

**A NEW MAINTENANCE STRATEGY FOR POWER  
HOLDING COMPANY NIGERIA TO CONTEST THE  
CURRENT POWER DEMAND PROBLEM**

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## **PREFACE**

This Research focuses on improving the power demand problem currently experienced at the Power Holding Company of Nigeria (PHCN).

This problem being linked to poor maintenance in PHCN is surveyed using questionnaires, oral interviews, case studies and other relevant maintenance manuals, books, journals, publications and internet resources.

This survey was made possible by the support of the staff and customers of PHCN to whom I remain grateful.

The findings/ results of this research were compared with findings from Eskom, the South African Power utility company though with some unexpected difficulties.

The primary emphasis of the research was on identifying flaws in the current maintenance strategy and the development of a new or revised strategy for the company with special reference to the Distribution side. Additions on a secondary level included the application of a work authorization system and the training of technical personnel in the company.

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## **ABSTRACT**

Power Holding Company of Nigeria (PHCN), responsible for generating, transmitting and distributing electricity in Nigeria is being faced with an apparent huge maintenance problem which seemingly contributes greatly to the power demand problem of the country.

This apparent maintenance problem is investigated by surveying its root causes through interviews, questionnaires and data gathered from selected case studies. Questionnaires were used scientifically with a confidence level of 95% and interval of  $\pm 5\%$  and  $\pm 4.4\%$  to establish a high level of integrity on data gathered. Findings and deliverables are compared to South Africa's power utility company Eskom for validation of the final deliverable.

With the findings of this survey, the research problem was overcome by developing a new maintenance strategy and work authorization system for the company while making some recommendations on the training being given to its maintenance personnel.

The New strategy called 'Utility Availability Centered Maintenance Strategy' or UACMS is presented in the form of a flow chart/ block diagram with its different sections fully explained. It mainly combines preventative, predictive and corrective maintenance strategies alongside other modern maintenance techniques. It's all linked to a computer database support to ensure high effectiveness. Furthermore, the work authorization system called 'Internal Task Authorization form' serves to ensure responsibility in task execution within the company.

During the course of this research, an excessive application of corrective maintenance strategy, lack of root cause analysis and unavailability of computer based applications were discovered in PHCN.

Furthermore, unavailability of spare parts and work authorization system, irresponsibility in task execution, slow response to faults, insufficient training, etc were also discovered. These abnormalities were effectively corrected in the UACMS.

Recommendations on the application of the UACMS and the work authorization system were also given at the end of this dissertation.

This research concentrated mainly on the distribution side of the company. Little research and interview on the transmission side (*also highlighted in this research work*) showed the application of corrective maintenance and similar problems found on the distribution side. Hence, the generation and transmission sections of PHCN were opened to future research work at the end of this dissertation.

## **KEYWORDS**

Utility Availability Centered Maintenance Strategy (UACMS)

Work Authorization System

Internal Task Authorization Form

Power Holding Company of Nigeria (PHCN)

Maintenance

Training

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## **LIST OF ABBREVIATIONS**

CBM-----	Condition Based Maintenance
FMEA-----	Failure Modes and Effects Analysis
FMECA-----	Failure Modes and Effects Criticality Analysis
ITA-----	Internal Task Authorization
LCC-----	Life Cycle Cost
PHCN-----	Power Holding Company of Nigeria
RBM-----	Risk Based Maintenance
RCA-----	Root Cause Analysis
RCM-----	Reliability Centered Maintenance
RTF-----	Run To Failure
TBM-----	Time Based Maintenance

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1) WHAT IS PHCN?**

PHCN is an acronym which represents Power Holding Company of Nigeria. It is the country's power utility company.

Nigeria has a total of 5900MW of installed capacity through its power generation units; however, the country is only able to generate 1600 MW because most facilities have been poorly maintained (*Mbendi, 2007*).

The transmission network of PHCN consists of 5000km of 330 kV lines, and 6000km of 132 kV lines (*FMPS, 2006*). The 330 kV lines feeds 23 substations of 330/132 kV rating with a combined capacity of 6,000 MVA or 4,600 MVA at a utilization factor of 80% (*FMPS, 2006*). The 132 kV lines feeds 91 substations of 132/33 kV rating with a combined capacity of 7,800 MVA or 5,800 MVA at a utilization factor of 75% (*FMPS, 2006*).

The PHCN distribution grid consists of 23,753 km 33 kV lines and 19,226 Km of 11 kV lines. These feed 679 substations of 33/11kV rating and 20,543 substations of 33/0.415 and 11/0.415 kV ratings. It also consists of 1,790 distribution transformers and 680 injection transformers (*FMPS, 2006*).

PHCN is discussed further in chapter two of this dissertation.

#### **1.2) THE PROBLEM**

Nigeria is a country of about 140million people (*CIA World Fact book, 2008*). In 2001, Nigeria had a mere power generating capacity of about 1400MW (*Nigeriabusinessinfo, 2001*). This leaves an average power of 10Watts per

person! In 2007 this improved to a mere 1600MW as mentioned above (*Mbendi, 2007*).

The special adviser to the Nigerian president on electric power recently said that; "In spite of the huge sum of \$6.3 billion gulped by the sector between 1999 to date, Nigeria can barely generate 30 watts of electricity per person!" (*Makoju, 2007*).

Generally, people see the lack of power as a result of low generation capacity. However, breakdown of transmission and distribution facilities also directly or indirectly lead to power interruptions.

Power generation, transmission and distribution networks in Nigeria are in a poor state such that only 30% of Nigerians have access to electricity (*Nasir Ahmad el-Rufai, 2007*).

The power supply problem is so intense that the Federal Government intends to declare a state of emergency in the power sector (*Gbola, 2008*).

At present, efforts are being made to increase the total power generating capacity of the country to 10,000MW for a start and 30,000MW by 2015 (*Turner, 2005*).

With much concentration on increasing power generating capacity in the country, fewer efforts have been put into other factors such as poor maintenance/ maintenance strategy of PHCN. These factors however, can contribute to a large extent to the power demand problems of the country as further discussed in this dissertation.

Maintenance could be defined as 'work that is done regularly to keep a machine, building, or piece of equipment in good condition and working order' (*Microsoft Encarta, 2006*).

One of the major causes of interruptions and losses in power generated and distributed in Nigeria was identified to be the poor maintenance of both the transmission and distribution (Grid) network (*Orihie, 2004*).

It is commonly known that constant load shedding, incessant trips on power equipment, breakdown of power transmission and distribution facilities, etc, have become the norm rather than the exception in Nigeria. Some of these power demand problems could largely be traced to poor maintenance of existing facilities (*Mbendi, 2007*).

These power interruptions cause huge power outages at the power transmission/distribution level and pose a huge threat to a constant and steady power supply in the country. This holds true even if the generation capacity is increased (*Obi, 2007*).

Training is 'the process of teaching or learning a skill or job' (*Microsoft Encarta, 2006*).

Adequate training of maintenance personnel is a necessary factor for a high quality maintenance team in any power utility company. The PHCN journal writers argue that adequate training of maintenance personnel would minimize load shedding (*Tom, 2006*).

Even though a maintenance department exists in this power utility company, the rate of power shortages due to poor quality of maintenance is still on the increase. Speaking on this, the Lagos PHCN Regional Transmission Manager stated that about 80% of the various causes of power system collapse are

transient in nature. Furthermore, he stated that the line traces constitute the greatest number of faults by trees, bamboo and raffia palms fouling the power lines (*Akinremi, 2007*).

This could be an indication that either the maintenance strategy or the way maintenance is being executed could be faulty.

Recent survey shows the excessive application of corrective maintenance in PHCN maintenance practices (*Questionnaire poll for PHCN maintenance personnel and public consumers in Owerri, Nigeria*).

This excessive application of corrective maintenance could be one of the reasons for these faults which lead to power interruptions as identified by Akinremi in the paragraphs above (*Oral Interview, October 9, 2007*).

The research problem could therefore be summarized as; the apparent inadequate maintenance strategy/ procedures in PHCN and the apparent poor skill levels possibly due to lack of training of its maintenance personnel seemingly affecting power supply in Nigeria.

More literatures on this problem is discussed in chapter two of this dissertation.

### **1.3) SOLVING THE PROBLEM**

As stated above, adequate maintenance of existing facilities whose breakdown leads to incessant power interruptions is yet another factor that can contribute effectively in solving the power demand problem in Nigeria (*Akinremi, 2007*).

Reviewing the current maintenance strategy and style or quality of maintenance training in PHCN would help in resolving this problem. This forms a huge basis for this research which seeks to critically re-investigate the effects of the current maintenance strategy/ procedures of PHCN on the power demand problems in



Nigeria. Furthermore, it seeks to analyze the technical skill level of their maintenance personnel with respect to training.

#### **1.4) AIMS OF THE RESEARCH**

The aims of this research include;

- ❖ To provide PHCN with an effective maintenance strategy and work authorization system if necessary, for maintenance of some units (e.g. poles, overhead conductors, feeder pillars) on its power distribution network.
  
- ❖ To investigate the flaws in the current strategy and provide a new or revised strategy that would help keep the units (some already identified above) that directly lead to power interruptions in a healthy state. If successfully implemented, this would help to maintain a steady power supply and would help to reduce outages.
  
- ❖ To investigate and make recommendations on the current level of training and skills of PHCN maintenance personnel and its link to the incessant power outages in Nigeria.

#### **1.5) RESEARCH PROCEDURE**

The Owerri PHCN business unit (distribution), Orlu PHCN business unit (distribution), Alaoji- Aba PHCN transmission station and their subsidiaries were used as case studies for the purpose of this research.

This research identifies some units of the distribution network with maintenance issues which directly or indirectly lead to power interruptions in Nigeria.

The maintenance strategies, practices and problems of these units were investigated with respect to their methodologies, implementation and

effectiveness. Furthermore, it will be compared with other international maintenance standards from stable power utility companies to determine their overall efficiency/ effectiveness.

A final conclusion based on research outcomes was then made which forms the basis for a new strategy.

The application of a work authorization system in PHCN and technical training level of PHCN maintenance personnel was also investigated. Necessary recommendations were then made with respect to the findings.

Research verification was done by comparing findings with other stable power utility companies/ standards around the globe like ESKOM in South Africa.

#### **1.6) BENEFICIARIES**

Beneficiaries of this work if successfully implemented, include; PHCN as a company (Provision of better services to customers) and Nigeria as a country (in terms of more efficient power supply).

Other beneficiaries include any individual or group interested in furthering a similar research in Nigeria or other developing countries with similar power demand problems.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1) HISTORY OF PHCN**

In the early 1960s the **Niger Dam Authorities (NDA)** and Electricity Cooperation amalgamated to form the **Electricity Cooperation of Nigeria (ECN)**. Immediately after the Nigerian civil war, the management of ECN changed its nomenclature to NEPA (*Wikipedia, PHCN*)

**National Electric Power Authority (NEPA)** was created by government Decree No. 24 of 1972 (*Nigeriabusinessinfo, 2001*). This Decree gave NEPA the mandate to "maintain and co-ordinate an efficient economic system of electricity supply for all part of the federation" (*Nigeriabusinessinfo, 2001*).

In 2005, NEPA ceased to exist and was renamed **Power Holding Company of Nigeria, PHCN**, with 18 business units (*Nigeriabusinessinfo, 2001*).

PHCN shares are held by the Ministry of Finance and the Bureau of Public Enterprises, in the name of and on behalf of the Federal Government of Nigeria (*MSMD, 2006*).

Under PHCN, the former NEPA assets are being unbundled into six generation, one transmission, and eleven distribution companies. The assets of NEPA are also being transferred to these companies and the companies will then be privatized (*MSMD, 2006*). PHCN is expected to manage these emerging companies during the transition period (*MSMD, 2006*).

With the Nigerian power sector being deregulated, the private sector started participating in power generation and this gave birth to the various Independent Power Plants seen in the country today (*Ikeonu, 2006*).

## 2.2) THE NIGERIAN POWER SITUATION

Combating power demand problems in Nigeria which in other words could be seen as fighting this problem with the aim of ameliorating it has become a subject of National and International interest. Across the country, there is a worsening situation of electricity for domestic and industrial consumption.

The Nigerian President Musa Yar Adua recently said that; 'a state of emergency would soon be declared in the Nigerian power sector costing about 8 to 10 billion dollars annually for six months' (*Gbola, 2008*).

According to the Managing Director of PHCN, Engr Makoju, plans are underway to build 17 new power stations in the country with a total capacity of 6000MW (*Tobe, 2005*).

A PHCN spokesperson Mrs. Igbo also stated that 'a sum of \$2.01billion (about N257 billion) was sunk into the construction of new power plants in the Niger Delta as well as the National Integrated Power Project (NIPP)' (*Louis, 2007*). Several Independent Power Projects have also kicked off in different parts of the country.

In the renewable energy guidelines policy document of 2006 it was stated that; 'Most parts of the Nigerian power transmission network has a poor voltage profile, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse and exceedingly high transmission losses' (*FMPS, 2006*).

Many System Outages are caused by disturbances in the grid system. These disturbances in turn are as a result of the quality of the network and necessitate a critical analysis of what solutions can be immediately put in place before a permanent solution will mature (*Akinremi, 2007*).

### 2.3) MAINTENANCE AS A PROBLEM

With much concentration on increasing the power generation capacity in the country, less effort have been put into the fact that achieving a constant power supply in the country also depends on the state of the transmission and distribution network. Speaking on the research problem, a PHCN senior manager Engr J. C. Onyekwelu stated that; 'If generation capacity is increased and parts of the grid system continues to collapse due to lack of maintenance, power interruptions are bound to persist, jeopardizing Nigeria's vision of providing an uninterruptible power supply for its citizenry' (*Oral Interview, October 9, 2007*).

Maintenance is a very important factor in any grid system. The Nigerian grid system is mostly made up of overhead transmission and distribution lines, poles, transformers etc.

The PHCN Regional Transmission Manager Engr. Akinremi identified the fouling of lines by raffia palms and trees (especially in the swamp) due to poor maintenance as a major cause of disturbances in the grid system (*Akinremi, 2007*). These disturbances could cause short circuits between transmission or distribution lines with its attendant effects on power stability.

Joseph et al. in their research identified vegetation-related failures as a large contributor to distribution system interruptions (*Joseph et al., 2006*).

Growth-related failures however, are maintainable and can be effectively controlled through regular tree-trimming (*As cited in Joseph et al., 2006*).

The PHCN spokeswoman Mrs. Igbo in a statement said that 'The lack of maintenance and replacement of damaged equipment has led to a wide gap between demand and supply' (*Louis, 2007*).

The renewable energy guidelines policy document stated categorically that 'PHCN's business units (Distribution) are inefficient and suffer from chronic under investment and poor maintenance' (FMPS, 2006).

