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Analysis of Energyauditing in Nigerian Power Systems

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Abstract
Energy is one of the major drivers for the economic development of any country. In order to reduce energy consumptions for sustainable development, continuous energy audit of industrial machines become necessary. Energy audit is one of the most comprehensive methods in achieving energy savings in industry and thus reducing excessive energy consumption. This paper analyzes energy auditing in power system in order to identify the sources of energy waste and assess the effectiveness of the strategies for energy savings using A and T Foods and Beverages PLC as a case study. This was with a view to recommending a policy that would enhance the effectiveness of electrical energy savings in the company. A detailed energy audit is adopted for energy project implementation plan and data from the publication of the International Standard Industrial Classification of All Economic Activities (ISIC) in Nigeria for the period of (2011 -2017)were used for the analysis. The sources of energy in the company comprised of electricity from utility company and use of generating sets (fuel). The result showed that the electrical energy consumption in the companies was mainly from generating set. In addition, the total percentage of electric energy consumed from utility company was 40.95% with an average percentage of 5.85%. The total percentage of fuel consumed by the company was 659.05% with an average value of 94.15%. The results identified areas where the company used and wasted energy, and where actions for energy conservation should be implemented. The study therefore established that energy was not sufficiently utilized, and therefore suggested possible strategies for efficient energy usage for the company.

Keywords: Energy Audit, Energy Saving, A and T Food and Beverages PLC, ISIC, Power System, Generating Set, Electric Utility Companies.

I. Introduction

Energy is regarded as the prime mover of any economy and engine of growth in which all sectors of the economy revolve. It is an essential ingredient in nearly all goods and services [1]. The overall energy system has been very inefficient due to the way it is sourced, produced and used. In addition, major environmental and social problems, both local and global, have been associated with the energy system. By improving the efficiency of energy used, an estimated 10-30% reduction in energy can be achieved at little or no cost. Thus, it becomes imperative that energy development, management, and improvement must have predetermined plans and strategies that are capable of driving the economy towards a sure path of sustainable development [2, 3].

Energy use in the industrial sector varies widely among countries and depends principally on the level of technology used, the maturity of plants, the sector concentration, the capacity utilization and the structure of subsectors [1]. In the industrial sector, energy is consumed for a wide range of activities, such as processing and assembly, space conditioning, and lighting. In aggregate, the industrial sector uses more energy than any other end-use sector, consuming about one-half of the world's total delivered energy. There is the need to conserve energy in the manufacturing industry which is of paramount importance [4, 5, 6].

An energy audit is an inspection, survey and analysis of energy flow for energy conservation in an industry, process to reduce the amount of energy input into the system without negatively affecting the output [2]. Energy audit is a testing and analysis of how the enterprises and other organizations use energy. Energy audit help to understand more about the ways energy and fuel are used in any industry, and helps in identifying the areas where wastes can occur and where scope for improvement exists. Energy audit give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme helps to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy [5, 7, 8, 9].

Energy audit represents the most important tool for current energy efficiency analysis in power plant in order to propose adequate measures for energy efficiency improvements. Such an audit involves; systematic data gathering about energy production and consumption, identification of power flow through the plant, defining the

measures for improving energy efficiency, economical and technical justification of proposed measures, and rating the proposed measures according to the established criteria [8, 9, 10].

The importance of carrying out energy audit on electrical energy usage in power plants involves; determining locations in power plant with the highest electrical energy losses, cost reduction for electrical energy production using measures proposed in energy audit, increasing of electrical energy production by improvement of efficient usage of turbine cycle and reduction of self-consumption, maintenance planning and improvement of availability, using on-line monitoring for important systems and equipment, and benchmarking of most important electrical equipment and systems [8, 10, 11, 12].

In general, energy audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame [6]. The primary objective of energy audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy audit provides a bench-mark for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization. It also provides an opportunity to look into energy use pattern and recommends way of eliminating losses and improving the efficiency of the system. The advantages obtained through energy audit are improved maintainability, reliability features coupled with loss reduction [8, 10, 12].

