RELIABILITY ANALYSIS FOR DISTRIBUTION OF POWER NETWORK

(CASE STUDY: PHCN (NEPA) MINNA DISTRICT, NIGER STATE.

BY

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DECLARATION

I hereby declare that this project is the result of my handwork and research. It was under supervision of DR. Y.A. ADEDIRAN, in Electrical and Computer Engineering Department, Federal University of Technology, Minna, Niger State and partly Engr. A.B. MUSTAPHA of Minna PHCN (NEPA) district , Niger State.

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CERTIFICATION

This is to certify that this thesis "Reliability Analysis for Power Distribution Network (case study: PHCN Minna District Centre)" is the original work of Amuda R. Idowu, carried out under the supervision of Engr: Dr. Y. A. Adediran, for the award of a Bachelor of Engineering (B.Eng) degree in Electrical and Computer Engineering, F.U.T.Minna.

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CHAPTER ONE

INTRODUCTION

Electrical power system is an important lifetime engineering system that has so much to do with national economy and people`s livelihood. In modern society, with high level of technology, power supply is expected to be available continuously. This is due to the fact that there is increase in the assumption of primary energy. On the other hand, electrical energy is tending to replace the other form of energy on account of it's extreme simplicity of control and it's distributions for use both in large and small quantities.

The process by which electrical power is conveyed from generating station to the consumer's premises may in general be divided into two distinct parts: Transmission and Distribution. Of course, there are various source of power generation ranging from Hydroelectric, Solar, Nuclear power station e.t.c.

Transmission is necessary after generated electricity has passed through some process like stepping- up to a considerable level for high voltage transmission.

Distribution, which is the last process to the consumer`s premises, takes the largest percentage in the overall investing cost. Distribution system can be divided into section; Feeders, Distributors and Sub-distributors.

Feeders are conductors which connect sub-stations to the distributors via distribution transformer which serves certain allocated arrears. From the sub-distributors, various tapping are made using service mains.

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 scheduling maintenance. In many cases alternative supply paths 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 required or desired function under stated conditions for a given period. 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 role in economic and social aspect of life, the need for design, operational cost reduction in highly competitive market and more are reasons that give reliability more attention or significance.

1.1 SYSTEM RELIABILITY

Power system would always experience a set of operational constraints. Some constraints are directly involved with the supply such as bus bar voltage and frequency variations. Others which are in direct but equally important in operating sense including equipment ratings, system stability limit and faults levels. It should be clear in our minds that the term 'Reliability' has a wide range of meaning and can not be associated to a single specific definitions, but in general, system reliability function in a given period. With this meaning system reliability of power both stochastic and 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 constraints. These include 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 to.

1.1.1 TYPES OF SYSTEM RELIABILITY

Before going through reliability system on generation, transmission and distribution, let us have a quick look at types of system reliability.

OPERATIONAL RELIABILITY

This results from the observation and analysis of the behaviors of two or more identical systems operating under the same conditions.

PREDICTED RELIABILITY

It is a measure of the future reliability assessed taking the system design and reliability of it's component into consideration.

EXTRAPOLATED RELIABILITY

This results from an extension by a defined interpolation of the operational reliability of the different durations or stress conditions.

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 it's conformity to the specification but also by it's ability to meet these specifications over it's entire lifetime. Meanwhile one of the basic characteristics of a product or services that contribute to it's quality is it's reliability. This 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 functions under a given condition. It is characterized by the following concept.

RELIABILITY

This can be defined as the probability of a component or system will perform it's prescribed duty without failure for a given time when operated correctly in a specified environment.

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

$F_{(t)} = 1 - R_{(t)}$

AVAILABILITY

This means ability of a system to be in the state of performance in required function under given condition at a given instant of times.

Unavailability is the reverse of availability, it is expressed as;

$U_{(t)} = 1 - A_{(t)}$

MAINTAINABILITY

This means the probability that a system will perform to specified condition within a given period when maintenance action is performed in accordance with prescribed procedure and resources.

Non – maintainability is the reverse and is expressed as;

$\square_{(t)} = 1 - M_{(t)}$

Maintenance comes in tree forms; Predictive, Corrective and Preventive maintenance.

1.1.4 NEED FOR RELIABILITY

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 1970s, planning for the construction of generating plant was relative uncomplicated, lead times were relatively small and cost was 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 a highly reliable electric power system. The same attention in the power electric reliability effect should also be given to other sectors like Banking, Industries, School as well as commercial enterprises because power outage is less reliable or low quality power supply has its effect on different angle to all these sectors mentioned above.

With the rapidly growing convergence of various services from telecommunication to manufacturing, the big question is what they really need in the way of back-up reserve time to maintain the high reliability that is expected in the power system in this country after various findings.