The United States in August 2003 experienced a black out in some parts of the country. Jeffery Merrifield (commissioner of U.S nuclear regulatory commission) speaking on the black out stated that; ' poor maintenance of transmission lines including tree trimming, lack of sensor and relay repair or replacement, poor maintenance of control room alarms, poor communications between load dispatchers and power plant operators, and a lack of understanding of transmission system interdependencies were all major contributors to the domino effect that resulted in plant after plant tripping off line' (Jeffrey, 2006).

This shows how poor maintenance can affect power stability in any system.

Some writers in one of the Nigerian national dailies argue that 'despite the reforms' initiative coupled with huge power generation and consumption profile of the nation, poor maintenance culture brought the national grid to near total collapse at the beginning of Olusegun Obasanjo regime in 1999 when the country barely generates 1,500mw' (Yetunde et al., 2008).

#### **2.4) MAINTENANCE STRATEGY**

Maintenance is defined as the process of restoring an item to its original condition or working order by repair, replacement of parts or total replacement of the item (U.W.A, 2003).

'Maintenance requires skilled labor, spare parts and tools as well as a plan to carry out work and in some cases, software to administer management' (Roberto José Ferrelli, 2007).

Maintenance Strategy is a long-term plan, covering all aspects of maintenance management which sets the direction for maintenance management, and contains firm action plans for achieving a desired future state for the maintenance function (*Sandy, 2007*).

For the purpose of this research, conciseness and clarity, maintenance strategies have been grouped under four general headings to be addressed later on in this chapter. These four general types of maintenance philosophies include; Corrective, Preventive, Predictive, and Reliability Centered Maintenance. (*Pierre, 2000*).

Most assets require one or more of these maintenance strategies: In power lines, it is basically corrective and preventive; in power transformers, it is preventive and predictive; in measurement transformers and breakers, it is predictive; and in protection, it is mainly predictive (*Roberto José Ferrelli, 2007*).

Around the Globe, Different power utility companies (e.g. ESKOM South Africa, PHCN Nigeria, TenneT Dutch, etc) adopt different strategies for its maintenance in order to optimize its performance (*IEEE/PES, 2001*).

Some of these strategies are further discussed below;

#### **2.4.1) PREVENTIVE MAINTENANCE**

Preventive Maintenance is that maintenance which is carried out to prevent an item failing or wearing out by providing systematic inspection, detection and correction of incipient failure (*U.W.A, 2003*).

It could be simply defined as 'a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures' (*Reliasoft, 2007*).

Preventive Maintenance is proactive in nature.

TenneT (administers of the Dutch high voltage grid) carry out routine inspections on the grid to prevent disruptions from occurring. They also try to reduce the number of inspections by identifying critical parts of the network that require more inspections than the order and prioritize their maintenance schedules (*TenneT*). This is a form of Preventive maintenance.

Two typical examples of preventive maintenance are the Risk Based Maintenance strategy (RBM) and Time Based Maintenance strategy (TBM).

In **Risk Based Maintenance**, the failure modes/ effects of equipment are critically analyzed via condition monitoring and probability of occurrence to determine the risk associated with it (*Joseph et al., 2006*).

For transmission systems, risk is defined as 'the time-dependent product of the consequence of an equipment failure and the probability of its failure' (*As cited in Joseph et al., 2006*).

TenneT (administers of the Dutch high voltage grid) sometimes use Risk-Based Maintenance strategy to ensure high reliability standards. Their maintenance strategy is aimed at minimizing the risks (of a disruption in the energy supply, damage to the environment and safety incidents) at socially acceptable costs (*TenneT*).

**Time based maintenance** (TBM) consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems (*Venkatesh, 2007*).

In Time-Based Maintenance, a piece of equipment is maintained or replaced after a fixed time period associated with it. This period is based on failure statistics analysis and may use expert judgment, trial-and-error methods, or more



analytical methods to estimate the optimal frequency of maintenance that is reliable and economical at acceptable levels (*Joseph, et al., 2006*).

A major limitation of TBM is that the application of periodic fixed-time replacements, however, can lead to the use of assets sub-optimally and unnecessary maintenance of equipment (*Joseph, et al., 2006*). A good example of TBM in a power utility company is the periodic inspection of its sub stations for vegetation growth problems.

#### **2.4.2) PREDICTIVE MAINTENANCE**

Predictive Maintenance compares the trend of measured physical parameters against known engineering limits for the purpose of detecting, analyzing, and correcting problems before failure occurs (*Michael, 1999*).

*Predictive Maintenance approach is based on the measurement of an asset's condition in order to assess whether equipment will fail during some future period and then taking action to avoid the consequences of those failures (Amelia et al., 2005).*

The "predictive" component of the term Predictive Maintenance stems from the goal of predicting the future trend of the equipment's condition (*Wikipedia, PM*).

This type of maintenance is based on forecasting a possible future state of an equipment/ unit and taking necessary maintenance actions in advance.

These techniques help to determine the condition of in-service equipment in order to predict when maintenance should be performed (*Wikipedia, PM*).

The ultimate goal of Predictive Maintenance is to perform maintenance at a scheduled point in time when the maintenance activity is most cost effective and

before the equipment fails (*John & Skog, 2008*). Protection schemes in power utility companies mainly use predictive methods.

An example of predictive maintenance strategy is **Condition Based Maintenance** (CBM). CBM is sometimes viewed as a type of preventive maintenance too.

CBM uses real-time data to prioritize and optimize maintenance resources (*Wikipedia, CBM*).

CBM is a set of maintenance actions based on real-time or near-real time assessment of equipment condition which is obtained from embedded sensors and/or external tests & measurements taken by portable equipment (*Kenn, et al., 2000*).

The purpose of CBM strategy is to perform maintenance only when there is objective evidence of need, while ensuring safety, equipment reliability and reduction of total ownership cost (*OPNAV INST., 1998*).

Powercor (Part owners and operators of the Australian Grid) uses CBM to maintain high reliability in their network through an enterprise-wide energy management system that provides real-time power monitoring and control capability across the entire distribution network (*Powercor, 2005*).

A PHCN (Alaoji transmission unit) Manager, Engr. J.C Onyekwelu, revealed that Condition monitoring which is vital in any power system is not applied in most PHCN facilities leading to unexpected equipment failures (*Oral Interview, October 9, 2007*).

### 2.4.3) CORRECTIVE MAINTENANCE

Corrective Maintenance is defined as “any maintenance activity which is required to correct a failure that has occurred or is in the process of occurring” (*As cited in Amelia et al., 2005*).

This activity may consist of repair, restoration or replacement of components.

A typical example of corrective maintenance is the **Run to Failure strategy** (RTF). Here, an equipment or unit in a system is kept in service until it fails. It involves no maintenance until failure upon which that equipment/ unit is replaced or serviced. The strategy is to run the asset to failure and then to repair it (*Amelia, 2005*).

In terms of reliability, this strategy can be disastrous. Its costs are relatively high because of unplanned downtime, damaged machinery, and overtime expenditure.

In some cases RTF could be advantageous when maintenance cost vs. down time cost implications are considered.

According to TenneT (administers of the Dutch high voltage grid); When handling disruptions with consequences that are still acceptable, they increasingly opt for the cheaper alternative of corrective maintenance (*TenneT*).

This means that TenneT perform some maintenance activities only when a component is faulty or a disruption occurs. This is a practical application of RTF strategy.

#### **2.4.4) RELIABILITY CENTERED MAINTENANCE (RCM)**

According to Moubray, RCM could be defined as 'a process used to determine what must be done to ensure that any physical asset continues to do whatever its users want it to do in its present operating context' (*Moubray, 2007*).

Rausand in his own words defined RCM as "a systematic consideration of system functions, the way functions can fail, and a priority-based consideration of safety and economics that identifies applicable and effective Preventive Maintenance tasks" (*Rausand, 1998*).

RCM can further be defined as an industrial improvement approach focused on identifying and establishing the operational, maintenance, and capital improvement policies that will manage the risks of equipment failure most effectively (*Wikipedia, RCM*).

RCM combines some aspects of other maintenance strategies to achieve a more reliable strategy.

Goodfellow while speaking on RCM stated that; 'While other power utility maintenance programs, such as vegetation management, and maintenance of sectionalizing devices, are considered as discrete and unrelated programs, RCM provides a method to integrate a variety of programs and tasks with a single global objective of improving system performance' (*Goodfellow, 2000*).

#### **2.4.5) FMEA, FMECA, LCC AND ROOT CAUSE ANALYSIS**

**FMEA** is an acronym for Failure Modes and Effects Analysis. FMEA is defined as a systematized group of activities to recognize and evaluate the potential failure of a product or process and its effects, identify actions that could eliminate or reduce the occurrence of the potential failure and document the process (*James et al. 2008*).

FMEA could also be defined as a systematic process for identifying potential design and process failures before they occur, with the intent to eliminate them or minimize the risk associated with them (*CCD, 2007*).

In other words, it could further be defined as a procedure in which each potential failure mode in every sub item of an item is analyzed to determine its effect on other sub items and on the required function of the item (*Web definition, FMEA*).

**FMECA** is an acronym for Failure Modes and Effect Criticality Analysis. It is a procedure by which each potential failure mode in a system is analyzed to determine the results, or effects thereof, on the system and to classify each potential failure mode according to its severity (*Bryan et al., 1996*).

FMECA is performed after a failure mode effects analysis to classify each potential failure effect according to its severity and probability of occurrence (*James et al. 2008*).

FMECA identifies potential design weaknesses through systematic analysis of the probable ways (Failure Mode) that a component or equipment could fail (*MTain, 2006*). It also includes the identification of the cause of the failure and its effect on the operational capabilities (functions) of an end item, be it an equipment or system (*MTain, 2006*).

**LCC** is an acronym for Life Cycle Cost. The LCC of any piece of equipment is the total “lifetime” cost to purchase, install, operate, maintain, and dispose of that equipment (*US DOE, 2001*).

LCC could also be defined as the Sum of all recurring and one-time (non-recurring) costs over the full life span or a specified period of a good, service, structure, or system (*Business Dictionary, 2008*).

LCC includes purchase price, installation cost, operating costs, maintenance and upgrade costs, and remaining (residual or salvage) value at the end of ownership or its useful life (*Business Dictionary, 2008*).

Life Cycle Costs should be considered for conductor/ structure optimization in sub transmission lines (*Johan, 2005*).

**Root Cause Analysis (RCA)** seeks to identify the origin of a problem and uses a specific set of steps, with associated tools, to find the primary cause of the problem (*Mind Tools, 2008*).

RCA can be defined as a class of problem solving methods aimed at identifying the root causes of problems or events (*Wikipedia RCA*).

RCA is a popular and often-used technique that helps people answer the question of why the problem occurred in the first place. (*Mind Tools, 2008*). RCA assumes that systems and events are interrelated. An action in one area triggers an action in another, and another, and so on (*Mind Tools, 2008*)

The practice of RCA is predicated on the belief that problems are best solved by attempting to correct or eliminate root causes, as opposed to merely addressing the immediately obvious symptoms (*Wikipedia RCA*).

## 2.5) WORK AUTHORIZATION (WA) SYSTEM

A Work Authorization System formalizes an agreement between people delegating work and those accepting responsibility to do work (*Steyn H et al., 2003*). WA is a formal document. It creates a level of responsibility on any task assigned to individuals or groups.

Standard forms used to delegate work in a WA system are called a Work Authorization Forms. Sometimes this form is also called a Work Package Definition Form (*As cited in Steyn H et al., 2003*).

Good examples of a Work Authorization Form include the 'Job Cards' used in some companies/ organizations. WA forms could include Scope of Work and Risk foreseen with other details necessary for an effective completion of such task.

As a trainee in Sasol Ltd South Africa, I closely watched the application and effectiveness of the work authorization (Job cards) system.

Some PHCN staffs (Onyekwelu- Alaoji transmission and Anuli- Owerri distribution) argue that such a system (Work Authorization) does not exist in PHCN (*Oral Interviews, October 9/10, 2007*).

Engr. Anuli Okey of the Owerri distribution unit further stated that oral communication is used in most cases for job allocation (*Oral Interview, October 10, 2007*).

For the full report of these interviews, see the 'Research Findings' chapter of this dissertation.

## 2.6) TRAINING AS A PROBLEM

Training as defined earlier is 'the process of teaching or learning a skill or job' (*Microsoft Encarta 2006*). Maintenance personnel with poor technical skills impacts negatively on the entire system in terms of quality of maintenance work carried out.

Obi Akwani, a public policy consultant, in one of his publications stated that; 'inadequate technical skills and poor workmanship in maintenance of service standards is one of the problems facing PHCN today' (*Obi, 2007*).

Obi further argued that; 'Poor service delivery by PHCN goes beyond limited national generation capacity and that even if power generation in this country is instantly raised to 20,000 megawatts today, the country's power shortage problems will persist and no little different than it is right now' (*Obi, 2007*).

Obi based his arguments on three factors of which inadequate technical skills and poor workmanship was a major contributor.

'Load reading' is the routine collection and recording of current and voltage measurements from transformer distribution boards (feeder pillar) to protect the life of the transformer and prevent burning of the feeder pillar and other accessories (*Okata, 2000*).

A PHCN Protection Engineer, Okey Anuli, during an interview session argued that load reading is not usually done in PHCN feeder pillars (*Oral Interview, October 10, 2007*).

Furthermore, the PHCN journal writer Dr Tom Inugonum, stated in one of his publications that; 'inefficiency in recording the correct load reading leads to manual unscheduled load shedding'. This holds true because accurate load



reading/ recording will ensure fast de-loading and transfer to alternative circuits (Tom, 2006).

On the power problems in Nigeria, Karim, the Shoreline Power boss stated that; "The government of Nigeria is investing heavily in building power plants to address the problem of power supply but the real problem has will start after the construction of those plants because there are no trained engineers who will run them" (Ejiofor, 2005). Karim further added that; 'The problem with the Nigerian engineers is that they don't develop their capacity and also fail to realize that they have better education than some of those expatriate engineers who come there to supervise them' (Ejiofor, 2005).

In another of his publication, the PHCN journal writer Dr Tom Inugonum stated that; 'Inadequate training for the maintenance and operating staff of PHCN leads to their inefficiencies and loss of man- hour'. He further suggested that Engineers should be trained on standards before sending them out to witness standard tests on equipment (Tom, 2007).

Employee training is also the responsibility of management (Greg, 1998). Hence, the management of PHCN management definitely has some questions to answer with respect to this problem.

## **CHAPTER THREE**

### **EMPIRICAL INVESTIGATION**

#### **3.1) INTRODUCTION**

Empirical Investigation is a factual enquiry carried out by simply recording what is observed or discovered (*Archeology Dictionary, 2003*).

This chapter presents the standard procedure followed in order to investigate the research problem as identified in previous chapters. Furthermore, the proposed solutions from this investigation are introduced.

It should however be noted that this chapter only serves as an introduction of work done in subsequent chapters. It only presents the research methodologies. The research methodologies followed are presented in further sections (3.2 to 3.5) of this chapter.

