ELIABILITY ANALYSIS FOR DISTRIBUTION OF POWER NETWORK (CASE STUDY: NEPA IJORA DISTRICT, LAGOS)

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NIGERIA

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PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT OF THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE

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NIGERIA.

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DECLARATION

I hereby declare that this project is the result of my handwork and research which has never been presented anywhere by any person. It was under supervision of Engineer M.D Abdullahi in Electrical and Computer Department, Federal University Of Technology, Minna, Niger state and partly Engineer Dim J.C manager P, C and M NEPA Ijora district Lagos.

--	15TH Oct., 2003.
(Student)	(Date)
KOLAWOLE M. BABATUNDE	

CERTIFICATION

This is to certify that this project titled; RELIABILITY ANALYSIS FOR POWER DISTRIBUTION NETWORK where NEPA IJORA DISTRICT LAGOS chosen as case study was implemented successfully by KOLAWOLE M. BABATUNDE (97/6051EE) under the supervision of Engineer M.D ABDULLAHI and submitted to Electrical and Computer Engineering Department, Federal University of Technology, Minna, Niger State in partial fulfillment of the requirement for the award of Bachelor of Engineering (B. Eng) degree in Electrical and Computer engineering field.

------------------------------	28/08/03
ENGR. M.D ABDULLIHI (Project Supervisor)	Date
------------------------------	18/4/04
ENGR. M.N. NWOHU (H.O.D)	Date
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EXTERNAL EXAMINER	Date

DEDICATION

This project is dedicated to my parent **ALHAJI KOLAWOLE YUSUF** and **ALHAJA FAUSAT EBUN YUSUF** for high value giving to Education, love, care and guidance from the early stages of my life.

ACKNOWLEDGEMENT

All glory to GOD Almighty for all HE has done form the genesis of this program to the present hours and ever in future. The same profound gratitude, as a debt to my parent Alhaji and Alhaja Kolawole Yusuf for value given to education caring form childhood and support, morally and financially.

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I would not forget each and every staff of Electrical and Computer Engineering department both academic and non-academic; my debts will everly extend to all my friends in my department and other Engineering Department who in one way or the other contributed to the success of this project.

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Respect for **UNCLE TUNJI BELLO** (Bell comp tech. USA) and the rest of the family in Abroad and Engr. Dim Manager (P.C. & M), NEPA Ijora District Lagos, All staff of O & M dept, Marketing dept of NEPA Ijora District for their hospitality & response while enquiring information for the implementation of this project.

I also remember my family members, brother, sisters, uncles, Grandmas both paternal and maternal, uncle and Yusuf Abidat Omolabake, wishing you all, long life and prosperity in all your endeavors.

Kolawole M. Babatunde

September, 2003

ABSTRACT

This project presents the analytical technique of solving complex distribution reliability evaluation of electric power system using NEPA Ijora District as a case study. It is concern with the system indices used like load point failure rate, average restoration time and annual unavailability in conjunction with SAIFI, CAIDI are important from an individual customer's point of view but they do not provide an overall appreciation of the system performance.

A result of analysis from the system performance which shows the validity of analytical technique is reliability analysis and a program is designed using BASIC for the problem to become much more faster and easier.

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CHAPTER ONE

1.0 INTRODUCTION

Electrical power system is an important lifetime engineering system that has so much to do with national economy and people's livelihood, social progress, electrical power systems is having a characteristics of high pressure, remoteness and capacity. Modern society because of its working habit, has come to expect that power supply should be continuously available, these are due partly increasing in the assumption of primary energy and on the other hand, electrical energy is tending to replace other forms of energy on account of it's extreme cleanliness, simplicity of control and obviously it's distribution for use both in large and small quantity.

The process by which electrical power is conveyed from generating station to the consumer's premises may in general be divided into two-district parts: Transmission and distribution. Of course, their various source of power generation ranging from Hydroelectric, fuel fired (Steam), solar, through wind, gas turbine and nuclear power station.

Transmission is due after when generated electricity passes through some process like stepping-up to a considerate level for high voltage transmission and at the same time synchronization.

Distribution, which is the last process that governs the task of conveying electric power to the consumer premises, takes the largest percentage in the overall investing cost. Distribution system can be divided into sections; Feeders, Distributors and Sub-Distributors. Feeders are conductors, which connect sub-station to the distributor via distribution transformer, which serves certain allocated areas. From the sub-distributors various tapings are made using service main.

There exist some sophisticated protection devices provided for each and every section of generation, Transmission and distribution of electric power to avoid or sense fault occurrence, high voltage loss, system collapse and even protection over the static equipment involved e.g. transformer. These protection devices also help in speeding up the repair time and in maintenance scheduled. In many case alternative supply path are available, so that consumers do not experience any interruption in supply of any form.

In strict sense, the word reliability means the ability of a system to perform a require or desired function under a stated conditions for a given period. This discipline can encompassed the area the following activities; System failure analysis, Operational, Observed, Data bases, Test, Methods and Safety Reliability. A computer program can also be design to analyze critically using some distributions reliability indices e.g. SAIDI, CAIDI, SAIFI, EENS, ASAI and ASUI etc. The available protection system and the network configuration in conjunction with statistical data on the likelihood fault occurrence can also be used to estimate the overall reliability of supply to any consumer.

Reliability plays an important roles in economic and social aspect of life, the need for design, operational cost reduction in highly competitive market and more, are reasons that gives reliability more attentions or significance.

1.1 SYSTEM RELIABILITY

Power system would always experience a set of operational constraint, some constraint are directly involved with the supply such as bus bar voltage and frequency variation, others which are in direct but equally important in operating sense including equipment ratings, system stability limit and fault levels.

It should be cleared in our minds that the term "Reliability" has a wide range of meaning and cannot be associated to a single specific definition, but in general, system reliability function in a given period. With this meaning system reliability of power both ~~hetaeristic~~ stochastic and ~~realistic~~ deterministic criteria divided into two: SYSTEM ADEQUACY AND SECURITY.

System adequacy relates to the existence of sufficient facilities within a system to satisfy the consumer load demand or system operational constraint. This includes, facilities to generate sufficient energy in conjunction with transmission and distribution facilities required to transport energy from generating plant to consumer ends.

System security relates to the ability of the system to respond to disturbance that arises within that system. It is also therefore, associated with response of the system to whatever perturbation it is subjected.

1.1.1 TYPES OF SYSTEM RELIABILITY

Before going through reliability system on generation, transmission and distribution, lets have a quick look at type system reliability

- ✓ OPERATIONAL RELIABILITY: This results from the observation and analysis of the behaviors of two or more identical system operating under same conditions.
- ✓ PREDICTED RELIABILITY: It is a measure of the future reliability assed taking the system design and reliability of its component into consideration.

- ✓ EXTRAPOLATED RELIABILITY: this result from an extension by a defined interpolation of the operational reliability of the operational reliability to a different duration or stress condition.

1.1.2 QUALITY AND RELIABILITY

The term "Quality" is defined by international standard organization as total features and characteristics of a product or services that being on its ability to satisfy its needs.

Quality of a product or services, to be precise is characterized not only by its conformity to the specification but also by its ability to meet these specifications over its entire lifetime. Meanwhile one of the basic characteristics of a product or services that contribute to its quality is its reliability by these reliability however becomes an extension of quality over a longtime.

1.1.3 DEPENDABILITY

Dependability can be defined as the science of failure; it therefore encompasses the knowledge of these failures, their assessment, their prediction measurement and control.

Dependability to be precise is the ability of a system to perform one or several required function under a given condition. It is characterized by the following concept.

Reliability: This is ability of a system to perform a required function under a given time interval. It is general measure by the probability that a system can perform its specific function under a given condition for the time interval (0,t). It is given as:

R (t) = P [system not failed during (0,t)]

Failure rate is the reverse of reliability and is expressed as;

F (t) = 1 - R (t).

AVAILABILITY: This means ability of system to be in the state of performance in required function under given condition, at a given instant of time. It can as well be expressed as A (t) at a given time (t)

A (t) = P [system not filed at instant t]

The reverse in unavailability, which is denoted as:

$\bar{A}(t) = 1 - A(t)$

Many concepts such as uptime, down time availability state are related with availability.

MAINTENANCE: It generally means the ability of a system to be restored to a state in which it can perform a required function.

Maintainability is measured by the probability that the maintenance of a system (E) performed under given condition using a stated procedure and resources. It is denoted as:

M (t) = P [E was repaired over (0,t)]

The reserves is non-maintainability

$\bar{M}(t) = 1 - M(t)$

Maintenance comes in three forms predictive, corrective and preventive, flexibility and cost are most factors to be considered. But these entire concept can be applied only to a repairable system i.e. ability of system to reserve the performance of its function after a failure.

SAFETY AND DURABILITY: safety is the inherent ability of a system not to cause a critical or catastrophe event under a given condition while a such, Durability is also ability of a system to remain able to perform maintenance, until a limiting state is reached.

1.2 RELIABILITY EVALUTION FOR POWER SYSTEM

The basic function of power system is to supply customer irrespective of their uses, be it residential, commercial or industrial with electrical energy as economical as possible and with an acceptable degree of reliability and quality.

Since we have a familiar with some concept or general meaning of "Reliability" as a term then, reliability evaluation on power generation, transmission and distribution can be discussed vividly for better understanding.

1.2.1 GENERATING RELIABILITY EVALUATION

Reliability evaluation of total generation is examined, it adequacy to meet total system load requirement. In this study, the transmission and its ability to move generated power to consumer load point is ignored. The only concern is in estimating the necessary generating capacity to satisfy the system demand and to have sufficient capacity to perform corrective and preventive maintenance on the generating facilities, formerly some deterministic criteria have been used, nowadays probabilistic criteria such as loss of load expectation (LOLE), loss of energy expectation (LOEE) AND FREQUENCY AND DURATION (F&D) can be used.

Loss of load expectation (LOLE) is the average number of days on which the daily peak load is expected to exceed the available generating capacity, By this meaning it indicates the expected number of days on which a load loss or deficiency may occur.

Loss of energy expectation, (LOEE) is expected energy that will not be supplied by generating system due to those occasions, when load demands exceeds available generating capacity.