Moreover, Farah saheed, an industry analyst at frost and Sullivan based in U.S.A said; 'A back up power system is a must, as more and more businesses are becoming mission critical in today's wired world. I think the power crises that California (U.S.A) experienced during year 2000 and 2001 made it clear that companies cannot depend on utility consistent and power.

If power crises, at consumer end can be experienced in U.S.A, as advanced as their technologies with experts in power protection analyst, then what do we think will be happening in a third world country like Nigeria with newly licensed mobile telecommunication (G.S.M) operators which for every switching centre installed at the expense of expansion f their network, go along with at least two generating plants connected in hot redundancy form, for continuous power supply to the switching station in order to hit the target of every effective and reliable communication service in Nigeria.

Power protection and analyst expert in U.S.A realized the significance of reliability to the economy, put up and present papers based on these priority topics at a INTELEC conference earlier

Power outage: causes and prevention

Reliability analysis of an A.C 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 uncertainty can 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.

1.2 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. The project aims at developing a software programmed to analyze critically using some distribution reliability indices, the available projection system and the network configuration in conjunction with statistical data on the like hood of fault occurrence 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.

1.3 LIMITATION

In electric power system which consists of Generation, Transmission and Distribution, reliability analysis can be carried out on the three functional zones. This project is however limited to only distribution level. All data used in the analysis were extracted from NEPA (PHCN) MINNA DISTRICT except assumptions made on the number of customers on the feeder and distance covered for easy analysis.

Moreover, this analysis is carried out on the basis that electricity is supplied from the 11KV substations 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 based and the computer programmed designed can be used to determine all reliability indices of feeder one at a time.

CHAPTER TWO

HISTORICAL BACKGROUND

Reliability consideration now occupies an important place in the entire engineering of complex systems and electrical systems. Application has generally included mechanical, chemical and electrical systems.

During the last decades it has become self evident that to minimize the probability of failures, human factor 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.

Human reliability analysis (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) techniques have gathered data from their basic discipline and the provide mechanism of estimating failure probabilities. Throughout early 1980`s, qualification techniques proliferated review of literature yields approximately 38 HRA techniques.

One major difference between performance reliability analysis (PRA) and human reliability analysis (HRA) is the fact that no complete source of data exists for human failure test. 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) hand book (Swain and Gultham,1983) and the Nuclear Computerized Library for Assessing Reactor Reliability

(NUCLARR) (Gertman et al, 1990). As these database develop, they will become major sources of databases containing failure rate information for Decision Base Errors (DBEs). Currently, the risk impact of DBEs is neither well identified nor qualified.

Exceptions exist in the application of the confusion matrix approach used in the 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 operation data, such as 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 form 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 estimate.

One of the really difficult problems faced by those responsible for planning of electric supply system 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 aspects 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 customers compliant 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. [1]

He also stated that, a major problem is design of power system arises from a combination of the desire to render reasonable continuous service and the inherent fallibility of the 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 [3] identified two classes of problems: The first is concerned with the chance "coincidence" of unrelated events, such as overlapping, random, independent outage number of generations. The second problem concern widespread and unpredicted catastrophic events which may double an entire generation or even the entire system. In such emergency, the mere multiplicity of generating unit or even generations may be little or no avail loss of land.

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 braking 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: The 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 must be equal to the outage expectation setup for the system as a whole.

Although Lyman and Smith 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 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. [6]

From his studies of relationship between overlapping capacity outages, Smith concluded that 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-connect with other systems the percentage of spare capacity can be increased without sacrifice of service reliability. These are root concept contained in two widely used planning indices for generating systems: interval 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 outage 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). [7]

The indices can reflect inter area tie live capacity, reliability and availability 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 problems involving generation, transmission and major substations near load centers. In modern text these are "bulk power supply" problems.

An attendant 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 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.

The application of probability methods to distribution system design extends over a period nearly as long as the application to generation.

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 asses 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 streams of activity as been imitated 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 method.

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 evaluation. [10]

A wide range of probabilistic techniques have been developed. These include technique for reliability evaluation, probabilistic load flow and probabilistic transient stability.

The fundamental and common concept behind each of these development is the need to recognize that power system behaves stochastically and all input, output state and event parameters are probabilistic variables. The probabilistic techniques 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. [12]

2.1 MONTE CARLO SIMULATION

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

The basic principle of MCS is that 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 com[putting time and storage in order to develop a good system model and therefore, it should not be used extensively if alternative 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 order words, the problem do not have to fit the model or technique instead the model is developed to fit problems.

Simulation technique can be use to quantitavely estimate the system reliability even the most complete system generating capacity situation. Existing method for calculating generating system adequacy indices do not explicitly consider certain unit functions and system operating policies. Monte Carlo simulation, however provides a methods of analysis which permits relaxation of many of the tradition assumption incorporated in the analytical technique used to calculate adequacy indices. It also provides a benchmark for comparison of various modeling assumptions associated with the analytical techniques.