A. Types of Energy Audits

The type of energy audit to be performed depends upon the function or type of industry. There are three types of energy audit which are [7]:

i. Preliminary energy audit
ii. General energy audit
iii. Detailed energy audit

i. Preliminary Energy Audit

The preliminary energy audit is the simplest and quickest type of energy audit. It is carried out in a limited span of times and it focuses on major energy supplies and demands. It aims at taking steps which are necessary for implementation of energy conservation program in an establishment. It involves activities related to collection, classification, presentation and analysis of available data in arriving at the most appropriate steps to be taken in establishing energy conservation. It involves collection of necessary data, minimal interviews with site operating personnel, a brief review of facility utility bills and other operating data and identifies glaring areas of energy waste or inefficiency [13, 14].

ii. General Energy Audit

The general energy audit (complete site energy audit) is an expansion of the preliminary audit in which more detailed information about facility operation are collected and more detailed in evaluation of energy conservation measures are performed. In this type of audit, utility bills for about 12 to 36 months period are collected to allow the auditor to evaluate the facility energy rate structure and energy usage profiles [15]. Additional metering of specific energy consuming systems is often performed to supplement utility data. This type of audit will be able to identify all energy conservation measures appropriate for the facility given its operating parameters. A detailed financial analysis is performed for each measures based on detailed implementation cost estimates, site specific operating cost savings and the customer's investment criteria. Sufficient detail is provided to justify project implementation [8, 16, 17].

iii. Detailed Energy Audit

Detailed energy audit (comprehensive audit) is an expansion of the general energy audit. It covers estimation of energy input for different processes, collection of past data on production levels and specific energy consumption. It is a comprehensive energy audit action plan to be followed effectively by the industry. It provides a dynamic model of energy use characteristics of both the existing facility and all energy conservation measures identified. The scope of this audit is to formulate a detailed plan on the basis of quantitative and control evaluation, to evolve detailed engineering options to reduce total energy costs and consumption for the product manufactured [12, 17, 18].

In Nigeria the energy efficiency and conservation measures by industries remain largely unexploited due to lack of awareness of the economic and social benefits of energy auditing. The country is passing through a serious energy crisis and it has been even more affected not by a lack of energy resources, but largely due to poor resource and financial management by most of the industries in the country [12].The cumulative effect is loss of competition in the global market by these industries and low after- tax returns which is constitutes a major disincentive to investment and sustainable industrial growth. It is in this direction that the paper aims to analyze the pattern of energy consumption in Distillation and Bottling Company in Nigeria in order to reduce the bottom line of business enterprise.

II. Material and Methods

The electrical energy demands of the A and T Food and Beverages Plc were evaluated by carrying out an energy audit to determine the average energy consumption of the companies. In this study, a detailed energy audit was adopted for energy project implementation plan. This type of audit offers the most accurate estimate of energy savings and cost. It conducts the interactive effects of all projects and accounts for the energy use of all major equipment.

A and T Food and Beverages Plc located at Ota, Ogun State is a multinational company specialized in the production and wholesale supply of treated water, water dispensers, soft drinks, foods and beverages industry in countries of Africa and Asia. The company is currently one of the Nigeria's largest and the most advanced Refilling Water Plant. The major sources of energy used in the factory includes: electrical and thermal (fuel) energy. The primary source of electrical energy is from the electrical utilities company and the company's power generating set with power rating of 1000kVA as standby generators. The company has some equipment/machines e.g. pumps, motors, boilers, chillers, filler machine, capping machine, compressors etc that uses electricity as their source of energy. The block diagram of the equipments is shown in Figure 1.