In addition, Frequency and duration (F&D) criterion is an extension of LOLE index, it is also identifies the expected frequency of encountering deficiency and expectation of deficiencies.

1.2.2 TRANSMISSION RELIABILITY EVALUATION

Reliability analysis at transmission level is called Bulk Transmission system evaluation. This analysis can be used to assess the adequacy of an existing or proposed system including the impact of various re-enforced alternative at both generating and transmitting level.

They do not include system dynamics or ability of the system to respond to transient disturbance. They simply measures the ability of the system to adequately meet its requirement is a specified set of realistic states. There are many complication in this type of analysis such as overload effect, re-dispatch of generation and consideration of independent, dependent, common cause station outage.

1.2.3 DISTRIBUTION RELIABILITY EVALUTION

The overall problem of evaluation can become more complex in power system, because distribution evaluation involves the entire functional zone (i.e. generating, transmitting and distributing), starting from generating point and transmitting ato individual load points.

Considering the reason above, distribution analyses usually carried out as a separate entity. The objective of this analysis is to obtain suitable adequacy indices at the actual consumers load points. The primary indices are the expected frequency (or rate) of failure and the annual unavailability or outage time of load points.

Moreover, reliability assessment of distribution is usually concerned with system performance at the load point. Additional set of indices are; System Average Interruption Frequency Indices (SAIDI), Customer Average interruption Duration Index (CAIDI.), Average Service Availability Index (ASAI), Average Service unavailability index (ASUI.) and Energy Not Supply (ENS).

Meanwhile, the reliability indices of distribution system are function of component failure, repairs and restoration time, which are random in nature.

1.2.4 HUMAN RELIABILTY

The term, "Human Reliability" is used to cover the situation in which people as "operator" or "maintainer" can affect the correct or safe operating system. In these circumstances people are fallible and can cause component or system failure in many ways. Human reliability must be considered in any design in which human fallibility might affect reliability or safety. Design which analyses should include specific consideration of human factors such as the possibility of in correct operation or maintenance, ability to detect and respond to failure condition and ergonomic or other factors that might influence them.

Attempt have been made to quantify various human error probability but such data be treated with caution, as human performance is too variable to be credibly forecast able from past records. Human error probability is usually dependent on training, educational, super visional and motivational factors, so they must be considered in analysis. In many cases the design organization has little or no control over those factors, but analyses can be used to highlight the need for specific training, independent checks or operator and maintenance instruction and warnings.

1.3 AIM AND OBJECTIVE OF THE PROJECT

Since the task of electricity supplying is to reach the consumer end (point load) regardless of the uses, with high quality and as economical as possible. This project will be designed to develop a software program to analyze critically using some distribution reliability indices e.g. SAIDI, CAIDI, EENS. e.t.c, the available projection system and the network configuration in conjunction with statistical data on the like hood fault occurrences will be used to estimate the overall reliability of supply to any consumer. This will give an expected number of hours lost for each consumer per annum and would be useful to engineers in designing new or improving the existing ones.

1.4 LIMITATIONS

In electric power systems which consist of generation, transmission and distribution, reliability analysis can be carried out on the three functional zones but this project is limited at only distribution level. All data used in the analysis extracted from 0 and m department of NEPA Ijora District except that assumption made on the number of customer on the feeder and distance covered for easy analysis.

More over this analysis is carried out on the basis that electricity is supply from the substations 11kv feeder to the low voltage side of each and every corresponding distribution transformer are considered and also, every fault that occur at these portions are considered, therefore any fault occurrence at lateral line or at customer end that leads to forced outage of the system or fault of any kind are neglected.

All Distribution Reliability Indices calculated are annually base and the computer program designed can be used to determine all reliability indices of feeder one at a time.

CHAPTER TWO

2.0 HISTORICAL BACKGROUND

Reliability consideration now occupies an important place in entire engineering of complex system and electrical systems. Application has generally included mechanical, chemical and electrical systems (Lewis 1987).

During the last decades it has become self evident that to minimize the probability of failures, human factors must be taken into account. Human error has also figured prominently in maritime, aerospace and electrical power industries. Human reliability analysis (HRA) practitioners employ systems engineering and behavioral sciences model and techniques in an effort to quantify the human contribution to risk.

HRA. has its root in the study of human performance; basic research conducted in experimental psychology and the behavioral science has supplied the building blocks upon which contemporary analysis and quantification techniques are built.

Many of the major HRA technique have gathered data from there basic discipline and then provided mechanism of estimating failure probabilities, throughout early 1980's, qualification technique proliferated review of literature yields approximately 38 HRA techniques.

One major difference between performance reliability analyses (PRA) and HRA is the fact that no complete source of data exists for human failure rates. Early efforts documented in manger et al. (1962) coolest reliability data for use by human factors professionals.

At that time no one was referring to himself or herself as an HRA practitioner, more recently efforts have been made to collect and store probabilistic data for HRA in data base such as nuclear regulatory commission (NRC) sponsored Technique for Human Error Prediction (THERP) handbook (Swain and Guttman 1983) and the Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR) (Gertman et. Al 1990). As these databases develop, they will become major sources, that are databases containing failure rate information for Decision Base Errors (DBEs). Currently, the risk impact of DBEs is neither well identified not qualified. Exceptions exist in the application of the confusion matrix approach used in the Oconee PRA and in the matrix approach employed by Wakefield in the PRA for Three Mile Island (TMI unit 1). The confusion matrix approach identifies the potential for confusion on the part of the operator because of the similarity of event signatures.

Minor modification of data based on operations data, such a the NRC sponsored License Even Report (LER) system and Nuclear Power Reliability Data System (NPRDS) or the US Department of Energy (DOE) unusual occurrence reporting system (UOR), could provide an excellent source of human failure rate data from nuclear power plant, similarly, the Federal Aviation data base on near misses for use in PRA, simulator studies conducted in either training simulators or research simulators have similar potential to provide failure rate estimates.

The use of such words as "reliability" and effectiveness in the 1938 paper by Dean:

One of the really difficult problems faced by those responsible for planning of electric supply systems is that of deciding how far they are justified in increasing the investment of their properties to improve service reliability, while this problem is not at all new in the industry, it has nevertheless taken on greatly increased significance in the past few years.

In general, there are three broad aspect of this reliability question. The first is to know thoroughly the present quality of one service and just who is harmed by the present outage and, how much. With such background of system performance it is not difficult to determine where in general the greater hazard lie.

The second aspect is knowledge of the methods at hand to improve service in many situations, which arise as well as the cost of these remedies. It is highly important that these methods of improved reliability be studied out in advance and their effectiveness and cost clearly defined.

The third and most important is the exercise judgment as to where and when, all things considered, expenditures should be made for increased reliability and how far to go with them. In theory, the criterion is that of customer's complain and what increased price he is willing to pay for more reliability.

W.J Lyman, in his prize-winning paper on power system planning stated that: three of the most vital problems around which the whole fabric of future planning is woven are forecasting, the relation between load and capacity and fixed capital replacements.

He also stated that: A major problem in design of power system arises from a combination of the desire to render reasonable continuous service and the inherent fallibility of equipment. A rather large proportion of the fixed capital is so occupied and a careful analysis of the relation between load and capacity is the starting point in an effort to reduce cost of service.

Lyman and Smith identified two classes of problems: The first is concerned with the "chance coincidence" of unrelated events, such as the overlapping, random, independent outage number of generators.

The second problem concerns widespread and unpredictable catastrophic events which may doable an entire generating station or even the entire system........... In such emergencies, the mere multiplicity of generating unit or even generating stations may be little or no avail in avoiding loss of load.

Smith claimed that for the first class problems, probability theory has its most useful application and that data for calculation for the catastrophic class were "difficult to determine".

Both also, introduced two criteria for appraising the reliability of generating supply. Lyman studied the "Probable interval between capacity outages: He reasoned that, there is very little question about providing for breakdown of one unit (boiler-turbine-generator) because this is known to occur quite often. Further, reserve is usually installed for a double outage because experience has shown that, this may occur every two to three years, however very little money is spent in anticipation of combination of breakdown that may occur on the average of, say, once every twenty or thirty years.

Smith, on the other hand, studied the risk of losing a part of the load: The problem of how much spare capacity to provide resolve itself into two distinct parts: First how reliable shall be the service? What expectation of load outage in a year shall be deemed satisfactory... ... secondly, once this standard has been agreed upon, the system should be engineered to meet it. From the coal pile to the customer meter exist a series of apparatus, a kind of chain, each link of which may at times fails, the sum of outage expectations of each of these links most be equal to the outage expectation setup for the system as a whole.

Although Lyman, Smith and Benner directed considerable attention in the paper to the generating capacity problem, lack of data and limitation of computation facilities severely restricted the numerical application of reliability procedure to the study of generating-system adequacy. A generating system with adequate capability is ready to serve a load as necessary considering the variability of load and the variability of operational capacity depending on the maintenance requirements and on schedule outage. It appears that probability methods were first applied to the study of spare generating capacity and that Lyman and Smith received the credit for the first proposal to utilize such method. From his studies of relationship between overlapping capacity outages, Smith concluded: It is not at least should be well recognized, either intuitively or though actual experience, that as the number of generating units in a system increases with growth in load, or due to inter-connection with other systems the percentage of spare capacity can be increased without sacrifice of service reliability.

These are roots concepts contained in two widely used planning indices for generating systems: intervals between outages "(which necessitate curtailment of load) and "loss-of-load probability"(that is the probability that generating capacity will be deficient). In both cases, attention is focused upon events in which there is insufficient capacity available to meet the demand due to overlapping outages of a portion of the units in generating system. The generation and loads are assumed to be connected to the same bus (Single Area) or, at most, a small number of buses (Multi Area). The indices can reflect inter area tie live capacity, reliability and available but because of the single-bus assumption cannot properly recognize intra-area lines.

Practical methods for developing these indices are available. The methods account for schedule maintenance and overhaul requirement, annual distribution daily peak demands, seasonal equipment loading and overloading limitations, overlapping forced outage events and risks of deviation in demand forecasts from realized demand.

The two methods treat independent generation-outage events, smiths "type one" problems and do not treat "widespread and unpredictable catastrophic events, "the type two" problems. It is evident that smith was concerned with the problem involving generation, transmission, and major substations near load centers. In modern text these are "bulk power supply" problems.