Also a major shortcoming of most analytical techniques is that they can not provide the distribution associated with the reliability indices. This distribution can be easily generated using simulation. [14]

2.2 ANALYTICAL TECHNIQUE

A general analytical approach or technique has been developed to determine approximate information in form of percentile to describe the distribution of the reliability indices. A reliability index can be expressed as :

$Z = F[X_1, X_2, X_3 \text{-------}]$ where X_1, X_2, X_3--------- are the random variables which denote 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 ------ are known.

Direct analytical methods are available for obtaining the exact form of some simple algebraic functions of random variable. 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 require three major steps

Step 1:

The first four raw moment of component failure and repair times and the system restoration times are determined

Step 2 :

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

Step 3

The Pearson method is utilized to evaluate the approximate percentile of the reliability indices. The Pearson method approximates the probability distribution of a random variable by utilizing moment. The solution obtained is approximate because a probability distribution is not fully described by the 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 computer programme has also been developed utilizing the analytical approach to determine the percentile and some distribution indices. [14]

2.3 RELIABILITY EVALUATION FOR POWER SYSTEM

The basic function of power system is to supply customers 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. Reliability evaluation on power generation, transmission and distribution can be discussed vividly for better understanding. [13]

2.3.1 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 Direction (F$D) can be found.

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 the expected energy that will not be supplied by generating system due to those occasions, when load demands exceeds available generating capacity.

Frequency and Duration (F$D) criterion is an extension of LOLE index. It also identifies the expected frequency of encountering deficiency and expectation of deficiencies. [13]

2.3.2 TRANSMMISSION 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 alternatives at both generating and transmitting levels. They do not include system dynamics or ability of the system to respond to transient disturbances. They simply measure the ability of the system to adequately meet its requirement in a specified set of realistic states.

There are many complications in this type of analysis such as overload effect, re-dispatch of generation and consideration of independent common cause's station outage.

2.3.3 DISTRIBUTION RELIABILITY EVALUATION

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 generation point and transmitting at individual load points.

Considering the reason above, distribution analysis are 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 Supplied (ENS).

Meanwhile, the reliability indices of distribution system are functions of component failure, repair and restoration time which are random in nature. [15]

2.3.4 HUMAN RELIABILITY

The term " Human Reliability" is used to cover the situation in which people as "operator" or "maintainer" can effect the correct or save 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 analysis 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 or other factors that might influence them.

Attempts have been made to quantify various human error probabilities but such data should 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 analysis can be used to high light the need for specific training, independent checks or operator and maintenance instruction and warnings. [16]

2.4 RELIABILITY DATA

The discussion of any quantitative reliability evaluation in various filed leads to discussion of 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. Its 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 is available. It should be clear in our mind that data collection and reliability evaluation are interrelated.

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 required for the purpose intended. It is therefore essential to identify how the data will be used before deciding what data to collect.

In real sense, data can be collected for two reasons; assessment of part performance and 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 respond to the factors that affect system reliability and is available to be modeled and analyzed. This means it should relate to system behavior process 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 compiled 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. [8]

CHAPTER THREE

METHODOLOGY

A distribution circuit normally uses primary or main feeders and lateral distributors, which describe its configuration.

The main feeders originate at the substation and pass through the major load centers. Distribution connects individual load points to the main feeders via distribution transformers. A main feeder is constructed using single parallel or mesh circuit. Many distribution systems used in practice have a single circuit main feeder and are defined as radial distribution systems.

Radial system configuration is commonly used in Nigeria due to its simple design and generally low cost.

These systems have a set of series component causing outage of the load points. Meanwhile, using extensive protection and sectionalizing scheme reduce the outage duration and number of customers affected due to component failure. The sectionalizing equipment provides a convenient means of isolating the faulty section. The supply can then be restored to the healthy section, maintaining the service to some load points while the faulty component is being repaired. The failure time to repair time is referred to as restoration time. In some system, there is 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 faults. The faulty 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.

3.1 NEPA (PHCN) MINNA DISTRICT, MINNA

This district is the distribution centre for NEPA (PHCN), Minna, which comprise the following departments:

- Operation and maintenance department (O&M)
- Planning and construction department (P&C)
- Protection, Control and Metering department (PC&M)

THE OPERATION AND MAINTENANCE DEPARTMENT (O&M):

The department is in charge of all operation in the distribution network, which includes monitoring of network frequency, daily fault report, daily power supply (mostly hour) 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 of the present situation needed at site. They also carry out maintenance throughout all substations which correspond to preplanned maintenance schedule.[4]

PLANNING AND CONSTRUCTION DEPARTMENT (P&C) :

The department is in charge of developing new site or where extension ahs to be made to relieve the existing ones, they carried out planning, surveying, and coming up with quality of material to be employed.

Sauction: which is the one rose 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?

