MAINTENANCE PRACTICES AND PERFORMANCE OF POWER SECTOR IN KENYA

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DECLARATION

I hereby declare that this research project is my own work and effort, and that it has not been submitted anywhere for any award.

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This Research Project has been submitted for examination with my approval as the university supervisor

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Much gratitude goes to my supervisor for his guidance, encouragement and continuous support throughout the research project writing.

DEDICATION

This research is dedicated to my wife who has encouraged me through this journey and to my family for their support, patience, encouragement and understanding.

ABSTRACT

The purpose of the study was to establish the maintenance practices at KenGen, to benchmark and evaluate the Practices with the world best maintenance practices and to determine the relationship between maintenance practices and plant performance in terms of availability and operation and maintenance costs.

The case study was done with a target population of all the three operational areas with different generation technology of hydro, thermal and geothermal. The study used primary data which was gathered by means of a self-administered questionnaire issued to respondents and secondary data which was extracted from internal operational reports in Eastern hydro power stations. The average of each aspect was calculated and the quantity identified to evaluate the maintenance practices at KenGen and to benchmark with the world best practices. The secondary data analysis involved the use of regression to determine the relationship between the maintenance practices and plants performance.

The study established that KenGen has in place good maintenance practices. When they were benchmarked with world best practice, it was apparent that breakdown maintenances works were extremely high but surprisingly the plants availability recording very good results. There was a weak relationship between O&M cost, number of breakdowns and the plant availabilities.

The study concluded that though KenGen has good maintenance practices, the high breakdown maintenances works recorded is as a result of poor maintenance works and contributes to a great extent the 13% revenue loss incurred by KenGen.

The study recommended that for reliable and competitively priced electric power in Kenya, there is need to have the power utilities enhance their maintenance practices for effective and efficient generation and distribution of power to meet the customers' expectations. This therefore calls for improvement of maintenance practices to meet world best practices by building internal capacities and having proactive internal technical trainings and audits.

ABBREVIATIONS

AA	Average Availability
BD	Breakdown
BM	Benchmark
CBM	Condition Based Maintenance
FO	Force Outage
GWhr	Gigawatthours
IPPs	Independent Power Producers
KenGen	Kenya Electricity Generating Company Limited
Ksh	Kenya Shillings
KWhr	Kilowatt-hour
OC	Operating Cost
OM	Operations and Maintenance
PM	Preventive Maintenance
SAP	Systems Applications Products
WO	Work Order

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

A number of surveys conducted in industries throughout the United States have found that 70% of equipment failures are self-induced. Maintenance personnel who are not following what is termed as ‘Best Maintenance Repair Practices’ substantially affect these failures. Between 30% and 50% of the self-induced failures are as a result of maintenance personnel not knowing the basics of maintenance. Maintenance personnel, who, although skilled, choose not to follow best maintenance repair practices, potentially cause another 20% to 30% of those failures (Smith, 2000).

This case study focuses on “Best Maintenance Practices” necessary for maintenance personnel to keep equipment operating at peak reliability and companies functioning more profitably through reduced maintenance costs and increased productivity and capacity. The potential cost savings can often be beyond the understanding or comprehension of management. Many managers are in a denial state regarding maintenance. The result is that they do not believe that repair practices directly impact an organization’s bottom line or profitability. More enlightened companies have demonstrated that, by reducing the self-induced failures, they can increase production capacity by as much as 20%. Other managers accept lower reliability standards from maintenance efforts because they either do not understand the problem or they choose to ignore this issue. A good manager must be willing to admit to a maintenance problem and actively pursue a solution. KenGen looses 13% of its expected revenue to maintenance practice related problems. Therefore, the maintenance function must ensure that all production and manufacturing equipment is in optimum operating condition. The normal practice of quick response to failures should be replaced with maintenance practices that will sustain optimum operating condition of all plant systems. The plant should not only be operating but reliably operate at or above nameplate capacity without creating abnormal levels of product quality problems, preventive maintenance downtime or delays. The objective should be maintenance prevention, not quick fixes of breakdowns.

A report by World Energy Council (WEC) published in the year 2004 reveals the availability is a critical indicator for assessing the overall performance of the power plant, both in technical and commercial terms. Moreover, it is a public demonstration of the service the plant provides to its customers. The importance of reliable service should not be underestimated, in particular in the increasingly competitive market environment in which many utilities around the world are operating today. The service provided by the industry – electric power – is not considered to be particularly exciting when things run well and the lights are on. Only when the service is not there, does it become exciting and hits the headlines. Only then do customers begin to understand and appreciate the real value of secure access to electricity and the full extent to which modern society depends on reliable supplies of electric power.

1.1.1 Concept of Maintenance and Performance

Maintenance is defined as "The combination of all technical and associated administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function" by British standard 3811. It includes inspection, testing, servicing, repair and reclamation. In sum maintenance encompasses all works carried out on a plant or a facility with the view to rectifying a defect or failure in its functioning or performance; preventing failure in its functioning and/or improving the state of the facility so as to sustain its utilization and value. In a production facility, maintenance acts as a support for the production process, where the production input is converted into specified production output. Industrial maintenance comes as a secondary process, which has to contribute for obtaining the objectives of production. Maintenance must be able to retain or restore the systems for carrying out a perfect production function. (Gits, 2010). There exists asset management software's in the market and established best world practice benchmarks which if well utilized could reduce maintenance costs to a great extent.

Best maintenance practices are defined in two categories: standards and methods. Standards are the measurable performance levels (benchmarking) of maintenance execution; methods and strategies must be practiced in order to meet the standards. The combination of standards with methods and strategies provides the elements of an integrated planned maintenance system. Achievement of the best maintenance practice standards (maintenance excellence) is accomplished through an interactive and integrated series of links with an array of methods and strategies. Maintenance planning and scheduling is an essential part of effective maintenance. Planners must develop and implement both preventive and corrective maintenance tasks that achieve maximum use of maintenance resources and the production capacity of plant systems. Good planning is not an option. Plants should adequately plan all maintenance activities, not just those performed during maintenance outages. Standard procedures and practices are essential for effective use of maintenance resources. The practices should ensure proper interval of inspection, adjustment or repair. In addition, these should ensure that each task is completed properly. Standard maintenance procedures (SMPs) should be written so that any qualified craftsperson can successfully complete the task in the minimum required time and at minimum costs. Adherence to standard operating practices (SOPs) is also essential. The workforce must have the training and skills required to complete their assigned duties. In addition, maintenance management must ensure that all maintenance employees follow standard practices and fully support continuous improvement.

The importance of power plant performance is poorly known to industry outsiders, although it is one of the major factors which could have a significant impact on the future of our planet. Analysis of generating plant performance data undertaken by the World Energy Council Committee performance of Generating Plant in 2004 demonstrates the enormous value of plant availability. It has been estimated that improving the availability of all power plants in the world to the performance levels achieved today by the 25% of best performing plants, is worth a staggering US$80 billion per year. In addition, this improvement in performance would reduce the annual global GHG emissions by 1 billion tonnes CO2 equivalent (i.e. by approximately 4%), along with proportional reduction of other pollutants. This could be achieved using existing best practice technologies at an average benefit to cost ratio of 4 to 1. Case studies from utilities and manufacturers around the world confirm that while some technology enhancements and equipment upgrades will be required, the majority of the improvement will come as a result of addressing human factor issues and power plant management. Moreover, if these “soft” issues are not addressed, new technology plants will be unable to achieve their inherent superior performance potential. Performance improvement of existing power plants is the most cost-effective way to increase the energy producing capabilities of a utility while improving the overall energy efficiency of the industry and producing substantial environmental benefits (Smith, 2000).

1.1.2 Energy Sector

The Kenyan economy grew at a rate of 7.1% in the year 2007 against the backdrop of a stable macroeconomic environment which enabled economic recovery and a rapid economic growth experienced in the Country since 2003. This growth was followed by a dip of 1.6% growth rate in the year 2008 which was occasioned by the effects of post election violence, drought which affected the hydro resources and the global economic crisis. The economy however started showing a positive growth at 2.6% in 2009 then 5.6% in 2010 before dropping slightly to 4.5% in 2011. The Kenya's Gross Domestic Product (GDP) is expected to maintain a positive growth but at a decelerated rate of between 3.5 and 4.5 percent in the year 2012 (Kenya National Bureau of Statistics, 2012).

Table 1.0 Kenya's GDP Growth. (Worldbank data, 2013)

Country	Indicator_Name	2002	2003	2004	2005	2006	2007	2008	2009	2010
Kenya	GDP growth (Annual %)	0.55	2.93	5.10	5.91	6.33	6.99	1.53	2.74	5.76

In tandem with the increased economic activities, the electric power sub-sector has experienced significant growth in demand for electric power over the last seven years. This growth momentum is expected to be sustained with an estimated annual demand growth of about 8% per annum, which may stretch gradually with the enhanced rural electrification program and the increased economic activities in the foreseeable future.

