

**ANALYSIS OF FACTORS AFFECTING THE QUALITY OF POWER
SUPPLIED TO MANUFACTURERS IN KENYA.**

BY

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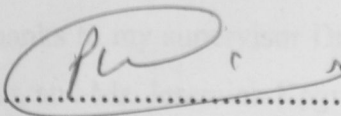
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DECLARATION

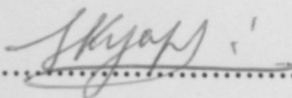
This research project is my own original work and has not been presented for a degree in any other college, institution or University.

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ABSTRACT

DEDICATION

This work is dedicated to my wife Esther, sons George, Antony and Ian Gitura for their support and patience during the course of this study.

The findings of this study were that voltage surges and voltage dips were very frequent. Voltage level was found to be mostly outside the acceptable range. Most manufacturers reported damage to equipment and revenue loss due to these factors. On the other hand, though power rationing was considered to have very severe impact on business, its occurrence was rare and hence this factor had little effect on business. Frequency variation and harmonics were not frequent, with many manufacturers stating that they did not notice these two factors.

The study also found that for 54% of respondents, electricity cost accounted for between 10 – 30% of production costs. This implies that the cost of electricity was significant in determining the final product cost. The results show that KPLC was slow in responding to breakdowns.

In summary, the quality of electricity supplied to manufacturers was found to be poor, specifically in the areas of voltage variation, voltage dips, voltage surges and response to breakdowns.

The study recommended that KPLC carry out further investigations to establish the cause of the numerous voltage dips, voltage surges and voltage variation and take corrective action. The study also recommended that manufacturers install power quality analyzers in their firms to monitor the various power quality parameters so as to make informed decisions that will help to improve production efficiency. This can be done at least level where possible or by initiating the necessary communication with KPLC for power quality improvement. There is also need for KPLC to improve on response to breakdowns.

ABSTRACT

This study was aimed at analyzing the factors that affect the quality of power supplied to manufacturers in Kenya. Specifically, the study sought to establish which of the various factors that define power quality were significant and the impact such factors had on the manufacturers business. Survey research method was used in this study. The population comprised of the 512 members of the Kenya association of Manufacturers, from whom a convenient sample of 50 members was taken.

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ABBREVIATIONS AND MEANING OF TERMS

- (i) **Power Quality:** Good power quality is characterized by supply of electricity which is reliable, having very few interruptions, very few incidences of voltage dips and surges and very little harmonic distortion within the declared limits.
- (ii) **Power interruption:** Unplanned power outage due to sudden disconnection of power supplies without prior warning, usually as a result of faults in the power supply system.
- (iii) **Voltage Surge:** A sudden voltage rise above normal. If severe, it can cause plant stoppage or damage to equipment.
- (iv) **System frequency:** This is a measure of the speed of the generators connected to the power system. In Kenya, the nominal frequency is 50Hz (hertz). Various manufacturing equipment require the frequency to be stable over defined limits, for proper operation. The Electric Power Act 1997 permits variation of 2% below and above the nominal 50HZ.
- (v) **Voltage dip:** A sudden voltage drop followed by recovery. The duration is from a few milliseconds to about a second. If severe, it has the effect of disrupting production, as motor drives and other control devices are unable to function if the dip magnitude and duration exceed the limits for these devices.
- (vi) **Power Rationing:** Supplying electricity in quotas to customers, due to inadequate generation or transformation. It can have severe economic consequences and sometimes has led to closure or relocation of business.
- (vii) **Harmonics.** This is the existence of other frequencies in the power supplies other than fundamental frequency of 50Hz. Harmonics are mainly caused by

non-linear customer loads like UPS, arc-welding, inverters, switched power supplies among others.

- (viii) Trip: Automatic isolation of a power plant (e.g. generator) from the rest of the power system when a fault is detected within the power plant.
- (ix) KPLC: The Kenya Power & lighting Co. Ltd.
- (x) KenGen: Kenya Electricity Generating Company.
- (xi) IPP: Independent Power Producers.
- (xii) ERB: Electricity Regulatory Board: This is a government body mandated to set rules and regulations that govern the generation and distribution of electricity in Kenya. The rules govern all participants in the electricity sub sector.
- (xiii) The Distributor: refers to Kenya Power & lighting Co. Ltd, the sole licensed electricity distributor in Kenya.
- (xiv) COMESA Common Market for Eastern and Southern Africa.
- (xv) SADC: South African Development Community. This is a trading bloc with membership from Southern Africa states.
- (xvi) MW: Megawatts. This is a measure of instantaneous energy.
- (xvii) Kwhs: Kilowatt hours; This the unit of measure of electrical energy
- (xviii) GWhs: Gigawatt hours (equal to 1,000,000 kilowatt hours).
- (xix) UETCL: Uganda Electricity Transmission Company Ltd.
- (xx) UEDCL: Uganda Electricity Distribution Company Ltd.
- (xxi) LCDP: Least cost Power Development Plan. A power development plan for Kenya initiated by KPLC.

1.0 CHAPTER ONE: INTRODUCTION

1.1 Background.

Kenyan manufacturers are increasingly facing stiff competition from foreign products both in the domestic and in the export market. In the domestic market, numerous foreign products that include sugar from Brazil, rice from Pakistan, textiles from China and electrical products from Korea are to be found in local supermarkets and many other outlets. In addition, Kenyan exports must compete for customers with products manufactured in many different countries including host countries. In October 2005, Kenya Association of Manufacturers (KAM) noted that 14 factories had been closed down during the previous one year, and 7,000 workers retrenched as a result of competition from China (www.ipsnews.net). In Sudan, Kenyan cement that was retailing at Kshs5000 per tonne was reported to have been edged out by competition from Egypt and Indonesia, whose cement retailed at Kshs4,000 per tonne (www.eastandard.net, March 5, 2006).

Though many factors determine customers' preference to certain products over others, price is a major determining factor, especially for mass produced consumer goods. The competition is even stiffer from COMESA countries, where internal tariffs are zero or near zero for member countries (www.comesa.com). The East African Customs Union, made up of Kenya, Uganda and Tanzania, came into effect in January 2005 and provides for free movement of goods and services as well as labour within the Region. It also stipulates Common External Tariffs (CET) for member countries (www.eac.int, July 2006). This will no doubt increase competition among manufacturers in member countries as goods freely move from country to country with more or less equal opportunity in the market. Kenya also faces competition from countries with superior technologies and those with advantage of economies of scale supported by their large populations, like China and India.

It is therefore necessary for Kenya to carry out critical analysis of the various factors that determine competitiveness of her products. In this respect, factors of production in the various manufacturing sectors need to be analyzed so as to understand how each factor

impacts on the final product cost. It would then be possible to develop national strategies that improve or modify the identified factors in order to lower the overall production cost of goods.

Several theories have been advanced to explain and enhance understanding of International trade, among these being the Mercantilist theory, the theory of absolute cost advantage, theory of comparative cost advantage, factor proportions theory, neo-factor proportions theory, country similarity theory and national competitive advantage theory.

In their contribution on this subject, two Swedish economists Eli Heckscher and Bertil Ohlin developed the factor proportions theory also known factor endowment theory in 1919. This theory explains that different countries are endowed with varying proportions of different factors of production (Sharan, 2003). A country with an abundant supply of one resource will produce at relatively lower cost, those goods that require this resource in significant quantities. For example labour intensive goods will be produced at a lower cost by that country that has abundant supply of labour. If a product requires a large amount of electricity in its production, then countries with abundant and cheap electricity will have a competitive advantage as they will be able produce that product at a relatively lower cost.

This study looked at electricity as one of the factors of production in Kenya. The study sought to establish the quality of electricity supplied to manufacturers in Kenya and how such quality affected the production costs and hence the final product cost. Poor power quality may not have identical effect on all manufacturers, as production processes, quantity of power and pattern of consumption differ from one manufacturer to another, but it can however cause a general rise in production costs and hence make Kenyan goods less competitive in the global market. Whereas the unit price of electricity is very important to a manufacturer as it affects the final price of manufactured products, the quality of such electricity is equally important for manufactured goods to be competitive, as every aspect that contributes to poor quality also contributes to additional costs for the final product. Programmed power interruptions or rationing, short interruptions due to breakdowns, power surges and voltage dips are all indicators of poor quality and have been witnessed in Kenya to various degrees. Unstable power supplies tend to have

varying negative effect on different production lines, and the quality of the final product will vary similarly.

Transmission and distribution of electricity over long distances is not without challenges. Power-lines are prone to weather related disturbances like lightening storms. Heavy rains and strong winds can bring down power lines. The resultant interruptions and voltage surges contribute to poor quality of electricity received by the end customer. Rapid growth in some cities result in overstressing and overloading of power-line equipment, which can result in low voltage or equipment failure and hence a power outage.

Good power quality is defined by several factors. Among these is that power supply is continuous without unplanned interruptions, voltage is stable and within defined limits and that there are no sudden voltage surges or dips in the supply. Absence of harmonics is also another indicator of good power quality. Planned interruptions should be very few, say up to 3 in one year period. Frequency variation should not exceed 2.5% below and above the nominal 50herz, as specified in the Electric Power Act 1997. Power rationing is an indicator of poor quality as the supply is inadequate to meet customer's demand.

A power quality problem exists if the power supply deviates significantly from the ideal. For example low or high voltage, exceeding the declared limit of 6% (Electric Power Act 1997), can cause a manufacturing plant to shut down as motor drives stall and controls become erratic. Similarly, a voltage surge can cause damage to electronic control equipment resulting in plant shut down (Alstom 2002). The repair time of such equipment increases the plant downtime adding to the overall cost of production. A voltage dip can cause control devices to drop out while electronic devices will malfunction and result in plant shutdown. The presence of harmonics in the power supply system causes overheating of transformers, erratic behaviour of electronic devices as well as interfering with electrical measuring devices. According to reports in the media and elsewhere, the most common power quality problem appear to be unplanned power interruptions. Power interruption causes work stoppage at the manufacturing plant. Sudden stoppage of plant results in spoilage; semi processed materials, which have to be scrapped, as the process has to be restarted afresh. The cost of idle labour and machine hours only helps to increase the cost of production. Even when supply is restored, some

plants have very high lead times as the intricate processes are started step by step and this can take several hours before full production is achieved. Overall, power interruption has the effect of reducing the production per month resulting in higher production cost per unit. As a firm will not change its selling price month by month, it means that profitability is greatly eroded. Interruptions and voltage surges impact on the quality of the final product, again reducing the competitiveness of such a product.