Sauction parameter includes information on the protection of new sites 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 sauctiuon along side with one line or schematic diagram drawn and release by these department.[4]

PROTECTION, CONTROL AND METERING DEPARTMENT (PC&M):

This is the most important department in terms of protection equipment involved at distribution level. In fact, this department is the backbone of the district functions. It consists 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 insulation test, continuity test, excitation test e.t.c. on 11KV/415V distribution transformer and calibration of relays to correspond to the required supply voltage in accordance with the circuit breakers. In addition, protection also made for each feeder be it over head or underground through necessary ampere of fuses to avoid what is called "system collapse". [4]

3.2 AVAILABLE PROTECTION

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

Most electrical faults are characterized by increase in system current, reduction in voltage, power factor and frequency. The protection available for the system from sub-station to individual end points is feeder protective relays in conjunction with circuit breaker and transformer protection. An ideal protective relays should have the following characteristic

I) **Reliability**

The relay should be reliable and must operate when it is required. Inherent reliability is a matter of design based on long experience. This can be achieved by high control pressure, dust free enclosure, good contact material and careful maintenance.

II) **Selectivity**

A relay 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 required 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 produces the least tendency for operation.

Fuses and lightning arrestor are the major external protection for distribution network, there are other protection of transformer which are internal, the protection against heat, oil temperature, insulation breakdown of oil and short circuit within the windings. Some transformer s use protective relay to protect equipment e.g. protection against high temperature.

3.3 SYSTEM ANALYSIS FOR POWER DISTRIBUTION

Before numerical reliability is to be carried out, it is 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 such as load flow, power factor, and voltage regulation e.t.c.

3.4 NETWORK ANALYSIS

As mentioned earlier, NEPA (PHCN) MINNA DISTRICT was used as a case study in which the analysis was based on PARLIAMENTRY FEEDER. The feeder supplies electric power to public buildings like HOUSING AND ENVIRONMENT, FATI ABUBAKAR COLLEGE, BARKIN SALE (1&2), KPAKUNGU, TAGWAI BAKERY, S.ODUOYE ESTATE, FEDERAL SECRETARIAT, e.t.c through a 11KV lateral feeders. It also contains a Ring Main Unit (RMU) for sectioning in case of any fault to be corrected along the feeder.

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 determined on the data collected from O and M department.

Since the area of study is the reliability or system performance at customer's 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 diagram is as shown below:

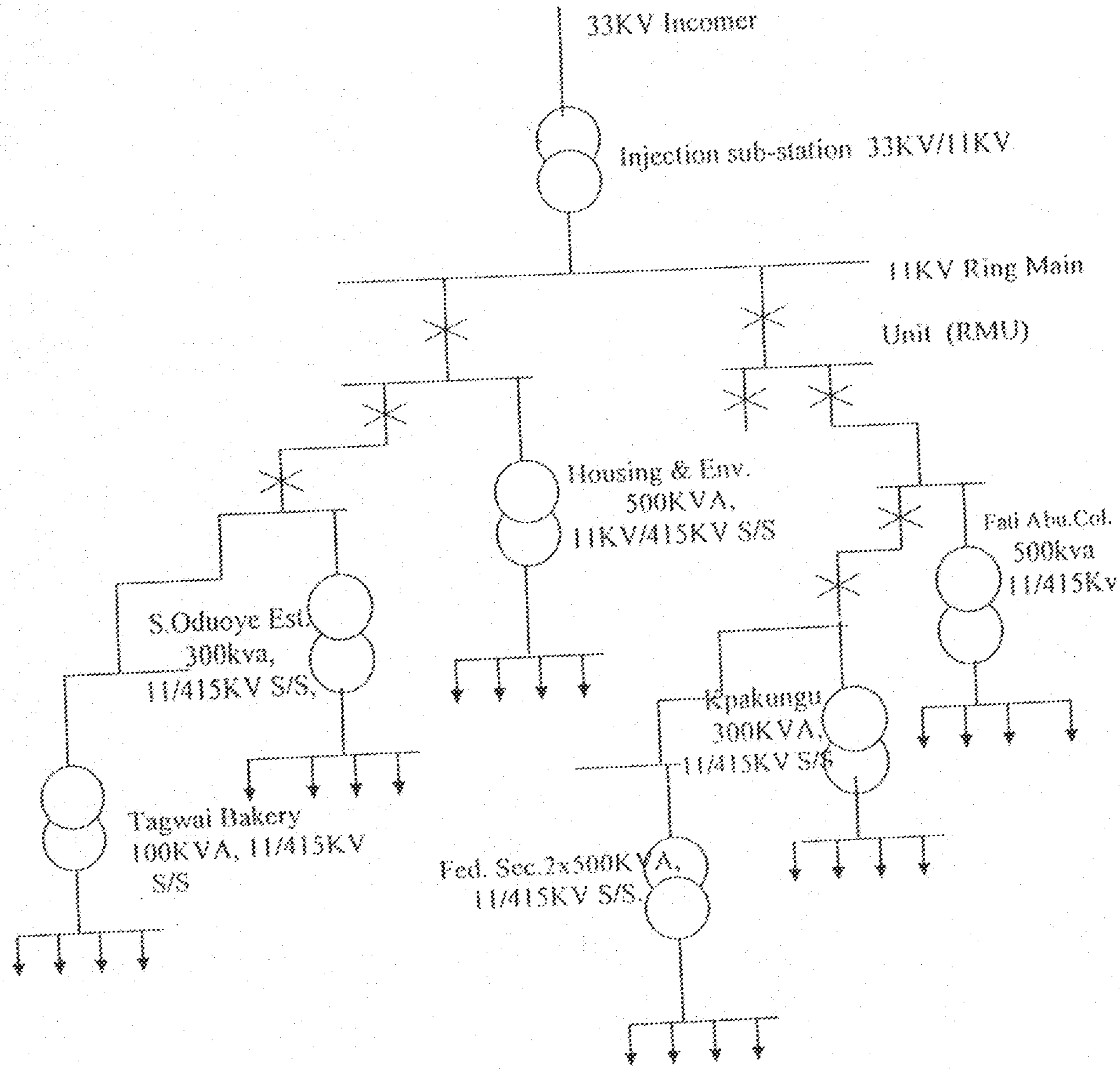
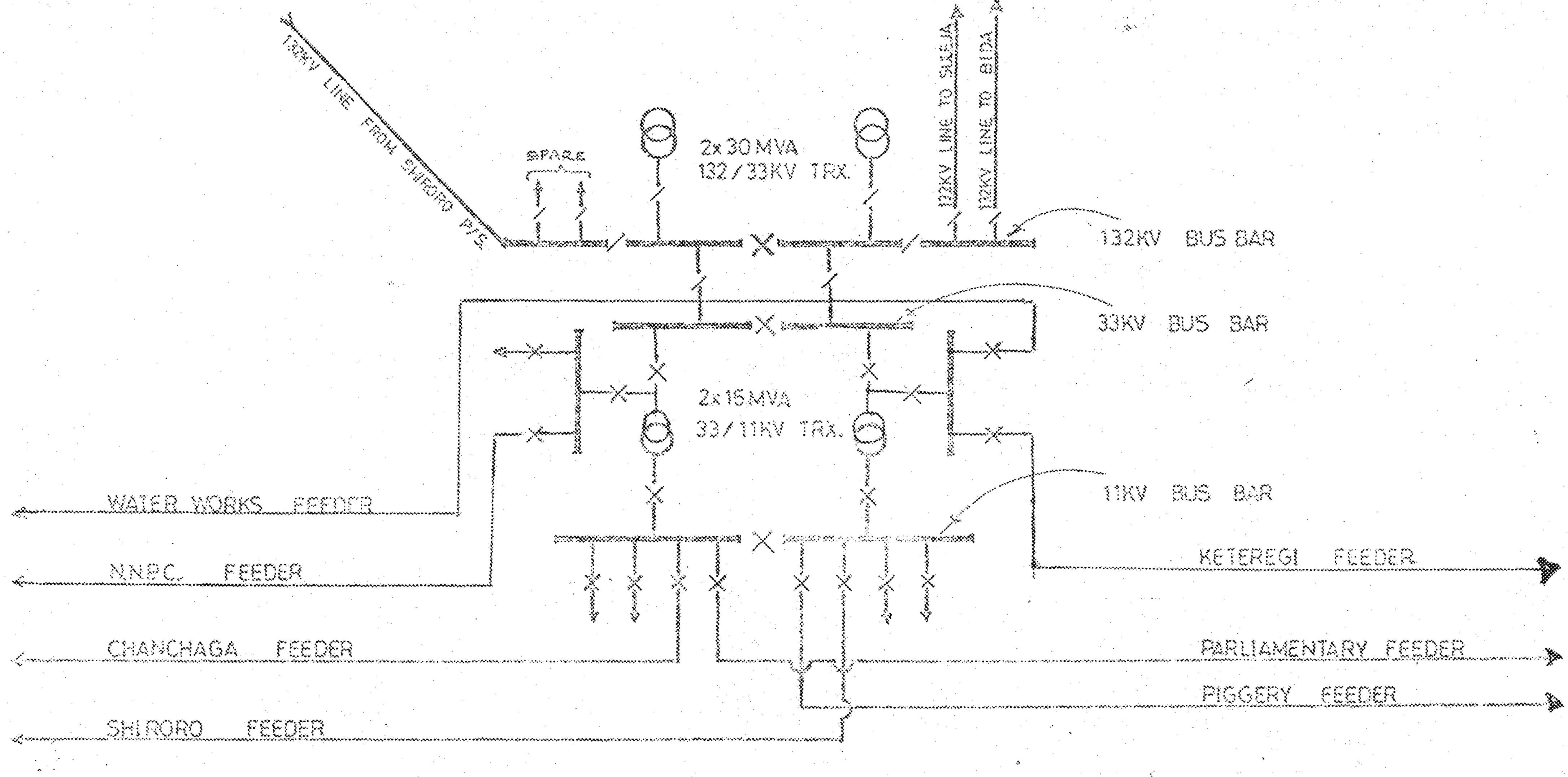