The Kenya Vision 2030 is a vehicle for accelerating growth in the country into a rapidly industrializing middle income economy by the year 2030. Energy is a key enabler of the economic pillar and flagship development projects identified under Vision 2030 will increase demand on Kenya's energy supply (GoK, 2008). The national installed capacity is 1722MW with a maximum demand of 1330MW. Kenya Electricity Generating Company Limited (KenGen) is the leading electric power generation company in Kenya accounts for about

74% of the total electricity generated while the Independent Power Producers (IPPs) and emergency power plant (EPP) account for 26% of the total generation capacity. (KenGen, 2012)

1.1.3 Key issues in the Power Sector

A World Bank enterprises survey reveals that Kenya has an average of 56 days per annum with power interruptions while in United States of America, its 1 day in 10years. More than half of the large firms in Kenya have back-up generators which is an indication of low dependability and reliability of the power supply from the power utility (Public Utility Research Centre University of Florida 2013). This is due to poor generation, transmission & distribution installations systems due to ineffective maintenance practices & upgrading programs. Power Infrastructure is underdeveloped and low per capita consumption. Studies indicate that there are few economies of scale in Africa. The installed capacities in 33 out of 48 countries have less than 500MW, 11 countries have less than 100MW and Kenya has 1722MW. Out of these up to a quarter of the capacities are unavailable due to poor infrastructure for generation, transmission and distribution (University of Florida, 2013)**.** The growth in capacity stagnates resulting to emergency short-term power plant leases. Large energy resources are also unexploited and are distant from main load centers, e.g. hydro in DRC and Ethiopia. Electricity consumption in Kenya is extremely low at 121 kilowatt hours (kWh) per capita (compared to 503kwh in Vietnam) and national access rate at about 15%. The access rate in rural areas is 4%. All this is changing rapidly as the country invests in power generation, in addition to policy and institutional reforms in the sector bring in new providers (GoK, 2008).

When comparing Africa against other world regions, its residential electricity price averages between 50 and 150 percent higher than the 8 cents/kWh in Latin-America, Eastern Europe, and East Asia, and up to 400 percent higher than average residential tariffs in South Asia. This is mostly due to high fuel prices used by thermal power plants including the temporary power plants, power losses both due to technical and non-technical issues such as illegal connections, nonpayment (including government bodies) and meter reading errors which contribute to almost 20% of the electricity bills. (University of Florida, 2013). The prices of electricity in Egypt range among the lowest in the world. The domestic price ranges from 1

US cents to the highest figure of 7US cents per kwhr while Commercial rates range from 4US Cents to the highest figure of 9 US cents per kWh depending on the total consumption per month. Kenya’s prices are US Cents 18 per kWh domestic and US Cents 16 per kWh for commercial. Egypt is completely dependent on fossil fuels for producing electricity, with a mere ten percent of the country's total generated electricity coming from wind turbines and hydroelectric plants, such as the Aswan High Dam, Naga Hammadi's barrage and the Aswan reservoir. Kenya’s major fifty percent supply is from hydro with the other supply mostly from thermal and geothermal plants.

Kenya suffers continued power supply inconsistencies anytime there is prolonged drought that reduces water levels in the KenGen hydro dams. This leads to low production from the cheaper hydro source and high power tariffs due to the replacement of the hydro capacity with the relatively more expensive temporarily emergency thermal sources. This has a great bearing on the national power supply as KenGen has 74% market share of which about 49% of the total national installed capacity is hydro based. This calls for greater diversification of the generation modes in future investment in the power sub-sector. To mitigate this risk, geographical diversification of hydro plants has commenced as well as the expansion of the storage capacity of Masinga Reservoir and proper water management. Future investments targets power generation from wind and all-weather generation plants such as geothermal and coal based thermal to reduce the exposure to incidences of electrocution of persons and damage of equipment due to poor power infrastructure and low health and safety standards have become common in Kenya’s power sector. Tragic end to play as live wire kills boy, 8 in the outskirts of Nakuru town (Daily Nation July 5, 2013).For many companies, maintenance is an activity which is carried out reactively, in response to interruptions, breakdowns and other unfortunate events.

The ramifications of this kind of approach can be severe, especially at operations such as processing plants, assembly lines and power plants, where the failure of a relatively minor component can disrupt the entire facility. As many companies have found out, the total cost of downtime and emergency around-the-clock repairs can be staggering. On the other hand, a preventive maintenance program ensures continuity of operation and lessens the danger of unplanned outages. Planned shutdowns take place during periods of inactivity or least usage, and as a result, troubles can be detected in the early stages and corrective action taken before extensive damage is done (Ontario Hydro, 1997).

Most of the issues raised above are caused by in-effective maintenance practices in the power utilities leading to poor performance. Good maintenance practices ensure that machines are available within its lifespan at their rated capacities. Best maintenance practices in a power system networks are benchmarking standards that, if carefully implemented enhances the integrity, reliability and maintenance costs of power networks (Kamoun, 2005) leading to good utility performance.

1.2 Statement of the Problem

This study reviews the existing maintenance practices in the power sector (particularly in KenGen). KenGen has plant maintenance (PM) software which is integrated in the SAP system to help in the management of maintenance practices. The study will collect data on the usage of the PM and benchmark it with the best world practices. The study will identify the existing gaps and come up with recommendations of enhancing the system. The study will go ahead to investigate the relationship between the maintenance practices and plants performance in terms of availability and revenue generation. The research will cover the main operational areas which specialize in hydro, geothermal and thermal modes of power generation. The performances of these areas as business centres will be compared with their maintenance practices.

The maintenance practices in KenGen affect the fuel cost charges of the electricity bills in Kenya which is a pass through cost to the customers. With a high effective and reliable generation capacity, the need to have expensive temporary thermal power plants which mitigate for any shortfall generation capacity will be reduced. This contributes to almost 28% of our current power bills as fuel cost charges but varies on monthly basis (Author, 2013). A good maintenance practice ensures that all the plants' capacities are available for generation at any given time.

There are many research issues which can be addressed in the Energy sector to mitigate the many challenges it's currently facing. Among these issues are poor infrastructure, poor reliability, high pricing, maintenance practice, quality of power, safety of both human and equipment etc. However, few of these researchers have focused on maintenance practices in the power sector.

The cost of maintenance in KenGen per year averages to Kshs 900 Million. This is a huge cost yet few researchers have focused on it. The study breaks new ground by focusing on maintenance of a power generation plant in the energy sector.
This study will seek to address the following research questions: What are the main maintenance practices in KenGen? Are the KenGen maintenance practices up to the world best? What is the relationship between maintenance practices and performance in KenGen?

1.3 Research Objectives

The main objective of this research was to benchmark KenGen maintenance practices to the world best practices.

1.4 Specific Objectives

1) To establish the maintenance practices at KenGen
2) To benchmark and evaluate the Practices with the world best maintenance practices.
3) To determine the relationship between maintenance practices and plant performance in terms of availability and revenue generation.

1.5 Value of the Study

The findings of this study will enrich existing knowledge in maintenance practices and plants performances amongst Kenya power utilities and hence will be of interest to both the researchers and academicians who seek to explore and carry out further investigations. This is more important considering that maintenance practices and performance is a relatively new field in Kenya. The study shall be beneficial to other power utilities, manufacturers and all those who use electricity as a source of energy. Good maintenances practices will lead to high plant availabilities, increased production and low operational costs and reduction to electricity bills. This will be of value to the government as it will assist it in coming up with policies and laws that would help reduce the cost of power. This is more so considering the key role the power sector plays in the Kenya's economic.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter covers literature on the power sector regulation & pricing, compares the local with international electricity tariffs and reveals the current KenGen's PPA rates with KPLC. A conceptual framework on what contributes to a maintenance system and the measure of performance in a power sector is analyzed. The main approach to maintenance, the established world best maintenance practices and performances parameters are identified and discussed. This information will be used for benchmarking KenGen's maintenance practices and their relationship to performance.

2.2 Power in Kenya

Development projects recommended under Vision 2030 and overall economic growth will increase demand on Kenya's energy supply. Adequate supply of Energy has been identified as one of the infrastructure enablers of the Social, Economic and Political pillars of the Vision 2030. Kenya must therefore generate more energy and increase efficiency in energy consumption. To facilitate this, the Government of Kenya has committed to continued institutional reforms in the energy sector, including a strong regulatory framework, encouraging private generators of power and the separation of the transmission from the distribution function. New sources of energy will be found through exploitation of geothermal power, coal, renewable energy sources and connecting Kenya to energy-surplus countries in the region.

About 10% of all commercial energy needs is from electricity. Strong electricity demand growth in Kenya is being driven by continued economic growth, increased rural electrification and reinforcement of the transmission and distribution network. On the supply side, cyclic drought conditions pose a challenge to power supply given the dominant nature of hydro sources that account for over 49% of all electricity supply. Existing projections place electricity annual average growth at about 8%. Currently, the highest recorded peak demand is at 1,194MW with a reserve margin of just above 10%, some of which is from the temporary Emergency Power Plant. This creates a sharp national focus on the Electric Power

Sub-Sector, which has been identified as one of the infrastructure enablers for the realization of the National Vision 2030 (KenGen, 2012). The current peak demand has increased to 1357MW as of July 2013 (KenGen/KPLC Technical Committee, 2013).

The institutional structure in the electricity sub sector in Kenya comprises of the Ministry of Energy (MOE), the Energy Regulatory Commission (ERC), the Kenya Generating Company (KenGen), the Kenya Power and Lighting Company (KPLC), the Kenya Electricity Transmission Company (KETRACO), the Rural Electrification Authority (REA), the Geothermal Development Company (GDC) and the Independent Power Producers (IPPs).