An attendance problem associated with the utilization of statistical concepts is the availability of applicable and consist data, and in this regards performance records of generating units have been kept for many years. Information suitable for generation reserve planning, such as operating data and scheduled and forced outage data has been collected and published by industry organization such as the EEI and IEEE.

Three vital problems in the future planning of generating plant are the following

- Long range forecasting
- Capital requirement prediction for addition and replacement of generating plant.
- Assessment of risk of generating-capacity deficiency.

Significant steps forward in use of probability method occurred with the model developed by Calabrese and Halperin and Adler, in both instance it appears to author that the key contribution was the development of a practical model and practical index of, or measure of generating-system adequacy. The essential element in both approaches was separation of generating and transmitting systems; both the Calabrese and Halper-Adler model concern the generating capability only. That is they assumed the generating capacity capability to meet load under the assumption of an adequate transmission system at all times.

The model was extended to study the import-export capability between two regions by cook and his co-workers, and S.Senzy suggested a model for multiple area system. This model used only simple capacity criteria and linear distribution factors for power flow between areas and hence, were extension of the capacity model studies. Transmission or bulk power supply models must involve both static and dynamic checks i.e. load flow evaluation with static contingencies and dynamic analysis of the system's ability to recover from specific condition. Only limited application of quantitative probabilistic methods has been made with bulk power supply evaluations. The cost of carrying out comprehensive evaluation and lack of data appear to be serious obstacles.

The application of probability methods to distribution system design extends over a period nearly as long as the application to generation. Dean in his 1938 paper, cited studies of means for improving the frequency and duration of sub-transmission and feeder outages and suggested certain goals for these parameters and means of achieving the improvement.

Reliability evaluation of generation and transmission system came under investigation in Europe and North America in 1960's. The term "composite system reliability evaluation" however first appeared in 1969. The basic objective has to assess the ability of the system to satisfy the real and reactive power requirement at such major load point within acceptable voltage levels.

Two concurrent and independent stream of activity in regards composite system reliability evaluation appear to have been initiated in Europe and America during the late 1960's. These approaches to the assessment of composite system reliability are fundamentally different and with subsequent development have become known as simulation and contingency enumeration methods respectively.

It is possible that the requirement for modeling generating capacity in generation played a key role in selecting a suitable approach to composite system reliability evaluation. The French and Italian system with significant hydro facilities including pumped storage were strongly motivated to develop a method capable of modeling hydro resources and therefore utilized Monte Carlos simulation methods.

Further work in both the area of simulation enumeration were reported in the early 1970's,the general area of power system reliability evaluation and particularly question regarding models and philosophy receive a considerable impetus as at 1978 at a workshop entitled "power system reliability research needs priorities which if not directly related are imported contributions to generation transmission and distribution reliability evaluations.

The IEEE power engineering society presented a panel discussion at the 1983 winter power meeting on the subject of transmission assessment and subsequently published two papers arising from this activity. These papers provided a timely reference on a number of different viewpoints. A related topic, which might be considered to lie some where between generating and transmitting reliability evaluation, is that of transfer capabilities between two areas.

A comparative study existing digital computer program for composite system adequacy evaluation was conducted on behalf of the Canadian Electrical Association Power System Reliability Sub-sections. The result provided an interesting illustration of different perception and therefore objectives in composite system evauation were reported in 1980's and work done on application for large system analysis.

It should be clear, however, that the need for probabilistic evaluation of system behavior has been recognized since at least 1930s and it may be questioned why such methods have not been widely used in the past. The main reason were lack of data, limitation of computational resources, lack of realistic technique and misunderstandings of the significance and meaning of probabilistic criteria and indices. None of these reasons need to be valid today a most utilities have relevant reliability databases, computing facilities re greatly enhanced, evaluation techniques are highly developed and most engineers have a working understanding of probabilistic techniques. Consequently constrain the inherent probabilistic techniques. Consequently, nowadays there's no need to artificially constraint the inherent probabilistic or stochastic nature of a power system into a deterministic framework.

A wide range of probabilistic technique has been developed. These include technique for reliability evaluation, probability load flow and probabilistic transient stability. The fundamental and common concept behind each of these developments is the need to recognize that power system behaves stochastically and all input, output state and event parameters are probabilistic variables. The probabilistic technique have been developed which recognize, not only the severity of state or an event and its impact on a system behavior and operation but also the likelihood of its occurrence.

A study of ways in which equipment and system fails in essential to any undertaking of reliability prediction or a reliability analysis; fowler offers the following observation regarding failure that occurred in the space industry. The position is taken that "the possibility that failures arise randomly, that is without understandable cause, is exchanged, but the stochastic element in failure observation is accepted".

In the analysis of failures occurring in the space industry, Fowler suggested three categories within which to put the system failure:

TYPE 1: The system failed because it could not have worked in the first place. The major sub-divisions of this type observed in practice are as follows:

a. The design is inherently in capable of performing the actual mission either because there is an unworkable combination of parts or because the system's functional logic doesn't correspond with the requirement.
b. The use environment was beyond the capability of the system either because it was never qualified for the actual environment or because the environment was estimated.

TYPE 2: The system equipment could have worked if it had been just like the drawing but it was not and hence failed. There are two major sub-divisions, which are as follows:

a. A faulty piece/part was built into the hardware.

b. The hardware was damaged in manufacture, test, repair or handling.

TYPE 3: The system could work and did work but has now worn out. The principle Sub-division of this class are as follows:

a. Some part of the hardware returned for enough toward thermodynamic Equilibrium so that the hardware no longer operates.

b. Some part accumulated environmental damage to the point where it no longer Perform its functions.

In addition to Fowler's categories, the most important aspect of failure analysis Concerns the condition under which the failure was discovered. Green discusses the Aspect of whether or not a failure/fault revealed or unrevealed. For example, a closed breaker in an operative condition may continue to function quite satisfactory until it is Called upon to trip. The cause of a stick breaker may or may not be detected depending on the tests, maintenance and operating procedures employed. The effect of component outage upon a system may be quite different depending upon the nature of the arising cause.

Considering the failure mode for circuit interrupting or circuit breaking equipment can see this. Two categories of breaker outages have proved useful in systems analysis. The first category involves cases where other protective equipment is required to remove the defective or inoperative breaker. For instant, if breaker has a fault, or if it fails to interrupt or fail to trip item the resulting fault must be cleared by back-up equipment, such action must increase the extent of effect of the fault. the other class of removal correspond to a maintenance outage or a trip out in which the device is removed by switch and in which the extent of the outage is confined to the path involving breaker, events such as test, schedule maintenance, as would false trip incident.

2.1 MONTE CARLO SIMULATION

There are two main reliability evaluation approaches, the analytical approach and the Monte Carlo simulation (MCS) approach.

The basic principle of MCS is that it initiates the operation of a system over a period of time. It involves the generation of an artificial history of the model of the system and the observation of the real system. This approach requires a large amount of computing time and storage in order to develop a good system model and therefore, it should not be used extensively if alternative analytical methods are available. The simulation technique however is easy to apply and can be used to solve not only simple problems but also problems where direct analytical solution may not exist.

Monte Carlo simulation is attractive because of the flexibility it permits as opposed to more resistive analytical methods. In other words, the problem does not have to fit the model or technique: instead, the model is developed to fit problems.

Simulation techniques can be used to qualitatively estimate the system reliability in even the most complex system generating capacity situation. Existing method for calculating generating system adequacy indices do not explicitly consider certain unit function and system operating policies. Monte Carlo simulation, how ever, provide a method of analysis which permits relaxation of many of the tradition assumption incorporated in the analytical techniques used to calculate adequacy indices. It also provides a benchmark for comparison of various modeling assumption associated with analytical techniques. Also a major shortcoming of most analytical technique is that they cannot provide the distribution associated with the reliability indices. This distribution can be easily generated using simulation.

2.2 ANALYTICAL TECHNIQUE

A general analytical approach or technique has been developed to determine approximate information in form of percentile to describe the distributions of the reliability indices.

A reliability index can be expressed as:

$Z = f[x_1, x_2, x_3 \ldots\ldots\ldots]$ where $x_1, x_2, x_3 \ldots\ldots\ldots$ Are the random variables, which donate the parameters, related to the component performance and system operation. The variable Z is a random variable because it is a function of a random variable. The function "f" takes a form, which depends on the system configuration and the reliability index represented by a function. The objective is to determine the probability distribution of the random variable $x_1, x_2, x_3 \ldots\ldots\ldots$ are known. Direct analytical methods are available for obtaining the exact form of some simple algebraic functions of random variables.

These methods do not provide solution for all types of probability distribution, which are usually used to represent random variables. Hence, the reliability indices are intricate functions of random variables such as component repair time, restoration time, e.t.c. Which can assume a wide range of probability distribution form.

The analysis requires three major steps:

A. STEP 1: The first four raw moments of component failure and repair times and the system restoration times are determined.

B. STEP 2: The average value and the second, third and fourth central moments of the reliability indices are evaluated using moment obtain in step 1 and the information regarding the system configuration.

C. STEP 3: The Pearson method is utilized to evaluate the approximate percentile of the reliability indices. The Pearson method approximately the probability distribution of a random variable by utilizing moment.

The solution obtained is approximately because a probability distribution is not fully described by ht e first four moments, this appropriation has however, been found to give a good result. The pearson technique can provide an analytical expression for approximate probability distribution. A table has been published to directly obtain the percentile of random variable. A computer program has also being develop utilizing the analytical approach to determine the percentile and some distribution indices.

2.3 SEISMIC RELIABILITY ANALYSIS OF ELECTRIC POWER NETWORK SYSTEM

An analytical solution to solve problems of fake mini-path and space complexity in evaluation of node-weight network reliability, therefore, it is especially suitable to analyze seismic reliability of large scale electric power network system using a case study which presented and analyze results showing the validity of the suggested method.

Earthquake resistance analysis of electrical power system stems from post-seismic inspection made by Ang A.H.S in early 1970s.