Fig 3.1: Showing the concerned section [4]



TITLE	
SCHEMATIC DIAGRAM 132 / 33 / 11KV TRANSMISSION STATION MINNA.	
DRWG Nº	NEPA / PCS / MIN / ABJ / 1674 / 2002
SCALE	N.T.S.

CALCULATIONS

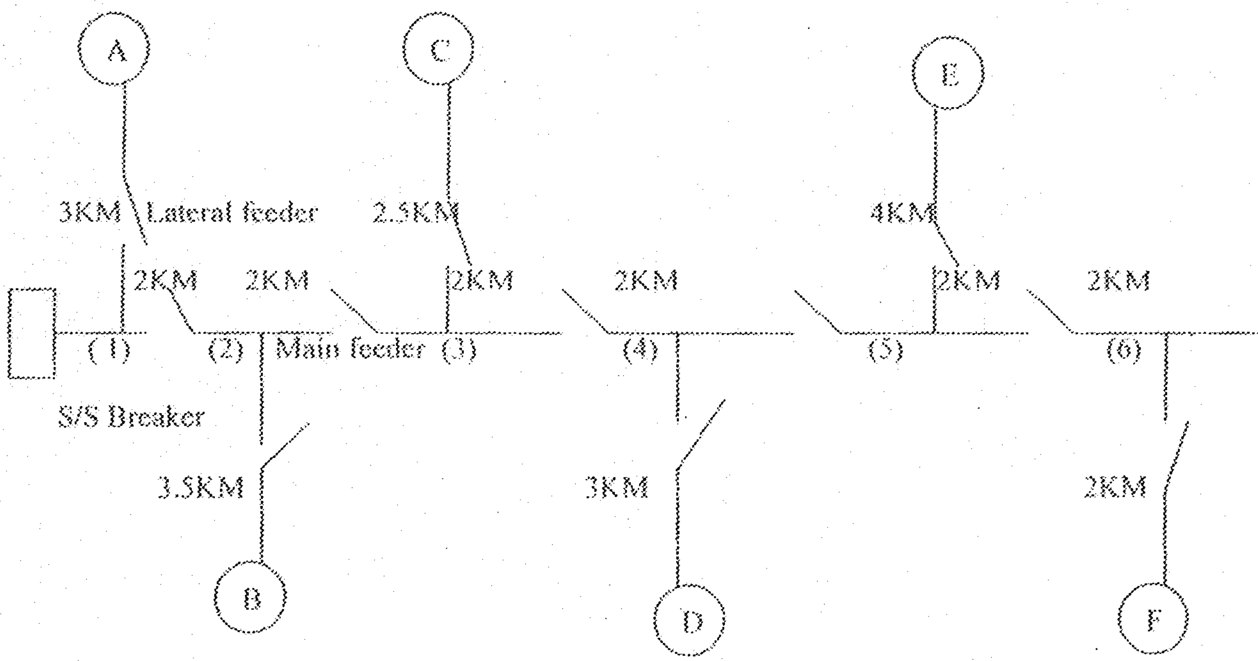


Fig 3.2: Showing a sectionalized primary main feeder (Parliamentary feeder) [4]

FEEDER A:

This is the feeder that serves the substation itself, and some residential buildings around. It covers about 3KM and has about five distribution transformer. The input parameters for the feeder are:

Average failure rate of feeder (Lat) = 0.2 faults per circuit Km

Average Repair time (Lat) = 1.5 hours

Average time for sectionalizing = 1.5hours

Average fault rate for primary feeder = 0.1 faults per circuit KM

Average Repair time for primary feeder = 5hours

Annual fault rate for feeder A:

$$\lambda_A = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_{A1}$$

λ_A = (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.2x3km)

$= 0.2 + 0.2 + 0.2 + 0.2 + 0.2 + 0.2 + 0.6$

$= \underline{1.8 \text{ fault/yrs}}$

It has to be sectionalized before calculating repair time

Ave. annual repair time:

$$R_A = \frac{\lambda_1 p_f + \lambda_2 R_{sect} + \lambda_3 R_{sect} + \lambda_4 R_{sect} + \lambda_5 R_{sect} + \lambda_6 R_{sect} + \lambda_A R_{lat}}{\lambda_A}$$

$$= \frac{(0.1x5) + (0.1x1.5) + (0.1x1.5) + (0.1x1.5) + (0.1x1.5) + (0.1x1.5) + (0.6)}{1.8}$$