Reforms in the power sector began in 1996 with a view to establishing a legal and regulatory framework to enhance efficient use of resources dedicated to the supply of electricity to the economy and encourage private sector investment in the industry. The 1996 power sector reforms ended with the enactment of the Electric Power Act, 1997, establishment of the Electricity Regulatory Board (ERB) in 1998, separation of generation function from transmission and distribution and licensing of independent power producers.

2.3 Power Tariffs - International Comparison

Domestic and industry electricity tariffs for Kenya were at US Cents 18 per kWh and US Cents 16 per kWh in 2010 higher than those of Korea (US cents 8 per kWh and US cents 6 per kWh), France (US 16 per kWh and US cents 11 per kWh), USA (US cents 12 per kWh and US cents 7 per kWh). Of importance to Kenya is Korea which has achieved an incredible record of growth and global integration to become a high-tech industrialized economy. Four decades ago, GDP per capita was comparable with levels in the poorer countries of Africa and Asia. In 2004, Korea joined the trillion dollar club of world economies, and currently is among the world's twenty largest economies. Kenya has borrowed very heavily on the Korea case in developing the Vision 2030. (GoK, 2007)

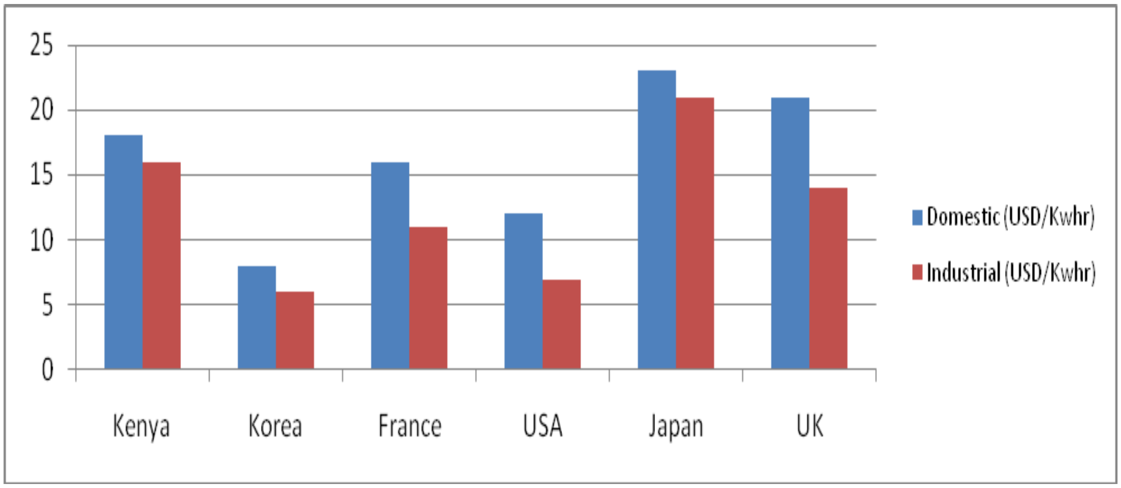

Figure 2.1 Power Tariffs - International Comparison

Japan has the highest tariff at 23 US cents per kWh for domestic followed by the UK with a domestic tariff of 21 US cents per kWh. The industrial tariff for Japan is the same as that of Kenya with the UK having a lower industrial tariff at US cents 14 per kWh. Figure 1 indicates the different tariffs for the six countries. (GoK, 2007).

This data seems to suggest that power is not as expensive in Kenya as popularly shared. Compared with other nations, electricity in Japan is relatively expensive, and, since the loss of nuclear power after the earthquake and tsunami disaster at Fukushima, the cost of electricity has risen significantly.

Kenya’s retail tariff is bundled and incorporates the combined cost of the different functional components that is generation, transmission and distribution and ensures sustainability as it is based on the revenue requirements of the transmitting and distributing company i.e. KPLC. The tariffs structure follows KPLCs underlying long run marginal cost structure such that the utility is able to meet its revenue requirements. The revenue requirements are based on prudently incurred costs including power purchase costs; transmission, distribution and retailing costs as well as a reasonable rate of return on the capital invested to provide the services. The retail tariff structure is as shown in table 2.

Table 2.1: Kenya's tariff

Tariff	Type of Customer	Supply Voltage (Volts)	Consumption (Kwh/Mth)	Fixed Charge (Kshs/Mth)	Energy Charge (Kshs/Kwh)	Demand Charge (Kshs/KVA/Mth)
DC	Domestic	240 or 415V	0-50	120	2.0	
			51-1,000		8.10	-
			Over 1,500		18.57	
SC	Small Commercial	240 or 415V	Up to 15,000	120	8.96	-
C11		415, 3 Phase		800	5.75	600
C12	Commercial	11,000	Over	2,500	4.73	400
C13	Industrial	33,000/40,000	15,000	2,900	4.49	200
C14		66,000	No Limit	4,200	4.25	170
C15		132,000		11,000	4.1	170
IT	Interruptible Supplies (Off-Peak)	240 or 415V	Up to 15,000	140.00 when used with DC or SC	4.85	-
SL	Street Lighting	240	-	120	7.5	-

In addition the retail tariffs structure provides for three pass-through costs that are considered uncertain and largely outside the control of the utilities. These are fuel oil cost adjustment (FOCA) the foreign exchange rate fluctuations adjustment (FERFA) and inflation adjustment.

2.4 KenGen/KPLC Power Purchase Agreement

KenGen has a power purchase agreements (PPA) with KPLC. The tariff has a specific two-tier tariff structure as shown in Table 3 comprising of: Capacity charge used to recovers all capital and related costs (repayment of foreign and local loans, financing costs, and return on equity, taxes, depreciation and duties) which are based on target availability and the contracted capacity. The capacity charge is adjusted for the actual availability using the target availabilities specified in the PPA capacity of the plant and Energy charge used to recover all the variable operation and maintenance cost based on the energy generated by the plant.

Table 2.2: KenGen/ KPLC Power Purchase Agreement (PPA)

PPA	PLANTS	CAPACITY RATE (KSHs/KW/MONTH)	ENERGY RATE (KSHs/KWh)
Hydros	ALL	838.88202	0.02869
GEOTHERMAL	OLKARIA II	2,947.39	0.09409
KDP I	KDPI	1,174.15	0.28228
KDP III	KDPIII	1,593.65	0.76622
OLKARIA I	OLKARIA I	0.00	3.01256
SANGORO	SANGORO	0.00	6.51211
EBURRU	EBURRU	0.00	7.36558
WELL HEADS	WELL HEADS	0.00	USD 0.055*
ENERGY PPA	WANJII	0.00	7.3269
	SAGANA	0.00	7.3269
	SOSIANI	0.00	7.3269
	GOGO	0.00	7.3269
	GARISSA	0.00	9.88963
	LAMU	0.00	11.85697
	NGONG WIND	0.00	6.09125

The power supply and demand curve changed dramatically from the late sixty's to 2004/2005 when the demand surpassed the KenGen's effective capacity. Any forced outages and unplanned maintenances had no adverse effect in the power system stability. This has changed with adverse effect in the reliability of the power systems in such a way that any breakdown or unplanned outages causes major system instability which has sometimes lead to national blackouts. This has resulted to the poor image of the power sector.

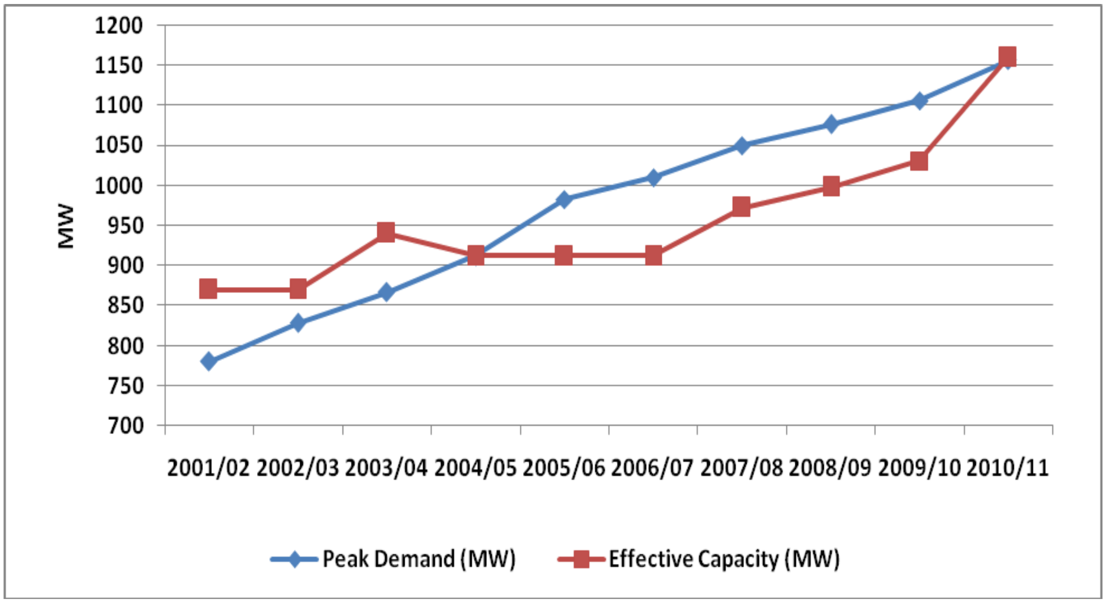

Figure 2.2: Peak demand vs KenGen's Installed Capacity (2001-2011)

KenGen provides low cost power to KPLC with the hydro and the geothermal plants being ranked highest in the economic order of dispatch. These operations and maintenance challenges compounded with the stringent PPA conditions has created a lot of demand on operation and maintenance managers in trying to contain the situation with the available resources to reduce the loss in revenue due to unavailability of plants and de-rating of power plants.