#### **3.2) IDENTIFICATION OF CASE STUDIES**

A case study is a detailed intensive study of a unit, such as a corporation or a corporate division that stresses factors contributing to its success or failure (*Houghton, 2003*).

A case study could also be defined as an analysis of a group or person in order to make generalizations about a larger group or society as a whole (*Collins, 2006*).

Four case studies were identified in Nigeria for the purpose of this research.

These include;

- ❖ The PHCN Owerri Business Unit and its subsidiaries (Distribution)
- ❖ The PHCN Alaoji- Aba 330/ 132kv Transmission Unit.

- ❖ The Owerri Municipal customers of PHCN.
- ❖ Maintenance personnel of PHCN Owerri business unit

The primary Case study used for data and result comparison is the South African power utility company ESKOM and specifically ESKOMs Distribution Department. The distribution department of ESKOM is used because most of the work done and problems identified on the Nigerian side were in the distribution business units of PHCN.

Other global case studies used in this research were;

- ❖ Sasol Synfuels pty South Africa
- ❖ TenneT Dutch (via internet)

### **3.3) INTERVIEWS**

Several interviews were conducted with senior management and maintenance personnel of the identified case studies. The aim of the interviews was to collect raw data from the field with respect to the research problem (as stated in section 1.2) and possible solutions.

Interviews conducted were with;

- ❖ Engr. J.C. Onyekwelu (Head, Protection Control and monitoring)- PHCN 330/132KV transmission station, Alaoji Aba
- ❖ Engr. Okey Anuli (Maintenance Engineer) - PHCN Distribution Business Unit, Owerri.
- ❖ Engr. J. Chukwu (Senior Manager Distribution) PHCN Distribution Business Unit, Owerri.
- ❖ Barr (Mrs.) C.O. Ewulum (Senior Manager Personnel and Administration) PHCN Distribution Business Unit, Owerri.

- ❖ Engr. Haruna Ajakaiye (Maintenance Engineer) - PHCN Distribution Business Unit, Owerri.
- ❖ Engr. Prince Osuagwu (Distribution Substation Operator) PHCN 33/11KV distribution substation, Owerri.

### 3.4) QUESTIONNAIRES

A Questionnaire can be simply defined as a set of questions used to gather information in a survey (*Microsoft Encarta, 2006*).

A Questionnaire could also be defined as a research instrument which consists of a series of questions and other prompts for the purpose of gathering information from respondents (*Wikipedia, Questionnaire*).

Questionnaires were distributed among PHCN maintenance personnel and customers in the case studies identified in section 3.2 above. The purpose of this questionnaire was to gather raw data from the field to gain more insight into the maintenance practices, fault response time, training, supervision and application of work authorization in PHCN.

The questionnaires captured questions relating to maintenance schedules and its limitations, causes of power failure, use of computers, training, and work authorization in PHCN.

Samples of the questionnaire used in this research are as shown in *appendices A and B* attached.

The Questionnaires for PHCN personnel were made a 'No name No blame' type to allow them give information as accurate as possible.

Three more local research case studies were added to the four listed above (section 3.2). These case studies include;

- ❖ The PHCN Orlu Business Unit (Distribution)
- ❖ The Orlu Municipal customers of PHCN.
- ❖ Maintenance personnel of PHCN Orlu business unit.

The procedure followed in validating these questionnaires and choosing the sample size are as attached in *appendix C* of this dissertation.

### **3.5) PHCN vs. ESKOM**

This section compares major aspects of the research relating to both PHCN (Nigeria) and ESKOM (South Africa). The aim of this section is to have a more efficient power utility company as a base for comparison of research findings.

Different aspects of PHCN and ESKOM considered and compared in the course of this research are highlighted in the following sub sections;

#### **3.5.1) MAINTENANCE**

The maintenance manuals, journals and publications in the two power utility companies will be further used to obtain supplementary maintenance data.

Maintenance problems, practices and procedures for three grid units (as identified in chapter 4) in the two companies (PHCN and ESKOM) will be highlighted in this section.

For clarity, these maintenance practices and problems identified in the two utility companies will be presented in a tabular form (Table 4.1) in chapter 4.

### **3.5.2) TRAINING AND ROLES OF MAINTENANCE PERSONNEL**

The roles of Engineers, technologists, technicians and artisans in maintenance in PHCN will be highlighted in this section. The idea here would be to have a reference to make and validate some recommendations on the roles of PHCN maintenance personnel in the maintenance activities of the utility company.

Furthermore, the nature and duration of training undergone by the maintenance teams in the two utility companies (PHCN vs. Eskom) are also considered. The aim here would be to identify the effects of training and the maintenance personnel skills on the research problem.

Most data here would be collected via oral interviews, questionnaires, internet sources and training manuals.

### **3.5.3) WORK AUTHORIZATION (PHCN vs. ESKOM vs. SASOL)**

The existence and application of a Work Authorization System e.g. job cards in the above companies would be investigated here. The effectiveness or ineffectiveness of this system would form a basis for conclusions and recommendations in this aspect of the research.

Data collection for this aspect of the research would be by direct participation in the system (Sasol and PHCN), oral interviews, research materials and questionnaires.

### **3.6) OVERVIEW OF PROPOSED SOLUTIONS**

This section gives an overview of the proposed solutions from this research. Basic information on the proposed solution is briefly highlighted in the following sub sections overleaf;

### 3.6.1) NEW MAINTENANCE STRATEGY

With the discovery that ESKOM applies an RCM type of maintenance strategy (*Peter, 2007*) whereas PHCN maintenance is mostly corrective, the new maintenance strategy proposed is expected to be more efficient than what is currently being used. This is evident from the facts that Eskom has severally been referred to as a more efficient power utility company when compared to PHCN (*Michael, 2007*), (*Chima, 2008*).

This new strategy would incorporate corrective maintenance practices alongside other preventive, predictive and modern maintenance techniques as in RCM. With this, it is expected to be better than the sole application of Corrective maintenance which only takes place during unit failure. This conclusion is based on the power availability implications of failure of some units in the grid system when allowed to 'Run to Failure'.

The New York Times in a report, referred to ESKOM as the worlds fourth largest power utility while stressing that virtually all businesses and many residents in Nigeria run private generators to supplement faltering public service (*Michael, 2007*).

Dr Chima Okereke an international correspondent for PMForum and PM World Today in one of his reports on the Nigerian power problem stated that; 'even though he heard of power cuts in south Africa, he spent a week in cape town – South Africa without a single power failure whereas he spent six weeks in Port Harcourt- Nigeria without experiencing a 24 hour uninterrupted power supply' (*Chima, 2008*).

The above notwithstanding, the final result would also depend on the findings of the empirical investigation as described in chapter 4 of this dissertation.

The New strategy would be fully discussed in chapter 5 of this dissertation.

For clarity purposes and easy interpretation, this strategy would be shown in the form of a Flow Chart and Functional Flow Diagram comprising different modern maintenance techniques such as FMECA, Root Cause Analysis etc.

### **3.6.2) WORK AUTHORIZATION**

A formal document for assigning duties and responsibilities to maintenance workers is expected at the end of this dissertation.

As stated in section 3.6.1 above, this work authorization document would also depend on the findings and data collected with respect to the research problem. These data are highlighted in chapter 4 while the work authorization is presented and discussed in chapter 5 of this dissertation.

### **3.6.3) RECOMMENDATIONS**

Recommendations were made with respect to training of maintenance personnel of PHCN. The concentration here was on the nature of training of maintenance Engineers, Technologists, Technicians and artisans in PHCN.

Findings and analysis from Chapters 4 and 5 form the basis for such recommendations. These recommendations are all stated in chapter 6 of this dissertation.

Finally for clarity purposes, it should be noted that this chapter (three) only serves as a design baseline for the empirical work done in this dissertation. The actual empirical work done for this dissertation is highlighted in subsequent chapters.



## **CHAPTER FOUR**

### **RESEARCH FINDINGS**

#### **4.1) INTERVIEWS**

Presented below are the findings (highlights) from the oral interview sessions conducted with some key players in the case studies used for this research.

- i) *Engr. J.C. Onyekwelu. (Head, Protection, Control and Metering, PHCN 330/132 kV transmission station Alaoji- Aba)*

While speaking on behalf of the station, the above stated that;

- "Lack of transportation for 'line patrol' on transmission lines through mangrove forests inhibits routine maintenance on overhead conductors. This increases the vegetation growth on these conductors and its attendant problems".
- "One-line network from Benin to Alaoji transmission stations makes preventive maintenance almost impossible without power interruption".
- "Corrective maintenance is applied in most power equipment at the station".
- "Unavailability of spare parts for equipment inhibits maintenance practices".
- "Maintenance personnel lack the working tools to perform their tasks adequately".
- "No 21<sup>st</sup> century training for maintenance personnel on new power equipment over the past one decade".
- "If generation capacity is increased and parts of the grid system continue to collapse due to lack of maintenance, power interruptions are bound to persist, jeopardizing Nigeria's vision of providing an uninterruptible power supply for its citizenry".
- "Condition and periodic maintenance on power equipment are not practiced".
- "Life span of power equipment not considered".

- “‘Right of way’ is the space meant to be left free for the transmission lines. This is not adhered to and inhibits maintenance”.
- “No work authorization forms for maintenance purposes”.
- “No Computerized Maintenance Management Strategy in PHCN”.

ii) *Engr. Haruna Ajakaiye (Maintenance Engineer) - PHCN Distribution Business Unit, Owerri.*

According to the above;

- “Overhead conductors, feeder pillars, transformers, Ring Main Units, Wooden poles and circuit breakers are some units that frequently fail and lead to power interruptions”.
- “Most poles and wooden accessories on the distribution network fail during the rain season due to inadequate maintenance during the dry season”.
- “Between March and April 2008 recorded over 10 major electric pole failures in Owerri leading to power interruptions. No preservation strategy is done on these wooden accessories during installation”.
- “Wrong usage of fuses in feeder pillars (transformer distribution board) leads to inadequate protection and its attendant effects”.
- “Daily load readings to avoid over loading that could burn the terminals of the solid link of feeder pillars are not taken. This leads to eventual breakdown of the distribution board and power interruption”.
- “Periodic cutting of bushes and trees with branches around overhead lines are not done. These sometimes bridge the lines leading to power failures”.
- “Spare parts for maintenance purposes are hardly available”.
- “Life span of overhead conductors is not considered during maintenance”.
- “Corrective maintenance strategy is practiced in most distribution units and sub units”.
- “Lack of adequate training for maintenance personnel leads to poor quality of maintenance”.

iii) *Engr. Okey Anuli (Protection and Maintenance Engineer) - PHCN Distribution Business Unit, Owerri.*

According to the above;

- "Permit system for work is mostly oral! This is in most cases not adhered to. A standard work authorization system does not exist in PHCN".
- "Bureaucracy leads to slow response to faults".
- "Sub standard equipments are used for maintenance purposes".
- "Load reading/ servicing of feeder pillars are not done".
- "Wrong fuse ratings are used on feeder pillars thereby leading to power interruptions when the contacts are burnt off".
- "Lack of a standard work authorization system in place leads to lack of responsibility in maintenance tasks".
- "Vegetation growth on overhead conductors leads to short circuits and power interruptions. This is common in Owerri Municipality".
- "Maintenance personnel lack the technical skill level to carry out maintenance tasks due to lack of training".
- "There is no standard for carrying out routine maintenance on the grid units. Maintenance only takes place upon equipment failure".
- "Most equipment is outdated. No preservation techniques for wooden poles".
- "Lifetime of most power equipment is not considered during maintenance".

iv) *Engineer Prince Osuagwu (Distribution Substation Operator). - PHCN 33/11KV distribution substation, Owerri.*

According to the above;

- "Bureaucracy leads to slow response to faults by maintenance personnel".
- "The procedures for obtaining power outage permission for repairs on grid system should be revised and standardized".

- “Power outages should be pre planned and measures taken to reduce it to the barest minimum”.
- “The power equipment in the substations needs to be serviced regularly and not only when it leads to a major breakdown”.

v) *Engr. J.C Chukwu (Senior Manager Distribution) -PHCN Distribution Business Unit, Owerri.*

While speaking on Maintenance issues, the above stated that;

- “When customers report faults to the complaints department, it is noted and then taken to the faults department for necessary action”.
- “Sometimes instructions for maintenance work could be oral”.
- “Funding affects the level of training given to maintenance personnel”.
- “Most maintenance work done in PHCN is corrective”.
- “Lack of spare parts affects maintenance schedules”.
- “Root cause analysis is not usually done due to lack of skilled/ trained personnel to carry out that analysis”.
- “Lack of computers and modern communication equipment for maintenance affects the maintenance procedure”.
- “The rate of failure of wooden poles and other outdoor distribution facilities is higher during the rainy season and windy conditions”.

vi) *Barr (Mrs.) C.O. Ewulum (Senior Manager Personnel and Administration) - PHCN Distribution Business Unit, Owerri.*

While speaking on personnel issues, the above stated that;

- “Lack of funding affects the level of training given to maintenance personnel”.
- “No ‘special engineers’ are assigned the responsibility of training personnel”.

- “Negligence of duty by some maintenance personnel affects the effectiveness of maintenance by the unit. This leads to delays in carrying out maintenance tasks”.
- “A more closely supervised maintenance procedure would improve commitment to work by the maintenance team”.
- “In general PHCN needs to improve in their level of maintenance”.
- “The use of computers and modern work authorization schemes would improve the effectiveness of maintenance in the business unit”.
- “A proper work authorization system would improve the level of responsibility of the maintenance team”.

#### **4.2) QUESTIONNAIRE POLL**

The questionnaires used for this section and the percentage responses from respondents are as attached in appendices A and B.

For clarity purposes, the maintenance personnel referred to in this section includes PHCN Engineers, Technicians and Artisans involved in maintenance in the case study being used. Furthermore, PHCN customers referred to in this section includes habitants of the municipality being surveyed that utilizes electricity supply from PHCN. Two sets of questionnaires are used for the survey. The results of this survey comprising of 50 maintenance personnel of PHCN and 500 public customers of the company is shown in appendices A, B, C and the following sub sections.

##### **4.2.1) Questionnaires for PHCN maintenance personnel.**

The questions are attached in *Appendix A*. In the bar graphs presented overleaf, the horizontal axis of the graph indicates the question number while the vertical axis indicates the number of personnel (respondents). The percentage calculation is further shown in appendix A.

Appendix C further shows the methodology for choosing the sample size and validating the questionnaire.