Manufacturing firms are not only concerned with the price of electricity but also its quality. Electricity in Kenya is perceived by many industrialists to be unreliable with many incidences of interruption and voltage fluctuations. Customers have also complained of voltage dips and voltage surges that cause damage to customer equipment, spoilage and expensive downtime.

1.2 State of Electricity in Kenya.

Electricity in Kenya consists of 70% hydro-generation, mainly from the Seven Forks dams of Masinga, Kamburu, Gitaru, Kindaruma and Kiambere, as well as the Turkwell Gorge power Station. The remainder is thermal generation using steam turbines and diesel plants at Kipevu and Nairobi, while geothermal is concentrated in Olkaria. A small proportion is imported from Uganda. The relatively high proportion of hydropower means that the availability is highly vulnerable to climatic conditions. In contrast, 89% of electricity in South Africa is produced from coal (mbendi.co.za), hence the availability is very high, as unlike water, coal availability does not change with climatic changes. In Kenya, dry periods mean low water levels in the dams, which means reduced hydropower capacity that often results in power rationing. The worst rationing case of was recorded in the year 2000 after prolonged drought. During this period, hydro generation dropped from 3274GWhs in 1998/99 to 1,325GWhs in 2000/01, corresponding to a 60% drop in output (KPLC Annual reports: 1999 and 2000). A 100MW emergency diesel generation plant that was installed in Nairobi helped ease the situation, but still this was not adequate to stop the power rationing and heavy losses were incurred by industry, with some operating at half capacity while some closed down with loss of jobs.

Kenya Power & Lighting Co Ltd (KPLC) is the sole distributor of electricity in Kenya, handling transmission and distribution of electricity. The Electricity Regulation Board, ERB was established by the Electric Power Act 1997, and is the electricity regulator on behalf of the government. KPLC purchases bulk power from the producers, namely, Kengen, Iberafrica, Tsavo Power and Orpower. Kengen is 70% owned by the government of Kenya with 30% public ownership, while Iberafrica, Tsavo Power and Orpower are independent power producers (IPPs). Kengen produces over 70% of all energy generated in Kenya, while the other private companies together contribute 30%. About 30MW of the over 900MW demand is imported from Uganda. Electricity is transmitted from the generating stations at 220kilovolt (KV) and 132 kilovolt levels. Distribution is done with 66KV, 33KV, 11KV and 415volts lines. Transmission lines are 3358 km in total length, while the distribution lines of various voltages are 21898 km in total (KPLC Annual Report, 2004).

Industrial and commercial customers consume about 60% of the electricity produced in the country, while domestic customers take up the rest. Panpaper, Bamburi Cement, East African Portland Cement and Mabati Rolling Mills, are among the large consumers of electrical energy

The average annual growth rate in electricity demand has been about 6% from 2001 to 2005 (KPLC Annual Report 2004). The growth rate has been higher in urban areas because of higher residential growth. High demand growth results in overstressing of existing electrical equipment and this often results in equipment failure due to overloading leading to power interruptions.

Over the years, manufacturing firms have expressed concern over the high cost and low reliability of electricity in Kenya. They have called on the government to do something about availability and frequent breakdowns as this has resulted in increased costs of doing business. KPLC customers reported breakdown incidences in the range of over 10,000 per month in 2004 (KPLC Annual report, 2004).

Other than complaints of high tariff, electricity reliability and overall quality has been of major concern to business community, with many businesses complaining of unplanned outages, occurrence of voltage surges and dips all which result in heavy losses being incurred by the business firms. For these reasons, electricity in Kenya is perceived to be

unreliable and expensive (NEWS AND TREND AFRICA-www.gasandoil.com). Among the reasons cited for high electricity costs are; ineffective power purchase agreements that lead to high tariffs, inefficient utility management, inadequate maintenance of the distribution system and a wasteful procurement system.

1.3 Statement of the problem.

Over the past several years, manufacturing firms and the service industry have expressed concerns over the quality of electricity supply in Kenya. They have complained of frequent interruptions, power rationing, voltage dips and surges. The number of power interruptions reported in Kenya was 10,000 per month as of February 2004 (The East African: February 23rd 2004). Losses due to these interruptions ranged from damaged television sets and refrigerators for domestic customers, while manufacturing firms like cement, steel and paper industries lose millions of shillings arising from loss of production, idle labour, damaged raw materials and semi-finished products due to stoppage. In its editorial, the Coast Express accused Kengen and KPLC of being arrogant because of the frequent and unexplained power outages throughout the country. It went on to state that electronic equipment worth millions of shillings had been lost due to power surges (www.nationaudio.com/News/CoastExpress). Some firms have been forced to install expensive equipment including generators to remedy these problems. It has also been reported that power surges and dips have resulted in damage to electronic equipment, causing longer outage in the manufacturing plants. KPLC was losing over Kshs 1 billion annually due to illegal connections (East African Standard: May 20th 2005). Illegal connections cause instability, overloading and short circuits, which eventually lead to blackouts. In Nigeria, over 350 industrial firms were forced to close down due to persistent power blackouts (www.odsyn.com/news). The argument from these pronouncements is that the quality of electricity in Kenya is poor and this results in high costs of manufacturing causing Kenyan products to be relatively more expensive and hence uncompetitive within the region and beyond. Poor quality electricity also affects the overall quality of manufactured products, reducing further the competitiveness of such products. From the point of view of businessmen and

manufacturers, the many interruptions, power surges, voltage dips, frequency variation, power rationing and harmonics are indicative of the poor quality of electricity in Kenya. This study therefore aims to find out which factors affect the quality of power. It will also be of interest to find out the relative significance of these factors and how such factors affect the production costs of manufacturing firms in Kenya.

1.4 Research Objectives.

The major objective of this study was to establish the significant factors that affect electrical power quality in Kenya and how such factors affected production costs for manufacturing firms.

The specific objective was to find out to what extent the following factors affected the power quality in Kenya:

- (i) Availability: To find out to what extent power is available when required and in the quantities required and the impact of power rationing to business when such rationing occurs.
- (ii) Power interruptions: To find out the frequency of unscheduled power interruptions as mainly caused by power equipment breakdowns and the impact to business of such interruptions. Such interruptions normally last from a few minutes to several hours.
- (iii) Low Voltage: To find out the frequency of low voltage incidences and the impact to business of such incidences.
- (iv) High Voltage: To find out the frequency of high voltage incidences and the impact to business of such incidences.
- (v) Voltage Surges: To find out the frequency of voltage surges and the impact to business of such incidences.

- (vi) Voltage Dips: To find out the frequency of voltage dips and the impact to business of such dips.
- (vii) Frequency: To find out how often we have incidences of high or low frequency above and below 2.5% of 50Hz and the impact to business of such incidences.
- (viii) Harmonics: To find out how often we have harmonics above 10% of the normal current and the impact to business of such incidences.

1.5 Importance of the study.

This study will be useful to the following:

- (i) The Government in developing economic plans and strategies for the country. It will assist the government in developing and implementing power generation plans to ensure adequate and reliable electricity at all times to match projected growth.
- (ii) Electricity generating companies. Generating companies can use the study to evaluate and optimize their operations towards improved availability and reliability of electricity.
- (iii) Electricity Distribution Company. The Distributor can use this study as an input to help optimize company operations and procedures so as to enhance efficiency, improve maintenance and reduce wastage of resources so as to supply continuous electricity of the expected quality. It can also be used as an input for further investigation into power quality issues.
- (iv) Business firms. This study will help the business firms to better understand the supplier and what goes into production and distribution of electric energy. They will be in a better position to understand the factors that impact on the power quality and possible impacts on business, and hence can make informed decisions.
- (v) Research Institutions and academia. This can be a useful input for further studies on the same or related topic.

- (vi) General public. Increase in awareness about the conditions prevailing in the electricity sub-sector and the issues relating to power quality.

The study will assist stakeholders to develop strategies that will improve electricity availability and ensure that the supplied electricity meets the minimum requirements of acceptable quality. The business community will be able to participate in defining the parameters that define acceptable quality. If quality is enhanced, then the hidden business costs of power rationing, unplanned outages, voltage surges and dips will be minimized.

1.6 Scope and Limitations of the study.

The scope of this study covered manufacturing companies. Not all business firms were studied.

Limitations: This study was limited to quality aspects of electrical power supplied to industry.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Manufacturers in Kenya are today faced with increased competition from across the world, and have to continuously revise their strategies in order to stay in business. Even firms that are not in the export business have to face competition locally from imported products. They have to continuously research and evaluate the factors that determine customers' preferences for the various products. The overall cost of production is a major determinant of the final selling price, especially for mass produced goods. Hence the various inputs into a production process must be analyzed to establish how each input can be optimized to achieve maximum efficiency. This is necessary if Kenyan goods are to remain competitive in a global market.

2.2 Theories of International trade

Several theories have been advanced to explain and enhance the understanding of International trade. Among these theories is the Mercantilist theory, the theory of absolute cost advantage, theory of comparative cost advantage, factor proportions theory, neo-factor proportions theory, country similarity theory and national competitive advantage theory.

2.21 Mercantilist theory

Mercantilism came into existence in the period from 1500 to 1750. It refers to a collection of similar attitudes toward domestic economic activities but cannot be classified as a formal school of thought (Appleyard and Field, 1998). According to Wikipedia encyclopedia, mercantilist ideas were the dominant economic ideology in all Europe in these times, with England and France playing a dominant role. Mercantilist held the view that national wealth was reflected in a country's holding of precious metals. It was also believed that one country's economic gain was at the expense of another. Acquisition of precious metals was seen as the means of increasing wealth and became the main focus of emerging states. Mercantilist also held that a strong army, strong navy and productive economy were critical to increasing the power of a nation. Manufacturing, rural sector and colonies were seen as the three sectors that controlled the economic system. Labour was identified as being the most critical factor of production. Mercantilist held that it was important for a country to strive to have more exports than imports so as to maintain a positive balance of trade. The use and exchange of precious metals was controlled by individual governments. Countries made every effort to prohibit the export of gold, silver and other precious metals (Appleyard and Field, 1998). The mercantilist theories were challenged by Adam Smith, who saw a Nation's wealth as being reflected in its productive capacity and not in the holding of precious metals.