$= \underline{1.03\text{hrs}}$

$$\text{Unavailability} = \frac{\text{Repair time}}{\text{Repair time + Mean time to repair}}$$

$$= \frac{1.03}{1.03 + (24x365 - 1.03)}$$

$= \underline{0.0118\%}$

Availability = 1- U

= 1- 0.000118

$= \underline{0.99}$

$= \underline{99\%}$

FEEDER B:

This feeder supplies FATI ABUBAKAR COLL. And some residential buildings, having about 20 distributions transformer and covers about 3.5KM . It has the following input parameters:

Average fault rate of feeders (Lat) = 0.2 fault/circuit KM

Average Repair time (Lat) = 1.5 hours

Average time for sectionalizing = 1.5 hours

Average fault rate for primary feeder = 0.1 fault/circuit KM

Average repair time for primary feeder = 5hours

Annual fault rate for feeder B:

$$\lambda_B = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_{B1}$$

= (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.1x2km) + (0.2x3.5km) =

1.9fault/yrs

Average annual repair time (R_B) (feeder 3,4,5,6, are sectionalized)

$$R_B = \frac{\lambda_{1pf} + \lambda_{2pf} + \lambda_3 R_{sect} + \lambda_4 R_{sect} + \lambda_5 R_{sect} + \lambda_6 R_{sect} + \lambda_B R_{lat}}{\lambda_B}$$

$$= \frac{(0.1x5) + (0.1x5) + (0.1x1.5) + (0.1x1.5) + (0.1x1.5) + (0.1x1.5) + 0.7}{1.9}$$

= 1.21hrs

$$\text{Unavailability} = \frac{R_B}{R_B + MTTR} = \frac{1.21}{1.21 + (24x365 - 1.21)} = 0.0138\%$$

Availability = 1 – U

= 1 – 0.0138% = 99.98%

FEEDER C:

This feeder supplies S.ODUOYE ESTATE and mostly residential buildings, it is about 2.5km long having about 15 transformers. The corresponding input parameters are showed below:

Average fault rate for feeder (Lat) = 0.2 fault/circuit km

Average Repair time (Lat) = 1.5hours

Average time for sectionalizing = 1.5hours

Average fault rate for primary feeder = 0.1 fault/circuit km

Average Repair time for primary feeder = 5hours

Annual fault rate for feeder C:

$$\lambda_C = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_{C1}$$

= (0.1x2km) +(0.1x2km) +(0.1xc2km) +(0.1x2km) +(0.1x2km) +(0.1x2km) +(0.2x2.5)

= 1.7faults/yrs

Average Repair time (R_C) =

$$\frac{\lambda_{1pf} + \lambda_{2pf} + \lambda_{3pf} + \lambda_4 R_{sect} + \lambda_5 R_{sect} + \lambda_6 R_{sect} + \lambda_C R_{lat}}{\lambda_C}$$

$$= \frac{(0.1x5) + (0.1x5) + (0.1x5) + (0.1x1.5) + (0.1x1.5) + (0.1x1.5) + (0.2x2.5)}{1.7}$$

= 1.44hrs

$$\text{Unavailability} = \frac{R_C}{Rc + MTTR} \qquad \frac{1.44}{1.44 + (24x365 - 1.44)}$$

= 0.00016

Availability = 1 – U

= 1 – 0.00016 = 99%

FEEDER D:

This feeder is named TAGWAI BAKERY sub-station. It also covers about 3km and having about 20 transformers. The corresponding input parameters are showed below:

Average fault rate for feeder (Lat) = 0.2fault/circuit km

Average Repair time (Lat) = 1.5hours

Average time for sectionalizing = 1.5hours

Average fault rate for primary feeder = 0.1 fault/circuit km

Average Repair time for primary feeder = 5hours

Annual fault rate for feeder D:

$\Lambda_D = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_{D1}$

= (0.1x2km) +(0.1x2km) +(0.1xc2km) +(0.1x2km) +(0.1x2km) +(0.1x2km) +(0.2x3km)

= 1.8 fault/yrs

Average Repair time R_D:

$$\frac{\lambda_{1pf} + \lambda_{2pf} + \lambda_{3pf} + \lambda_{4pf} + \lambda_5 R_{sect} + \lambda_6 R_{sect} + \lambda_D R_{lat}}{\lambda_D}$$

$$= \frac{(0.1x5) + (0.1x5) + (0.1x5) + (0.1x5) + (0.1x1.5) + (0.1x1.5) + (0.2x3)}{1.8}$$

= 1.6hrs

$$\text{Unavailability} = \frac{R_D}{R_D + MTTR} \qquad \frac{1.6}{1.6 + (24x365 - 1.6)}$$