However, electric power system didn't analyzed as an integrated system until 1990s. up to now, methods most in use include PNET method, because NP-had problem exists in evaluation of system reliability, most of above analytical method becomes invalid for reliability analysis of large electric power system. On the other hand, although Monte Carlo simulation method has capacity to analyze seismic reliability of large electric power system, it can't estimate error bound of analysis dimension. An analytic method is presented in a paper written by Jie Li and Jun He both in building engineering, Tongji university shanghai china, they used a disjoint decomposition technique, the method can directly get disjoint into mini-paths and mini-cuts of system. So the problems of space complexity and fake mini paths introduced by tradition analytical algorithm can be solved.

2.3.1 RELIABILITY ALGORITHM OF LARGE NODE-WEIGHT NETWORK

If analysis aim is to Assess importance of power plan and electric substations in electric power network, damage of transmission can be neglected. Therefore, the electric power system may be regarded as node weight network systems which node weight denote seismic reliability of power plans and electric sub stations. In reliability computation a larger scale node weight networks, there are two problems involving including space complexity and time complexity, therefore, analysis of the problem becomes much more easy.

Assumptions Li and He made are

1. Nodes failure is S-independent
2. System and its node have two states: operative and failure.

From the basics or fundamental, definitely an arbitrary smallest minimal path from the source to terminal of a network system as

$L_O = (s_{1,s2,s3 \ldots\ldots\ldots} S_{/SO/})$ where $S_{i,\ i=1,2,\ldots\ldots\ldots,/s_o/}$ are nodes or edge of the system, $/s_o/$ is the number of component making up $/s_o/$.

They made system structure system to be function $\Theta(G)$, then using absorption law, there is

$\Theta G = Lo + L\Theta G \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$

According to de Morgan law, there exist

$\Theta G = Lo + /S_1/\ \Theta(G) + (S_1S_2)\ \Theta\ G_2 + \ldots\ldots\ldots\ldots\ldots + (S_1S_2 \ldots\ldots Si)\ \Theta(Gi) + (S_1S_2 \ldots\ldots Si \ldots S_{/so/}) \Theta\ G_{/so/} \ldots\ldots\ldots(2)$

Where G_i is a subdivision received through deleting component S_i E h_o from original G.

If sub-graph $G_{i\ I=1,2,\ldots\ /S1/}$ in equation (3) still has minimal path $Si_{,\ i=1,2,\ldots\ldots\ldots/s_i/}$ from the source to terminate and making C_i to be responding co-efficient term in front of $\Theta\ (G_i)$ and is named decomposition factor then the equation can be transformed to as

$\Theta\ (G) = Lo$

$$\phi = Lo + \sum_{I=1}^{/S_i/} C_1\ s + \sum_{I=1}^{/S_i/} C_1\ s\phi(G_i) \ldots\ldots\ldots\ldots(3)$$

Where Si is decomposed according to eqn (2).

Then there are /So/- $/S_1/$ sub-graphs Gj = j = 1,2,....../So/ - $/S_1/$ in eqn (3) that do not have mini-paths from the source to thee terminal, they also made Fj to be the responding co-efficient term in front of ΘGi then according to complementation

$$\phi'(G) = 1 - \phi(G) = \sum_{I=1}^{/S_o/ /S_i/} F_J + Q$$

Where Θ' (G) is a failure function of the system, Q is the remaining term. According to the above principle Eqn. (3) can be continually recursively decomposed until all generated sub-graphs do not exist any minimal paths from the source to the terminal, Then there exist

$$\phi(G) = Lo + \sum_{i=1}^{|S_1|} G_i S_i + \sum_{i=|S_1|+1}^{|S_1|+|S_2|} + \ldots\ldots + \sum_{i=|S_1|+|S_{..}|+1}^{|S_1|+\ldots+|S_n|} G_i S_i \ldots\ldots\ldots (5)$$

$$= \sum_{i=0}^{N} L_i \ldots\ldots\ldots\ldots (5)$$

Where N is the total number of disjoin minimal paths, $L_i = C_iS_i$ is the i. The disjoin minimal path of original system G

The integrated form of Eqn 4 can be obtain as follows

$$\phi' G = \sum_{J=1}^{M} F_J \ldots\ldots\ldots\ldots (6)$$

Where F_j is the disjoin minimal cut of the system G, M is the total number of disjoin minimal cuts.

According to Eqn 6, reliability of system is

$$R(G) = \sum_{I=1}^{N} P_R(L_I) \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$P_R(L_I) = \prod_{I=1}^{N_I} (1 - P_I) \cdot \prod_{I=N+1}^{N_I+k_I} \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where P_i is the reliability of i-th component in network system G, Ni is the number of failure component in L_i, K_i is the number of operative components in Li

Meanwhile failure reliability of the system is as follows

$$\bar{R}(G) = \sum_{J=1}^{M} P_R(F_J) \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Where M_j is the number of failure component in F_j, K_J is the number of operative component in F_j.

It was concluded from the paper presented by Jie and Jun 2002 that: in fact, a recursive decomposition algorithm for system seismic reliability estimation of electric power system with the aim at solving space complexity in analysis of system reliability. Because categoricalness of structure function is not destroyed during copulation an avoid getting fake elementary paths during calculation of node weight system seismic reliability, accurate value of system seismic reliability can be evaluated than ever.

2.4 NEED FOR POWER SYSTEM RELIABILIITY

The economic, social and political climate in which the electric power supply industry now operates has changed considerably during the last few decades. In the periods between 1960 and the end of 1970's, planning for the construction of generating plant was relative uncomplicated, lead times were relatively small and cost were relatively stable. This situation changed in the mid 1980s. Inflation and huge increase in oil prices created a rapid increase in consumer tariffs and fluctuation growth patterns. Their combined effects introduced considerable uncertainty in predicting future demand.

Now that the communication sector is growing fast in Nigeria, what safe guards the effective communication at a considerate or economical airtime tariff to the customer is a need to have in place to maintain "high 9's" reliability on electric power system. The same attention in the power electric reliability effect should also be given to other sector like Banking, Industries, Schools as well as commercial because power outage is less reliable or low quality power supply has its effect on different angle to all these sector mention above.

The 24th Annual International Telecommunication Energy Conference (INTELEC) held in September29 - October 3 2002 in Montreal showcases the latest development in energy system and related power processing device and circuits. The theme of this conference is "reliability Energy" The driving force behind Dependable communications.

Bob Boruer, president, Emerson power network north America said "Reliability dos not demand a strategic power reserve architecture that keeps telecommunication and other critical system up and running 24hrs+7days a week.

"With the rapidly growing convergence of various services from Telecommunication to manufacturing, the big question is what do they really need in the way of back-up reserve time to maintain the high reliability that expected in the power system in this country after various findings? Said Engineer Makoju, NEPA Managing Director during a visit to Egbin Therma station in may 2003.

Moreover, Farah Saheed, an industry analyst at Frost and Sullivan based in USA said " A back-up power system is a must, as more and more business are becoming mission-critical in today's wired world. "I think the power crisis that California (USA) experience during year 2000 and 2001 made it clear that companies cannot depend on utility consistent and power he added.

If power crisis, at consumer end can be experience in USA, as advance they are technologies (and any other aspect) with experts in power protection an analyst. Then what do we think will be happening in a third world country like Nigeria with newly licensed mobile telecommunication (GSM) operator like MTN and ECONET? Which for every switching center installed at expense of expansion of their network, go along with at least two generating plant connected in hot redundancy form, for continuous power supply to the switching to the switching station in order to hit the target of very effective and reliable communication service in Nigeria. Presently about sixty thousand (60,000) generating plant has been imported due to random power outage in the country according to MTN marketing manager in Lagos, I believe by the end or conclusion in Network Expansion, nothing less than a hundred thousand (100,000) more generating plant would be needed, which we should realized the economy effect of the action.

Power protection and analysts expert in USA realized the significance/need of reliability to the economy, put up and present papers based on these priority topics at a INTELEC conference mentioned earlier.

- Power outage: Causes and Prevention
- Reliability Analysis of an AC voltage
- Distributed Power Architecture in the context of cost effective data center
- Consideration on rectified sizing

The only way in which all these competing and diverse uncertainties be Weighted together in an objective and consistent fashion is by the use of qualitative reliability evaluation techniques.

The result can then be related to the economic aspect of system planning and operation, the impact of which is playing an increasing role in present and future power system development.

In addition, the industry is capital intensive; it plays a major role in economic and social well being of a nation and indeed, quality of life. Government, licensing bodies are expressing representative, environmental conservation groups are expressing their concerns in a way that present reliability technique, concept and models to be developed, utilized and scrutinized.

2.5 RELIABILITY DATA

The discussion of any quantitative reliability evaluation in various leads to a discussion of the data available and the data required backing such studies. Valid and useful data are expensive to collect, but it should be recognized in the long run that it would be even more expensive not to collect them. It's sometimes arranged as to which comes first: Reliability data or reliability methodology. Some do not collect data because they have not fully determined what to do with it (methodology). Consequently, they do not conduct reliability studies because no data available. It should be clear in our mind that data collection and reliability evaluation are interrelates and therefore is iterative.

When collecting data it should be remembered that an unlimited amount of data can be collected. It is efficient and undesirable to collect analyze and store more data than is require for the purpose intended. It is therefore essential to identify how the data will be used before deciding what data to collect.

In concept ional terms, data can be collected for one or both of two reasons, assessment of part performance and/or prediction of future system performance, hence collection of data is therefore essential as it forms the input to relevant reliability models technique and equations. Data should therefore reflect and responds to the factors that affect system reliability and available it to be modeled and analyzed. This means it should relate to system behavior processes involved i.e. failure process and restoration process.

The quality of data and evaluated indices depends on two important factors; confidence and relevance. The quality of the data and thus the confidence that can be placed in it is clearly dependent on the accuracy and completeness of the information complied by operation and maintenance personnel. It is obvious that they should be made fully aware of the future use to which the data will be put and the importance it will contribute in later development of the system.

The problems indicates in the impossibilities to compare and/or substantiate the result obtain from various methods in reality was recognized by IEEE subcommittee application of probability method (APM) which, in 1979, published the IEEE reliability Test System (RTS). This is a reasonably comprehensive system containing generation, Transmission and load data; this will enable result obtained by different people using different methods to be compared. The RTS is used extensively in application on generation and transmission except distribution since the RTS does not have any distribution define for it. The use of RTS not only provide consistent vehicle for describing the various application, it also enable a comprehensive understanding of the system to be derived and presented.