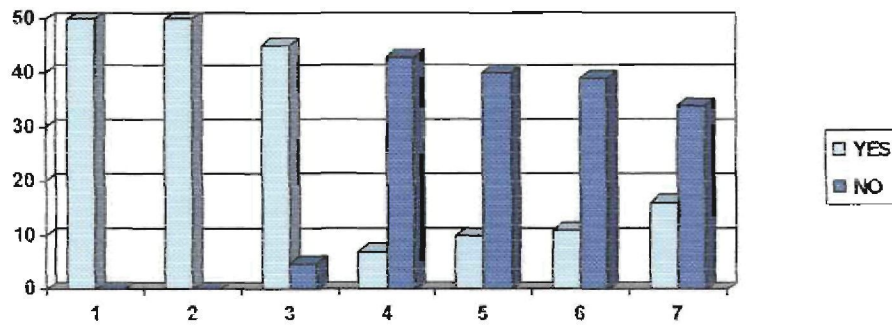


Fig 4.1a: PHCN Maintenance Personnel Questionnaire Bar Graph (q1 – q7)

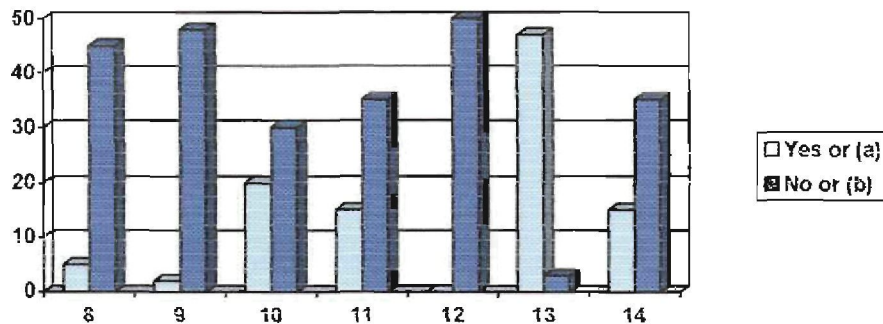


Fig 4.1b: PHCN Maintenance Personnel Questionnaire Bar Graph (q8 – q14)

#### 4.2.2) Questionnaires for customers of PHCN.

The questions are attached in [Appendix B](#). In the bar graph presented overleaf, the horizontal axis of the graph indicates the question number while the vertical axis indicates the number of people (respondents).

The percentage calculation is further shown in appendix B while Appendix C shows the methodology for choosing the sample size and validating the questionnaire.

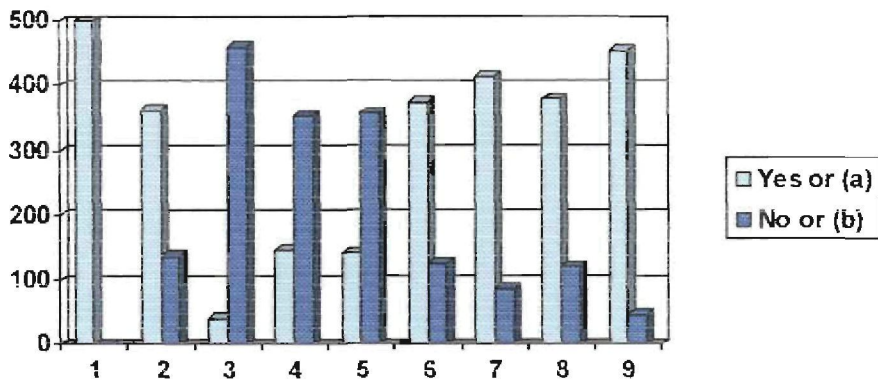


Fig 4.2: PHCN Customers Questionnaire Bar Graph (q1 – q9)

#### 4.3) PHCN vs. ESKOM

This section presents some more findings from the field. Some maintenance and personnel issues relating to the research problem in the PHCN and ESKOM are highlighted here for comparison and result validation purposes.

##### 4.3.1) MAINTENANCE ISSUES

Three grid system units are used as examples; wooden poles, overhead conductors and feeder pillars (transformer distribution board)

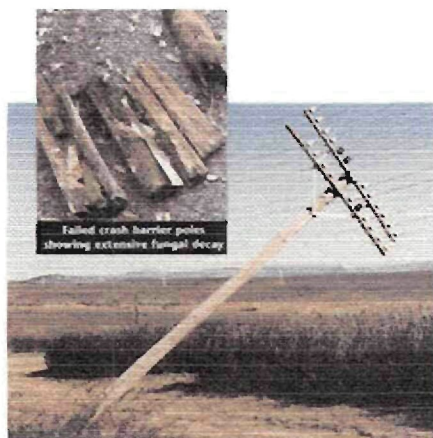


Fig 4.3; Wooden pole breakdown due to lack of preservation

Examples	ESKOM	PHCN
Wooden Poles	<p>Maintenance Strategy; RCM  <i>Source; Internet see appendix D</i></p> <p>Field Liners and creosote (wood preservatives) are used to preserve and elongate wood life as a preventive strategy. Field Liners have been in commercial use in Eskom since 1994  <a href="http://www.pplfieldliners.com/eskom_trial.htm">http://www.pplfieldliners.com/eskom_trial.htm</a></p> <p>The Field Liner been tested on Eskom Electricity poles since 1995, and the recent results of 6-year inspections of Eskom's utility poles at Umbumbulu in KwaZulu-Natal are truly remarkable <a href="http://biotrans-uk.com/enter.php?http://www.biotrans-uk.com/biotrans-products/biotrans-utilities/biotrans-utilities.php">http://biotrans-uk.com/enter.php?http://www.biotrans-uk.com/biotrans-products/biotrans-utilities/biotrans-utilities.php</a></p>	<p>Maintenance Strategy; RTF  <i>Source; Interviews, Questionnaires, field data, maintenance manuals.</i></p> <p>Poles are changed only when they are broken down. This is a corrective maintenance strategy</p> <p>Poles are not maintained once installed. No preservation techniques are applied while they are being installed.</p> <p>Inferior poles are often used for power distribution. Furthermore, Life cycle of poles is not considered.</p>
Overhead Conductors	<p>Standards including Eskom rights and responsibilities exist for maintaining lines and cutting vegetation on overhead conductors as a preventive strategy.</p> <p>A good extract from the standard is; "No tree shall be allowed to grow to a height in excess of the horizontal distance of that tree from the nearest conductor of any power line or to grow in such a manner as to endanger the line should it fall or be cut down" (<i>Eskom, (2003)</i>)</p> <p>The complete standard has been seen and accepted by Management Board Environmental Steering Committee (MB-ESC) The Environmental Liaison Committee (ELC)</p> <p><i>Source; Eskom (2003). See ref.</i></p>	<p>On the distribution side, there is no maintenance schedule to cut down vegetation growth on these conductors until it leads to short circuit or a breakdown occurs</p> <p>On the transmission side, lack of vehicles to access swamp prevents maintenance. Lack of standards for maintenance of overhead lines and bush clearing.</p> <p>Wrong conductor sizing reduces their life span. The life cycle of these conductors are not considered during installation.</p> <p>Sags on conductors are neglected which eventually leads to their breakdown.</p>



Feeder	Data not readily available	Daily load readings are not taken on this distribution board and this often leads to phase unbalance faults.
Pillars	See appendix E	This power transformer distribution board is only serviced when it leads to a fault. Due to lack of spares, wrong fuses are used to replace the damaged ones. This increases the heating effect on the unit which eventually leads to unit breakdown Vegetation growth is not checked in some substations and this sometimes causes short circuits.

*Table 4.1: Maintenance Practices, Procedures and Problems; PHCN vs. ESKOM*

N.B. According to PHCN procedural manuals (*Agomuoh, 2000*), some of these aspects of maintenance should be done regularly (e.g. feeder pillar load readings). However implementation poses a huge problem to these maintenance issues as discussed in chapter 5.

#### **4.3.2) ROLES OF MAINTENANCE PERSONNEL**

This section highlights the roles of maintenance personnel in PHCN. The Distribution (Business) units of these two utility companies are used as a reference.

These roles are as highlighted in table 4.2 overleaf.

## MAINTENANCE PERSONNEL

## PHCN

ENGINEERS

Planning, Directing, Budgeting, Implementing, designing, supervision, forecasting and execution of projects.

TECHNOLOGISTS

Hands On Supervisors. They supervise practical work on the field.

TECHNICIANS

Operators, fitters, cable jointers, etc. They carry out practical work on the field. They are the second line of maintenance.

ARTISANS

They are craftsmen. They are the first line of maintenance. They carry out hands on work in the field.

*Source; Oral Interviews, PHCN Procedural manuals.*

*Table 4.2: Roles of maintenance Personnel in PHCN*

### 4.3.3) TRAINING OF MAINTENANCE PERSONNEL

The table overleaf highlights type of training given to the maintenance personnel in PHCN and ESKOM on assumption of duty. The Distribution (Business) units are used as a reference.

	TYPE OF TRAINING	TYPE OF TRAINING
MAINTENANCE PERSONNEL	ESKOM	PHCN
ENGINEERS	Eskom has a training college in Midrand Johannesburg for training technical personnel.	Two year rotational training from Generation, Transmission and Distribution called 'PUPILLAGE TRAINING'. After this training, a formal posting (job allocation) is then issued to the trainee. Finance mostly hinders the nature and quality of this training. Most courses during the engineer working life are also skipped due to finance. Some training is also done on the job. However, some modules and courses are skipped during the training period.
TECHNOLOGISTS	Eskom has a training college in Midrand Johannesburg for training technical personnel	Same as the engineers above. Some technologists however, argue that most of these modules and courses are skipped during their training period.
TECHNICIANS	Eskom has a training college in Midrand Johannesburg for training technical personnel	On the job training with the supervision of engineers in a particular zone. The engineer they are attached with assesses their competence level for the job after their training. No specified duration is given for this training.
ARTISANS	it takes about 2 years for an artisan to qualify in South Africa. Average pass rate of 42%. Trade test is required before appointment. Eskom plans to expand its training college at midrand Johannesburg to boost the supply of artisans.	On the job training with the supervision of senior artisans or technicians. Trade test is taken after 6 months. Most artisans in the PHCN Owerri business unit argue that the training received is not enough and reduces their overall skill level on the job.

Source; Brown (2008) see ref.

Source; Oral Interviews, e-mails, Internet., PHCN Training manuals, dailies

Table 4.3: Training of maintenance Personnel; PHCN vs. ESKOM

#### 4.4) WORK AUTHORIZATION; ESKOM vs. PHCN vs. SASOL

	ESKOM	PHCN	SASOL
Formal document for work Authorization	Exists	Does not exist	Exists
Medium for delegating work	Formal <i>Source;</i> <i>See 'A' below</i>	Oral or written	Formal
Level of Supervision after a job is completed		Low. Sometimes supervision is not done.	High
Computer aided applications for maintenance activities.	Exists <i>Source;</i> <i>See 'A/B' below</i>	Does not exist	Exists

*Source; Questionnaires, Oral Interviews, Personal Experience, Internet, case studies.*

*A; <http://www.allbusiness.com/energy-utilities/utilities-industry-electric-power/5931452-1.html> B; [http://www.emcom.co.za/case\\_studies.html](http://www.emcom.co.za/case_studies.html)*

*Table 4.4: Work Authorization ESKOM vs.; PHCN vs. SASOL*

#### 4.5) SUGGESTIONS ON THE MAINTENANCE PROBLEM

- a) Most PHCN staffs agree that a Work Authorization system would increase the level of commitment, supervision, and effectiveness of their maintenance team. *Source; Questionnaires and Oral Interviews.*
- b) A personal (informal) random sample of SASOL maintenance employees revealed that the existing Work Authorization system (job cards) contributes greatly to their overall effectiveness.
- c) Most PHCN maintenance personnel suggest that they should be sent on more technical training to improve their effectiveness. They also suggest that the style and approach to maintenance should be revised. *Source; Questionnaires and Interviews*
- d) Most PHCN customers suggest that the response time to faults by PHCN maintenance personnel should be addressed. They further suggest that

PHCN maintenance personnel should be more proactive and should not only act when a fault occurs. *Source; Questionnaires*

- e) By 1999, three years into the 'Field liner' trial, Eskom issued a National Stock Number for the Field Liner, adopting them as a standard for installation on utility poles. From a personal point of view, this further validates the need for such preventive maintenance strategy in PHCN.

*Source; [http://www.pplfieldliners.com/eskom\\_trial.htm](http://www.pplfieldliners.com/eskom_trial.htm)*

*\*Info on 'field liners' are also highlighted in section 4.3.1 and fig 5.1\**

- f) Some customers argue that corruption and lack of commitment on the management side of PHCN further contributes to the maintenance problem.

*Source; Questionnaires*

- g) A Technical senior manager in another distribution department of PHCN who preferred to remain anonymous (*reasons best known to him*) stated that a new maintenance strategy and work authorization system is definitely needed in PHCN. He further stated that some PHCN technical personnel lack the basic skills and training for their job description. *Source; Oral Interview.*

- h) Some customers also stated that the customer complaints department of the company should be overhauled and made more effective.

*Source; Questionnaires*

## **CHAPTER FIVE**

### **RESULT DISCUSSION AND INTERPRETATION**

#### **INTRODUCTION**

This chapter presents the analysis, discussion and interpretation of information gathered during the research problem investigation. It further presents personal views and proposed solutions to help resolve the research problem. The new maintenance strategy and work authorization system proposed is as shown in the flow diagram presented in sections 5.4 and 5.5 respectively.

#### **5.1) ANALYSIS OF INTERVIEWS**

From the oral interviews it was further deduced that the maintenance problems cited in the literature review (chapter 2) actually exists in PHCN.

All the maintenance personnel interviewed agree to the excessive application of corrective maintenance in PHCN maintenance practice. From a personal point of view, this should not be the case considering the fact that corrective maintenance should only be applied to a unit whose failure does not lead to a production loss in factories or power interruptions in a utility company.

Spare parts unavailability, poor training, and oral permit system, identified during these interviews are factors which can inhibit maintenance effectiveness in a utility company. These issues are being corrected by the new maintenance strategy and Work authorization system discussed later in this chapter (sections 5.4 and 5.5).

Furthermore, the lack of computers for good information management, Root Cause Analysis (RCA) and other modern maintenance practices in PHCN is a burden for its maintenance activities. If included, RCA would help eliminate the

foundation causes of a problem and hence reduce failure rate. These abnormalities have therefore been included in the new maintenance strategy.

## **5.2) QUESTIONNAIRE ANALYSIS**

The bar graphs (figs 4.1a/b and 4.2) pictorially show the findings of the questionnaires used in this research. The percentage interpretations (Appendix A and B) shows mathematically the results of these questionnaires. The full validation procedure for these questionnaires and the methodology used in choosing the sample size is as attached in appendix C of this dissertation.

Most respondents both from the PHCN maintenance side and the customer side agree to the application of corrective maintenance in PHCN (appendix A & B).

The questionnaires confirm the lack of computers in PHCN maintenance, the poor state of some PHCN units like overhead conductors and wooden poles and the low level of training. It further confirms the frequent power interruptions, low response time to grid faults and the lack of a work authorization system in PHCN.

These abnormalities all contribute to the power problems of the country hence the inclusion of a work authorization system and some preventive maintenance schemes in this new maintenance strategy discussed later in this chapter.

Further analysis of the questionnaires used in this dissertation, the way the sample size was determined, the confidence level and interval are all highlighted in Appendix C attached.