2.22 The theory of absolute cost advantage,

The theory of absolute cost advantage was advanced by Adam Smith in 1776. He was of the opinion that productive efficiency among different countries differed because of diversity in the natural and acquired resources possessed by those countries (Sharan, V, 2003). The difference in natural advantage is manifested in varying climate, quality of land, availability of minerals, water and other natural resources. The theory concludes that a given country should specialize in producing those goods that it can produce with greater efficiency, hence at lower cost, and exchange those goods with goods of their requirements from a country that produces them at a lower cost. This then leads to greater utilization of resources in both countries. This theory explains how trade helps increase the total output of two countries. Hence, according to Smith, countries should specialize in and export those goods in which they had absolute advantage (Appleyard and Field, 1998). In most of English speaking countries, Adam Smith's refutation of mercantilism was widely accepted but rejected in the United States by leading figures including Abraham Lincoln (en. Wikipedia.org/wiki/mercantilism).

2.23 Theory of comparative cost advantage

David Ricardo advanced the theory of comparative cost advantage as an improvement of the theory of absolute cost advantage (Sharan, V, 2003), quoting from Haberler, (1950). Ricardo focuses on relative efficiency of the countries for producing goods. In a two-country, two-commodity model, he explains that a country should only produce those goods that it is able to produce more efficiently. Sharan, V, (2003) notes that the theory suffers from several limitations. First it only considers one factor of production; labour, ignoring other factors as encountered in real world. The theory assumes full employment which is never the case. The theory also assumes that resources are mobile domestically and immobile internationally. This is not correct as labour and capital move slowly across nations. However, the theory holds in so far as it suggests how a country could achieve the consumption level beyond what it could achieve in the absence of trade.

2.24 Factor proportions theory

In their contribution towards the understanding of International trade, the two Swedish economists Eli Heckscher and Bertil Ohlin developed the factor proportions theory also known factor endowment theory in 1919 (Sharan, V, 2003). In a two-country, two-factor, two-commodity model, this theory explains that different countries are endowed with varying proportions of different factors of production. For example a country like China has a large population with large labour resource, while Japan has abundance of capital and short of labour by comparison. A country with an abundant supply of one factor will produce at relatively lower cost, those goods that require this resource in significant quantities. For example labour intensive goods will be produced at a lower cost by that country that has abundant supply of labour. If a product require a large amounts of electricity in its production, then a country with abundant cheap electricity have a competitive advantage as it will be able produce those goods at a relatively lower cost. The Factors proportions theory was refined by Samuel, (1948,1949). He considered the effect of trade upon national and the prices of factors of production (Sharan, V, 2003). He was of the view that the effect of free trade among nations would be to increase the overall welfare by equating not only the prices of goods exchanged but also the prices of factors of production. For example, in a case of two countries, A and B, country A with abundant labour and country B with abundant capital. Labour will be relatively cheap in the first country while capital will be cheaper in the former. But after trade, more capital intensive goods are produced in country B and more labour intensive goods will be produced in country A. As a result, price of capital will increase in country B while wage level will increase in country A.

The factor proportions theory was put to test by Leontief in 1954 and came to a paradoxical conclusion. He found out that USA, which was the most capital abundant country at that time, exported labour intensive goods and imported capital intensive goods. This result was thereafter known as the Leontief Paradox as it contradicted the expected outcome.

There were several explanations of the Leontief paradox. The Linda hypothesis was proposed by economist Staffan Linda in 1961 as a possible resolution to leontief

paradox. Linda hypothesis holds that nations with similar demands would develop similar industries. These countries would then trade with each other with similar but differentiated goods (en.wikipedia.org/wiki/Linda_hypothesis). The hypothesis presents a demand based theory of trade in contrast to the usual supply based theories involving factor endowments.

2.25 Neo-factor proportions theory

Some economists emphasize the point that it is not only the abundance or scarcity of a particular factor but also the quality of that factor of production that influences the pattern of international trade (Sharan, V, 2003). Quality is held to be so important that the trade theory is analyzed in a three-factor framework. The first two factors being labour and capital, the third factor is in the form of human skill, skill intensity, economies of scale and research and development. Sharan, V, (2003) quotes Kraus (1956), who suggests that better education and training should be treated as a factor just like physical labour. It is hence argued that a country with improved human capital will maintain an edge over other countries in regard to the export of commodities that require improved human capital. A similar argument can be advanced for skills intensity as skill intensity is part of human capital. Sharan, (2003) quotes Keesings (1965, 1971), whose study revealed that labour is a non-homogeneous factor and it is the differing quality of labour in terms of skills that determines the pattern of international trade.

The hypothesis of economies of scale explains that with rising output, unit cost decreases and the producer achieves internal economies of scale. Thus a country with large production output will have a lower per unit cost and thus will have an edge over other countries. Research and Development (R&D) enhances a manufacturers competitiveness. Sharan, (2003) refers to Krugman and Obstfeld (1994) and explains how different countries are ranked on the basis of technological advancement and how goods are ranked by technological intensity. The higher ranked countries will always maintain an absolute advantage over the low ranked countries as far as goods of high technological intensity are concerned.

2.26 Country similarity theory

Most manufacturers will tend to manufacture goods designed for the domestic market. After meeting the demands of the domestic market, a manufacturer expands in order to achieve economies of scale and it at this stage that the manufacturer looks at the export market (Sharan, V, 2003). Most of these goods are exported to similar countries with the same level of incomes because such goods may not be accepted in countries with different levels of income. Hence international trade in manufactured goods is influenced by similarity of demand. For example clothes manufactured in United Kingdom may not find a ready market in Kenya and many other African countries because the standard of living in U.K is much higher than that in Kenya. But U.K manufactured goods are likely to find a ready market in the U.S.A where income levels are similar and consumption patterns may not be very different. Sharan, V, (2003) quotes Linda expressing that the more similar the demand structure of two countries, the more intensive potentially is trade between the two countries. Linda hypothesis had observed that nations with similar demand patterns would develop similar industries. The nations would then trade with each other with the same but differentiated goods (en.wikipedia.org/wiki/Linda_hypothesis).

2.27 National competitive advantage theory.

The national competitive advantage theory was explained by Porter (1990). The theory explains why a particular country is more competitive in a particular industry. Factor conditions, Demand conditions, related and supporting industries, and firm strategy, structure and rivalry are the four factors identified as being associated for this competitive advantage (Sharan, V, 2003). In factor conditions, the quality of the factor is identified as being very important. Thus abundant labour may be an advantage but skilled labour is an added advantage. Porter has identified that it is not only the size of the market that is important, but the intensity and sophistication of the demand is significant. Porter also recognizes that stiff competition helps firms to strive to produce better quality goods at lower costs in order to stay in business. Industry structure and rivalry among different companies is also important, with strong rivalry credited with strengthening the competitiveness of the industry.

2.3 Role of Electricity in Industry.

Electricity is an important input to the economic growth of any country, with many industries relying on it to power the various processes. There are thousands of jobs that are directly or indirectly related to electricity generation, transmission and distribution as well as the many industries and commercial enterprises that constitute the electricity consumers. Governments receive huge revenues in form of taxes from the electrical industry. The electricity per capita consumption of a country is a very important parameter to a potential investor, as it is indicative of relative purchasing power and hence the market potential. Kenya's electricity per capita consumption is about 200Kwh compared with Zibambwe760Kwh, Zambia 550Kwh or Botswana 1,000Kwh (PriceWaterhouseCoopers: Sub-Saharan Africa's Energy conundrum; www.pwc.com/prodev).

Electricity is generated by converting water potential energy in dams (hydro), steam from the ground, diesel, solar, nuclear as well as wind energy. Mostly, generators are several hundred kilometers from load centres, hence requiring lengthy transmission lines to the step down transformers that feed the distribution network. From generation through transmission to distribution to end customers, electricity is affected by many factors as the transmission lines are exposed to the vagaries of weather. In Europe and America, transmission towers have been known to collapse under heavy loads of ice during winter, interrupting power supply to large areas. The problem of ice loading has not been experienced in Kenya but storms and lightening strikes have severally put power lines out of service.

Power rationing is one of the major indicators of poor quality electricity. Power rationing is a result of inadequate generation capacity to meet customer demands. Rationing can also occur due to breakdown of one of the main transmission equipment but this is rare as these equipments are normally duplicated, such that there would be an alternative source of power even if one power plant failed. The reasons for inadequate generation can be low water levels in the dams due to drought, generation plant breakdown or customer growth at a rate higher than electricity development. The 1999/2000 power rationing in Kenya was caused by prolonged drought. Thermal generation was stepped up and the fuel bill rose to 48% of revenue collected by KPLC as compared to an average of 16% in past

years (KPLC Annual Report 2004). The extra cost of fuel was passed on to the customers. Apart from these direct costs, manufacturing industry and service industry suffered heavy losses as they were operating at reduced capacities. This in turn reduced the amount of goods available for sale and hence the cost per unit was higher as the fixed costs remained constant with low production. Businesses incurred extra costs in running standby generators. Five star Hotels were reported to be spending up to USD 2,657 on diesel daily (Sylvia Lyall: Economy the Top casualty of Power Deficit; Daily Nation, September 14 1999). Tetra Pak was quoted as having invested Kshs2.2Million to protect their machines against power surges and dips. Power rationing is not unique to Kenya. In 2001, Sri Lanka experienced severe rationing, that led to some companies closing down and others relocating to United Arab Emirates. Analyst argued that these power cuts would further discourage foreign investments. (World Socialist Web-site-www.wsws.org). Other countries that have experienced rationing include California (USA) in 2000 and Brazil in 2001(BBC News-www.bbcnews.com). In the case of California, electricity costs went up by 40% during the rationing period. The overall cost to business must have been far much higher as there must have been several production stoppages during the rationing period.

2.4 Factors that affect Power Quality

2.41 Over loading of Power Lines and other Equipment

Overloaded distribution lines have high losses and are the cause of many quality related problems to electricity customers. First the customer must pay for those losses and this increases the overall cost of electricity. A high loss distribution line will almost always cause undesirable low voltage at the far end from the line, and frequently such supply is of unbalanced voltages. High losses are mainly caused by overloading, which means allowing electric currents that are far above the design values for these lines. This often happens in high growth areas like Ongata Rongai, Kayole, Dandora and Mathare estates in Nairobi. Overloaded lines are prone to breakdowns such as short circuits or open circuits as conductor joints melt and snap due to overheating. While announcing a 4.5billion shillings World Bank loan to KPLC, the then Energy minister Achillo Ayako noted that power outages were caused by weak distribution and transmission lines that

were vulnerable to heavy downpours and strong winds (Stephen Mburu: Donors back Shs.4.5billion Power Plan: Daily Nation; 10th June 2003).