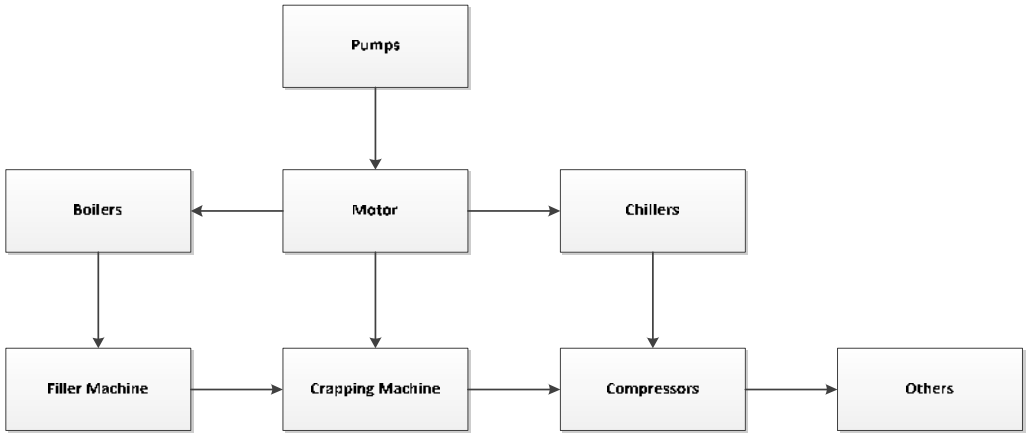

Figure 1: The block diagram of the company equipments

A. Data Collection and Analysis

The basic source of data for this study is the secondary source data for the period of seven years (2011-2017) obtained from the publication of the International Standard Industrial Classification of All Economic Activities (ISIC) in Nigeria and from text book and published article in the subject matter.

From the data collected, the detailed analysis of data was done by identifying the energy types used by the company, calculate the energy consumption for each type in MWh, calculate the percentage breakdown of total consumption of each energy used to establish utilization pattern. In addition, the database prepared was studied and the results are presented, this helped to identify the areas with maximum energy saving potential.

B. Mathematical Equation for Energy Consumption

The quality of electricity from utility company used by the machine in the manufacturing process is determined using.

$$E_p = \eta pt \quad (1)$$

The thermal energy input is calculated based on quantity of fuel used to generate steam in the boiler as:

$$E_{Th} = C_f W \quad (2)$$

Therefore, for each unit operation the total energy input is given as:

$$\mathrm{E_t} = \mathrm{E_p} + \mathrm{E_{Th}} \quad (3)$$

The percentage of total energy consumption is given as:

$$\mathrm{E_T\%} = \frac{\mathrm{E_p}}{\mathrm{E_t}} \times 100 \quad (4)$$

and

$$\mathrm{E_T\%} = \frac{\mathrm{E_{Th}}}{\mathrm{E_t}} \times 100 \quad (5)$$

The electrical load factor of the machine in the manufacturing process is determined by opening the motor controller or switch box of the motor and connecting a clamp-on ammeter and current for reading the current entering the motor.

The load factor of the manufacturing machine is given as:

$$LoadFactor = \frac{Actualloadcurrent}{Fullloadcurrentonnameplate} \quad 6$$

where;

E_p is the electrical energy power input in kWh
η is the motor efficiency
t is hours of operation
E_{Th} is the thermal energy input (J)
C_f is the calorific value of fuel (J/l)
Wis the quantity of fuel (w)
E_t is the total energy input

III. Results and Discussion

The analysis of results for various unit operations at the A and T Food and Beverages Plc for period of seven years (2011-2017) is presented in Figure 2 to Figure 7.

The primary power supply for the companies is through the11 kV feeders connected to the plants and the secondary power is from the two (2) 1000kVA generating sets. The results of energy usage pattern in the companies are presented and discussed. The electricity bill in MWh consumption for the period of seven years (2011-2017) and Power factor (P.F) are presented in Figure 2 and Figure 3 respectively.

From Figure 2 it was observed that the energy consumed varies from a maximum value of 688.7 MWh in the year 2012 to a minimum value of 627.3MWh in the year 2017. The variation of power factor from Figure 3 shows that the power factor value varies between 0.926 and 0.984. The difference between the values of the power factor is found to be 0.058.

Figure 4 shows the variation of energy consumption using the generating set. The results show that the values of energy consumption for year 2011 to 2017 were 10606MWh, 9790MWh, 9633MWh, 10117MWh, 10192MWh, 12712MWh and 13071MWh respectively. The highest energy consumption is 13071MWh in the year 2017 which is due to the epileptic power supply in that year, while the least energy consumption is 9633MWh in the year 2013.

Figure 5 shows the variation of total energy consumption with the year. However, the average total energy consumption was computed to be 11,540.4MWh per year. The highest total energy consumption of 13698.3MWh was recorded in the year 2017. The least total energy consumption of 10304.9MWh was recorded in the year 2013.