## **5.3) ANALYSIS OF MAINTENANCE ISSUES (PHCN vs. ESKOM)**

This section briefly compares the maintenance strategies of PHCN and ESKOM using three grid unit overhead conductors, feeder pillars (transformer distribution

unit) and wooden poles as examples. The findings here are as highlighted in table 4.1.

In PHCN it is clearly seen that these units only adopt a corrective maintenance strategy. This affects the power availability. Using the wooden poles as example, the oral interviews and questionnaires shows a frequent failure of these units hence plans should be made to maintain them routinely especially at installment and during the dry season.

Furthermore, I would personally recommend 'Field Liners' designed and patented by Biotrans UK for any wooden poles been used in Nigeria with appropriate authorizations from the patent company. However, the management of PHCN reserves the right to choose otherwise. The figure below further illustrates the Field liners.

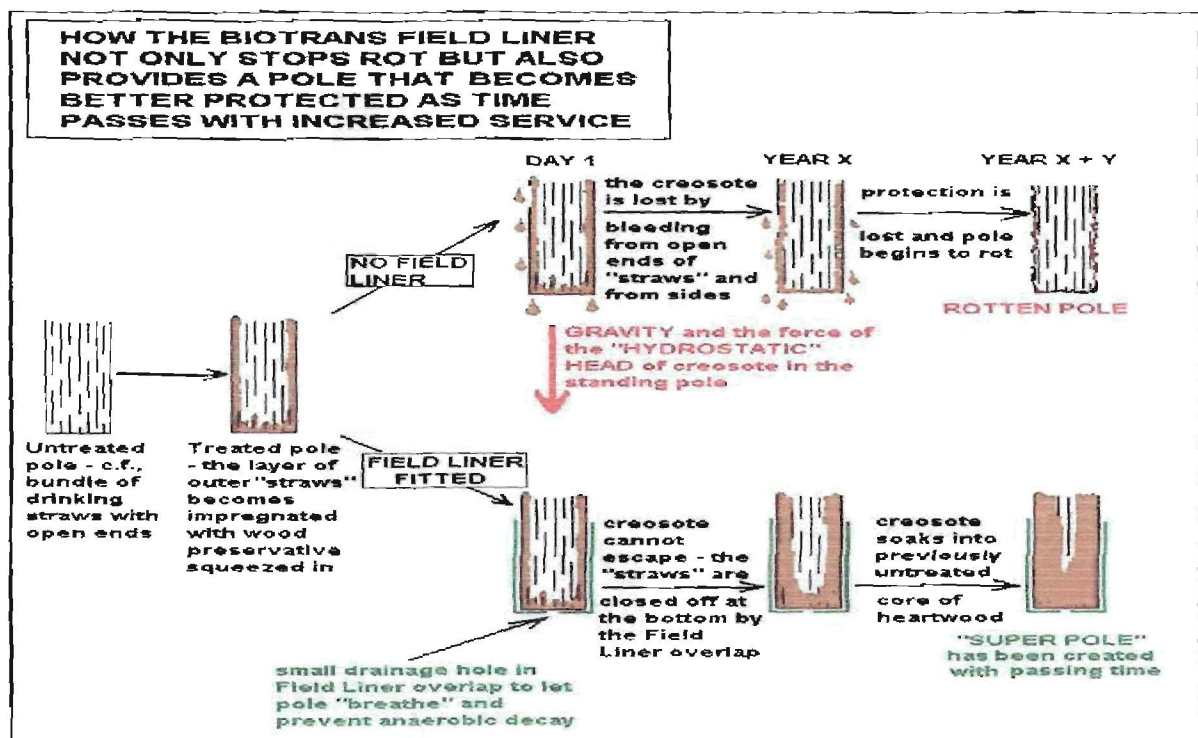


Fig 5.1: Biotrans field liner; microbiological biotransformation of wood.

Source; <http://www.biotrans-uk.com/>



For the overhead conductors, the vegetation growth seen on these conductors should be cut down regularly with a time based approach to prevent a possibility of short circuits along the lines. These preventive measures could help to reduce the number of power failures associated with these conductors.

For the feeder pillars, the daily load readings should be enforced by appropriate authorization systems as this would increase the level of commitment and responsibility by the maintenance personnel assigned to such a task. Furthermore, spare parts for this unit must be fully stocked to prevent wrong useage of fuses and its attendant problems.

Due to these abnormalities, a spare part analysis block, task/ frequency analysis, work authorization system, etc have all been included in this new strategy as discussed in section 5.4 of this dissertation.

#### **5.4) NEW MAINTENANCE STRATEGY**

The maintenance Strategy called **UTILITY AVAILABILITY CENTERED MAINTENANCE STRATEGY (UACMS)** is as discussed in the sections below;

*\*The diagram for the UACMS is as derived and modified from the next generation maintenance strategy of MAINTENANCE MANAGEMENT (IIOB 882) module Part 1, Compiled by Professor Harry Wichers of the North-West University of South Africa.\* (Harry, 2007)*

- a) **UACMS PHILOSOPHY:** This Strategy combines modern maintenance practices such as FMECA, Task/ Frequency and Root Cause Analysis together with appropriate authorizations and tradeoffs implemented via computer database support to ensure effective maintenance and power availability in a power utility company.

The block diagram of this newly developed strategy is shown in fig 5.2 below;

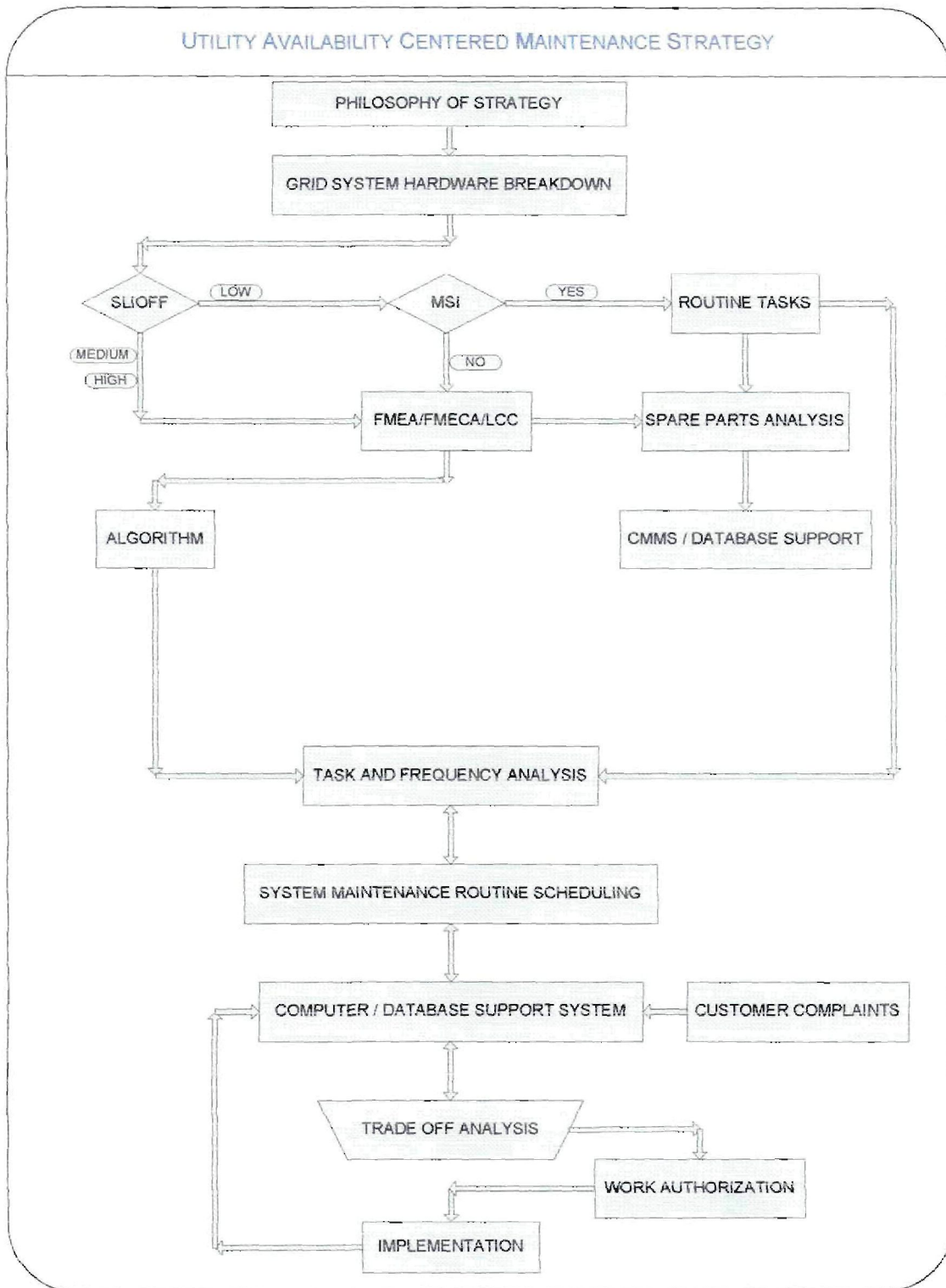


Fig 5.2: Utility Availability Centered Maintenance Strategy Flow diagram

b) **GRID SYSTEM BREAKDOWN STRUCTURE:** Here the units of the grid system are broken down into sub units e.g. distribution - poles, overhead conductors, transformers, feeder pillars, circuit breakers, relays etc.

c) **SLIOFF (System Level Impact Of Functional Failure):** This is similar to the PLIOFF studies/ analysis. Here the impact level of failure of any unit or component in the grid system is analyzed. This determines to which level the failure of a particular unit affects the grid in terms of power interruptions and stability.

This Impact of failure will be classified as high, medium or low in this strategy.

d) **Maintenance SIGNIFICANT ITEM (MSI):** Here, cost of maintenance and cost of failure are considered together. If the cost of failure is lower than cost of maintenance, it is tagged 'Not Maintenance significant.' A further FMECA study is carried out to determine if it should generally be left to 'Run to failure'. If however, the cost of failure is higher than the cost of maintenance, it is tagged 'Maintenance significant'. The routine maintenance tasks are however continued on that unit.

It should however, be noted that high cost of failure when mentioned here also implies a direct interruption of power supply. In this analysis, the longer the interruption time, the higher the cost of failure.

e) **ROUTINE TASKS:** This includes routine preventive maintenance tasks that are performed on units as specified by the manufacturer or maintenance department. It could be time based or risk based maintenance (see lit review).

f) **FMEA/ FMECA/ LCC:** This acronym stands for **Failure Modes Effects Analysis/ Failure Modes Effects Criticality Analysis/ Life Cycle Costs**. These acronyms are discussed in the literature review chapter of this dissertation.

Here the potential failure modes for the units are analyzed, to assess the risk associated with the failure modes.

The criticality of failure is ranked in terms of importance. The probability of its occurrence also determined.

Furthermore, the Life Cycle Costs of the units are considered to determine if a particular style of maintenance would have a very high impact on this cost. Some little trade offs are also done here.

Data from the above analysis are then used for the algorithm block.

- g) ALGORITHM: This block comes into play after FMECA has been carried out on specific units according to the flow diagram of fig 5.1

The algorithm block is shown in fig 5.3 overleaf.

Here, if a unit is faulty, the *Failure Frequency* is considered. If this frequency is low, it can be replaced or repaired with the appropriate authorizations.

If on the other hand, the failure frequency is high, the Root Cause Analysis of that failure is done to eliminate base causes. The RCA results are fed into the computer database for documentation and analysis purposes. After the RCA, the base causes are eliminated and the unit repaired according to the authorization procedure of the UACMS as shown in the UACMS flow diagram.

If any of these units is not yet faulty, the criticality level is considered (FMECA). If a high criticality exists, the UACMS flow of preventive maintenance tasks is continued. If however, the criticality level is low, the unit is allowed to '*Run to Failure*' as shown in the algorithm overleaf.

This unit would also have a computer management system for storing data from the field such as customer complaints and units requiring maintenance as identified by the maintenance personnel during routine system inspections.

The algorithm is as shown in fig 5.3 below;

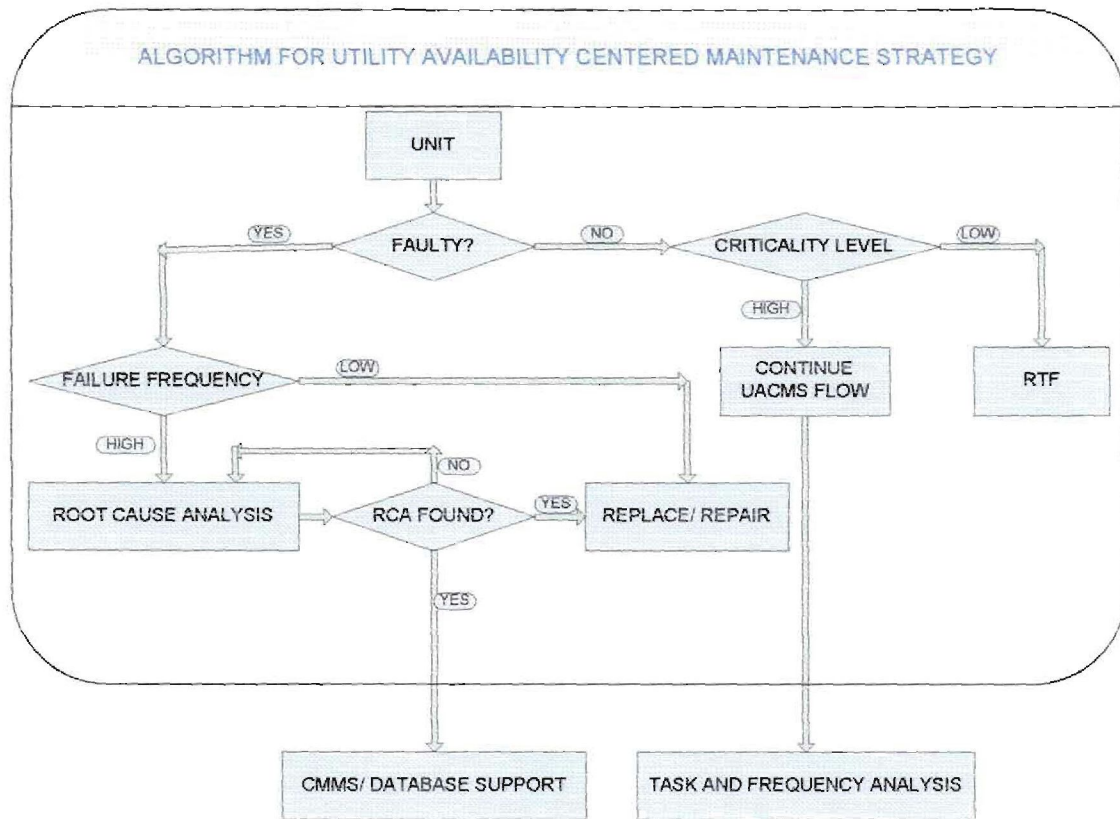


Fig 5.3: Algorithm for Utility Availability Centered Maintenance Strategy

h) SPARE PARTS ANALYSIS: Sequel to the complaints of unavailability of spare parts for maintenance in PHCN, this block was hence included in this strategy.