2.5 Operation and Maintenance Management

Visser (1998) modeled maintenance as a transformation process encapsulated in an enterprise system such as shown in figure 2. The way maintenance is performed will influence the availability of production facilities, the rate of production, quality of end product and cost of production, as well as the safety of the operation. These factors in turn will determine the profitability of the enterprise. As described from the systematic view of maintenance in fig. 2 herebelow, there are four strategic dimensions of maintenance (Tsang, 2002). The dimensions start with Service-delivery options which are related with the input some are labor, material, spares and external services. This explains the choice within the inside capability and outsourcing. The second and third dimensions are related to the design and selection of maintenance methodologies. The performance will play a major role on the output, in which some are productivity output, safety, maintainability and the profit of the whole enterprise. The last and final dimension is related to the support system which is explained as the design that is supporting maintenance (Tsang, 2002).

The cost of (parts) inventory is almost always an area where cost reduction can be substantial. With the help of suppliers and equipment vendors, purchasing usually can place contracts or service level agreement (SLA) that guarantee delivery lead time for designated inventory items. It just makes sense that your facility should shift the bulk of the cost of maintaining inventory to the suppliers.

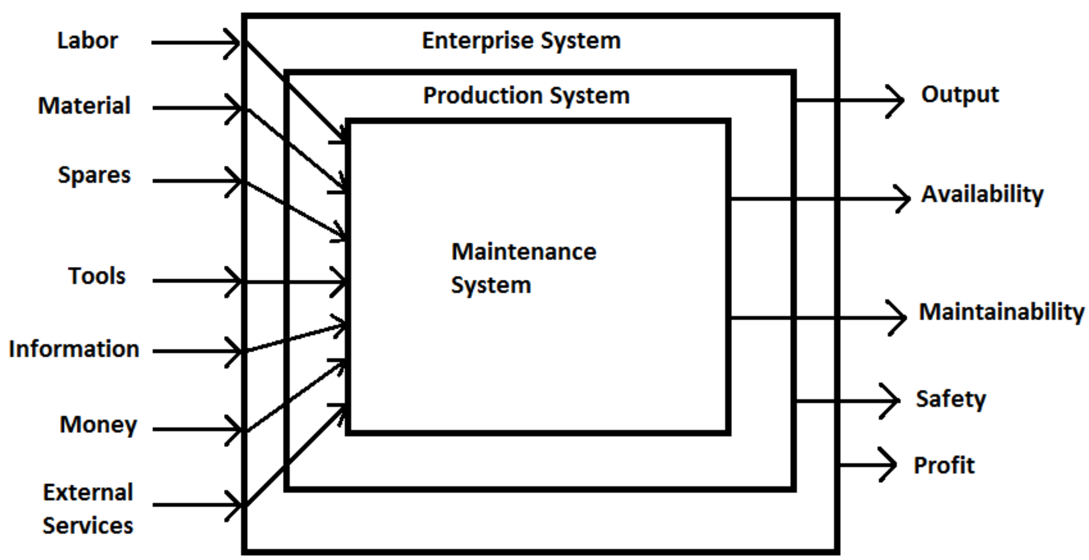

Figure 2.3: Conceptual Model

Source: (Input-output model of enterprise with respect to Maintenance (Al-Turki, 2011)

Reliability is the probability that an engineering system will perform its intended function satisfactorily (from the viewpoint of the customer) for its intended life under specified environmental and operating conditions. Maintainability is the probability that maintenance of the system will retain the system in, or restore it to, a specified condition within a given time period. Availability is the probability that the system is operating satisfactorily at any time, and it depends on the reliability and the maintainability. Reliability is basically a design parameter and must be incorporated into the system at the design stage. It is an inherent characteristic of the system, just as is capacity, power rating, or performance

Skills and training plays a major role in maintenance. Most of the work is normally carried out by Craftsmen and Technician/Foremen. Most of them have learned their skills on job trainee on the basis of watch and learn. However, with the expansion in mechanization and automation of machines structured technical training programs have been developed to upgrade the skills for the maintenance teams. This is critical for an effective maintenance practice. The competence of human resources in the maintenance department is considered an important factor in a successful maintenance program (Nakajima, 1988; Cholasuke et al., 2004; Kelly, 2006). Competence can be described as a combination of knowledge, skills, ability, willingness, interest and personal characteristics. Educational resources, which can include technical consultation as well as training, must be available and accessible to employees with identified needs (Tsang, 2002, Elsevier, 2009)

Performing a job task analysis (JTA) will help define the skill levels required of maintenance department employees. The JTA should be followed with a skills assessment of employee knowledge and skill levels. Analyzing the gap between required skills and available skills to determine the amount and level of training is necessary to close the gap.

Investment in maintenance is considered a very important factor for leveraging the value of industrial assets. It could be in people, training or technology. In spite of the increasing awareness of maintenance and its influence on both enterprises and society, maintenance is still considered just as an unpredictable and unavoidable expense, i.e. a necessary evil. This could be due to, among other reasons, the difficulty of seeing the impact of maintenance on companies' bottom-line results (Bob, 2007, Alsyouf, 2007). Every organization should set enough budgets for maintenance works and refurbishments. The amount provided has direct impact on the effectiveness of maintenance practices. In the power sector, there is normally enough funds allocated for planned outages, however, no allocation is set aside for breakdown maintenances. This at times results to prolonged outages as you seek for funds to facilitate procurement of any major equipment breaks down.

2.6 Main Approach in Maintenance

Several maintenance approaches, i.e. strategies and concepts, have been implemented by practitioners or suggested by intellectuals. Maintenance approaches and their development are discussed by many authors; see, for example (Moubray, 1991; Kelly, 1997; Mckone and Wiess, 1998; Dekker, 1996; Sherwin, 2000; Swanson, 2001;Tsang, 2002; Alsyouf, 2007). Usually, maintenance actions are aimed at minimizing failure and the consequences of failure of industrial plant, machinery and equipment as far as possible. These actions can take several forms such as breakdown maintenance, preventive maintenance (PM), i.e. replacing components at a pre-determined time using statistical models based on collected historical failure data, or condition-based maintenance (CBM) by monitoring the condition of the component using one (or more) condition monitoring (CM) techniques. However, in all cases, the decision maker needs to select from all the applicable maintenance approaches the right policy for each component, module or equipment. The identification and implementation of the appropriate maintenance policy will enable the managers to avoid premature replacement costs, maintain stable production capabilities, and prevent the deterioration of the system and its components. (See among others Williams et al., 1994) According to ISO/SS 13306 standards, maintenance approaches has been divided into two groups, such as Corrective maintenance and Preventive maintenance (Fig: 3). In practice, there are many combinations of these two approaches.

The corrective approach is further subdivided into immediate and deferred. The preventive maintenance has two subgroups such as Condition based maintenance and predetermined maintenance. This states that the preventive maintenance approach can be condition or time concerned. The preventive maintenance is proactive while the corrective maintenance is reactive form of maintenance. For all these approaches time plays an important role (Smith, 2002).

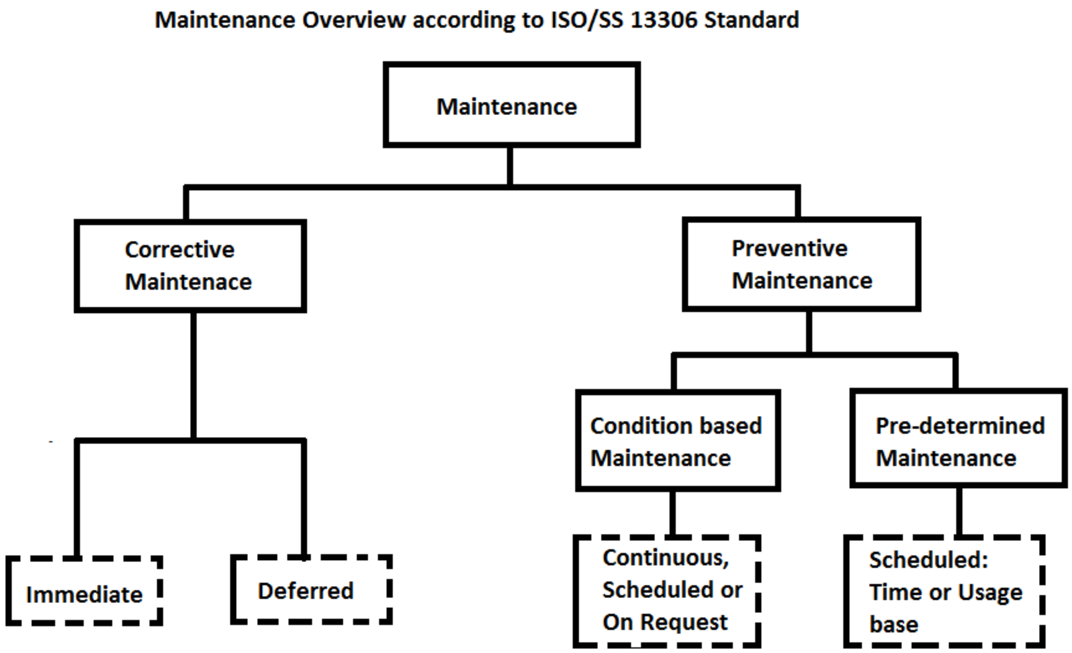

Fig. 2.4: Maintenance overview according to ISO/SS 13306 Standard

The corrective maintenance is defined as "Maintenance carried out after fault recognition and intended to put an item into state in which it can perform a required function." (SS-EN 13306, 2001, p.15). The cost of repairing the equipment is high as it is stopped unplanned. This type of maintenance will not be able to forecast the time when an item fails. (Starr, 2000) The best usage of corrective maintenance would be in places where predicting of failures is difficult. The preventive maintenance is defined as "Maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item." (SS-EN 13306, 2001, p.14). Planned actions carried out on the basis of time, production, machine which works for the extension of life period and also detects the failures. This process enables replacing or repairing based on the condition (Garg & Deshmukh, 2006).