2.42 Electricity theft

Electricity theft is another contributor of poor quality electricity, mostly due the manner in which the theft is carried out. Theft is mainly done through illegal connections that are not professionally done, leading to frequent short circuits that disrupt supplies to other customers. Others steal electricity by bypassing the meter so that the meter does not record. Losses through theft can be very high. In 1998, New Delhi in India is reported to lose over 47.9% of electricity through theft (www.metering.com: Magazine Archive – 2002 Issue 1), while Uganda Electricity Distribution Company (UEDCL) reports overall losses between 20 to 30%. The proportion of stolen electricity varies from country to country, but it is more pronounced in developing countries. Various methods have been devised to enable electricity theft. Some hook electric cables directly onto low voltage lines, especially streetlights. This method is common in slums and densely populated low-income areas. Small industries like bakeries, welding workshops, fish and chips outlets have been known to interfere with electricity meters so that either the whole amount is not metered or only a fraction is metered. Electricity theft is closely related to levels of poverty, and generally the higher the poverty levels in a country; the more severe is the problem. Illegal connections not only lead to disruption of power to other customers but also make electricity overall expensive, as the regular customers must pay for the stolen electricity. Illegal connections affect power quality in that they contribute to short circuits, overloading, voltage imbalance and low voltage. Because of the poor connections, such supplies can be a source of voltage dips and surges during short circuits, or even total power outage. This is in addition to being very dangerous to other residents as cables are roughly routed without regard to safety. In South Africa, several cases of electrocution have been reported. In some areas, children are advised by their parents never to play outside while barefoot.

2.43 Weather and Environment related problems

Electricity transmission and distribution lines are mostly of overhead construction in Kenya, as is the case all over the world. These are prone to weather related disturbances like lightening strikes that occur during storms and result in short circuits and severe voltage surges, leading to power interruption that affect the majority of customers in the immediate neighbourhood and beyond. The result is similar even if the lightening strike is not direct but within the vicinity of the power lines. Overhead power lines are also prone to disturbances from strong winds that cause the conductors to clash thereby causing short circuits and hence power outage. In the rainy season, strong winds are common that are often accompanied by lightening thunder. Moisture has the effect of reducing the insulating properties of air. If at the same time there are strong winds that sway the conductors, the likelihood of a flashover is very high. Birds like to perch on power lines and will occasionally cause short circuits. In Kenya, especially the Machakos area, boys have been known to aim and hit the glass disc insulators using catapults. As the insulators shatter, it is great fun for the boys and they hence compete to hit more. The destruction of the insulators will lead to a short circuit either immediately or much later. Each disc shattered reduces the insulation properties and eventually a flashover occurs between the conductor and the metallic tower.

In built up areas like Nairobi's Central Business District (CBD), Power distribution is through underground cables, this being the case in most cities of the world. Underground cables are more reliable than overhead lines as they are less prone to weather related problems like overhead lines. However, as cables age, so does the insulation properties deteriorate and eventually faults are inevitable. There is also the problem of the many contractors digging trenches along and across roads for one purpose or another. If due consultation is not done, such contractors end up puncturing the underground power cables, causing power interruptions to parts of the city served by such cables.

2.44 Vandalism

Vandalism is very common in Nairobi and other urban centers. It is less common in rural areas. In Nairobi, Kisumu and Mombasa, several cases of power transformer vandalism have been reported in recent times. Vandals tap oil from such transformers for sale in the

informal market for various uses. Some vandals are after the copper in the transformers for sale as scrap metal. Stealing of power line conductors has been reported in areas like Athi River and Kiambu in the vicinity of Nairobi. Using saws or axes, vandals bring down poles carrying the power line, after which they cut several hundred meters of cable for sale as scrap aluminium. Many vandals have died from electrocution, as the lines are sometimes not dead or become live when the vandal is in the process of cutting the cables. Other vandals target steel towers, where steel members are unbolted for sale in the informal market. Some communities vandalize power line parts to make ornaments and traditional weapons. Copper earth strips and earth rods have been ripped off for sale as scrap copper. All these activities lead to power blackouts, affecting tens of customers in the case of distribution transformers to thousands of customers in the case of steel towers.

2.45 Power Line Design

One cannot guarantee power quality unless the power lines are of good design. KPLC has developed standards that define the depth of holes for poles, minimum distance between conductors, conductor clearance to ground, inter-pole distance or span length for each class of voltage, size of conductors for given power range, type and class of insulation among others. If these standards are violated, there will be numerous problems when the lines are in operation and such lines cannot transmit reliable power. Why would anybody want to violate established standards? There are several reasons. Unavailability of correct materials and the customer has to be connected. It could be the wrong pole size, wrong conductor span, wrong conductor size, and so on. Such jobs are done on temporary basis to connect the customer while awaiting the correct materials to arrive in stores so that the situation can be rectified. Sometimes the temporary arrangement can remain for several years and frequently forgotten. As staffs are transferred from department to department, region to region, new staffs come to regard what they find in the new region as normal. Sometimes materials procured do not meet the required standards, leading to numerous breakdowns while in service. Therefore strict adherence of design and construction standards, backed by procurement of the right materials in the right quantities and in time, is a must if quality electricity is to be delivered.

2.46 Choice of Materials

The greater part of KPLC's distribution network power lines are on wooden poles, with only a few kilometers of concrete and steel poles. Wooden poles have inherent problems. They will rot and collapse especially in the rainy season when the ground is soggy. The problem can be compounded by procurement of poles that are not properly treated. Wooden poles are also prone to catching fire initiated by lightning or power line faults like short circuits. In a case of Perth Metropolitan in Australia, more than 25,000 homes and businesses were left without power after light rain caused more than 40 pole-top fires. The utility, Western Power Doug Aberie was planning to replace wooden poles with steel ones stage by stage to eliminate the problem. According to a Government spokesman, 1.5 million dollars would be spent in 2006 on a program aimed at replacing damaged poles with steel ones (Jane Hammond: Rain causes major blackouts; www.theadvertiser.news.com, 3rd Jan 2006). Steel poles and concrete poles are more durable and resistant to weather related corrosion. Hence there are fewer power interruptions with steel or concrete poles power lines.

2.47 Need for Strategy to Deal with power quality

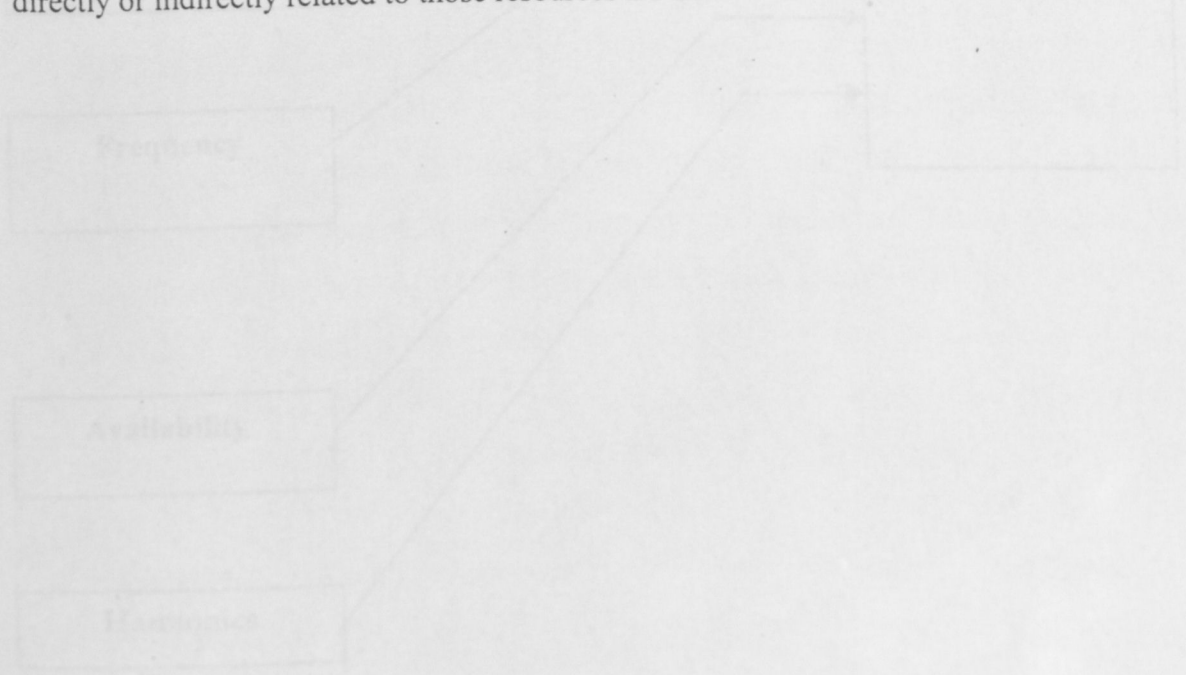
Businesses require to adopt the appropriate strategy to deal with the various power problems right from power outages to voltage surges. The adopted strategy will vary from one business to another. Most business may opt to have standby generators to mitigate against power outages, but this is not feasible in every situation, especially where power requirement is high, like tens of megawatts, investing in standby generators can be very expensive considering the installation and running costs. Power surges may require surge arrestors for the electronic equipment, but there is no real cure as a power surge can cause a production plant to shut down. Most power quality problems like low frequency and low voltage, voltage dips and surges may not have an immediate solution at the business level, and the matter will have to be referred to the utility for solutions. Availability of abundant supply of electricity is an incentive to a potential investor. Such electricity should be of desired quality, reliable and fairly priced. An investor will definitely be comparing several countries within the same region or in different regions, while looking for the best returns on investment. Analysis would show the expected cost

of production, the selling price and expected returns. Apart from tariff costs, a business is concerned by reliability and quality of electricity, as poor quality is indicative of substantial hidden costs. These hidden costs of electricity consist of plant downtime and spoilage costs as a result of power supply outages, voltage dips or surges among others.

INDEPENDENT VARIABLES

The economic growth of a country can be accelerated by capital inflows from foreign investors. Governments all over the world have recognized the benefits of foreign direct investments that include capital inflows, increased exports, employment, technology transfer, increased government revenue in form of taxes, increased trade and opportunities for local industry to grow as they trade with the multinational companies.