This analysis will be done to rationalize the spares to an optimal level that will be appropriate for the maintenance of the grid units and meet the reliability targets. The spare part Analysis will ensure that spares are not over stocked or under stocked at any time.

FMECA, LCC, frequency of maintenance and other aspects of the strategy would be considered in the spare parts analysis.

The results of the Spare Parts Analysis will be fed into the Computer Database support system and updated regularly.

- i) **TASK AND FREQUENCY ANALYSIS:** This block ensures that necessary maintenance is given to each unit in terms of time and duration.

This analysis determines the frequency of maintenance of each unit. Unit manufacturer's maintenance data, weather conditions, and criticality level of unit are all considered in this analysis to determine the style, nature and periodic intervals/ duration for maintenance activities. A good example is the fact that it would be better to maintain the outdoor accessories such as poles and overhead conductors more in the dry season to prepare for the windy and rain season where complaints of more failures have been reported during the oral interview sessions of this research.

- j) **SYSTEM MAINTENANCE ROUTINE SCHEDULING:** This block would work with the Task and Frequency Analysis results while considering personnel availability and skill level to ensure that maintenance tasks are carried out when due.

This scheduling procedure will allow the optimum workforce level to be determined by calculating the number of men required for the known routine maintenance while giving an allowance for possible breakdown.

The results of this analysis would be put into the Computer/ Database support system for documentation and appropriate authorizations.

- k) **CUSTOMER COMPLAINTS:** With the finding that the PHCN customers are not entirely happy with the response time to complaints by PHCN maintenance personnel, this block has been included in this strategy.

Data from the customers complaints block would be uploaded directly into the computer database and appropriate authorizations prepared for the maintenance or rectification of such a fault. The database which would be audited regularly will keep track of the complaints time and mean time to repair. This would ensure that the personnel causing the delays are held responsible and other bottle necks eliminated.

- l) **COMPUTER/ DATABASE SUPPORT SYSTEM:** The lack of computers and modern communication equipment in maintenance in PHCN led to the inclusion of this block.

This system will serve as a central database for the UACMS maintenance strategy. The database will be populated with data from Spare parts analysis, FMEA/FMECA, Root cause analysis, Task and frequency analysis, System maintenance routine scheduling, customer complaints and work authorizations.

The Computer Database will be updated, populated and audited regularly to ensure efficiency of the entire strategy. It will act like the well known Computer Maintenance Management System (CMMS).

- m) **TRADE-OFF ANALYSIS:** This involves determining the effect of decreasing one or more key factors and simultaneously increasing one or more other key factors in a decision, design, or project (*Business Dictionary, 2008*).

Trade-off analysis can also be seen as a systemic approach to balancing the trade-offs between time, cost and performance (*Dynamic Solutions, 2004*).

In this block, the task from the database is further discussed and analyzed by the responsible officials for that task.

If the need arises for a little trade off due to any unforeseen circumstance, the strategy to perform the task can be traded off for a more effective one before the necessary authorizations are signed. If the responsible officials are okay with the procedures, then the task is carried out without any further delay.

This block allows room for flexibility since the UACMS will be applied to an existing grid system (PHCN Grid).

- n) **WORK AUTHORIZATION:** This is as discussed in section 5.5 of this dissertation. Data to this block will be generated by the Computer database after considering necessary tradeoffs.

The authorization to do the work is signed by the necessary authority and responsible officials before the work is started. This would ensure an increased level of responsibility and accountability for that particular task. After the work is done and the appropriate columns of the form signed off, the data in the form is fed back into the Database and updated.

- o) **IMPLEMENTATION:** This block simply represents the point in the UACMS strategy where the maintenance tasks are carried out after the necessary considerations are done and authorizations signed. On task completion, the computer database is updated.

These 15 blocks discussed above basically gives the description of the new strategy as developed for this dissertation. Recommendations for implementing the strategy are highlighted in chapter 6 of this dissertation.



## 5.5) INTERNAL TASK AUTHORIZATION FORM

Work authorization (as defined in the literature review) is a formal document for delegating duties in organizations.

In table 4.4 it was highlighted that such a document does not exist in PHCN (as found in case studies- Owerri business unit). Furthermore, the oral interviews conducted shows that the low level of supervision could be attributed to the lack of authorization.

In solving this research problem, a work authorization was included in this dissertation with different aspects that would ensure a higher level of supervision, responsibility and commitment by the maintenance personnel.

With the work authorization being generated from the computer data base (see fig 5.2), which would be audited regularly, the level of responsibility and commitment towards task accomplishment in the organization is expected to increase.

The work authorization form designed for this dissertation is as shown in fig 5.3.

This new authorization form is called an '**INTERNAL TASK AUTHORIZATION FORM**' (ITA Form). The word 'Internal' here was chosen because the form is meant for delegating work within the organization. Task is 'a job assigned to somebody' (*Microsoft Encarta, 2006*). Hence, the word 'Task' was included. The word 'authorization form' is further included in the name for clarity purposes.

The Internal Task Authorization form and the features are as highlighted and discussed overleaf;

<b>COMPANY NAME</b>			
TASK ID:	COMPANY LOGO		
<b>INTERNAL TASK AUTHORIZATION FORM</b>			
TASK TITLE:			<b>FAULT REPORTED</b>
			NAME:
			DATE:
TASK CREATED BY:	SCOPE:	START TIME:	
TASK ASSIGNED TO:		END TIME:	
DESIGNATION		REVISION:	
	OUTAGE TIME:		
	PERMIT SIGNED:		
	<b>MAINTENANCE PERSONNEL</b>	<b>TASK SUPERVISOR</b>	
TASK ACCEPTED	SIGN:      DATE:	SIGN:      DATE:	
TASK COMPLETED	SIGN:      DATE:	SIGN:      DATE:	

Fig 5.4: Internal Task Authorization Form

- a) **COMPANY LOGO:** This is the organizations label (PHCN in this case). It is used to recognize the company that owns the authorization form.

- b) **TASK ID:** This is the identification number of that particular task on the computer database. This would also bear a reference number to show which business unit of PHCN is generating such a task.  
Task ID block was included for easy task tracking, recording and auditing purposes.
- c) **TASK TITLE:** This column contains the name of the task to be performed. It is a descriptive heading for that particular task.
- d) **FAULT REPORTED:** This column contains the name of the maintenance personnel or customer that reported the fault. It also contains the date on which the fault was reported for auditing and record purposes. This column can be neglected if the authorization is for routine maintenance.
- e) **SCOPE:** This contains the boundaries of the task. What is exactly expected from the maintenance personnel responsible for the task is highlighted in this column.
- f) **TASK CREATED BY:** This contains the name of the responsible official that created the task from the computer database information.
- g) **TASK ASSIGNED TO:** This contains the name of the maintenance personnel such a task is been assigned to.
- h) **DESIGNATION:** This represents the position of the maintenance personnel (e.g. Engineer, Technician etc) being assigned such a task. This will be useful for auditing the type of work being executed by each level of maintenance. It would also help check the excessiveness or shortage of a particular group of maintenance personnel.
- i) **START TIME:** This is the time a task is expected to start.

- j) END TIME: This is the time a task is expected to end. The 'start and end times' are useful in keeping a track record of the time used in executing such a task (Mean Time To Repair).
- k) OUTAGE TIME: This column is used to indicate the time of power interruption if required for that particular task. However, it should be noted that this is different from the 'start and end times' because a particular task can require only a minimal period of power interruption while being executed.
- l) WORK PERMIT: This column is necessary if a particular task is being executed with a work permit. Here the responsible official for the permit signs to ensure safety of personnel. A good example here is outage electrical permits to ensure the safety of workers during task execution and to have a level of responsibility should anything go wrong.
- m) REVISION NUMBER: This is used in case a task is assigned again to same or other maintenance personnel due to competency reasons or other unforeseen circumstances. Each revision has the number increased arithmetically e.g. Rev 01, Rev 02, Rev 03 etc. It will also be useful for task management and auditing purposes.
- n) TASK ACCEPTED/ TASK COMPLETED: This column is to be signed by the maintenance personnel and his line supervisor or person delegating the work. It is signed on accepting and completing such a task. The dates for such a task are also included here.

The authorization forms are marked off in the computer database after any task is completed and the database updated.

## **5.6) ANALYSIS OF TRAINING AND ROLES OF MAINTENANCE PERSONNEL**

From the oral interviews and questionnaire data it is shown that lack of adequate training poses a huge threat to the effectiveness of maintenance in PHCN.

Trainee technicians are assigned to any engineer who declares them competent after their training period. In my own view this training should not just be the responsibility of any engineer. The engineers with the responsibility of training these technicians should also have their knowledge base upgraded through special training sessions.

From a personal experience in SASOL South Africa, It was observed that artisans attend a two year formal training with periodical appraisals before they take the final trade test and are declared competent. This is not the case in PHCN as highlighted in table 4.3.

Artisans are the first line of maintenance and their skill level impacts directly on the quality of work done by the maintenance team. Hence, artisan training in PHCN should be more formal as obtainable in other global companies.

Comparing with Eskom it would be seen that here, efforts are been made to increase the training capacity of the industry via its training college in Midrand Johannesburg. Furthermore, the artisans go through a two-year formal training before they are certified competent to work. This impacts positively on the effectiveness of maintenance been done by the company as a well trained personnel would definitely perform better than an untrained or partly skilled one.

Training of personnel should not be overlooked in PHCN as this would generally improve the quality of maintenance thereby increasing system reliability.

Recommendations on training related issues are given in chapter 6 of this dissertation.

## **CHAPTER SIX**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **6.1) CONCLUSIONS**

When compared to other global case studies like ESKOM South Africa, TenneT Dutch and SASOL South Africa, the almost sole application of corrective maintenance being applied in PHCN can hardly be found. Hence this newly developed strategy which involves preventive, predictive and corrective maintenance is expected to be more effective and well in line with modern day practices elsewhere.

Furthermore, the necessity of a work authorization system in a Power utility company cannot be over-emphasized. Hence, the management of PHCN should adopt this newly developed authorization system immediately to ensure a high level of responsibility in carrying out its maintenance activities.

On training, the absence of training officers, negligence of important technical courses, lack of maintenance manuals etc found in PHCN generally affects the competency level of its maintenance personnel. This also affects their overall efficiency and effectiveness in executing maintenance activities.

The recommendations as stated in section 6.2 should be seriously considered and implemented as the competency and skill level of the maintenance personnel has a direct impact on the quality of maintenance work being done in the grid system and its overall stability.

All the recommendations stated overleaf could first be implemented on Business Unit (Distribution section) level especially the case studies for this research and then further implemented in other affected units.

## **6.2) RECOMMENDATIONS ON TRAINING OF MAINTENANCE PERSONNEL**

The following recommendations are made on the style and nature of training given to PHCN maintenance personnel with respect to this research;

- ❖ An independent supervising unit should be established to examine and assess the engineers/ technologists in training after their training period. This would ensure that they are only 'declared competent' after they have successfully completed all required training modules.
- ❖ Artisans should be given a more formal training like the one obtainable in SASOL (personal experience) where a two year formal training and continuous assessment programme is done with a final trade test at the end of the training duration.
- ❖ A fixed percentage of the funds generated from the sale of electricity to customers should be dedicated for the training of PHCN maintenance training.
- ❖ 'Training Officers' (special engineers or technologists) should be appointed in PHCN units for technician training. This would ensure that technicians gain a wider knowledge apart from the knowledge gained from the engineer they were originally seconded to. Furthermore, the 'Training Officer' should be the person to declare the technician competent before he/ she is given full responsibility of maintenance management and execution.
- ❖ Standard maintenance manuals should be made readily available to all maintenance personnel involved in maintenance activities after their training.

## **6.3) RECOMMENDATIONS ON MAINTENANCE STRATEGY**

Recommendations on the maintenance strategy as discussed in section 5.4 of this dissertation are as highlighted overleaf;

- ❖ An Information Technology department should be set up for managing the computer database. Their tasks would include ensuring timely backups of the computer database system and its overall efficiency.
- ❖ The computer database auditing function should be considered serious. An external auditing firm should be assigned the responsibility of auditing so as to increase the functionality of the entire system. This would also ensure that the audit results are as transparent as possible. Furthermore, monthly audit results should be sent to top level management for appraisal.
- ❖ A department for managing the entire strategy should be set up. This will ensure the effectiveness of the different blocks as shown in fig 5.2 of this dissertation. This department would also coordinate and manage bottlenecks in gathering necessary results from the different blocks (sub departments).
- ❖ **This newly developed strategy should be adopted by the Power Holding Company of Nigeria.** The implementation must start first at business unit (Distribution unit) level and as its effectiveness is further proved, it must be wholly synchronized into one standard for the entire utility company. See *Areas for Further Research (section 6.5)*

#### **6.4) RECOMMENDATIONS ON THE NEW WORK AUTHORIZATION SYSTEM**

The work authorization system which is implemented via the newly designed form called 'Internal Task Authorization Form' should be adopted immediately in PHCN with the following recommendations;

- ❖ A department for ensuring compliance to work authorization procedures such as signing on/ off, task generation, task uploading/ downloading from the database etc should be set up to increase overall efficiency of the entire system.
- ❖ The scope of the work must be clearly defined in the Internal Task Authorization form.



- ❖ The work authorization forms must be duly signed at the beginning and end of each task.
- ❖ From personal experience while working with PHCN, I observed that some tasks only require little outage time for some aspects of that task to be executed but power is however interrupted throughout the period of executing such a task. Hence I would recommend that the outage time (if necessary) be well calculated in advance to reduce the period of power interruption while executing a task especially when power availability poses no threat to the maintenance personnel carrying out such task.
- ❖ Any deviation in the time frame allocated for each job due to incompetence, lack of spare parts etc should be taken seriously by the management and auditing team.
- ❖ **This work authorization system should be adopted by PHCN as a matter of urgency** because the effects of 'responsibility' in task execution in any company can never be over-emphasized.

#### **6.5) AREAS FOR FURTHER RESEARCH**

Further research can also be done on any of the following;

- ❖ PHCN Transmission Section; This dissertation concentrated more on the distribution section of PHCN with little insight into the transmission section (section 4.1). Hence, further research on the maintenance practices in the transmission section could also be done to ensure optimal performance of the entire grid system in Nigeria.
- ❖ The maintenance strategy and work authorization system in the generating section of PHCN could also be researched to totally eliminate the more obvious and known maintenance problems of PHCN.