CHAPTER THREE

3.0 METHODOLOGY

A distribution circuit normally uses primary or main feeders and lateral distributors, which described its configuration. The main feeder originates at the substations and passes through the major load centers. Distributors connect individual loadpoints to the main feeders via a distribution transformers. A main feeder is constructed using single, parallel or mesh circuit. Many distribution system used in practice have a single circuit main feeder and are defined as radial distribution systems.

'Radial system configuration are commonly used in Nigeria due to their simple design and generally low cost. These systems have a set of series components between the substations and load points. The failure of any of this component causes outage of the load points. Meanwhile, using extensive protection and sectionalizing scheme reduce the outage duration and number of customer affected due to component failure. The sectionalizing equipment provides a convenient means of isolating the faulted section. The supply can then be restored to the healthy section, maintaining the service to some load points while; the faulted component is being repaired. The failure (down) time to repair (up) time is referred to as restoration time. In some system, there's provision for alternative path to supply in case of failure.

Fuse element or equipment is usually provided on the radial system of distribution, therefore faults on radial system or distribution transformer are normally cleared by this equipment and however, service on the main feeder acts to clear the fault. The faulted lateral distribution is then isolated and supply is restored to the rest of the system by closing the circuit breaker. The reliability analysis must therefore include the probability associated with the successful operation of the fuse. A direct analytical approach utilizing the available or moment data will be employed in these analyses on distribution network concerned in the chapter.

3.1 NEPA IJORA DISTRICT LAGOS

NEPA Ijora District happens to be one of the largest districts in Lagos Zone; this may be due to land space acquired that accommodates every sector and materials.
It comprises of Zonal personnel that handle every subject mainly faults and protection at 132/33kv transmission line or transformer and distribution is their area of concern. The distribution level comprises mainly the following departments.

a. Operation and maintenance department (O&M)
b. Planning and construction department (P&C)
c. Protection, control and meeting department (PC&M)

The operation and maintenance department (O&M) as the name tagged are in charge of all operation in the distribution network, which includes monitoring of network frequency, daily fault report, daily power supply (mostly hourly) to consumer and keeping of all products involving daily fault, outage time, rectification and restoration time which are stored in necessary log books.

Their function also includes, effective communication with all the engineers or personnel in the site for keeping them informed with the present situation or needed at site. They also carry out maintenance throughout all substations will correspond to preplanned maintenance schedule. Infact this is department where all data referred to, in this project were gotten.

Protection, control and metering department (PC&M) is the most important department in terms of protection equipment involved at distribution level, infact, this department is the backbone of the district functions. It consist of power engineer, technologist and technicians working as a team to maintain stability, reliability and provide protection to all the equipment in distribution system like testing be it, insulation test, continuity test, excitation test e.t.c. On 11kv/415v distribution transformer and calibration of relays to corresponds to the required supply voltage in accordance with the circuit breakers.

In addition, protection also made for every feeder be it overhead or underground through necessary ampere of fuses and communication system while the AC is down to avoid what is called SYSTEM COLLAPSE.

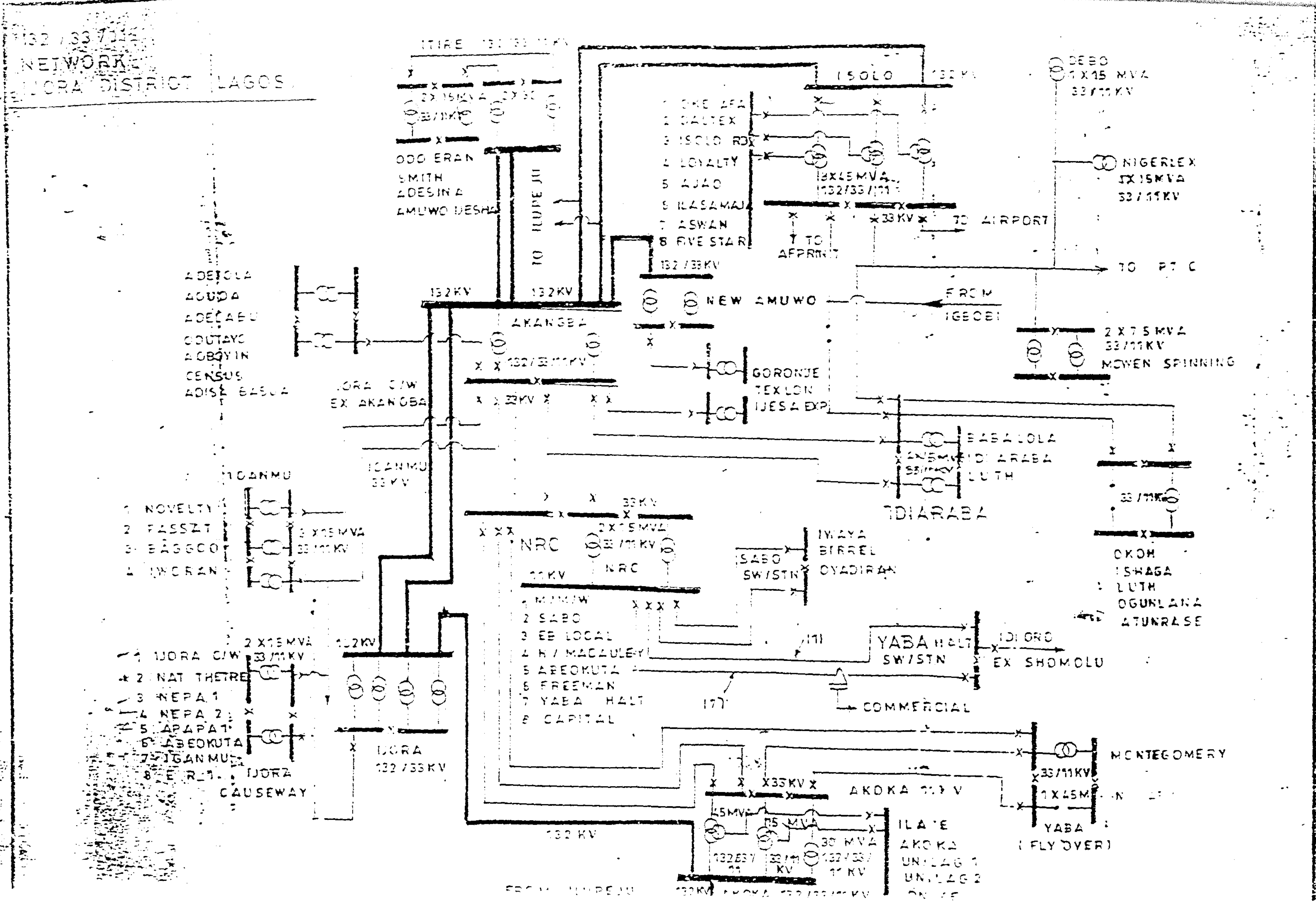
Planning and Construction department (P&C) however, are to function when new site are to be develop or extension has to be made in to relieve the existing ones. They carried out plan, survey and come up with quality of material to be employed. What is called SANCTION is raised at this department after planning and survey, which contained the quantities of material to be needed for the project that will also indicate the overall material cost.

Sanction parameter includes information on the protection of new site's stationary equipment like transformer, or protection information on the existing site to know whether to provide more or the forecast load studies can still withstand the existing protection. All these have to be shown in sanction along side with one line or schematic diagram drawn and release by these departments.

There are other Departments in this district like administrative & marketing under which there are sub like Records, Welfare and Establishment.

NEPA IJORA DISTRICT, secure under her, a total of eleven Injection sub-station namely AKOKA which feeds UNILAG, IGANMU, IDIARABA, IJORA CAUSE WAY, ISOLO, LUTH, NITEL, NEW AKANGBA, NEW YABA, NRC and ORILE, each having different number of feeders configured radially and supply the consumers with their respective uses. Among the injection sub-stations analysis made in this chapter emphasis on Ijora causeway injection sub-station which posses eight feeders including feeder that supplies National Art Theatre. All eight feeders has an alternative path of supply because it was supplied through two other injection sub-station namely Ijora and Iganmu. This reduced the restoration time with any fault occurrence.

A schematic or one line diagram at 132/33/11 kV network of NEPA Ijora District Lagos is shown in page 37 identified as fig 3.1 for a lucid explanation.


132/33/11KV
NETWORK
IJORA DISTRICT LAGOS
ITIRE
ODO ERAN
SMITH
ADESINA
AMUWO DESHA
TO ILUPEJU
ISOLO
132KV
1 OKE AFA
2 DALTEX
3 ISOLO RD
4 LOYALTY
5 AJAO
6 ILASAMAJA
7 ASWAN
8 FIVE STAR
3X45MVA
132/33/11
33KV
TO AIRPORT
TO AIRPORT
DEBO
1X15 MVA
33/11KV
NIGERLEX
1X15MVA
33/11KV
TO PTC
FROM IGEOBI
NEW AMUWO
132/33KV
2X7.5MVA
33/11KV
MOWEN SPINNING
ADEJOLA
ADUDA
ADEBABU
ODUTAYO
ADOBOYIN
CENSUS
ADISA BASUA
132KV
AKANGBA
132/33/11KV
33KV
IJORA C/W
EX AKANGBA
GORONJE
TEXLON
IJESA EXP
BABALOLA
IDI ARABA
LUTH
IDI ARABA
IGANMU
33KV
IGANMU
1 NOVELTY
2 FASSZT
3 BAGGCO
4 IWORAN
3X15MVA
33/11KV
33KV
2X15MVA
33/11KV
NRC
NRC
11KV
1 MUMUW
2 SABO
3 EB LOCAL
4 H/MACAULEY
5 ABEOKUTA
6 FREEMAN
7 YABA HALT
8 CAPITAL
IWAYA
BIRREL
OYADIRAN
SABO SW/STN
YABA HALT SW/STN
IDI ORO
EX SHOMOLU
COMMERCIAL
OKOH
ISHAGA
LUTH
OGUNLANA
ATUNRASE
33/11KV
1 IJORA C/W
2 NAT THETRE
3 NEPA 1
4 NEPA 2
5 APAPA
6 ABEOKUTA
7 IGANMU
8 EBR
2X15MVA
33/11KV
IJORA CAUSEWAY
132KV
IJORA
132/33KV
MONTEGOMERY
33/11KV
1X45M
YABA
(FLY OVER)
AKOKA
33KV
45MVA
15MVA
30MVA
132/33/11KV
ILAJE
AKOKA
UNILAG 1
UNILAG 2
132KV
FROM ILUPEJU
AKOKA 132/33/11KV

3.2 AVAILABLE PROTECTION

The capital investment in a power system for the generating transmission and distribution of electrical power is so great that proper transmission must be taken to ensure that the equipment not only operates a nearly as possible to peak efficiencies, but also that it is protected from accidents.