The summary of the percentage of total energy consumed for the seven years period for the company are given in Figure 6.This might be as a result of epileptic nature of power supply from utility company. The diesel fuel energy (generating sets) in operating diesel engine was exhausted in operating the generator and was the highest energy consumed with average energy consumption from 94.15% of the total energy input for the period of seven years.

Figure 7 shows the patterns of electrical energy consumption by various company equipment used for different stages of operation. The result shows that electric motor accounted for highest electrical energy consumption of 54%, Chillers accounted for energy consumption of 20% of total energy consumption in the production line. In addition, boilers and filler machine has percentage values of energy consumption of 5% each from the total energy consumption. The least energy consumption equipment is pumping machine with the value of 3% and other equipment such as A/C, fan, bulbs which have energy consumption of 5%.

Some of the electrical losses in this equipment can be improved by using capacitor banks or other power factor correcting mechanisms to reduce the reactive power losses. In addition, cooling problem of electrical loss can be reduced by using of soft-starting A/Cs and better electrical housekeeping.

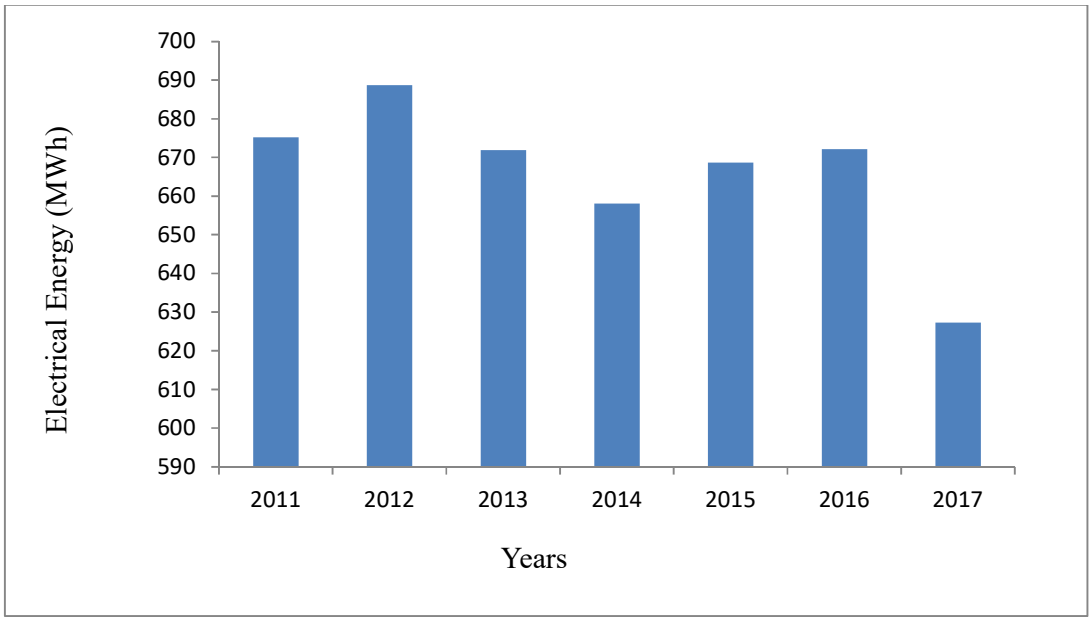

Figure 2: Electrical energy power input for period of (2011-2017)