## APPENDIX A

### SURVEY QUESTIONS (A) FOR MAINTENANCE PROBLEMS OF PHCN IN NIGERIA.

*Tick as appropriate. (PHCN personnel only) Percentage response from respondents is also given*

- 1.0) Are you a PHCN Staff?      i) Yes.....100% (ii) No.....0%
- 2.0) Are you in the Technical side of PHCN?      i) Yes.....100% (ii) No.....0%
- 3.0) Are the Maintenance problems in PHCN one of the causes of power demand problems in Nigeria?  
i) Yes.....90% (ii) No.....10%
- 4.0) Do you think a work authorization system (e.g. job cards) exists in PHCN?  
i) Yes.....14% (ii) No.....86%
- 5.0) Do you have adequate training for your current job description?  
i) Yes.....20% (ii) No.....80%
- 6.0) Are the maintenance methodologies of your unit effective?  
i) Yes.....22% (ii) No.....78%
- 7.0) Do you think the maintenance methodologies of PHCN as stated in the procedural manuals are adhered to?  
i) Yes.....32% (ii) No.....68%
- 8.0) Do you use computers and other modern communication equipment in maintenance? i) Yes.....10% (ii) No.....90%
- 9.0) Which of these two is mostly practiced in PHCN?  
a) Preventive maintenance... 4.2% (b) Corrective maintenance... 95.8%
- 10.0) Do you have adequate (standard) tools for your maintenance work?  
i) Yes.....40% (ii) No.....60%
- 11.0) Do you think the response time to system (Grid) faults by PHCN is fast?  
i) Yes.....30% (ii) No.....70%  
If No, why? .....

- 12.0) Do you have a mechanism in place for finding 'root cause' for each fault encountered by your unit?  
 i) Yes.....0% (ii) No.....100%
- 13.0) Do you think a work authorization system (e.g. job cards) would increase the level of commitment, supervision and effectiveness of the maintenance team of PHCN?  
 i) Yes.....94% (ii) No.....6%
- 14.0) Do you consider the Life Cycle of units in maintenance.  
 i) Yes.....30% (ii) No.....70%
- 15.0) Which of these units do you think often lead to power interruptions due to maintenance issues? Tick top 5 according to criticality.
- i) Transformers ii) Feeder pillars iii) Lightening arresters iv) Circuit breakers
  - v) Overhead Conductors vi) Ring main Units vii) Wooden poles
  - viii) Transmission towers ix) Protection Relays x) Earthing Systems.
- 16.0) In one sentence; what can be done about the PHCN maintenance problems if they exist?  
 .....  
 .....

## **APPENDIX B**

### **SURVEY QUESTIONS (B) FOR MAINTENANCE PROBLEMS OF PHCN IN NIGERIA**

- 1.0) Are you a PHCN customer?      i) Yes.....100%    ii) No.....0%
- 2.0) Do you think that Maintenance problems in PHCN are one of the causes of power demand problems in Nigeria?
- i) Yes.....72.4%    (ii) No.....27.6%
- 3.0) Which of these two is practiced in PHCN?
- a) Preventive maintenance. 8.2%    (b) Corrective maintenance. 91.8%
- 4.0) Is the response time to system (Grid) faults by PHCN acceptable?
- i) Yes.....29.2%    (ii) No.....70.8%
- If No, why? .....
- 5.0) Are you satisfied with the quality of maintenance work done by PHCN maintenance personnel in your area?
- i) Yes.....28.4%    (ii) No.....71.6%
- 6.0) Do you often see broken PHCN poles and their accessories (e.g. cross arms) in the municipality?
- i) Yes.....75%    (ii) No.....25%
- 7.0) Do you often see vegetation growth on overhead conductors in the municipality?
- i) Yes.....82.6%    (ii) No.....17.4%
- 8.0) Do you often see vegetation growth in PHCN substations housing the transformers and feeder pillars?
- i) Yes.....75.8%    (ii) No.....24.2%
- 9.0) Does PHCN need to improve on their style/ level of maintenance?
- i) Yes.....90.4%    (ii) No.....9.6%
- 10.0) What is the average number of power interruption per day in your house?
- a) Zero...0%      (b) one to two... 89%      (c) greater than three... 11%
- 11.0) In one sentence; what can be done about the PHCN maintenance problem?
- .....
- .....

## **APPENDIXC**

### **CHOOSING THE SAMPLE SIZE AND VALIDATING THE QUESTIONNAIRES**

Questionnaires were included in this research to get data required for evaluating the research problem. The lack of documentation personally experienced in PHCN further buttressed the need for a questionnaire in this research work.

A total of 50 questionnaires were distributed to PHCN maintenance personnel while 500 questionnaires were distributed among PHCN customers.

Highlighted below are the procedures used in choosing the sample size and validating the questionnaires used in the course of this research. This procedure was followed to ensure that data collected can be trusted within tolerable limits of accuracy.

Firstly before initial survey, 10% of the questionnaires were given to the target groups (random sampling) to see if some questions required clarification or rephrasing. Survey results revealed that the questions were clearly understood.

**1) Maintenance Personnel Questionnaire;** Maintenance personnel referred to in this section includes PHCN technical staff from Engineers to Artisans involved in maintenance. A total of 50 PHCN maintenance personnel were surveyed during the course of this research.

a) *Choosing the population and sample size:*

I downloaded three statistical sample size calculators from the internet for this survey and compared the sample sizes calculated. These include;

❖ Creative research systems sample size calculator software.  
<http://www.surveysystem.com/sscalc.htm>

❖ Raosoft.Inc sample size calculator software.  
<http://www.ezsurvey.com/samplesize.html>

❖ Custominsight.com sample size calculator software.  
<http://www.custominsight.com/articles/random-sample-calculator.asp>

Data inputted into the software include;

- i) Confidence interval: This tells us the interval within which we can be confident with our results. I chose a confidence level of **+ - 5%** for this survey. This means a 90% result would have a confidence interval between 85% and 95%.
- ii) Confidence level: This tells us the percentage accuracy of our results. I chose a confidence level of **95%** for this survey. This means I am 95% sure that my results would lie within the confidence interval chosen above.
- iii) Percentage: In a yes/no or true/false questionnaire like the one I used, the accuracy level also depends on the percentage of the sample that picks a particular answer. If about 98% picks 'yes', and 2% picks a 'no' the chances of error are lesser than when 52% picks a 'yes' and 48% picks a 'no'. For this survey I chose the worst case scenario of **50%**. This would ensure a higher confidence on my results
- iv) Population size: This is the size of the population being surveyed. The PHCN data shows a total size of **60** maintenance personnel involved in the owerri municipal maintenance tasks. *Source; PHCN Owerri Senior Personnel Manager data book.*
- v) **SAMPLE SIZE:** Having inputted the above data into the software a sample size of **52** was obtained and was rounded off to **50**.

The 3 software used showed the same results for the sample size. Hence fifty was chosen as the sample size for this survey.

b) *Validating the questionnaires*

- ❖ Three weeks after data collection, 30% of the blank questionnaires were re administered to the maintenance personnel of PHCN Owerri business unit to confirm consistency with the original data collected from the same business unit. The results showed a 0.5% deviation from the original data collected.
- ❖ Twenty five questionnaire samples were taken to another PHCN business unit (Orlu). The data collected from the Orlu business unit was virtually the same with the original data from the Owerri business unit being used as the research case study with only a 1.5% deviation.

The mean of 'yes' responses from Owerri unit were 41.87% while that of Orlu unit was 40.36%. The difference in these mean values is 1.51%.

Pictorially the 'yes' results of the two units (PHCN Owerri and PHCN Orlu) are shown in the line graph below;

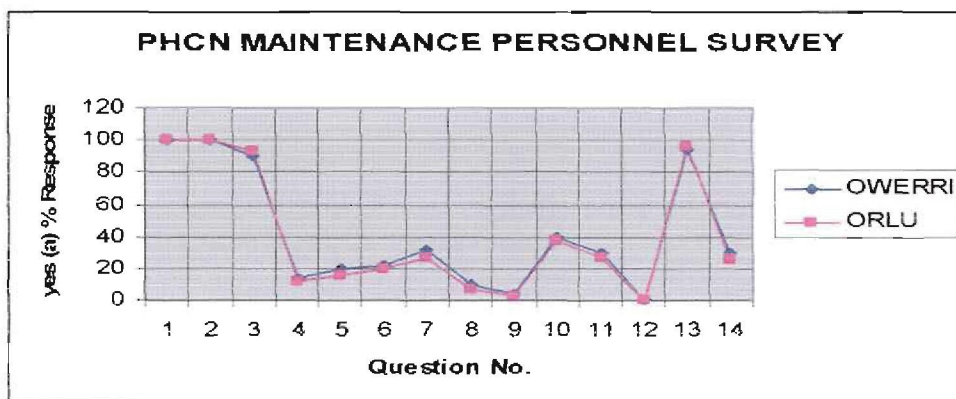


Fig: PHCN Maintenance Personnel Survey

- ❖ Some questions (q5, q10, q13 and q14) whose answers were already given by authoritative sources in the unit during interviews were included in the questionnaire. These questions showed an average of 93.95% consistency with that given by the authoritative sources in the unit.
- ❖ Three Weeks later, six filled out questionnaires whose original respondents were known to me were re administered to the same respondents. Their second response showed 100% consistency with their original forms.

**2) PHCN Customer Questionnaire;** PHCN customers referred to in this section includes habitants of the municipality (Owerri-Nigeria) that utilizes electricity supply from PHCN. A total of 500 PHCN customers were surveyed during the course of this research.

a) *Choosing the population and sample size:*

The same software listed above was used in determining the sample size

Data inputted into the software include;

- vi) Confidence interval: This tells us the interval within which we can be confident with our results. I chose confidence level of  $\pm 4.4$  for this survey. This means a 90% result would have a confidence interval between 85.6% and 94.4%.
- vii) Confidence level: **95%**. As discussed in PHCN maintenance personnel sample size calculation.
- viii) Percentage: **50%**. As discussed in PHCN maintenance personnel sample size calculation
- ix) Population size: This is the size of the population being surveyed. The PHCN data shows an approximate customer size of **50,000** in the owerri municipal feeders. *Source; PHCN Owerri 33/11kv distribution substation operators data book*
- x) **SAMPLE SIZE:** Having inputted the above data into the software a sample size of **491** was obtained and was rounded up to **500**.

The 3 software used showed same results for the sample size. Hence Five hundred was chosen as the sample size for the survey.



b) *Validating the questionnaires*

- ❖ Three weeks after data collection, 10% of the blank questionnaires were re-administered to the PHCN customers in Owerri municipality to confirm consistency with original data collected from the same municipality. The results showed only an average of 3% deviation from the original data collected.
- ❖ Some questionnaire samples (200) were taken to another set of PHCN customers in Orlu environs (another PHCN customer settlement). The data collected was virtually the same (1.3% deviation) with the original data from the Owerri municipality being used as the research case study.

The mean of 'yes' responses from Owerri customers was 62.4% while that of Orlu customers was 61.1%. The difference in these mean values is 1.3%.

Pictorially the 'yes' results for the two sets of customers (PHCN Owerri and PHCN Orlu) are shown in the line graph below;

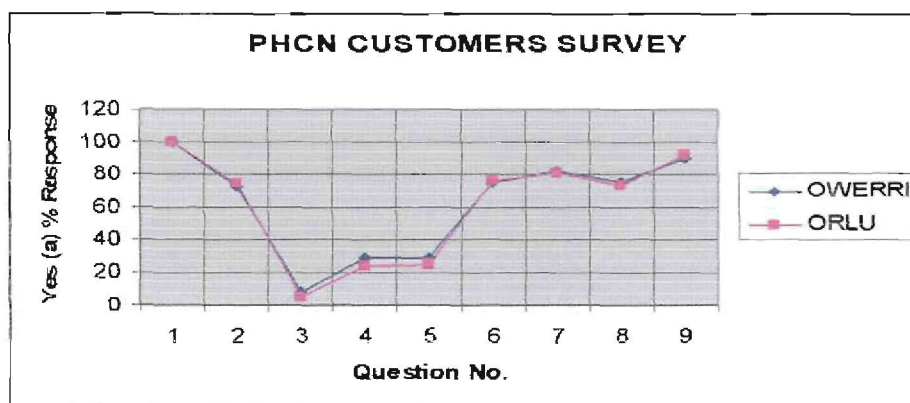


Fig: PHCN Customers Survey; Owerri vs. Orlu

- ❖ Some questions (q3, q7 and q9) whose answers were already given by authoritative sources in the unit during oral interviews were included in the questionnaire for validation. These questions showed an average of 88.3% consistency with that given by the authoritative sources in the unit.

## **APPENDIX D**

### **Reliability Centered Maintenance applied in ESKOM**

'Application of R.C.M. type Maintenance Methodology within Eskom Distribution'

By

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Senior Consultant, Maintenance and Transformers,  
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Distribution Technology.

[www.ameu.co.za/events/folder.2007-04-17.2838454948/folder.2007-11-05.1999939984/15.%20%20Peter%20Busch.pdf](http://www.ameu.co.za/events/folder.2007-04-17.2838454948/folder.2007-11-05.1999939984/15.%20%20Peter%20Busch.pdf)

**APPENDIX E**

**RESEARCH ARTICLE**

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## A NEW MAINTENANCE STRATEGY FOR POWER HOLDING COMPANY NIGERIA TO CONTEST THE CURRENT POWER DEMAND PROBLEM

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### ABSTRACT

With the current power demand problem of Nigeria being linked to the poor maintenance activities of the Power Holding Company of Nigeria (PHCN), the maintenance strategy, work authorization and training given to its maintenance personnel are investigated through case studies, questionnaires, oral interviews etc. Sequel to the findings of this investigation, a new maintenance strategy called **Utility Availability Centered Maintenance Strategy** which combines preventive, predictive, corrective strategies and other modern maintenance techniques is developed for PHCN. Furthermore, a work authorization system is also developed for PHCN and recommendations made on the training given to its maintenance personnel.

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**Article Type:** Research Paper

**Key Word(s):** Utility Availability Centered Maintenance Strategy (UACMS), Work Authorization System, Power Holding Company of Nigeria (PHCN), Maintenance, Training

**Asset Management & Maintenance Journal**

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### INTRODUCTION

One of the major causes of interruptions and losses in power generated and distributed in Nigeria was identified to be the poor maintenance of both the transmission and distribution (Grid) network (Orhie, 2004).

The PHCN spokeswoman Mrs. Igbo in a statement said that 'The lack of maintenance and replacement of damaged equipment has

led to a wide gap between demand and supply' (Louis, 2007).

Furthermore, the PHCN journal writers argue that adequate training of maintenance personnel would minimize load shedding and power interruption (Tom, 2006).

This research seeks to investigate the maintenance flaws of PHCN and propose a new maintenance strategy, work authorization

system and effective recommendations on maintenance personnel training.

Nigeria as a country, PHCN as a company and anyone seeking to research into similar power demand problem around the globe stands to gain from this research work.

#### **PROBLEM STATEMENT**

Power Holding Company of Nigeria has been recently faced with a huge problem of maintenance contributing greatly to the power demand problem of the country, and necessitating the investigation of its current maintenance strategy.