Most electrical fault is shunt faults, which is characterized by increase in system current, reduction in voltage, power factor and frequency.

The protection available for the system from sub-station to individual bad points is feeder protective relays in conjunction with circuit breaker and transformer protection. An ideal protective relays should have the following characteristics

i. Reliability: the relay should be reliable a basic requirement it must operate when it required, inherent reliability is a matter of design based on long experience. This can be achieved partly by high control pressure, dust free enclosure, good contact material and careful maintenance

ii. Selectivity: A relay requirement, should be able or possible select which part of the system is faulty and which is not and isolate the faulty one from healthy one selectivity can be achieved in two ways unit system of protection and non-unit system of protection.

iii. Speed: a protective relay must operate at require speed, it should neither be too slow which may result in damage to the equipment, nor should it be too fast which may result in undesired operation during transient faults.

iv. Sensitivity: A relay should be sufficiently sensitive so that it operates reliably when required under the actual conditions in the system, which produce the least tendency for operation.

Feeder protection used at the substation is over current relay protection; because it is the simplest and cheapest form of protection, it most difficult to apply and needs readjustment should a change in circuit occur. Over current relaying for the distributing circuit besides being simple and cheap provides advantages like

a. Very often the relays need not be directional and hence no ac voltage source is required

b. Two phase and one earth fault relays are required for the complete protection of three phase circuit a shown in fig 3.2. From the table of failure rate deviation it was found that reliability of relay without time specification to be

$\lambda r = 0.650 x 10^{-5}$/hour.

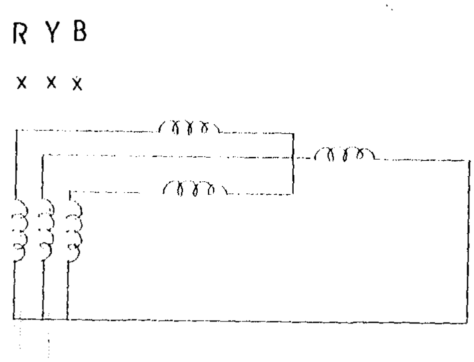


FIG 3. 2 3 PHASE CT AND RELAY

Protection on distribution are mainly fuses and lightning arrester, these are two are external protection, there are other protection of transformer which are internal, the protection against heat, oil temperature, insulation breakdown of oil and short circuit writhing the windings. Some transformers use protective relay to protect these equipment e.g. protection against high temperature.

It is very rare to have a transformer breakdown or faulty, this is due to the protection surrounding the equipment. Most fault or lightning discharge are cleared simply by fuse cut, isolating the fault cable and transformer, from the parameters gathered and probability calculated or failure rate of transformer which are variable and most fault by fuse having the probability of 0.2.

3.3 SYSTEM ANALYSIS FOR POWER DISTRIBUTION

Before numerical reliability analysis is to be carried out, it is better or appropriate to have a brief discussion on factors, generally that affect power system reliability at distribution levels in Nigeria. There are many factors that affect the reliability of power on reliability is discussed here. Factors to be considered include load flow, power factor, voltage regulation short circuit insulation co-ordination and harmonic diffusion.

3.3.1 NETWORK ANALYSIS

As mentioned in the previous section of this chapter NEPA ijora district, Lagos has been used as the basic configuration for the study. It totally overhead distribution system extending during its secondary transmission to eleven injection sub-station. But, the concerned sub-station is Ijora causeway substation, it extension invariably, was about

10km North of the base station through about 14km south and 16km southwest, the system supplies electric power to public buildings like national theatre, offices like, Lagos state water co-operation head quarter, numerous companies and residential houses. It has eight primary feeders (11kv) in which an alternative path is provided for all these feeders in case of any emergency condition (fault) from nearby injection sub-station called Iganmu. These are shown in fig 3.1

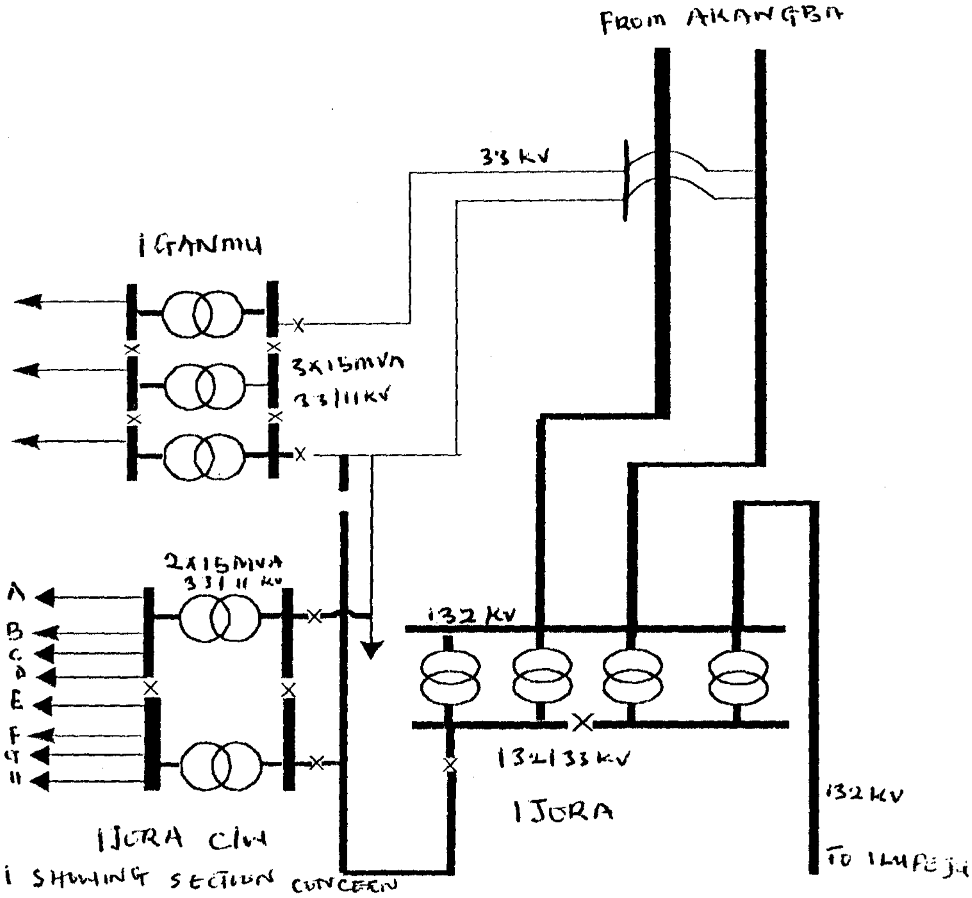


FIG 3.1 SHOWING SECTION CONCERN

The failure rate and repair time of components, the system restoration times and the probabilities associated with fuse operation and the availability of the alternative supply are normally the input parameters for the reliability analyses of a distribution system the parameters are determine on the basis of historical data of year 2001 from O and M department.

Since the area of study is the reliability or system or system performance at customers end then the basic indices to be considered are: load point failure rate, average outage duration and annual unavailability, load point failure can be caused by cable failure, transformer failure which is most time cleared by fuse, due to short circuit.

The analytical techniques to perform failure mode and effect might result into tables in which the following basic steps are required from an equation. Suppose a line observed for an interval of time in which N cycle of failure (permanent fault) and repair are noted, then, several time to failure cycle can be represented by m*i*, similarly corresponding time to repair to be represented by r*i* for *i*th cycle. Then,

$$m_i = 1/N \sum_{1}^{N} m_i \quad \text{and} \quad r = 1/N \sum_{1}^{N} r_i$$

The sum of average time to failure and average time to repair becomes

$$\bar{T} = m + r$$

Availability can be given as a ratio of average uptime m to average cycle time T as follows:

$$\Lambda = \bar{m}/\bar{r} = \bar{m}/\bar{m}+\bar{r}$$

The reciprocal of meantime to failure is often designed as failure rate "λ" meanwhile failure rate of a series reliability system is the sum of device failure, therefore,

$\lambda s = \lambda_1 + \lambda_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots + \lambda_i$

$\lambda s = \sum \lambda_I$ f/yr i.e failure per year

$r_s = \sum \lambda_I r_i / \sum \lambda_I$ hr/ i.e hour per failure

And reliability can be given as

$U_s = \lambda_s \; r_s$ hr/yr i.e. hour per year

It should be known to us that feeder that supply electricity to all customer are made therefore all feeder failure rate per year are calculated from the fomular

λ_{fdr} = Failure rate of feeder, which is sum of

λ_{OH} = Failure rate of overhead cables per year and

λ_{UG} = Failure rate of under ground cables per year and

λ_{CT} = Failure rate of cable termination per year.

And it is assumed that every load point or customer end are supplied with quantity power provided that no fault occur at the feeder and their corresponding distribution transformer.

Moreover, all the eight sub-station feeder are labeled feeder A, B, C... In ascending order.

From these basic distribution reliability indices, common indices that can be derived are discussed below only that they involves the number of customer or consumers.