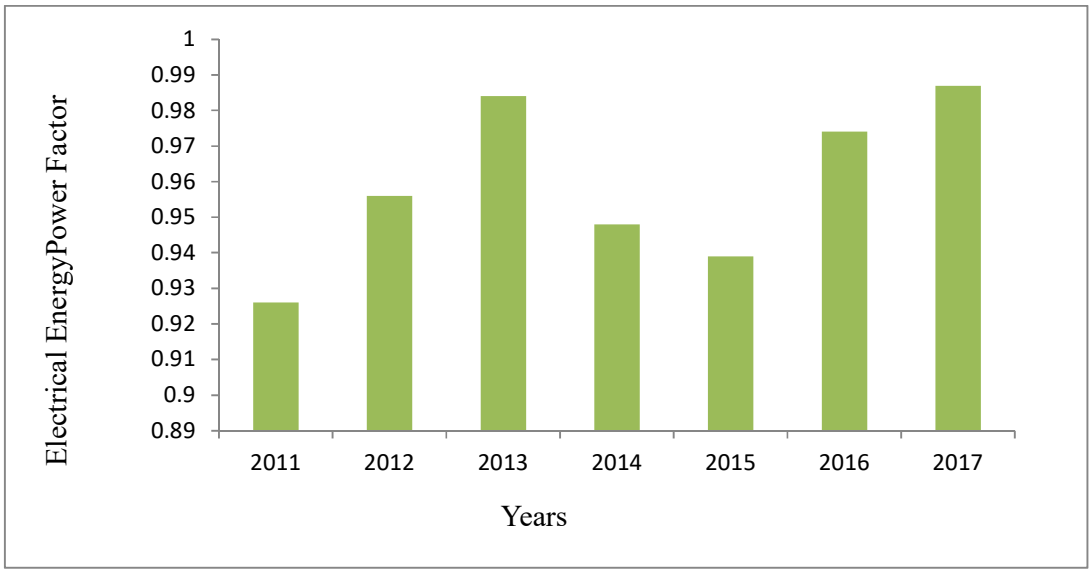

Figure 3: Electrical energy power factor for period of (2011-2017)

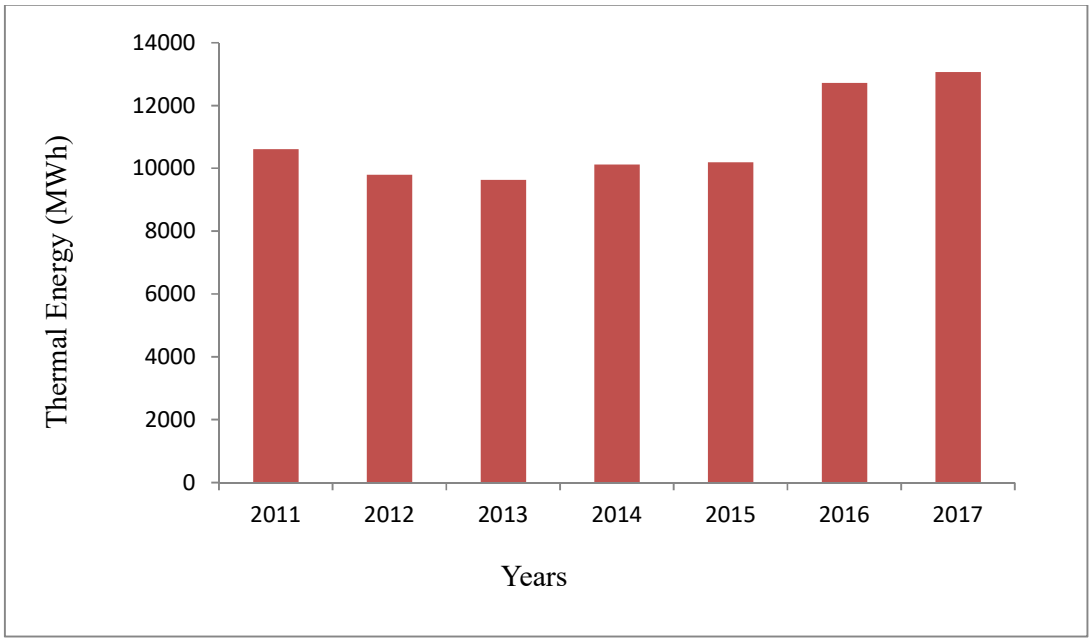

Figure 4: Thermal energy (fuel) input for period of (2011-2017)

