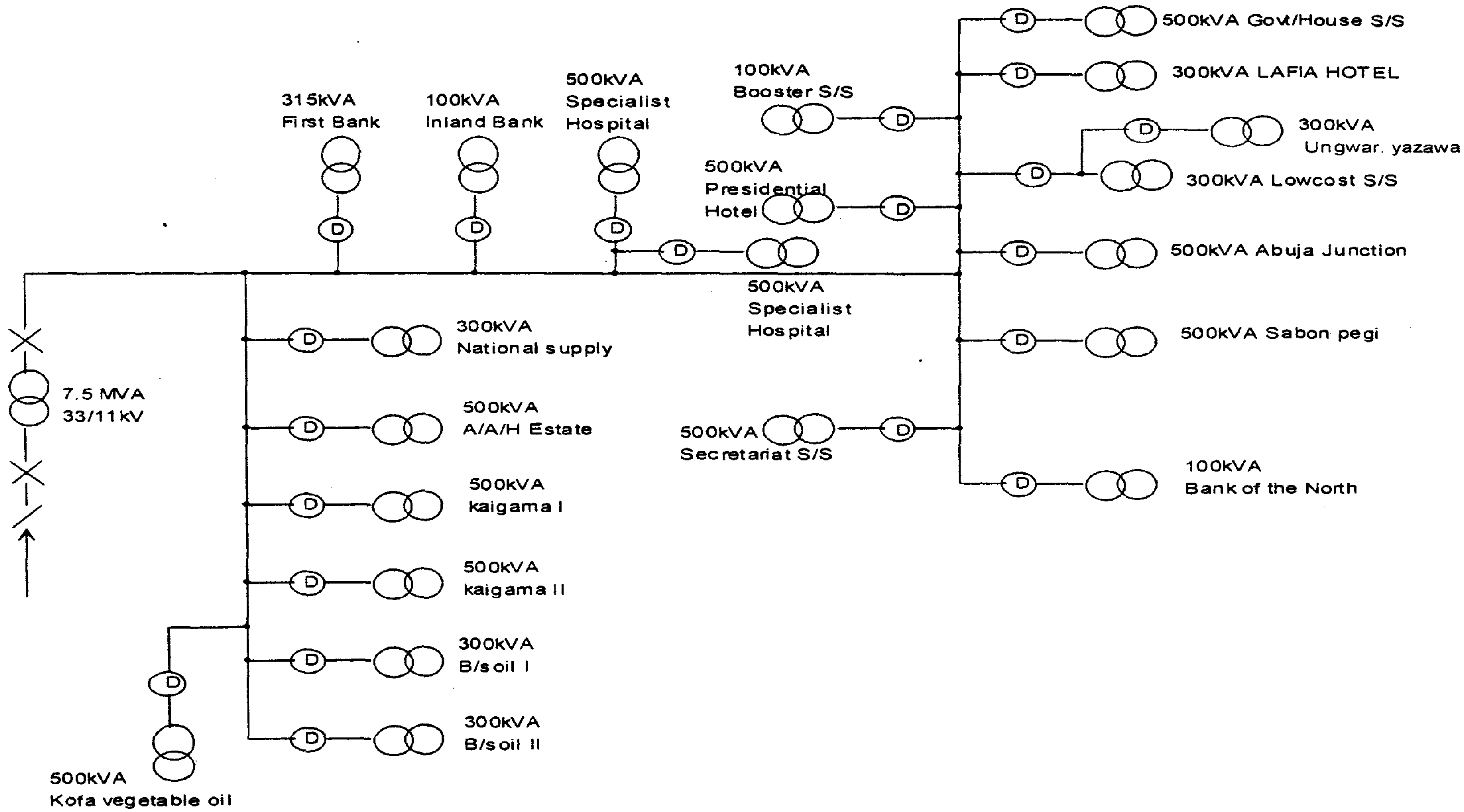
[4] PHCN Lafia business unit "Daily Peak Load Record; Operations Section, August 2004.



DISTRIBUTION AT LAFIA INJECTION SUBSTATION



FEEDER I SINGLE LINE DISTRIBUTION SCHMATIC DIAGRAM



FEEDER II SINGLE LINE DISTRIBUTION SCHMATIC DIAGRAM