Foreign direct investors consider at several factors in a prospective host country. Of interest is the country market potential, population, level of education (skilled and non skilled labour), purchasing power, and infrastructure like roads, railway and telephone, energy sources like oil and electricity and raw materials. A potential investor would establish which factors were in abundant supply in a given country, and how such factors would favour investments in such a country. The existing political environment is also an important consideration. For example countries with huge oil reserves like Saudi Arabia, Iraq and Nigeria have attracted investors in the oil industry, while countries with large mineral reserves have attract investors who exploit those reserves. Other industries directly or indirectly related to those resources are born.



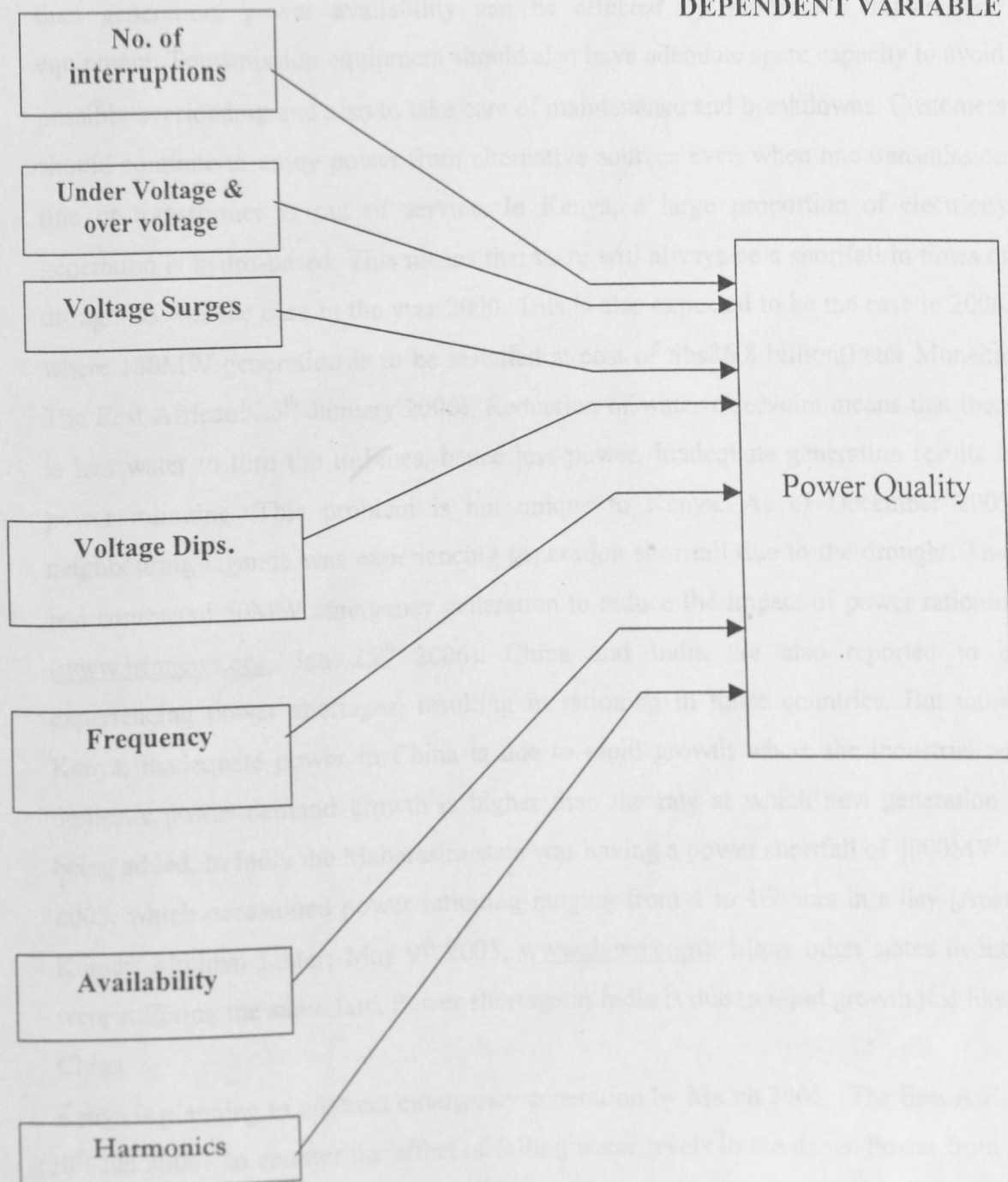
2.5 Theoretical Framework and review of other works.

2.5.1 Power Availability.

POWER QUALITY

INDEPENDENT VARIABLES OR FACTORS

DEPENDENT VARIABLE



2.51 Power Availability.

Availability of electricity is subject to adequate generation. The generation should also be reliable with enough spare capacity. As of June 2005, the combined capacity of Kengen, Iberafrika, Orpower, and Tsavo power was 1150Megawatts. The peak customer demand from KPLC system was 800MW, leaving a spare capacity of 350MW, which is good and allows for breakdowns and routine maintenance. Other than generation, power availability can be affected by inadequate transmission equipment. Transmission equipment should also have adequate spare capacity to avoid possible overloading and also to take care of maintenance and breakdowns. Customers should continue to enjoy power from alternative sources even when one transmission line or transformer is out of service. In Kenya, a large proportion of electricity generation is hydro-based. This means that there will always be a shortfall in times of drought as was the case in the year 2000. This is also expected to be the case in 2006, where 180MW generation is to be installed at cost of Shs36.8 billion(Peter Munaita: The East African: 25th January 2006). Reduction of water reservoirs means that there is less water to turn the turbines, hence less power. Inadequate generation results in power rationing. This problem is not unique to Kenya. As of December 2005, neighbouring Uganda was experiencing generation shortfall due to the drought. They had contracted 50MW emergency generation to reduce the impact of power rationing (www.irinnews.org, Jan 25th 2006). China and India are also reported to be experiencing power shortages, resulting in rationing in those countries. But unlike Kenya, inadequate power in China is due to rapid growth where the industrial and domestic power demand growth is higher than the rate at which new generation is being added. In India the Maharastra state was having a power shortfall of 4000MW in 2005, which occasioned power rationing ranging from 4 to 16hours in a day [Anand Kumar: Mumbai Letter; May 9th 2005, www.dawn.com). Many other states in India were suffering the same fate. Power shortage in India is due to rapid growth just like in China.

Kenya is planning to contract emergency generation by March 2006, (The East African (20th Jan 2006), to counter the effect of falling water levels in the dams. Power from the

emergency generation is always more expensive per unit compared with existing sources. Also, emergency generators use diesel fuel, the cost of which is again passed on to the customer. This means the higher production costs for the various industries. Cost of power rationing is very high. Government estimates showed that the power rationing of 1999/2000 cost Kshs 8.1 billion in lost business (Jaindi Kisero: Daily Nation May 30, 2000). Kenya power & Lighting Co Ltd lost Kshs 6.1 billion in revenue due to unsold energy.

2.52 Power interruptions

Power interruptions or non-scheduled interruptions are mainly caused by breakdowns in the power system. Breakdowns may result from broken cables, short circuits or equipment failure for example transformers. The frequency and duration of interruption are critical determinants of the impact over a period. The more frequent, the higher the impact of disruption. The longer the duration the more the negative impact. Longer duration say from six hours to one day are caused by power system plant failure e.g. transformers. High frequency of interruptions would be most like be due to aging power lines and equipment. Overloading can also cause interruptions as equipment fail due to excessive stress. Vandalism is another cause of power interruptions. Vandals are known to steal transformer oil, copper, aluminium and steel from the power system network. Such theft always leaves some customers without supply. Restoration work may take appreciable time, as new equipment has to be identified and installed.

Weather related incidences like lightning normally cause momentary interruptions. A tree touching a power line will be sensed as a fault and there will be a brief interruption followed by automatic restoration as long as the tree touching even was a transient one. Tree branches do fall on power lines and when this happens there will be power interruption. Birds often cause a short circuit as they fly or perch on power lines. Strong winds usually causes power cables to clash with each other, causing a short circuits and hence outages. Motor vehicle accidents are another common cause of power interruptions. It could be normal accidents when vehicles hit power lines or drunken drivers who drive into power structures. Cases of falling trees and earthquakes have been reported to cause power outages. Human error contributes to power outages.

Operators and maintenance personnel in the utilities occasionally make error of judgment by either switching the wrong equipment out or overloading equipment leading to automatic shutdown of that piece of equipment. Cases of madmen interfering with electrical equipment and causing outages have been reported.

Planned power interruptions are not as serious as the unplanned ones because customers are warned in advance and are able to take contingency measures in most cases. Planned outages are for the purpose of maintenance by the utility or generating companies. Sudden shutdown of a generating facility due to internal faults can cause widespread power outages as a result of the reduced generation. The problem is more serious if the affected generator is large relative to the total generation at that time. In August 2003, there was widespread power interruption in the USA and Canada.

2.53 Voltage level stability

Voltage level at a customer's premises is required to be within the defined accepted limits if all the devices in the manufacturing plant are to function properly. Continuous high voltage above the defined limit can cause overheating of components leading to insulation failure. Over voltage is caused by sudden load-switching, capacitor switching and poor system voltage regulation. Continuous over voltage will cause insulation failure in some electrical equipment, which will lead to total failure. On the other hand, low voltage or under voltage is caused by overloading of the power system network, poor power factor and lack of adequate voltage compensation at key installations. Under voltage causes over current in motors, leading to overheating and possible damage. Heating equipments are unable to deliver the required amount of heat under these circumstances, as the heating process is slow.

2.54 Voltage Surges

A voltage surge is a sudden rise in voltage well above normal. Surges are caused by sudden switching off of near by loads and fault occurrence in neighboring circuits (Alstom 2002). Surges are more severe if the power system is weak, i.e. it is overloaded and the source is far from the load. Surges can damage electronic equipments that are part of the control system of large manufacturing plants. In addition, the surge can cause

the malfunction of control systems, which will result in whole plant to shutdown even when there is no other damage. The frequency of the surges should be very low for good quality power.