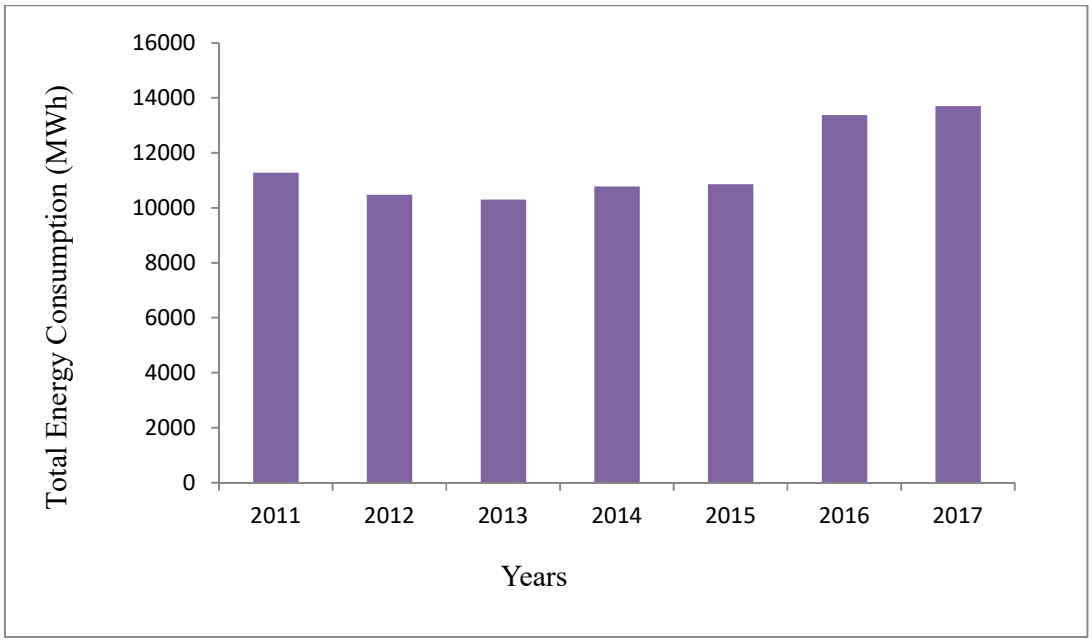

Figure 5: Total energy consumption for period of (2011-2017)

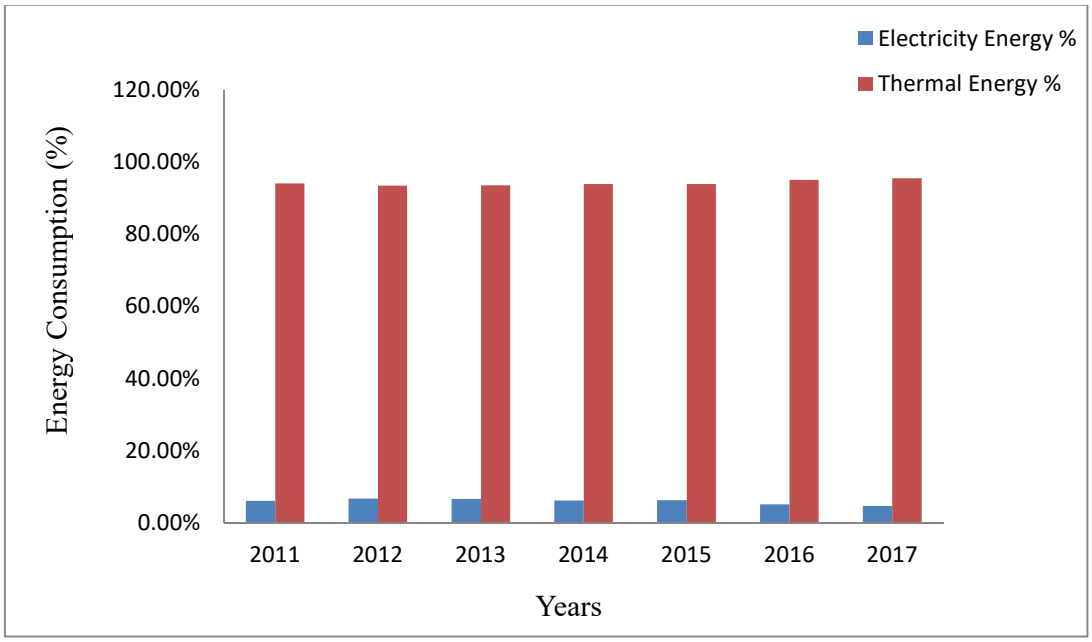

Figure 6: Comparison of energy consumption for period of (2011-2017)