#### **RESEARCH METHODOLOGY**

Several local and global case studies were used for the purpose of this research. Oral Interviews were further conducted and questionnaires distributed in order to survey this research problem. Necessary deductions were then made.

#### **EMPIRICAL FINDINGS/ DISCUSSIONS**

From the questionnaire survey 95.8% of PHCN technical personnel agree to the excessive application of corrective maintenance in PHCN! 90% agree to the lack of computers in maintenance activities! 86% agree to the lack of work authorization! Only 20% feel they have adequate training for their job, all within a confidence level of 95% and an interval of +-5%. About 89% of the PHCN customers agree to one or two power interruptions per day! 71.6% are not satisfied with the quality of maintenance work. Another 70.8% think the response time to

grid faults is too slow, all within a confidence level of 95% and an interval of +-4.4%.

From the oral interviews, it was further deduced that; lack of responsibility in task execution, application of corrective maintenance, lack of spare parts, insufficient training of maintenance personnel due to lack of funds, poor supervision, training duration, incomplete training modules etc, all contribute greatly to the maintenance problems of PHCN. Comparing these with findings from maintenance manuals, textbooks and appropriate reviewed literatures, most of these flaws were found to be great maintenance abnormalities in any power utility company.

#### **UTILITY AVAILABILITY CENTERED MAINTENANCE STRATEGY (UACMS)**

Sequel to findings of this investigation, a new maintenance strategy called Utility Availability Centered Maintenance Strategy (UACMS) was developed for PHCN. This strategy, shown in figure 1 overleaf is presented in the form of a next generation maintenance flow chart/ block diagram (Harry, 2007).

The different blocks are allocated to different departments in PHCN for higher efficiency.

The UACMS mainly combines preventative, predictive and corrective maintenance strategies alongside other modern maintenance techniques. It's all linked to a computer database support to ensure high effectiveness.

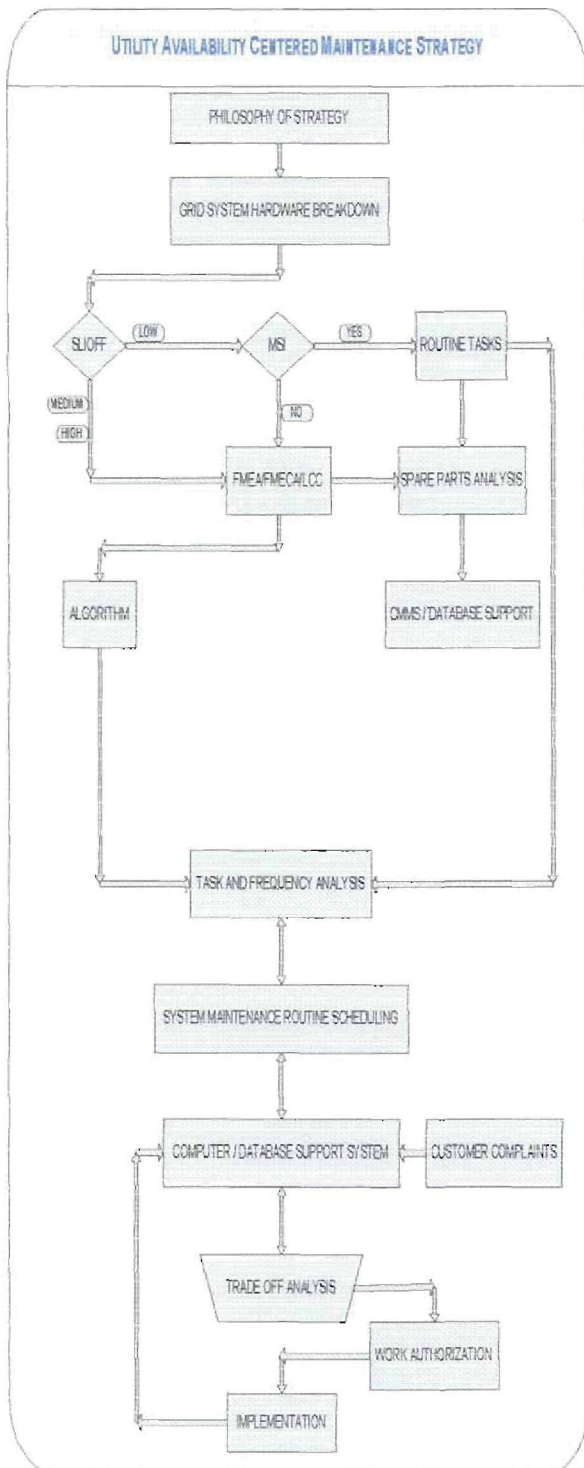


Fig 1: Utility Availability Centered Maintenance Strategy Flow diagram

The UACMS divides the components of the grid into sub units via the Grid hardware Breakdown block. It then considers the 'System Level Impact of Functional Failure', 'Maintenance Significant Items' and 'Failure Modes Effects Criticality Analysis' of each unit to determine the appropriate strategy/ maintenance technique to be applied to it. The results are then fed into the algorithm block (see fig 2 overleaf). The Algorithm caters for 'Root Cause Analysis' and decisions to be taken if a unit is faulty. The criticality level here is determined from the FMECA studies. 'Task/ Frequency Analysis' and the System Maintenance Routine Scheduling blocks work together to ensure that maintenance work is carried out when due. These blocks considers factors such as personnel availability, skill level and maintenance methodology to appropriately schedule maintenance tasks. In this strategy, the 'Spare Parts Analysis' block serves to ensure that spare parts identified as a major barrier to maintenance activities in PHCN are adequately stocked. A customer complaints and work authorization block are also included having been identified as major contributors to the research problem. The 'Trade off Analysis' block allow for flexibility (via trade offs) in the strategy since it is to be applied on an existing grid. The entire strategy is linked to a central computer database support block for information management purposes.

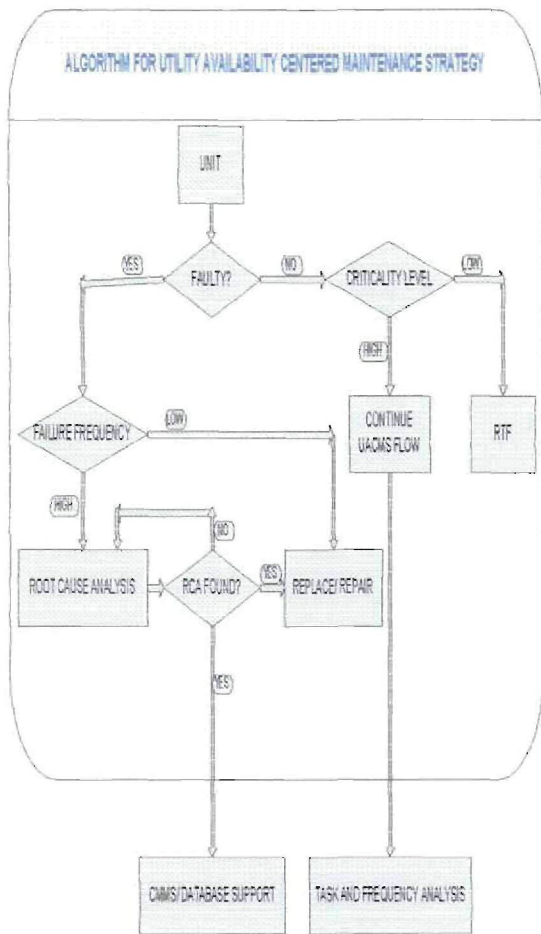


Fig 2: Algorithm for Utility Availability Centered Maintenance Strategy

### WORK AUTHORIZATION SYSTEM

A work authorization system implemented via a form called 'Internal Task Authorization form' was developed for PHCN to ensure high responsibility in task execution within the company (see figure 3). In this form, the personnel responsible for each task and the supervisor sign on task acceptance and completion with the respective dates. Furthermore, the 'Task Title', 'Scope', 'Start Time', and 'End Time' are all clearly stated to eliminate unnecessary delays in execution.

Fig 3: Internal Task Authorization Form

The 'Outage Time' column serves to eliminate prolonged and unnecessary outages for tasks that only require a minimal period of power interruption for some aspects while being executed.

The 'Fault Reported' column serves for auditing purposes to check the time lapse between faults being reported and rectified.

The 'Task ID' column serves as a trace of any particular task on the computer database of the UACMS. Tasks are appropriately marked off on the UACMS on completion via this ID.

## RECOMMENDATIONS

Recommendations on the training of maintenance personnel include;

- ❖ An independent supervising unit should be established to examine and assess the engineers/ technologists in training after their training period.
- ❖ Artisans should be given a more formal training as in other global companies.
- ❖ 'Training Officers' (special engineers or technologists) should be appointed in PHCN units for technician training.
- ❖ A fixed percentage of the funds generated from the sale of electricity to customers should be dedicated for the training of PHCN maintenance personnel.
- ❖ Standard maintenance manuals should be made readily available to all maintenance personnel involved in maintenance activities after their training.

Other recommendations include that the work authorization system should be adopted by PHCN as a matter of urgency to ensure 'responsibility' in task execution. Furthermore, a department should be set up in PHCN for managing the entire UACMS strategy.

## AREAS FOR FURTHER RESEARCH

Further research on the maintenance practices, strategy and work authorization in the generating and transmission section should also be done. This would ensure optimal performance of the entire grid system and totally eliminate

the more obvious and known maintenance problems of PHCN.

## CONCLUSION

Utility companies worldwide cannot over emphasize the need for a modern maintenance strategy. With Eskom of South Africa (a more stable company when compared to PHCN), the sole application of corrective maintenance does not exist. Other modern maintenance strategies such as FMECA, FMEA etc also exists. Furthermore with Sasol, an effective work authorization system exists. This emphasizes the need for a new maintenance strategy such as the UACMS to be immediately adopted and applied in PHCN to combat the current power demand problem of the country being linked to poor maintenance.

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## **APPENDIX F**

### **PROBLEMS ENCOUNTERED**

This appendix presents the problems encountered especially with data required from ESKOM Distribution for the empirical investigation, recommendations and analysis of the results of this dissertation. It further highlights the contacts made, and alternative solutions adopted.

#### **F.1) TRAINING AND ROLES OF MAINTENANCE PERSONNEL**

Highlighted below are the data required as per the training and roles of maintenance personnel in this dissertation.

- a) Type/ Nature/ Duration of training given to the maintenance personnel as identified above on assumption of duties. This would also be presented in the summary format of table 4.3 of the dissertation.

*Need for Data: This would help further complete table 4.3 of this dissertation where the level of training given to the maintenance personnel in the two utility companies on assumption of duties are being compared. It would also help make further recommendations at the end of the dissertation. See table 4.3*

#### **F.2) WORK AUTHORIZATION**

Highlighted below are the data required as per work authorization in this dissertation.

- a) Does a Work Authorization System e.g. Job cards exist in ESKOM Distribution? How is work authorization done in ESKOM Distribution?

*Need for Data: This would help further complete table 4.4 of my dissertation. This table (4.4) highlights the existence of a work authorization system in PHCN, ESKOM and SASOL. It would help buttress the point on the need of a work authorization system in PHCN. See table 4.4*

- b) Does ESKOM use Computer aided applications for its maintenance activities.

*Need for Data: As in 'a' above. A computer database support system has been included in the new strategy. This data would also buttress the need for computer aided applications in generating maintenance schedules.*

### **F.3) MAINTENANCE/ MAINTENANCE STRATEGY**

Highlighted below are the data required as per the training of maintenance personnel and the maintenance strategy in this dissertation.

- a) Procedure and problems encountered in maintaining wooden poles, Overhead Conductors, and Feeder pillars (Transformer distribution board) in ESKOM distribution.

*Need for data: This would help further complete table 4.1 of the dissertation. Here the maintenance practices and problems in the two utility companies are highlighted for comparison, result validation and recommendations. The three units listed above were used as references for this analysis. See table 4.3*

- b) Are Root Cause Analysis, Life Cycle Costs, FMEA and FMECA applied in ESKOM Distribution?

*Need for data: Having included the above terms in the new maintenance strategy being designed, I want to find out if they are also being applied in ESKOM Distribution.*

- c) What is the nature (major features) of the maintenance strategy used in ESKOM (summary not detailed)

*Need for data: If possible I want to compare the features of the new strategy with the features of ESKOMs strategy.*

*See New Strategy; flow diagram of fig 5.1*

#### **F.4) CONTACTS MADE IN SEARCH OF DATA**

In search of the above data, I decided to establish contact with some ESKOM personnel via emails and phone calls. The contact addresses and days contacted are as highlighted below;

- ❖ Marcus Ratlhallane Marcus.Ratlhallane@eskom.co.za  
Date: Feb. 15<sup>th</sup> / Aug 20<sup>th</sup> 2008. Tel No: 0132958708
- ❖ Goodman Ndlovu Goodman.Ndlovu@eskom.co.za  
Date: Feb. 15<sup>th</sup> / Aug 20<sup>th</sup>, 2008
- ❖ Khulekani Ngcobo Khulekani.Ngcobo@eskom.co.za  
Date: Feb 20<sup>th</sup>, 2008. Tel No: 0820896981
- ❖ Peter Busch Peter.busch@eskom.co.za  
Date: July 28<sup>th</sup> / Aug. 20<sup>th</sup>, 2008.

#### **F.5) PROBLEMS ENCOUNTERED WITH CONTACTS AND DATA**

The moves made to retrieve the required data from ESKOM proved abortive due to some reasons. These reasons are further highlighted below;

- ❖ Contacts say it is against company (Eskom) policy to give out such data by a staff member without appropriate authorization.
- ❖ Contacts were thinking in terms of '*information confidentiality without any infringement to information security policies*'. Hence no response.

- ❖ Contacts suggest I “*approach Eskom Distribution through my lecturer and get limited access to their documents so that I can reference them in my dissertation*”.
- ❖ Legalities as regards information usage prohibit the release of such data except general publications in journals, dailies, internet etc which must be referenced accordingly.

With this associated problems, retrieving exact data needed was difficult.

#### **F.6) ALTERNATIVE SOLUTION ADOPTED**

Use reliable published internet sources and manuals with appropriate acknowledgement. These data were a bit more general and safe to use.

Some of these data sources include;

- ❖ <http://www.biotrans-uk.com/>
- ❖ Eskom (2003) see ref.
- ❖ [http://www.pplfieldliners.com/eskom\\_trial.htm](http://www.pplfieldliners.com/eskom_trial.htm)

*Other internet sources are indicated below the tables in the dissertation where they are cited. I assume the above data are correct based on their dates of publication and company/ website integrity.*

However, the Eskom data does not form a major aspect of this research survey. It only serves as a base for some data comparison. The major survey has been done and properly validated via the case studies, questionnaires, interviews and other literature sources leading to the design of the new maintenance strategy cum work authorization system for PHCN.

\*\*\*It should be noted that all data used from the internet for the Eskom part of this dissertation are subject to verification if need be. If these data are found to be inconsistent with any verified data, some aspects of the final analysis can be altered. \*\*\*

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