1). System Average interruption frequency index (SAIFI), this index is defined as the average number of interruption per customer served per time unit. It is estimated by dividing the accumulated of customer served.

$$SAIFI = \frac{\text{No. of customer} - \text{Interruptions}}{\text{Total no. of customer served}} = \text{x/customer year}$$

2). Customer Average Interruption frequency index (CAIFI), this index is defined as the average number of interruption experience per customer affected per time unit. It is estimated by dividing the number of customer interruption observed in a year by number of customer affected,

$$CAIFI = \frac{\text{Total customer Interruption}}{\text{Customer affected}} = \text{int/yr/cus/yr}$$

3). System average interruption duration index (SAIDI), this can be defined as the average interruption duration for customers served during a year. It is determined by dividing the sum of all customer sustained in interruption durations during the year by the number of customers served during a year.

$$SAIDI = \frac{\text{Cumulative customer -- minite Interruption}}{\text{Total no. of customer served}} = \text{hr/by.lost}$$

4). Customer average interruption duration index (CAIDI), this index is defined as the interruption duration for customer interrupted during a year. It is determined by dividing the sum of all customer sustained interruption durations during the specified period by the number of sustained customer interruptions during the year

$$CAIDI = \frac{\text{Cumulative customer --hr Interruptions}}{\text{Total no of customer interrupted}} = \text{hr/cus.int}$$

5). Average service availability index-(ASAI), this is the ratio of the total number of customer hours that service was available during a year to the total customer hours demanded. The complementary value to the index i.e. average service unavailability index (ASUI)

3.3.2 CALCULATON

FEEDER A

This is the feeder that serves he substation itself some residential buildings around; it covers about 3km and has about five-distribution transformer. The input parameters for the feeder are:

Failure rate of feeder = 0.015 f/km Yr

Repair time = 3hrs

Failure rate of transformer = 0.002 f/yr

Replacement of transformer = 4hr

Probability fuse clear the fault = 0.6

Probability of alternate supply = 0.2

$\sum X_i = \lambda_S = \lambda_{fdr} + [\lambda_T \times N_T \times P(fuse)]$ in f/yr

Where

λ_S = Sum of fault rate/year in series

λ_{fdr} = Feeder fault rate/year

λ_T = Transformer fault rate/year

N_T = No. Of transformer involved

P (fuse) = probability fuse clear transformer fault.

There

$\lambda_{SA} = 0.015 \times 3 + (0.002 \times 5 \times 0.6)$

$= 0.045 + 0.006$

$= 0.051$ f/yr

The basic reliability indices for sub-station A are:

$\lambda_{SA} = 0.051$ f/yr

$r_{SA} = 3.1$ hr/yr and

U_{SAP}

Reliability$_A$ = 0.99998%

Other distribution indices can still be calculated from the basic indices like base in the assumption that 1000 customers are served and for any fault occurrences 600 customer are affected then

$$(SAIFI)\ A = \frac{\text{Total no. of Customer interruptions}}{\text{Total no. of customer served}}$$

$$= \frac{600}{1000} \times 0.051 = 0.036 \text{ customer - yr}$$

$$(SAIDI)\ A = \frac{\text{Cumulative customer – hr interruptions}}{\text{Total no. of customer served}}$$

$= \frac{600}{1000} \times 0.61 = 0.366$ hr/system customer

(CAIDI) $A = \frac{\text{Cumulative customer – minute interruption}}{\text{customer interrupted}}$

$= \frac{0.61}{0.051} = 11.96$ hr/cus. Int

(ASAI) $= \frac{\text{Customer hours of available service}}{\text{customer hours demanded}}$

$= \frac{1000 \times 8760 - 600 \times 0.61}{1000 \times 8760} = 0.99995$

and $r_s = \frac{\sum \lambda_I r_i}{\sum \lambda_I}$ = hr/ i.e hour per failure

Where ri = time to repair each and every faulted equipment in hr
And rs = Total sum of annual outage duration of the system in hr/fault

$r_{SA} = \frac{0.045 \times 3 + 0.006 \times 4}{0.051}$

$= 3.1$ hr/fault

$Us = \lambda_S \times r_S$ where Us is the annual unavailability in hrs/yr

Then

$U_{SA} = \lambda_{SA} \times r_{SA}$
$= 0.051 \times 3.1$
$= 0.16$ hr/yr

For P (alternative supply path) = P (0.2)
U_{SAP} = USA x 0.2
$U_{SAP} = 0.032$

Unavailability = 0.16 hr/yr. And we have 8760 hrs in a year
That means
Availability = 8760 – 0.16
= 8759.84 hr/yr

Reliability $= \frac{\text{Availability}}{\text{Total sum of hour demanded}}$

R (t) = 0.99998

$\approx$ 99.9%

The overall analysis for feeder A can be given as;

λ_{SA} = 0.051 f/yr

r_{SA} = 3.1hr/fault

U_{SA} = 0.062hr/yr

Reliability = 0.999

(SAIFI) A = 0.0306 customer/yr

(SAIDI) A = 0.336hr/system customer

(CAIDI) A = 11.96

(ASAI) A =0.99995

FEEDER B

This feeder supplies National Theatre, Offices and some residential buildings, having about 20 distributions transformer and covers about 5km, it has the following as input parameters:

Failure rate of feeders = 0.15f/km-yr

Repair time = 4hr

Failure rate of transformer = 0.008f/yr

Replacement of transformer = 10hr

Pr (fuse) clear fault = 0.2

Pr alternate supply = 0.8

Using the same techniques we have

λ_{SB} = 0.7820 f/yr

r_{SB} = 4.25 hr/yr

U_{SB} = 3.32 hr/yr

U_{SBP} = 2.66 hr

Rel = 0.9996

Assuming 5000 customers served and 2000 affected with interruption then

(SAIFI) B = 0.31

(SAIDI) B = 1.33

(CAIDI) B = 4.25ASAI =0.9998

ASAI = 0.9998

FEEDER C

This is called NEPA 1 and has about 2000 customer; this feeder supplied mostly residential building and some private companies. It is about 8km long and the corresponding input parameters are: having about 15 transformers

Failure rate of feeders = 0.45 f/km-yr

Repair time of feeders = 5 hrs

Failure rate of transformer = 0.15 f/yr

Replacement of transformer = 10 hr

P (fuse) clear the fault = 0.6

Probability alternate supply = 0.8

λ_{Sc} = 4.95 f/yr

r_{Sc} = 6.36 hr/f
U_{Sc} = 31.48 hr/yr
U_{Scp} = 25.18 hr/yr
Rel = 0.99712

Assuming about 2000 customers and 1800 affected with the interruptions or outage

(SAIFI) C = 4.46
(SAIDI) C= 28.32
(CAIDI) C= 6.3
ASAI = 0.99675

FEEDER D

This feeder is named Apapa; it supplies most of Apapa south and about 10km distance. About 20 distribution transformers. It has the following input parameters

Failure rate of feeder = 0.42 f/km-yr
Repair rate of transformer = 6 hrs
Failure rate of transformer = 0.55 f/yr
Probability fuse clear the fault = 0.5
Probability alternate supply = 0.2
Replacement of transformer = 36 hrs

Assumed 10,000 customers and at least 4,000 are affected by interruption then,

(SAIFI) D = 3.88
(SAIDI) D = 89.24
(CAIDI) D = 9.66
ASAI = 0.9898

Feeder D and E have approximately the same parameter, then they are equal

FEEDER F

This feeder is called Abeokuta; it covers almost about 8km and having about 12-distribution transformer. The feeder supplies mostly residential buildings. The input parameters are:

Failure rate of feeder = 0.6 f/km-yr
Repair rate of transformer = 10 hrs
Failure rate of transformer = 0.15 f/yr
Replacement rate of transformer = 0.15 f/yr
Probability fuse clear the fault = 0.8
Probability alternate supply = 0.8
Replacement of transformer = 36 hrs

Then

λ_{Sf} = 6.24 f/yr
r_{Sf} = 16 hr/f
U_{Sf} = 99.84 hr/yr, approximately 14.16 days/yr
S_{Sfp} = 79.87 hr/yr
Rel = 0.98860

Assumed 10,000 customers and at least 6,000 are affected by interruption then,

(SAIFI) F = 3.74
(SAIDI) F = 59.9
(CAIDI) F = 16
ASAI = 0.99316

FEEDER G

This is Igamu feeder supplies mostly industrial estate and very limited population of residents. About 5 dedicated transformer and covers 6km. The input parameters are

Then

Failure rate of feeders = 0.52f/km-yr
Repair time = 4hrs
Failure rate of transformer = 0.25f/yr
Replacement of transformer = 48hr
Pr (fuse) clear fault = 0.2
Pr alternate supply = 0.2

Then

λ_{SG} = 3.37 f/yr
r_{SG} = 7.26 hr/yr
U_{SG} = 24.5 hr/yr
U_{SGP} = 4.9 hr/yr

FEEDER H

Like feeder G above, feeder h is the last feeder that supplies also industrial estate. Around Iganmu side of logos it covers about 10km and 15 dedicated transformer. Input parameters are:

Then

Failure rate of feeders = 0.75f/km-yr
Repair time = 6hrs
Failure rate of transformer = 0.45f/yr
Replacement of transformer = 48hr
Pr (fuse) clear fault = 0.6
Pr alternate supply = 0.2

Then

λ_{SH} = 3.37 f/yr
r_{SH} = 7.26 hr/yr
U_{SH} = 24.5 hr/yr
U_{SHP} = 4.9 hr/yr

CHAPTER FOUR

4.0 DISCUSSION OF RESULT

The table below (Table 4.1) shows the result of analysis got from the previous Chapter, in which the main cause of outage are cable made of feeder and transformer as well as their respective restoration time are mostly the input parameter considered.

The output or determining objectives from the analysis are basic reliability distribution, which includes annual total failure rate, annual total restoration time and annual unavailability with or without alternative path of supply at each and every failure. Likewise the system indices involving consumers irrespective of their uses.