2.55 Voltage Dips

A voltage dip is a sudden drop in voltage far below normal values. This is normally followed by recovery in a few milliseconds to several seconds. Dips are mainly caused by fault occurrence in neighbouring circuits (Alstom 2002). Large motors can also cause dips in neighbouring circuits when starting. Plants will withstand a dip up to some specific duration, after which the plant will shutdown resulting in production loss. Different plants have different dip withstand capabilities. Frequent dip occurrence is an indicator of poor power quality.

2.56 Voltage unbalance

Uneven loading of the power system, or faulty equipment causes voltage unbalance in the power system (Alstom 2002). This is fairly easy to rectify and should not be frequent. Unbalanced voltages can cause mal-operation of customer's equipment and possibly lead to plant shutdown.

2.57 Frequency

The frequency of the power supply is expected to be 50 hertz with a 2.5 % variation above and below (Electric Power Act, 1997). The most common frequency related problem is under-frequency, caused by inadequate generation (Alstom 2002). Some equipment will malfunction if frequency falls below a specified limit. Frequent operation outside the defined limits is an indication of poor quality power.

2.58 Harmonics

Harmonics are higher frequency current and voltages superimposed on the fundamental frequency of 50Hz. The main cause of harmonics are non-linear loads such as rectifiers, inverters, UPS systems, Static var compensators, arc welding and arc furnaces. Presence of harmonics in power supply leads to heating in generators, motors, transformers and

capacitors, leading to possible shutdown. The equipments responsible for generating harmonics are owned both by the customers and the utility, but the customers produce a large proportion of the harmonics. High levels of harmonics will cause protective devices to mal-operate and either shut down plants or cause widespread power interruption depending on the actual location of such protective devices.

Some quality factor limits set by EN50160 standard.

Type of Disturbance	Voltage level	Limits from EN50160
Voltage variation	230V	+/- 10%
Rapid voltage changes	230V	5% to 10%
Rapid voltage changes	1KV to 35KV	Less than 6%
Short interruptions	230V	
Under voltage	230V	Less than 10%
Voltage surge	230V	Less than 150% of nominal voltage
Frequency variation		+/- 1%
Harmonics		THD less than 8% up to 40 th harmonic

Source: Alstom 2002, Network Protection & Automation.

THD: Total harmonic distortion.

EN50160 is a European standard that defines limiting values on voltage quality. Similar limits have been set by IEEE1159 and many national standards bodies.

The Electric Power Supply Rules (2005) stipulates frequency variation not to exceed 2.5% above and below 50Hz. Maximum voltage variation allowed is 6% above and below 230V, for low voltage and 10% variation for high voltage (www.erb.go.ke).

2.59 Research by Others

A research on Pricing of Electricity by Bulk Power Producers was done in 2002 by Joseph Kiiru in his MBA project. The study aimed at finding out how bulk electricity prices were developed by the generating companies. The broad findings of this study were that each generating company had a different power purchase agreement (PPA) with

the retail company KPLC. This study is related to the current study in as far as it deals with the price of electricity issues; otherwise the issue of power quality was not an objective and hence was not dealt with.

2.60 Need for this study

The impact of power quality on business firms in Kenya is currently unknown. There is therefore a need to carry out a study to identify the significant factors that lead to poor power quality, and the effect such factors have on the overall production costs in the manufacturing firms. Results from such a study will assist in formulating strategies to counter this problem.

3.0 CHAPTER THREE: RESEARCH METHODOLOGY.

3.1 Research Design

Survey research method was used in this study. Considering the diversity of the manufacturing companies, this method was considered the most suitable to get the appropriate data for statistical analysis.

3.2 Population and Sample of the study

In this study, the population was the 525 members of the Kenya Association of Manufacturers, who were chosen in this study to represent the business community. A convenient sample of 50 companies within Nairobi was used.

3.3 Data Collection

Data on business firms were obtained through questionnaires. This dealt with power quality issues of availability, power interruptions, voltage dips, voltage surges, harmonics and the impact of these factors on business firms

3.4 Data Analysis.

The data received from questionnaires were presented in a tabulated form for each question. The percentage of respondents that chose a particular answer was shown.

The analysis show how prevalent a given factor is from the point of view of the manufacturers.

4.0 CHAPTER FOUR: DATA ANALYSIS AND FINDINGS

4.1 Introduction

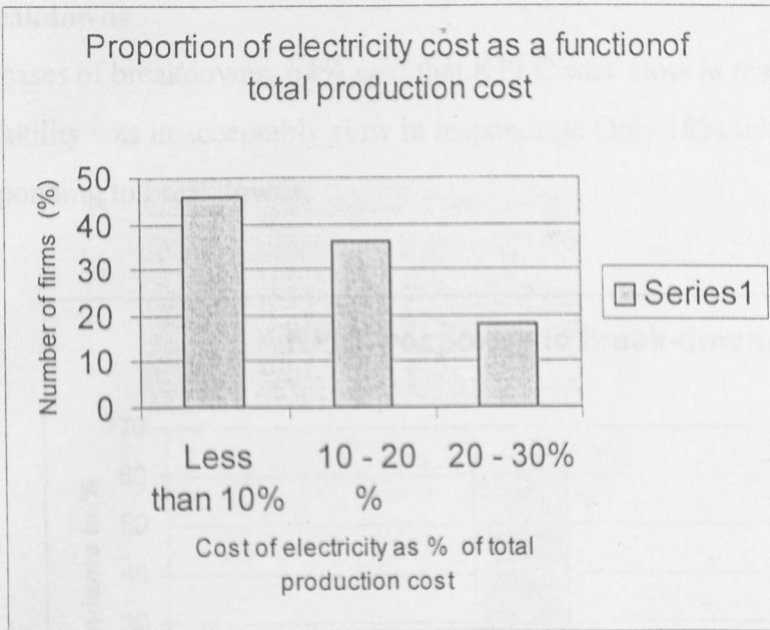
This chapter presents Research Findings and Analysis of data received from respondents. Responses were received from 32 of the 50 questionnaires sent out to manufacturers, who had been selected conveniently from the 512 members of the Kenya Association of Manufacturers.

4.2 Power consumed by manufacturers

Amount of power consumed by the firms: 64% of respondents said their respective firms consumed less than 1MW, while 36% said they consumed 1 – 5MW. There were no respondents for the above 5MW category. Though such firms like Bamburi and PanPaper power in excess of 5MW, the number of firms in this category are few and could be estimated to be about 1% of the total number of manufacturing firms.

4.3 Cost of electricity versus total production cost

Proportion of electricity cost as a percentage of total production costs: To 46% of respondents, electricity accounted for less than 10% of production costs. 36% of respondents indicated that electricity constituted 10 – 20% of production costs, while 18% of respondents indicated that electricity accounted for 20 – 30% of production costs. Summing the later two groups we find that 54% of respondents have electricity costs accounting for between 10 – 30% of production costs. These costs are substantial and are hence significant in determining the final product costs.



4.4 Electricity availability

68% of respondents indicated that the number of unscheduled power interruptions were few, while 32% said the frequency of power outages was high. On power rationing; 59% of respondents said they had not experienced power rationing in the last two years. A further 32% said power rationing was rare, while 9% said power rationing was frequent. These results indicate that power rationing is not a common phenomenon among the manufacturing firms, though it is recognized as a very serious issue when it occurs.

4.5 Voltage level variation:

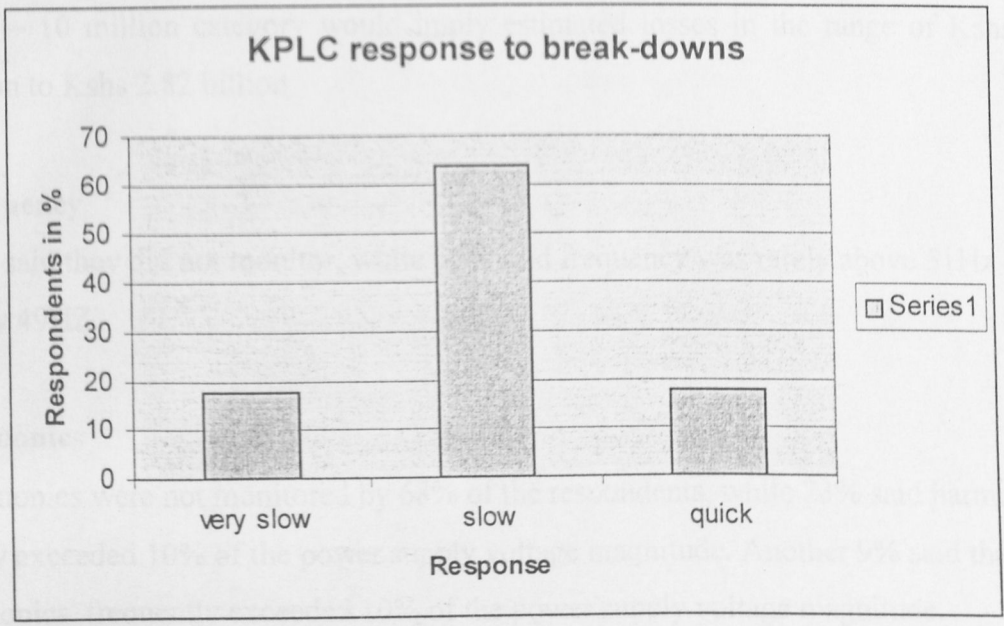
55% of respondents said that the level of voltage supplied was unpredictable while only 32% felt that the voltage was normally within defined limits. This is an indication that voltage is generally poor, and is rarely within defined limits.

4.6. Voltage surges

41% of respondents said the surges were frequent while a further 9% said the surges were very frequent. 50% felt that voltage surges were few. These results indicate that voltage surges occur fairly frequently and there is need for the utility to initiate corrective action.

4.7 Breakdowns

In cases of breakdowns, 64% said that KPLC was slow in responding while 18% said the utility was unacceptably slow in responding. Only 18% felt that KPLC was quick in responding to breakdowns.



4.8 Losses due to power quality related problems

On losses incurred due to sudden power interruptions, 91% of respondents said they had experienced loss of production, spoilage arising from semi-processed goods and damage to electronic equipment.

4.9. Ability to resume operations after a brief power interruption

The ability to resume operations after a brief power interruption was assessed. 41% of respondents said that it took less than 30 minutes, 14% took 30 minutes to one hour, 36% took 1 hour to 3 hours, while 9% took over 3hours to resume. That the majority takes over 30 minutes to resume operations even after a brief interruption means that losses due to downtime are very high, hence such interruptions should be taken very seriously and strategies to reduce them put in place.