The Preventive maintenance can be divided further as shown in Fig 3 into Condition based maintenance and Pre-determined maintenance. Condition based maintenance explained by Tsang in his paper on strategic dimensions of maintenance management as when preventive maintenance are carried in a scheduled basis there is an opportunity of over maintenance, monitoring the condition of an equipment on a regular basis allows performing preventive maintenance when a failure is probably going to take place (Tsang, 2002). The condition of equipments is monitored with the help of sensors which are placed in equipments (Wireman 1990).

The most widely used three condition based maintenance techniques which are capable of detecting a large variety of failures explained by AG Starr are as follows (Starr, 2000). They are monitored when the machines are running. The concept of vibration analysis is used for measuring the vibrations that are taking place in a machine and thus by analyzing. This helps to have a closer look at the condition of equipment and thus by performing the required actions. Monitoring wear, balance and alignment are calculated by the vibration analysis (Tsang, 2002). The concept of thermal analysis is used for identifying the faults which has occurred or going to happen. This analysis measures the temperature variations that are taking place in a machine which access the performance of the machine. This is best carried out when the machine is at its full capacity. The concept of lubricant analysis is based on the analysis that is carried on the lubricant. Starr in his paper on "A structured approach to the selection of condition based maintenance" identifies two major areas. The first is checking the condition of the lubricant and the second is the amount of debris that is carried by the lubricant. This can be carried out when the machine is running or shutdown depending on the procedure for sampling the oil.

2.7 Best Maintenance Practices and Performance

A study by Fernando and Gilbert (2009) revealed that the availability of a complex system such as a gas turbine is strongly associated with its parts reliability and a maintenance policy. That policy not only has influence on the parts repair time but also on the parts reliability affecting the system degradation and availability. Therefore the maintenance practices of any utility have a relationship to its plants availability performance.

Best maintenance practices are defined in two categories: standards and methods. Standards are the measurable performance levels of maintenance execution; methods and strategies must be practiced in order to meet the standards. The combination of standards with methods and strategies provides the elements of an integrated planned maintenance system. Achievement of the best maintenance practice standards (maintenance excellence) is accomplished through an interactive and integrated series of links with an array of methods and strategies. KenGen has a computerized maintenance management system by the name Plant Maintenance (PM) which is integral to the company's SAP system. All the maintenance work is captured on a work order. This includes planned/scheduled, corrective, emergency, etc. The work order is the primary tool for managing labor resources and measuring department effectiveness. The PM output provides maintenance, engineering, operations, supply chain and upper management with accurate and effective reports for evaluation and management. The following are types of reports and data tracking obtained from a PM includes: open work orders, closed work orders, mean time between failures (MTBF),cost per reports, scheduled compliance, plant maintenance overdue, labor allocation, spare parts demand and usage reports

KenGen has a SCADA (supervisory control and data acquisition) system installed and commissioned system in its Eastern Hydro and Turkwel power plants. This is a computer controlled systems that monitor and control industrial processes that exist in the physical world such as energy, telecommunications etc. The machines in these power plants are remotely operated and automatically controlled hence they are un-manned. Any faults occurring in these units are easily captured by the system, easing the troubleshooting process. During the data analysis, it will be interesting to see the impact on the maintenance costs after the SCADA system was commissioned

The standards for best maintenance practices according to (Smith, 2002) and (Frampton, 2013) include:

Table. 2.3 Benchmarks

Item	Description	Benchmarking
1	Percentage of a maintenance person's time is covered by a work order	100
2	Percentage of work orders are generated by preventive maintenance inspections and is planned	90
3	Percentage compliance of scheduled (programmed) work is met	90
4	Percentage of scheduled work is planned	90
5	Percentage of all work is preventive maintenance	30
6	% age of the required reliability level is reached 100 percent of the time	100
7	Spare parts stock-outs are rare	<1 month
8	Percentage variation of maintenance cost from budget	2%
9	Individual training program for maintenance team per year	>15days
10	Maintenance callouts per month	<2
11	%age of maintenance works assigned to maintenance team on daily basis	>65%
12	Availability of technical and historical data for any equipment	>95%
13	Compliant to occupational health and safety standard	100%

Table 2.4. Industry O&M metrics and benchmarks (NASA 2000)

	Metric	Variables and Equation	Benchmark
1	Equipment Availability	% = Hours each unit is available to run at capacity /Total hours during the reporting time period	> 95%
2	Schedule Compliance	% = Total hours worked on scheduled jobs / Total hours scheduled	> 90%
3	Emergency Maintenance Percentage	% = Total hours worked on emergency jobs Total hours worked	< 10%
4	Maintenance Overtime Percentage	% = Total maintenance overtime during period Total regular maintenance hour during period	< 5%
5	Preventive Maintenance Completion Percentage	% = Preventive maintenance actions completed Preventive maintenance actions scheduled	> 90%
6	Preventive Maintenance Budget/Cost	% = Preventive maintenance cost Total maintenance cost	15% – 18%
7	Predictive Maintenance Budget/Cost	% = Predictive maintenance cost Total maintenance cost	10% – 12%

It will be interesting to know to what extent KenGen Maintenance team follows the above standards in maintaining its installations.

The plants performance will be measured on availability and revenue generated. The above data will assist in establishing the gap in KenGen's maintenance practice to the world best maintenance practices and the improvement required to close up.

2.8 Summary

From the literature above, it's clearly evident that all maintenance practices falls under two categories of either preventive or corrective maintenance. This is regardless of whether its planned, breakdown or condition based types of maintenance. The maintenance adopted by any organization affects its performance on its plant's availability with financial implication. The case of KenGen's last two years 2011/12 and 2012/2013 revenue reports demonstrates that KenGen looses above 10% of its expected revenue for not meeting the availability and Energy sales threshold as stipulated in the PPA tariffs. This demonstrates the importance of the role played by maintenance function in an organization.

From the input-output model, the literature review reveals that maintenance does not only involve the technical staff but it's a contribution of all the other departments namely, Supply Chain for supply of spare parts and cordial relationship with the contractors, Human Resource for training of staff, Finance for budget support and prompt payment to suppliers, ICT for support of plant maintenance and SCADA systems, Top management for support of upgrading & refurbishment of old equipment and finally proactive attitude of all the staff.

Kenya's tariff has also been highlighted in the literature review and it has been compared internationally with Kenya recording a high cost in both domestic and industrial. Therefore, to find out the kind of maintenance practices carried out in KenGen, it's important to establish the existing maintenance programs &, compliance to the schedules, maintenance procedures, and utilization of the plant maintenance system (i.e. work orders management), availability of plants against set threshold, spare parts inventory, supply chain & finance efficiency, knowledge and training of staff, proactive culture, maintenance cost and profitability of the company. The above key maintenance practices when benchmarked with available best maintenance as highlighted by (NASA 2000),(Smith, 2002 and(Frampton, 2013), KenGen could enhance its reliability, profitability and competitive advantage if they could improve to meet these standards.

Ontario Power Generation is one of the largest producers of electricity in North America and operates 65 hydroelectric, 5 thermal and 2 nuclear stations producing more than 19,000 megawatts of electricity. Throughout 2012, the availability of Ontario Power Generations (OPG) in Canada remained at high levels of 91.4 percent (Ontario Power Generation, 2013).
In conclusion, the literature review will help the researcher in meeting the main objectives of the research namely: Identifying the maintenance practices at KenGen, benchmarking the maintenance practice with the world best, investigating the relationship between maintenance practices & profits and finally make recommendations on how to improve the maintenance practices at KenGen.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This chapter gives a detailed description of how the research was conducted. It contains the research design, target population, sample size, sampling procedure, research instruments, validity of research instruments, reliability of research instruments, data collection procedures and data analysis techniques.

3.2 Research Design

This is a case study of cross sectional nature which adopted a description research design. This design involved observations in identifying maintenance practices at KenGen, comparing them with world best and determining the influence it has on the plants performance. The primary data was collected to establish the maintenance practice current in place and they were compared with the world best. The data also helped in determining the relationship between maintenance practices with KenGen's performance in terms of plants availabilities. These two data helped in coming up with recommendations of improving maintenance practices and hence profitability.

3.3 Population of the Study

The population of study was drawn from Eastern Hydro, Geothermal and Thermal power stations in the company under review since they produce almost the entire company's power supply. Stratified random sampling method was used to select sample unit. According to (Riley & Wood, 2000), a sample of 25 percent of the population is adequate when the sampling frame is well stratified.