= 0.00018

Availability = 1 – U

= 1 – 0.00018 = 99%

FEEDER E:

This feeder supplies KPAKUNGU area and some residential buildings, it covers almost about 4km and having about 12 distribution transformers. The input parameters are showed below:

Average fault rate for feeder (Lat) = 0.2fault/circuit km

Average Repair time (Lat) = 1.5hours

Average time for sectionalizing = 1.5hours

Average fault rate for primary feeder = 0.1 fault/circuit km

Average Repair time for primary feeder = 5hours

Annual fault rate for feeder E:

$\Lambda_E = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_{D1}$

= (0.1x2km) +(0.1x2km) +(0.1xc2km) +(0.1x2km) +(0.1x2km) +(0.1x2km) +(0.2x4km)

= 2 fault/yrs

Average Repair time R_E

$$R_E = \frac{\lambda_{1pf} + \lambda_{2pf} + \lambda_{3pf} + \lambda_{4pf} + \lambda_{5pf} + \lambda_6 R_{sect} + \lambda_E R_{lat}}{\lambda_E}$$

$$= \frac{(0.1x5) + (0.1x5) + (0.1x5) + (0.1x5) + (0.1x5) + (0.1x1.5) + (0.2x4)}{2}$$

= 1.73hrs

$$\text{Unavailability} = \frac{R_E}{R_E + MTTR} = \frac{1.73}{1.73 + (24x365 - 1.73)}$$

= 0.000197

Availability = 1 – U

= 1 – 0.000197 = 99%

FEEDER F:

This feeder supplies FEDERAL SECRETARIAT sub-station and residential building. It is about 2km long having 12 distribution transformers. The input parameters are showed below:

Average fault rate for feeder (Lat) = 0.2fault/circuit km

Average Repair time (Lat) = 1.5hours

Average time for sectionalizing = 1.5hours

Average fault rate for primary feeder = 0.1 fault/circuit km

Average Repair time for primary feeder = 5hours

Annual fault rate for feeder E:

$$\Lambda_F = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_{F1}$$

= (0.1x2km) +(0.1x2km) +(0.1xc2km) +(0.1x2km) +(0.1x2km) +(0.1x2km) +(0.2x2km)

= 1.6

fault/yrs

Average Repair time R_F :

$$R_F = \frac{\lambda_{1pf} + \lambda_{2pf} + \lambda_{3pf} + \lambda_{4pf} + \lambda_{5pf} + \lambda_{6pf} + \lambda_{Flat}}{\lambda_F}$$

$$= \frac{(0.1x5) + (0.1x5) + (0.1x5) + (0.1x5) + (0.1x5) + (0.1x5) + (0.2x2)}{1.6}$$

= 2.125hrs

$$\text{Unavailability} = \frac{R_F}{R_F + MTTR} = \frac{2.125}{2.125 + (24x365 - 2.125)}$$

= 0.000243

Availability = 1 – U

= 1 – 0.000243 = 99%

The calculation continues up to Futuminna, Maikunkele and Beji Feeders.

CHAPTER FOUR

DISCUSSION OF RESULT

The table below (table 4.1) shows the results of analysis got from previous chapter, in which the main cause of power outage was fault along the feeder. The output or determining objectives from the analysis are basic reliability distribution, which includes Annual total failure rate, Annual total restoration time, Annual unavailability and Annual availability.

Table 4.1: SUMMARY OF RELIABILITY INDICES FOR THE FEEDERS [4]

Feeders / Indices	A	B	C	D	E	F	
Annual fault rate (fault/yrs)	1.8	1.9	1.7	1.8	2	1.6	
Annual Repair time (hrs)	1.03	1.21	1.44	1.6	1.73	2.125	
Unavailability	0.000118	0.000138	0.00016	0.00018	0.000197	0.000243	
Availability	0.99	0.99	0.99	0.99	0.99	0.99	

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

Failure rate at feeders "E" is very high while at feeder "A,B,D" almost the same, it might be due to overloading of transformer mainly caused by dense population and it is a function of power consumption.

Fault may also be due to fuse blown off, broken pole, cross arm broken, pole fell along the network, insulating disk shattered, wire cut, Aluminum cable dropping along the network e.t.c.

Meanwhile, it will be observed that feeder "F" has the highest restoration time which the unavailability depends, this may be due to managerial problem or lack of material and mostly bureaucratic factor.

CHAPTER FIVE

CONCLUSION

The behavior of all engineering system is essentially stochastic in nature that is 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 constrain 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 occurs 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 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.

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

5.1 RECOMMENDATION

5.1.1 IMPROVING COMPONENT RELIABILTY

Reliability engineer are very often called upon to make decision as to whether to improve certain component in order to achieve minimum required system reliability. This minimum required system reliability if for a specific time.

There are two approaches to improve the reliability by using high quality and high reliable components and usually less expensive that fault tolerance.

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.

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