4.10 Quantifying losses related to power quality problems

Respondents were asked to quantify losses related to power quality problems like interruptions, voltage surges and low voltages among others. 36% said the incurred losses up to Kshs1million, 55% said between 1million and 10 million, while 9% said they incurred losses between Kshs10million to 50million. For the 512 members, the 55% of the 1 – 10 million category would imply estimated losses in the range of Kshs 281.6 million to Kshs 2.82 billion

4.11 Frequency

45% said they did not monitor, while 55% said frequency was rarely above 51Hz or below 49HZ.

4.12. Harmonics

Harmonics were not monitored by 68% of the respondents, while 23% said harmonics rarely exceeded 10% of the power supply voltage magnitude. Another 9% said that harmonics frequently exceeded 10% of the power supply voltage magnitude.

4.13 Voltage dips

Voltage dips were rare for 36% of respondents, while 64% said voltage dips were frequent.

4.14 Unscheduled power interruption

Unscheduled power interruption was assessed. 64% said that the impact was serious resulting in heavy losses, while 36% felt that resulting losses were not very significant. The problem of single phasing was rare as indicated by 64% of respondents. 27% said that single phasing was frequent while 9% said it was very frequent.

4.17 Relative rating of the various factors

Respondents were asked to rate the various power quality according to how serious each factor affected the business of the firm. Rating5 was the most serious(corresponding to work stoppage and heavy losses) while rating 1 was the least serious(inconvenience but no significant losses).

Table shows how the respondents rated the various factors.

	No. of respondents for each rating					
	Rating5	Rating4	Rating3	Rating2	Rating1	Rating4 +Rating5
Voltage surge	41%	45%	9%		5%	86%
Power rationing	82%	9%	9%			91%
Unscheduled interruption	86%	9%	5%			95%
Voltage dip	27%	45%	27%			72%
Harmonics	23%	59%	9%		9%	82%
Low voltage	45%	50%	-	5%		95%
High voltage	41%	45%	-		14%	86%
Over frequency	9%	64%	9%	9%	9%	73%
Under frequency	14%	59%	9%	9%	9%	73%

In the above table, Rating 4 and Rating 5 represent severe and very severe effect on business.

All the factors rated serious and very serious are the sum of rating4 column and rating5 column. This summation is shown in the 7th column.

The results of column 7 indicate that 72% of the respondents perceive the various power quality factors to have severe effects on business. Rating1, rating2 and rating3 had very few respondents for these factors.

5.0 CHAPTER FIVE: CONCLUSIONS AND RECOMENDATIONS

5.1 Introduction

From the viewpoint that electricity is an important factor of production, this study sought to establish the factors that significantly affect the quality of electricity supplied to manufacturers in Kenya and the impact such factors have on the firms. Questionnaires were sent to 50 firms who had been conveniently selected from the 512 members of the Kenya Association of Manufacturers (KAM). The questionnaires were sent through electronic mail. Responses were received via e-mail as well as the Post Office. In all, there were 32 respondents, representing a 64% response.

5.2 Conclusions

The study found that for 54% of respondents have electricity costs accounted for between 10 – 30% of production costs. This implies that the cost of electricity is significant and hence it has an impact on the final product cost. Considering that 91% of respondents said power rationing was rare or none existent for the past two years, it can be concluded that power rationing was not of immediate concern to manufacturers as it rarely occurred. The frequency of unscheduled power interruptions was found to be significant, with 32% indicating that power outages were very frequent. The 55% respondents that said voltage was unpredictable clearly show that there was lack of dependability on this parameter. It is therefore a concluded that voltage supplied to customers was of poor quality. Voltage surges and dips were frequent as indicated by 50% and 64% of respondents respectively. In addition, these dips and surges were rated high in their potential to disrupt business. Frequency variations were not significant with 55% indicating that they did not experience any variations while 45% said they did not monitor frequency. Harmonics were not monitored by over 68% of respondents. However, there is need for each manufacturer to monitor harmonics as these can have an effect on performance of various plant equipment that form part of the production process.

In summary, the quality of electricity supplied to manufacturers was found to be poor, specifically in the areas of voltage variation, voltage dips and voltage surges.

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5.3 Recommendations

The electricity utility KPLC needs to initiate investigations to establish the causes of voltage dips, voltage surges and voltage variations. The response to breakdowns needs to be improved so as to satisfy customers and reduce downtime.

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APPENDICES

APPENDIX 1

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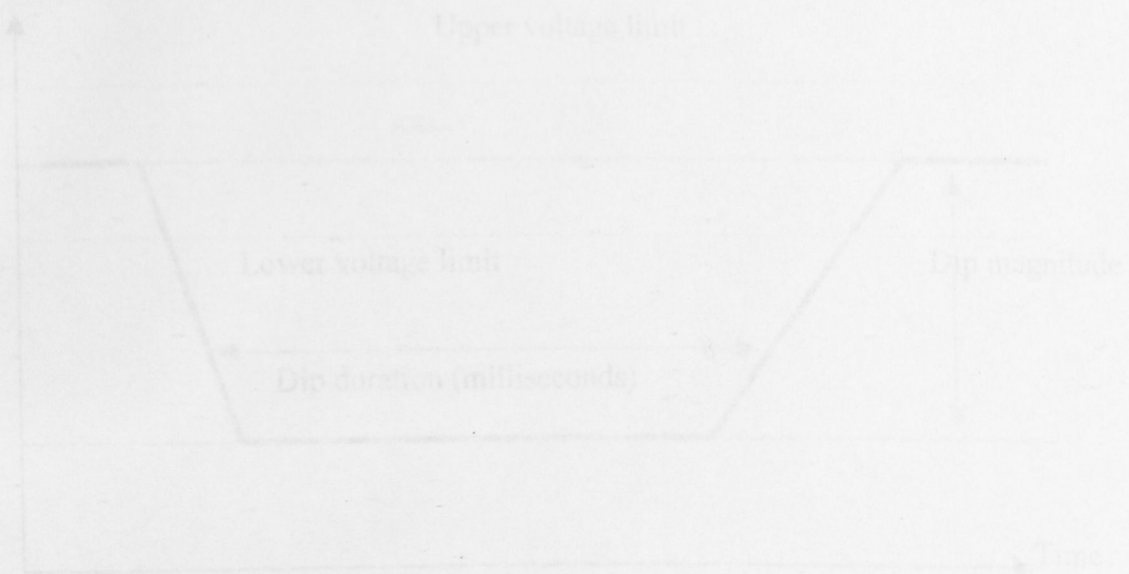
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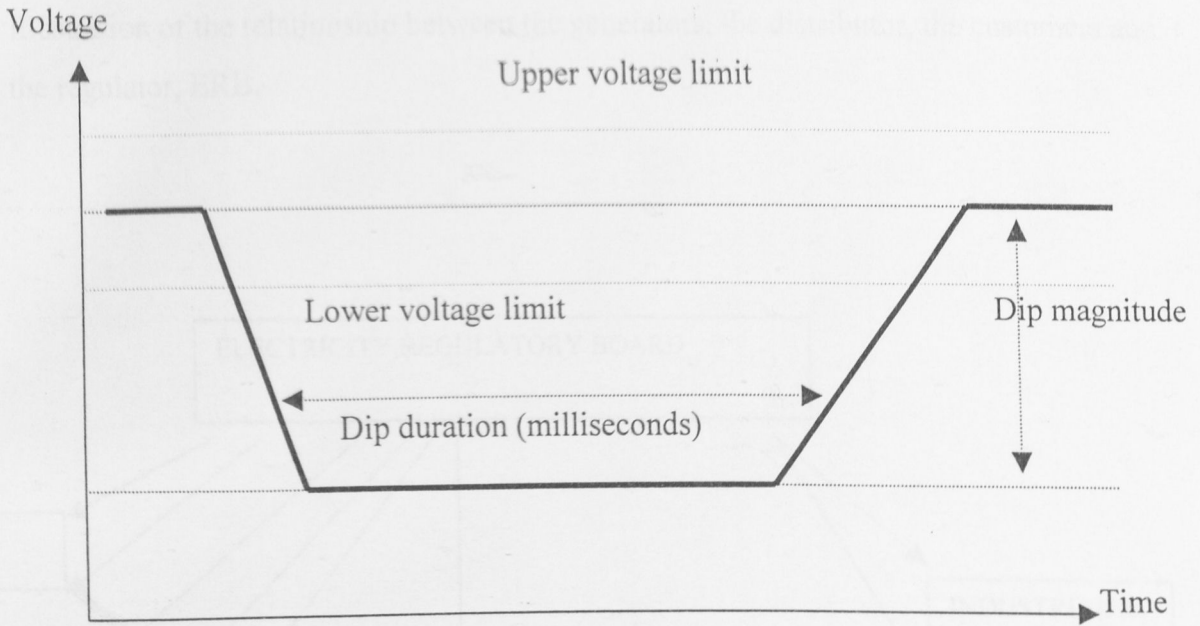
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Source: Axtom 2402, Network Protection & Assurance