3.4 Data Collection

Both primary and secondary data was used in this study. The primary data was gathered through objective observations and survey. The main instrument for data collection was structured questionnaires that allowed for uniformity of responses to questions administered through email. Questions were constructed so as to address specific objectives and provide a variety of possible responses. The respondents included Operations Managers, Chief Engineers, Engineers and Technicians. The study targeted a sample population of 36 maintenance staff in all the three operational areas of a population of 150 staff. The distribution of the targeted population is given in Table 3.1 below.

Table 3.1. Target and Sample Population

	Operation Areas				
Designation	Hydro	Geothermal	Thermal	Target population	Sample population
Managers	3	2	2	7	3
Chief Engineers	7	3	2	12	7
Engineers	28	13	15	56	12
Technicians	50	10	15	75	14
Total				150	36

Source: Researcher Compilation

To establish the relationship between the maintenance practices and plants performance, secondary data was required. The secondary data like past studies, finance and operation's departments reports were utilized in this study. The data collected under this category were for a period not less than 5years. However, due to the difficult of establishing past detailed maintenance practices, the data captured on maintenance will be limited to costs on operations & maintenance and forced outages as a measure of maintenance practices.

3.5 Data Analysis

The study used quantitative method of data analysis. To ensure ease of analysis and minimize the margin error, the questions were coded according to each of the separate variables. Available data analysis tools and software packages were used to analyze the primary data. The statistical technique of regression analysis was specifically used to analyze the secondary data to determine the relationship between the plant availability against the plants breakdowns and operation and maintenance costs.. The raw quantitative data was keyed into the computer and analyzed using Statistical Package for Social Sciences (SPSS) program.

The findings of the study were presented by use of tables and graphs as applicable to convey the visual impressions of the meaning or to clarify information that may otherwise be hidden within the data. Study conclusions were based on the summary of the data analysis.

The model used in the study is given as:

$$Y = a + \beta_1 X_1 + \beta_2 X_2$$

Where β_1, β_2 = Correlation co-efficients

Y = Plants Performance in terms of availability

X_1 = Operation and Maintenance costs

X_2 = No of Breakdowns

CHAPTER FOUR: DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter presents data analysis, presentation and interpretation in terms of tables and following the three objectives of the study namely: to establish the maintenance practices at KenGen, to benchmark and evaluate the Practices with the world best maintenance practices and to determine the relationship between maintenance practices and plant performance in terms of availability and revenue generation

4.1.1 Response Rate

The questionnaires were administered to 39 plant maintenance staff of Hydro, Geothermal and thermal power plants at KenGen, Kenya, 37 of them responded. This translates to 94.87% response rate. This was as a result of administering the questionnaire through email and following up with requests through the phones. The entire return rate is statistically representative, therefore, enhancing generalization of the research results. The statistical results were triangulated with extensive literature to draw lessons learnt from other similar research works.

4.2 Demographic Characteristics of Respondents

This sub section describes the demographic characteristics of respondents who participated in this study. These characteristics include plant maintenance staff's age, gender, level of education, and years of service.

4.2.1 Age distribution of plant maintenance staff

This data represents data on the age of the plant maintenance staff surveyed.

Table 4.1: Age distribution

Age in years	Frequency	Percentage
<30	1	2.70
30-40	8	21.62
40-50	17	45.95
>50	11	29.73
Total	37	100.00

As shown in Table 4.1, 45.95 of the plant maintenance staff who participated in this study are aged between 40-50 years while 29.73% are above 500 years of age and 21.62% were aged between 30-40 years old. This is an implication that the staffs involved were well experienced. This was expected because of their senior level in management.

4.2.2 Level of Plant Maintenance Staff Gender Distribution of Plant Maintenance Staff

Table 4.2 section presents data on the gender of plant maintenance staff surveyed.

Table 4.2: Gender distribution

Gender	Frequency	Percent
Female	2	5.41
Male	35	94.59
Total	37	100

As shown on Table 4.2, of the 37 plant maintenance staff who participated in this study 2 of them, equal to 5.41% was female while 35 of them equal to 94.59% were male. There are fewer women than men as expected since this is an engineering profession which attracts very few women. A study conducted at University of Wisconsin – Milwaukee indicated than women comprise more than 20% of engineering school graduates but only 11% of the practicing engineers are women. This has been attributed to the perception of engineering as being inflexible of engineering work place culture as being non supportive of women (Nadya, 2011).

4.2.3 Education

Table 4.3 presents data on the education level of plant maintenance staff surveyed.

Table 4.3 Education level

Education	Frequency	Percent
Diploma/HND	17	45.95
Degree	16	43.24
Masters	4	10.81
Total	37	100.00

As shown on Table 4.3, of the 37 plant maintenance staff who participated in this study, 17 of them, equal to 45.95% had attained diploma or higher national diploma level of education, 16 of them equal to 43.24% had degree level of education and 4 of them equal to 10.81% had masters' degree. This indicates that the plant maintenance staffs have attained necessary technical skills.

4.2.4 Designation of the Plant Maintenance Staff

Table 4.4, presents a summary of findings with respect to the designation of the plant maintenance staff.

Table 4.4: Designation

Designation	Frequency	Percent
Manager	4	10.81
Chief Engineer	9	24.32
Engineer	13	35.14
Technician	11	29.73
	37	100.00

The distribution above is an indication that the respondents had pre-requisite knowledge, both technical and management.

4.2.5 Distribution of Respondents from the 3 areas of Operations

Table 4.5, presents a summary of findings with respect to the 3 areas of operations.

Table 4.5: Operational Areas

Area	Frequency	Percent
Geothermal	9	24.32
Thermal	11	29.73
Hydro	17	45.95
	37	100.00

As shown from table 11, of the 37 maintenance staff who participated in this study, 17 of them equal to 45.95% were from Hydro, 11 of them equal to 29.73% were from Thermal while 9 of them equal to 24.32% were from Geothermal. Hydro generation represents 50% of the national demand hence the high sample population in this area. This distribution indicates that all the areas were represented.

4.3 Main maintenance practices in KenGen

Table 4.6 addresses the objective of establishing the maintenance practices at KenGen.

Table 4.6: Scores on Maintenance Practices

VAR	Description	Frequency Yes	%age
1	Are you familiar with corrective based maintenance?	37	100
2	Are you familiar with preventive based maintenance?	37	100
3	Are you familiar with condition based maintenance	37	100
4	Are you familiar with Plant Maintenance module in SAP?	36	97.3
5	Does your plant have a maintenance procedure for all its equipment	35	94.59
6	Do you use the Plant Maintenances in management of your maintenance works	34	91.89
7	Is the maintenance procedures (checklist) followed during the maintenances?	34	91.89
8	Are the measured parameters during the maintenance works benchmarked to any known standard?	33	89.19
9	Does your station have an annual training plan for every maintenance staff?	21	56.76
10	Do you have a service level agreement for provision of spares with manufacturers?	5	13.51

As shown in table 4.6, all the respondents (100%) were familiar with the three types of maintenances (BD, CBM and PM) and over 90% of them use the plant maintenance software module in system applications products (SAP) in their maintenance management works. Equally, over 90% of the respondents use maintenance procedure & checklist in their maintenance activities and 89.19% indicating that measured parameters are benchmarked to known standards. The respondents were divided in the ratio of 21:16 on existence and non existence of an annual training program for the maintenance staff. However, majority (86.49%) of them indicated there were no service level agreements between KenGen and spare manufacturers or suppliers.

As mentioned in the literature review, KenGen upgraded its maintenance approach by introducing a plant maintenance software module in their SAP system to make operations more efficient. The high scores recorded on the respondent's awareness of maintenance practices and aspects of maintenances is a confirmation of establishment of good maintenance systems. However, the low score on service level agreement (SLA) with manufacturers was expected since its not common practice to find government organization having SLA in place and requires a major transformation initiative which may require time to be implemented. The respondents on training program were satisfactory which is an indication of existence of training but may not be sufficient.

4.3.1 Types of Maintenance approach used in KenGen Plants

Table 4.7 presents a summary of the findings with regards to the Types of maintenance approach used in KenGen plants.

Table 4.7 Maintenance Approaches

Type of	Hydro		Geothermal		Thermal	
Maintenance	Frequency	Percent	Frequency	Percent	Frequency	Percent
Corrective	1	5.88	1	11.11	1	9.09
Preventive	9	52.94	1	11.11	4	36.36
CBM Based	0	0.00	1	11.11	2	18.18
All	7	41.18	6	66.67	4	36.36
Total	17	100	9	100	11	100

As shown in table 4.7, a mix of the 3 types of maintenance approaches namely corrective, preventive and condition based maintenances scored high relatively high marks from the respondents of all the areas with Geothermal recording the highest score of 66.67%, followed by Hydro 41.18% and Thermal at 36.36%. Preventive maintenance was dominant in the Hydro plants recording a high score of 52.94% of their respondents.

As revealed from table 4.6 that maintenance practices which involves use of maintenance planning and procedures, this would explain the high respondents on preventive maintenance since these are the tools you require when carrying planned outages. A fully establishment of a CBM is a cost intensive exercise and the system is yet to be established in KenGen, this would explain the low score recorded on CBM. Corrective maintenance on the other hand is not popular and staffs are reluctant to disclose their weaknesses hence the low score under this aspect and high score in favour of the 3 approaches. Therefore, we can generalize that all the 3 types of approaches of maintenances are the most applicable in all the power generating plants with Hydro power plants having most of its approach being preventive maintenance.