FEEDERS INDICES	A	B	C	D	E	F	G	H
BASIC λ (f/yr)	0.051	0.78	4.95	9.70	9.70	6.24	3.37	11.55
R (hr/yr)	3.10	4.25	6.36	23.10	23.10	16.00	7.26	20.72
U (hr/yr)	0.16	3.32	31.48	223.10	223.10	99.84	24.5	239.32
U_A (hr/yr)	0.032	2.66	25.18	44.62	44.62	79.87	4.9	47.86
Rel	0.9998	0.9996	0.9971	0.9750	0.9750	0.9886	0.9972	0.9727
SYSTEM SAIFI	0.03	0.31	4.46	3.88	3.88	3.74	-	-
SAIDI	0.37	1.33	28.32	89.24	89.24	59.9	-	-
CAIDI	11.96	4.25	6.30	9.66	9.66	16.00	-	-
ASAI	0.9999	0.9998	0.9968	0.9898	0.9898	0.9932	-	-

TABLE 4.1 SUMMARY OF RELIABILITY INDICES FOR THE FEEDERS

It can be deduced from the table that the load point failure rate are dependent upon the component exposed to failure and even degree of short circuit of any form, at the line or feeder, which may be as a result construction at planning stage or degree of manual isolation of failed equipment in the network.

Failure rate at feeders, D, E, F and H are higher it might be due to overloading of transformers mainly caused by dense population and it is a function of power consumption. At the same time the transformer rating for use in industries, if it is dedicated transformer the rating must be appropriate like in case of feeder G and H.

Meanwhile the restoration hours which the unavailability depends is so higher at the same four feeders (i.e D,E,F and H), this may due to managerial problem or lack of material and mostly beaucratic factor. The availability of an alternative path or back feeding helps in reducing the annual unavailability of the system because feeder A,D,E,G and H (with alternative supply probability of 0.2) are reduced to about 80% in annual unavailability period while the rest (P alternative supply are 0.8) are reduced to about approximately 20% this can be visualize in fig 4.1 in a chart form.

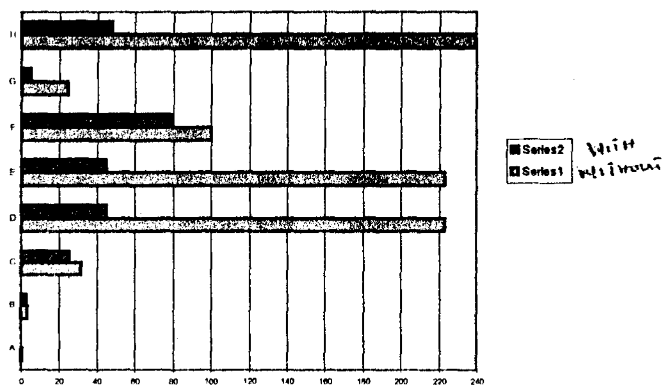


FIG. 4.1 GRAPH SHOWING UNAVALABILITY WITH/WITHOUT ALTERNATIVE PATH

The system indices ASAI of feeder derived from basic indices and reliability of the feeder are approximately equal thereby ASAI of a particular feeder can be represented as the reliability of the feeder, only that ASAI involved number of consumer using that feeder.

The system indices for feeder G and H are not calculated due to the fact that, they are supplying industries with dedicated transformer and number of consumer cannot be quantified. Moreover, the overall reliability of feeders in the substation supply to consumer can calculated this:

$$R(T)\ OVERALL = \prod_{I=A}^{H} RI = R_A R_B \cdots\cdots\cdots R_H$$

R (t) overall = 0.9109

4.1 PROGRAM

In the process to analyses the basic reliability indices of these feeder of the substation, it was realized that it is very tedious and bound to error if proper care is not taken, therefore, to circumvent these, a computer software program is design using the well known BASIC high-level language to calculate reliability indices of a feeder which involves failure rate (transformer and feeder) per annum, annual restoration time and annual unavailability, likewise the system indices involving customers. The program goes thus:

```
10  PROGRAM TO DETERMINE DISRIBUTION RELIABILITY INDICES
20  INPUT "FEEDER FAILURE PER Km"; F
30  INPUT "FEEDER COVERED BY FEEDER"; D
40  INPUT "DISTANCE PERIOD FOR FEEDER"; RF
50  INPUT "FAILURE RATE OF TRANSFORMER"; FX
60  INPUT "REPLACEMENT PERIOD FOR TRANSFORMER"; RX
70  INPUT "NO. OF TRANSFORMER UNDER A FEEDER"; NX
80  INPUT "PROB. FUSE CLEAR FAULT"; PF
90  INPUT "PROB. ALTER. SUPPLY"; PA
```

```
100 INPUT "NO. OF CONSUMER SERVED"; NC
110 INPUT "NO.. OF CONSUMER AFFECTED";NA
120 LET λF = F*D
130 LET λX = TF*N*PF
140 LET λS = λF +λX
150 LET RS = [λF*RF + TF*RX]/ λS
160 LET US = RS*λS
170 LET USA =US*PA
180 LET REL = (8760-US)/8760
190 REM DETERMINATION SYSTEM INDICES
200 LET SA = (NA*λS)/NC
210 LET SD = (NA*US)/NC
220 LET CA = US/λS
230 LET AI =[(NC*8760)-(NA*US)]/NC*8760
240 PRINT "TOTAL ANNUAL FAILURE RATE OF FEEDER ";λS
250 PRINT "TOTAL ANNUAL RESTORATION TIME"; RS
260 PRINT "ANNUAL UNAVAILABILITY"; USA
270 PRINT "UNAVAILIBILITY WITH ALTER."; USA
280 PRINT "RELIBILITY OF FEEDER & TRANSFORMER"; REL
290 PRINT "SAIFI"; SA
300 PRINT "SAIDI"; SD
310 PRINT "CAIDI"; CA
320 PRINT "ASAI"; AI
330 END
```

CHAPTER FIVE

5.0 CONCLUSION

The behavior of all engineering system is essentially stochastic in nature i.e. it varies randomly with time. Consequently, it is necessary to use model and analytical technique that reflect this stochastic behavior in order to objectively, evaluate future predictions, to achieve this, it requires the use of probabilistic assessment; to constraint the problem into a deterministic domain is unrealistic and prevent the effect of all system parameter to be quantitatively predicted. But present day study suggests that the "worst case" system condition which occur very infrequently should not be utilized as case study or criteria carried out any reliability analysis because of economic restrictions.

An electric power system is a complex interconnected network of components; overall system reliability is dependent upon the design, reliability of the individual component and system in conjunction with availability or replacement of faulted components. The relationship between cost and reliability is also a complex relationship of equipment and instability in cost, lost revenue lost energy production and other factors.

The analytical technique presented or utilized in this project is in fact, decomposition algorithm for system reliability estimation of electric power system with aim of solving complexity in analysis of system reliability. This project is designed and developed a software program to analyses critically using some distribution reliability indices e.g. CAIDI, SAIDI, SAIFI e.t.c the available protection system and network configuration in conjunction with statistical data on the likelihood fault occurrence to estimate the overall reliability of electric power supply to any consumer (supplied from the sub-station used as case study).

This gives an or results to estimation of an expected number of hour lost for each consumer per annum and will be useful to engineers in designing new network or improving the existing ones.

5.1 RECOMMENDATION

5.1.1 IMPROVING COMPONENT RELIBILITY

Reliability engineers are very often called upon to make decision as to whether to improve certain components in order to achieve minimum required system reliability. This minimum required system reliability is for a specified time. There are two approaches to improve the reliability by using high quality and high reliability components and usually less expensive that fault tolerance. Fault tolerance on the other hand, is achieved by redundancy. Redundancy can result in increasing design complexity and cost through additional weight, space e.t.c.

Before deciding whether to improve the reliability of a system by fault tolerance or avoidance, a reliability assessment of each component in the system should be made. Once the reliability value of component can be qualified then analysis can be performed in order to determine if that system's reliability cannot be achieve at the specific time, steps can be taken to determine the best way to improve the reliability of the system to reach the derive target.

5.1.2 IMPROVING SYSTEM RELIBILITY

De-regenerated in the monopolies electric power industry min Nigeria is compelling utilities to face hard decision on maintaining and expansion is distribution system. In conjunction with financial constraints brought by de-regulation, the increased popularity of distributed generation is presenting utilities with an opportunity and a challenge as they retool to meet increasing demand for power with an infrastructure at or exceeding capacity.

Looking into distributed generation (DG) as a way to expand generating capacity reinforce their distribution network or ensure "always on" or "high 9s" for customer sensitive to power supply distributions. However, from a technical perspective, the idea of interconnecting DG to distribution system runs contrary to the design principles upon with almost the entire electric distribution infrastructure is based.

Planning framework is better able to consider and evaluate alternative such as DG than conventional methods, which may limit choices to reinforcement options such as building new sub-station and feeder for relieving.

Planning methods based largely on peak capacity being built. They fail to show where incremental option like DG might be economical. This method consists of a multilevel screening analysis progressing from high-level economical analysis to detail engineering analysis. A typical set up of a DG planning is shown in fig 5.1.

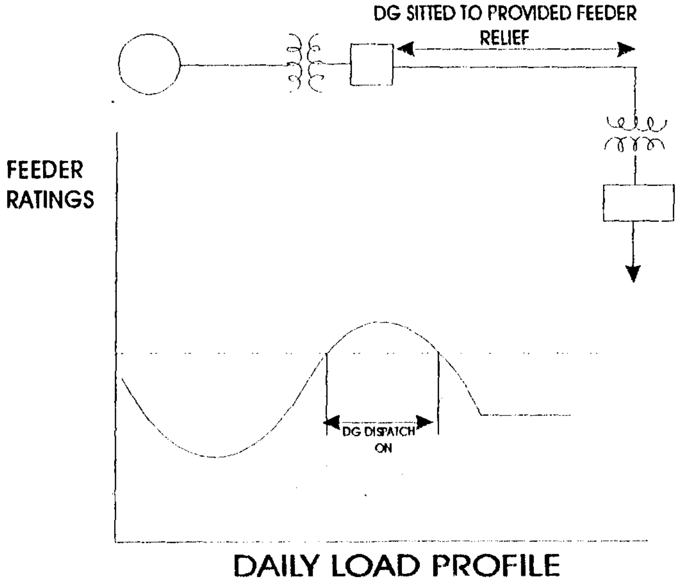


FIG. 5.1
USING DG TO RELIEF FEEDERS

Simulation on DG application needs one or more of the following, depending on needs or requirement.

- Voltage Regulation
- Sub-station and Line capacity
- Transformer thermal re-rating
- Looses (sub-station and feeder)
- Reliability [expected unserved energy]

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