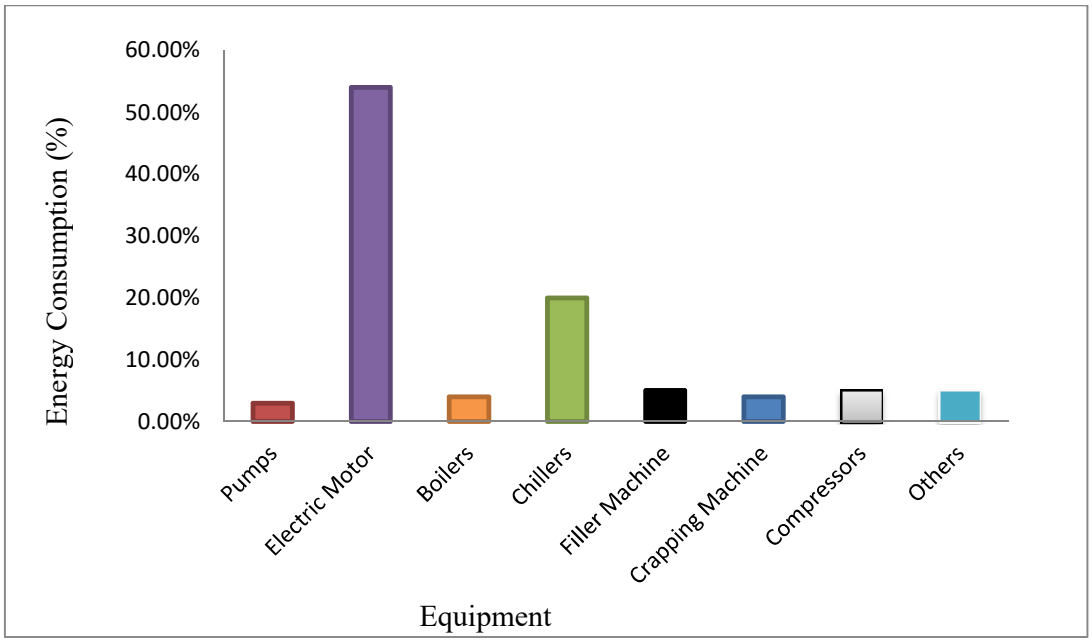

Figure 7: Energy consumption for various company equipments

IV. Conclusion

This paper has investigated the pattern of energy consumption at A and T Food and Beverages Plc to identify the sources of energy waste and assess the effectiveness of the strategies for energy savings in the companies. This was achieved by obtaining the companies data from the computation based data of International Standard Industrial Classification of All Economic Activities (ISIC) in Nigeria, and published article for the period of (2011-2017).The data collected were analyzed using computer calculation and the results were presented and discussed. The sources of energy in the companies comprise of electricity from utility company and use of generating sets (fuel).

The electrical energy consumption in the companies was mainly from generating set. This is due to either low voltage or epileptic power supply from the utility company. The results showed that the total percentage of electrical energy consumed from utility company is 40.95% with average percentage of 5.85% for period of seven years (2011-2017), whereas, the total percentage of fuel consumed was 659.05% with average value of 94.15% for period of (2010-2017). This research paper therefore identified areas where the companies used and waste energy, and where actions for energy conservation can be implemented.

V. Recommendations

Energy auditing is not an exact science, but a number of opportunities are available for improving the accuracy of the recommendations. Techniques which may be appropriate for small-scale energy audits can introduce significant errors into the analyses for large complex facilities. From the results of energy audit carried out at the A and T Food and Beverages Plc, it was observed that energy wastes were due to lack of good energy conservation practices, fuel leakage and ageing of equipment used. Therefore, the study recommended the following:

i. Heating, ventilating, and air-conditioning are important uses of energy in the industrial sector. Heat exchangers should be regularly cleaned for easy heat transfer and the A/C should not be placed in direct access to sunlight or heat dissipating objects.
ii. Procurement of test equipment for energy monitoring in the company should be done regularly.
iii. Proper maintenance and control of all the equipment and generating sets must be done in order to reduce the energy use and waste.

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