4.4 Benchmarking KenGen's Maintenance Practices with World Best

Table 4.8 addresses the objective of benchmarking and evaluation of KenGen's maintenance practices with the world best.

Table 4.8: Benchmarking KenGen's Maintenance Practices with World Best

Var	Description	KenGen's Mean	Standard Deviation	Benchmark	% Variance
1	Plants Availability **BM(95**)	90.27	0.73	95	4.98
2	Percentage of daily work allocated to staff is preventive maintenance BM **(>65%)**	55.34	3.2	65	14.86
3	Variance between maintenance works and budgeted amount **BM (5%)**	5.93	0.53	5	(18.60)
4	Percentage of maintenance work carried by a work order **BM(100)**	73.43	3.87	100	26.57
5	Percentage of programmed work is done as scheduled **BM(90)**	60.49	3.05	90	32.79
6	Percentage of opened work orders that are closed in a month **BM(100)**	64.44	3.92	100	35.56
7	Percentage of work orders generated is planned before the outage **BM(90)**	57.49	3.85	90	36.12
8	Technical Training days to staff per year **BM(15)**	7.14	0.65	15	52.40
9	Percentage of total overtime against total maintenance time **BM (5%)**	9.86	0.84	5	(97.20)
10	Percentage of PM and CBM costs to the total maintenance cost **BM (15-30%)**	45.01	3.3	22.5	(100.04)
11	Callouts per month **BM(<2)**	4.27	0.46	2	(113.50)
12	Percentage of work orders generated by breakdown maintenances **BM(10)**	44.28	4.46	10	(342.80)

As shown in table 4.8, there were four parameters where the KenGen's maintenance practices variance against the world best practices were in the range from 26.52% to 36.12% close. These variables were percentage of maintenance work carried by a work order, percentage of programmed work is done as scheduled, and percentage of opened work orders that are closed in a month and percentage of work orders generated are planned before the outage.

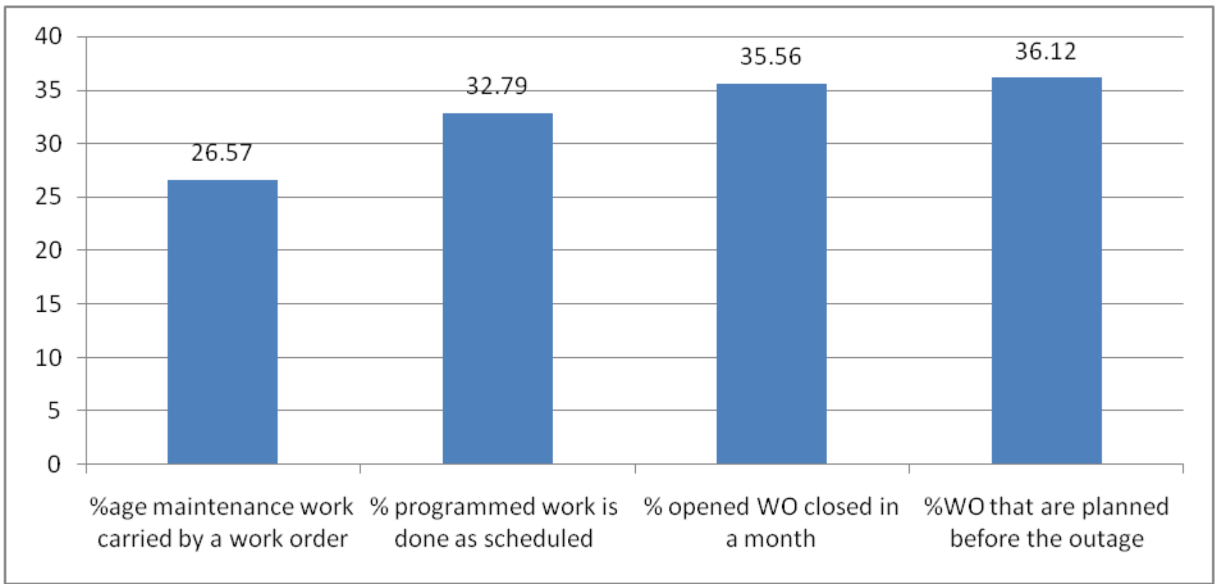

Figure 4.1: Variance against Benchmarks

All the four aspects of maintenance practices shown in fig. 4.1 involve use of plant maintenance software. The utilization of this software by maintenance staff has been low in the range of 55% - 65%, this can explain the big variance recorded when benchmarking them. There is an area of concern where the variances were extremely high as shown in fig 4.2 below.

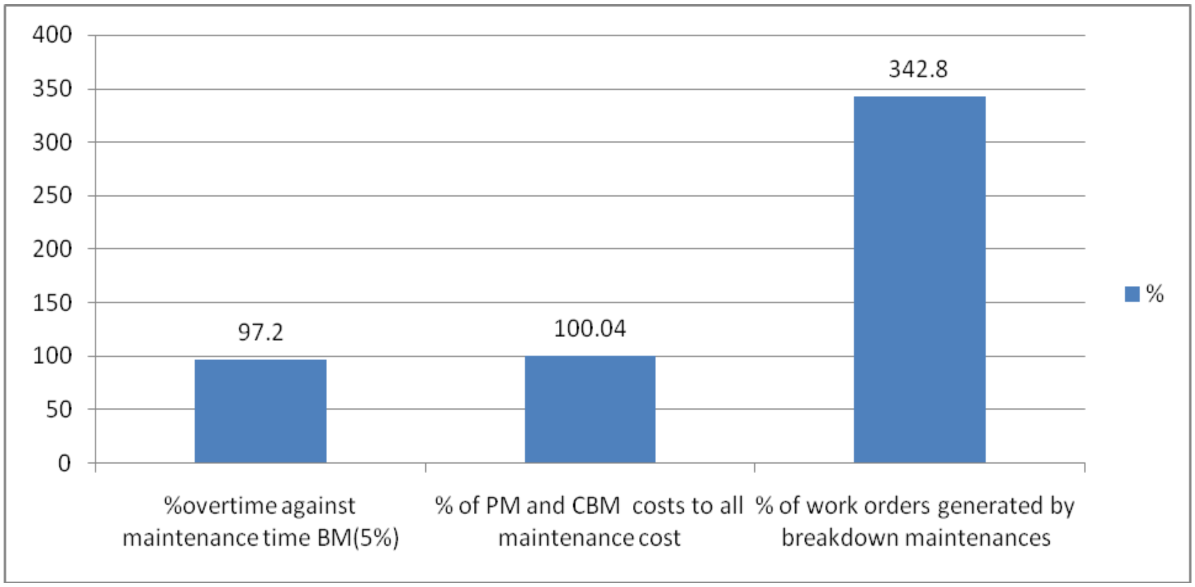

Figure 4.2: Maintenance Aspects

The figure 4.2 above compares maintenance aspects that are directly related to machine breakdowns measures the quality of the maintenance works done. With the highest score of 342.8% recorded on percentage of work orders generated by breakdown maintenances, the overtime and maintenance cost would also be expected to be high. This really compromises the reliability and quality of power. Comparatively, the plant's availability recorded the best performance of a small variance of 4.98%.

4.5 Relationship between Maintenance Practices and Plant Performance in Availability

This section presents secondary data on the relationship between independent variables namely O&M costs, unplanned maintenances and energy production cost (Ksh/kwhr) against the dependent variable availability which is a measure of the plants performance. The data collected covered Eastern Hydro (Hydro) Olkaria 1 (Geothermal) and Kipevu 1 (Thermal).

Table 4.9: Relationship between Maintenance Practices and Plant Performance in Availability

Eastern Hydro				
	Year	(A) Average Availability (%)	(B) Operating & Maintenance Costs (000,000)	(C) Number of Unplanned maintenances (breakdowns)
1	2005/06	93.43	777.37	63
2	2006/07	90.72	737.75	61
3	2007/08	88.27	866.76	84
4	2008/09	82.5	785.57	88
5	2009/10	77.05	1,449.52	108
6	2010/11	95.21	1,043.00	67
7	2011/12	86.86	1,234.00	86
8	2012/13	91.84	1,134.00	66

Table 4.10: Olkaria 1 (Geothermal) Data

Year	(A) Average Availability (%)	(B) Operating Costs (000,000)	(C) Forced Outages (Hrs)
2007/2008	96.41	131.8	615.47
2008/2009	92.69	123.4	294.9
2009/2010	94.3	143.9	384.88
2010/2011	78.45	129.9	1447.64
2011/2012	69.48	267.9	1631.19
2012/2013	96.43	301.8	575.52

Table 4.11: Kipevu 1 (Thermal) Data

Year	(A) Average Availability (%)	Operating Costs (000,000)	No. of Breakdowns
2008/2009	85.38	827.21	382
2009/2010	76.95	761.36	487
2010/2011	74.78	797.36	375
2011/2012	66.18	605	401
2012/2013	94.02	546	255

4.6 Regression Results

The model is of the form:

Table 4.12: Regression Results

Eastern

Eastern Hydro - Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	T	Sig.
1	(Constant)	113.976	4.638		24.575	.000
	OM	.004	.005	.159	.815	.452
	BD	-.379	.072	-1.029	-5.266	.003

a. Dependent Variable: AA

Model:

$$AA = 113.976 + 0.004\ om - 0.379\ bd + e$$

(4.638) (0.005) (0.072)

The numbers in the brackets represent the respective standard errors of the variables.