APPENDIX 2

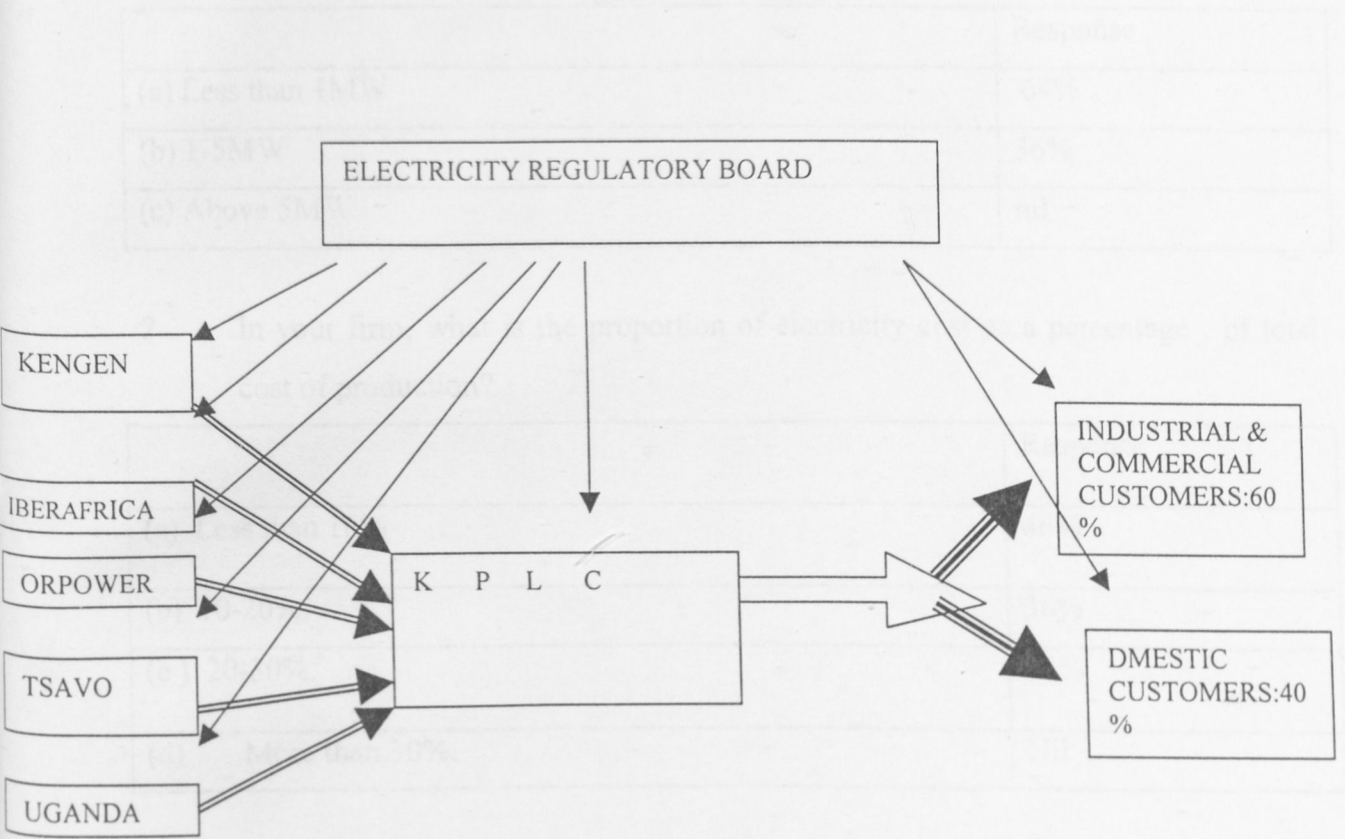
Voltage Dip illustration



Source: Alstom 2002, Network Protection & Automation

APPENDIX 3

Illustration of the relationship between the generators, the distributor, the customers and the regulator, ERB.



Source of data: KPLC Annual report 2003/2004

APPENDIX 4

RESPONSE TO QUESTIONNAIRE

1. What is the power demand of your business?

	Response
(a) Less than 1MW	64%
(b) 1-5MW	36%
(c) Above 5MW	nil

2. In your firm, what is the proportion of electricity cost as a percentage of total cost of production?

	Response
(a) Less than 10%	46%
(b) 10-20%.	36%
(c) 20-30%.	18%
(d) More than 30%.	Nil

3. What would you say about electricity availability at your premises?

	Response
(a) Always available.	Nil.
(b) Has few outages	68%
(c) Very many outages	32%

4. What is the level of the voltage of power supplied?

	Response
(a) Always within limits.	32%.
(b) Mostly higher than normal	Nil
(c) Mostly low	13%
(d) Unpredictable.	55%

5. What is the frequency of voltage surges?

	Response
(a) Very few	50%
(b) Frequent	41%
(c) Very Frequent	9%

6. In case of power breakdown, how is the response from KPLC?

	Response
(a) Quick	18%
(b) Slow	64%
(c) Unacceptably slow	18%

7. Availability. How often have you experience power rationing in last two years

	Response
(a) Nil	13
(b) Rarely	7
(b) Frequent	2
(c) Very frequent	nil

8. Which of the following do you experience when power goes off suddenly.

	Response
(i) Loss of production. (only)	
(ii) Semi-processed goods are damaged and have to be scrapped.	
(iii) Damage to electronic equipment.	
Those who chose (i) only	4.5%
Those who chose (ii) only	4.5%
Those who chose (iii) only	Nil
Those who chose (i) and (ii)	36%
Those who chose all three	55%

9. If power goes off temporarily, how long does it take your plant to resume full operations?

	Response
<input type="checkbox"/> Less than 30 minutes.	41%
<input type="checkbox"/> Between 30 minutes and 1 hour.	14%
<input type="checkbox"/> From 1 hr to 3 hrs.	36%
<input type="checkbox"/> Over 3 hrs	9%

10. How would you quantify your annual loss due to supply interruption, low voltage, voltage surges and other power quality problems?

	Response
Up to Kshs 1 million.	36%
Between 1 and 10million.	55%
10 to 50Million.	9%
Over 50Million.	Nil

11. How often have you had frequency below 49Hz?

	Response
<input type="checkbox"/> Rarely	55%
<input type="checkbox"/> Up to 2 incidents per day	Nil
<input type="checkbox"/> Between 2 and 10 incidents	Nil
<input type="checkbox"/> Over 10 incidents per day	Nil
<input type="checkbox"/> Frequency is not monitored	45%

12. How often does the power supply frequency exceed 51Hz?

	Response.
<input type="checkbox"/> Rarely	55%
<input type="checkbox"/> Up to 2 incidents per day	Nil
<input type="checkbox"/> Between 2 and 10 incidents	Nil
<input type="checkbox"/> Over 10 incidents per day	Nil
<input type="checkbox"/> Frequency is not monitored.	45%

13. If you monitor power supply harmonics, how often does the harmonics exceed 10%?

	Response
<input type="checkbox"/> Rarely	23%
<input type="checkbox"/> Often	9%
<input type="checkbox"/> Very frequent	Nil
<input type="checkbox"/> We currently do not monitor	68%

14. How often have you experienced a voltage dip?

	Response
<input type="checkbox"/> Rarely	36%
<input type="checkbox"/> Often	64%
<input type="checkbox"/> Very frequent	Nil

15. How often have you experienced a voltage surges?

	Response
<input type="checkbox"/> Rarely	50%
<input type="checkbox"/> Often	41%
<input type="checkbox"/> Very frequent	9%

16. What is the impact of unscheduled power interruption on production?

	Response
<input type="checkbox"/> Little impact	Nil
<input type="checkbox"/> Serious but losses not very significant	36%
<input type="checkbox"/> Very serious with heavy losses	64%

17. How often have you experienced single phasing?

	Response
<input type="checkbox"/> Rarely	64%
<input type="checkbox"/> Often	27%
<input type="checkbox"/> Very frequent	9%

In the table below, respondents were asked to rate the listed factors according to what effect such factors have on respondent's manufacturing plant, with rating5 being the most serious (i.e. Leads to work stoppage and high losses), and rating1 being the least serious (Inconvenient or nuisance but no significant losses).

Table shows how the respondents rated the various factors.

	No. of respondents for each rating				
	Rating5	Rating4	Rating3	Rating2	Rating1
Voltage surge	41%	45%	9%		5%
Power rationing	82%	9%	9%		
Unscheduled interruption	86%	9%	5%		
Voltage dip	27%	45%	27%		
Harmonics	23%	59%	9%		9%
Low voltage	45%	50%	-	5%	
High voltage	41%	45%	-		14%
Over frequency	9%	64%	9%	9%	9%
Under frequency	14%	59%	9%	9%	9%

APPENDIX 5

QUESTIONNAIRE

Factors that affect the quality of electricity

1. What is the power demand of your business?
(a) Less than 1MW (b) 1-5MW (c) Above 5MW
2. In your firm, what is the proportion of electricity cost as a percentage of total cost of production?
(a) Less than 10% (b) 10-20% (c) 20-30%
(d) More than 30%
3. What would you say about electricity availability at your premises?
(a) Always available (b) Has few outages
(c) Very many outages
4. What is the level of the voltage of power supplied?
(a) Always within limits. (b) Mostly higher than normal
(c) Mostly low (d) Unpredictable
5. What is the frequency of voltage surges?
(a) Very few (b) Frequent (c) Very Frequent

6. In case of power breakdown, how is the response from KPLC?
interruption, low voltage, voltage surges and other power quality
- (a) Quick (b) Slow (c) Unacceptably slow
7. Availability. How often have you experience power rationing in last two years
1 and 10million.
10 to 50Million.
- (a) Nil (b) Rarely (b) Frequent (c)Very frequent
8. Which of the following do you experience when power goes off suddenly.
11. How often have you had frequency below 49Hz?
- Loss of production.
 - Semi-processed goods are damaged and have to be scrapped.
 - Damage to electronic equipment.
- Up to 2 incidents per day
Between 2 and 10 incidents
- For this question you may tick more than one as appropriate.
9. If power goes off temporarily, how long does it take your plant to resume full operations?
- Less than 30 minutes.
 - Between 30 minutes and 1 hour.
 - From 1 hr to 3 hrs.
 - Over 3 hrs

10. How would you quantify your annual loss due to supply interruption, low voltage, voltage surges and other power quality problems?

- Up to Kshs 1 million.
- Between 1 and 10million.
- 10 to 50Million.
- Over 50Million.

11. How often have you had frequency below 49Hz?

- Rarely
- Up to 2 incidents per day
- Between 2 and 10 incidents
- Over 10 incidents per day
- Frequency is not monitored

12. How often does the power supply frequency exceed 51Hz?

Rarely

Up to 2 incidents per day

Between 2 and 10 incidents

Over 10 incidents per day

Frequency is not monitored.

13. If you monitor power supply harmonics, how often does the harmonics exceed 10%.

Rarely Often Very frequent

We currently do not monitor

14. How often have you experienced a voltage dip?

Rarely Often Very frequent

15. How often have you experienced voltage surges?

Rarely Often Very frequent

16. What is the impact of unscheduled power interruption on production?

- Little impact
- Serious but losses not very significant.
- Very serious with heavy losses

17 How often do you experience single phasing (loss of one phase)?

- Rarely
- Often
- Very frequent

Rate the following factors according to how serious they will affect your manufacturing plant.

	Rating				
	5	4	3	2	1
Voltage surge					
Power rationing					
Unscheduled interruption					
Voltage dip					
Harmonics					
Low voltage					
High voltage					
Over frequency					
Under frequency					

Key

Rating 5: Most serious (e.g. Leads to work stoppage and high losses)

Rating 1: Least Serious (Inconvenient or nuisance but no significant losses).