Testing for Statistical Significance

This is used to test the null hypothesis that the K[th] independent variable considered does not explain a significant amount of variation independent from variable Y; that is

$H_0: \beta = 0.$

$H_1: \beta \neq 0.$

The p value approach was used to test for the significance of the predictors. When P<0.05 we reject the null hypothesis and conclude the coefficient is different from zero and is therefore a significant predictor. The calculated p values for the variables Operation Maintenance, Break Down were 0.452 and 0.003 respectively. The test showed the following:

Operation Maintenance: 0.452>0.05 NOT SIGNIFICANT.

Break Down: 0.003<0.05 SIGNIFICANT.

Table 4.13: Olkaria 1 Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	102.279	6.024		16.978	.000
	OC	.006	.030	.046	.214	.844
	FO	-.019	.004	-.947	-4.427	.021

a. Dependent Variable: AA

Model:

$$AA = 102.279 + 0.006\,oc - 0.019\,fo + e$$

(6.024) (0.030) (0.004)

The numbers in the brackets represent the respective standard errors of the variables.

The calculated p values for the variables Operation Cost, Forced Outage were 0.844 and 0.021 respectively. The test showed the following:

Operation Cost: 0.844>0.05 NOT SIGNIFICANT.

Break Down: 0.021<0.05 SIGNIFICANT.

Table 4.14: Kipevu 1 - Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	101.047	31.473		3.211	.085
	OC	.028	.052	.325	.539	.644
	BD	-.108	.077	-.847	-1.402	.296

a. Dependent Variable: AA

Model:

$$AA = 101.047 + 0.028\, oc - 0.108\, bd + e$$

(6.024) (0.030) (0.004)

The numbers in the brackets represent the respective standard errors of the variables.

The calculated p values for the variables Operation Cost, Break Down were 0.644 and 0.296 respectively. The test showed the following:

Operation Cost: 0.644>0.05 NOT SIGNIFICANT.

Break Down: 0.296>0.05 NOT SIGNIFICANT.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the study, discussions and conclusions. The researcher then presents the major limitations of the study and the recommendations for both the research and for policy and practice.

5.2 Summary

The study found that the maintenance practices are well established in all KenGen's power plants with maintenance software in place to enhance it but it's underutilized. The main approach to maintenance was found to be mainly a mix of corrective, preventive and condition based maintenances in the entire organization with preventive maintenance being the dominant practice in Hydros. There were no spares contract between the organization and the manufacturers and the level of breakdown maintenances were found to be extremely high compared with world's best practices. The plants availability was the best performance on the benchmarked categories. The study further showed that the numbers of breakdowns in a plant have a profound effect on plants availability than operations and maintenance costs.

5.3 Discussions

The only major gap from majority of the respondents was lack of service level agreements which they indicated was lacking in their plants. On the comparison of KenGen maintenance practices to the world best practice, the best performance was recorded on the plant's availability which had the smallest variance of 4.98%. This was an indication of good overall plant performances. However the major concern was the high percentage of work orders generated for breakdown maintenance works which recorded an extremely high variance of 342%. This compromises the reliability and quality of the power generated and requires to be addressed.

There was a weak relation between O&M cost, number of breakdowns and the plant availabilities. This could be attributed to poor records of the expenses incurred during all the types of maintenances which should be well captured and differentiated.

5.4 Conclusion

From the study it can be concluded that KenGen has plant maintenance software in place which is under-utilized by their maintenance staff. Their maintenance practices compare well with the best world best but high variance in the percentage of breakdown works raises concerns on the quality of the maintenance work being carried out in the company. This leads into the conclusion that KenGen has implemented the methods and strategies aspect of maintenance practices but the standards of the maintenance execution are yet to be achieved. This agrees with the survey conducted in the industries in United States where it indicated that between 30% and 50% poor maintenance failure are due to maintenance personnel not knowing the basics of maintenance and that KenGen loses 13% of its revenue as a result of poor maintenance practices. There is therefore need for KenGen to develop and implement both preventive and corrective maintenance tasks that achieve maximum use of maintenance resources and the production capacity of the plants systems.

The relationship between plants availability and O&M costs and maintenance activities leads to the conclusion that maintenance practices has a direct relationship to the plants performance. It’s important that all the expenses incurred on maintenance works are well captured to help the management in realizing the benefits of good maintenance practices.

5.5 Recommendations

It is recommended that the major power generation company in this study enhances its maintenance practices to reduce the losses being incurred owing to the high breakdown maintenances being experienced in the power plants. The organization should undertake a quantitative survey to determine the actual impact of improving maintenances practices in terms of reduction in reliability of power and profitability of the organization.

The organization should start spare parts maintenance contracts with manufacturers, build internal capacities utilize well the plant maintenance software in place and introduce periodic proactive internal technical audits.

5.6 Limitation of the Study

The researcher encountered a challenge related to the research and particularly during the process of collection of the secondary data. The application of the 3 technologies (hydro, thermal and geothermal) of power generation was a big challenge in analyzing the secondary data for assessment of KenGen's performance as an entity. Lack of proper documentation of O&M costs made it difficult to establish the maintenance practices used during the periods of study.

5.7 Suggestions for Future Research

Arising from the study, the following direction for future research in maintenance practices are as follows. First, the study focused on KenGen and therefore generalization cannot adequately extend to other utilities. Future study should focus on other utilities including the IPPs who are believed to have an efficient system. A broad based study on the role of maintenance practices in both public and private organizations should also be carried out.

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APPENDIX I: ELECTRICITY BILL

APPENDIX II: QUESTIONNAIRE

Research Questionnaire for Plant Maintenance Staff

Instructions

Please answer the questions to the best of your knowledge

Write your responses in the space provided

Please put a tick (√) where appropriate.

Section A: Background Information

1. What is your age group?

   Below 30: ( ) 30-40 yrs: ( ) 40 – 50 yrs: ( ) Above 50yrs( )

2. What is your gender?

   Female: ( ) Male: ( )

3. What is the highest level of education you have attained?

   a. High school or equivalent: ( )
   b. Certificate: ( )
   c. Diploma/ higher diploma or equivalent: ( )
   d. Degree: ( )
   e. Masters: ( )
   f. Doctorate: ( )

4. What is your designation?

   a) Manager

   b) Chief Engineer

   c) Engineer

d) Technician

Section B: Main Maintenance Practices in KenGen

	Yes	No
5. Are you familiar with corrective based maintenance?		
6. Are you familiar with preventive based maintenance?		
7. Are you familiar with condition based maintenance		
8. Are you familiar with Plant Maintenance module in SAP?		
9. Do you use the Plant Maintenances in management of your maintenance works		
10. Does your plant have a maintenance procedure for all its equipment		
11. Is the maintenance procedures (checklist) followed during the maintenances?		
12. Are the measured parameters during the maintenance works benchmarked to any known standard?		
13. Does your station have an annual training plan for every maintenance staff?		
14. Do you have a service level agreement for provision of spares with manufacturers?		

15. Which type of plant maintenance is more used in your plant?

Corrective or Breakdown ( ) Preventive: ( ) Condition based: ( ) All ( )

Section C: Benchmarking Maintenance Practices with World Best Practice

16. What is the average number of work orders generated within a month? ………………..

17. How many of these work orders are closed within the month? …………………..

	0-20	**21-40**	**41-60**	**61-80**	**81-100**
18. What percentage of your maintenance work is carried out by a work order? **(100)**					
19. What percentage of the work orders are generated by breakdown maintenances?(**10)**					
20. What percentage of the work orders in (15) above is planned (labour, materials, checklists etc) before the outage? **(90)**					
21. What percentage of programmed work is done as scheduled without any delay due to lack of outage, materials etc (monthly, quarterly, annual maintenances) **(90)**					
22. What percentage of the work allocated to the maintenance team on a daily basis is preventive maintenance? **(>65)**					
23. What is the estimate of the %age of the preventive and condition based maintenance to the total maintenance cost **(15-30%)**					

24. What is the percentage of the time spent on overtime against the total maintenance time**? (Less than 5%)**

    0- 5( ) 5-10 ( ) 10-15( ) 15-20( ) more than 20( )

25. How many times are you called within a month to attend to unplanned work after working hours? **(2%)**

    0-2 ( ) 3-5 ( ) 6-7( ) 8-10( ) more than 10 times ( )

26. What is the variance between maintenance works and the budgeted amount? **(2%)**

    0-2 ( ) 3-5 ( ) 6-7( ) 8-10( ) more than 10% ( )

27. What is your plants average percentage availability for the financial year 2012/2013? **(More than 95%)**

Less than 80 ( )   80-85 ( )   85-90( )   90-95( )   more than 95% ( )

28. In your annual training plan, how many days are maintenance staffs offered technical training related to their maintenance work per year? …………………days. **(15days)**

	Year	Average Availability (%)	Operating Costs (000,000)	Generated Units (Gwhr)	Number of breakdowns or forced outages
1	2005/06				
2	2006/07				
3	2007/08				
4	2008/09				
5	2009/10				
6	2010/11				
7	2011/12				
8	2012/13				