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ELECTRICAL ENERGY AUDIT AT BROTHERS FLOUR AND BISCUIT FACTORY

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DECLARATION

I, the undersigned, declare that this thesis is my original work, has not been presented for any degree or otherwise in this or any other university, and all sources of materials used for the thesis have been fully acknowledged.

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I, the undersigned, certify that I read and hereby recommend for the acceptance by Addis Ababa University a thesis entitled, ''Electrical Energy Audit at Brothers flour and Biscuit factory" in partial fulfilment of a degree of Masters of Science in Electrical Power Engineering with my approval as a university advisor.

Dr.Getachew Bekele Beyene   _______________   _____________

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ABSTRACT

Electrical energy plays a vital role almost everywhere, especially those that are energy intensive institutions. As there are limited resources and increased cost to generate electricity, it is our keen duty to save resources for future use by doing research about energy conservation, which energy audit is one to consider in different sectors such as the one this research work is attempting. This would help the factory to be competent in the market because their production cost depends on electric power.

This thesis presents about electrical energy audit in Brothers Flour and Biscuit Factory, which is one of the intensive energy consumer industries currently flourishing in our country. For the purpose of data analysis, a historical data regarding their energy consumption and energy intensive equipment's, such as electric motors and lighting systems were collected. Countries with energy efficient Biscuit and Flour factory have been selected as a benchmark to compare the energy efficiency of the factory. From the data analysis it is found that the factory loses 31% and 22% of total energy for biscuit and flour respectively due to inefficient electrical energy consumption and pays a total of 4,320,216 ETB/year.

Modelling and simulation of the whole power distribution system based on the primary data collected and one-line diagram have been done with Electrical transient analyzer program (ETAP 12.6.0) software package. Annual technical energy loss of the factory power distribution system has been investigated and its value is 1.2%. i.e. ideal loss within acceptable range, which is 3-6%. But, expenditure for technical energy loss due to distribution transformers is high in comparison to distribution cables.

The factory accomplishes its activities with extra and inefficient lamps and also with low efficiency of electric motor due to under load operation of the motor for specific application. At the end of factory's electrical energy audit the possible total energy saving potential in KWh per year from lighting only was 338.7 MWH/year by using energy efficient lamps and optimizing the illumination of the existing lighting system. Hence the total saving in Ethiopian birr per year from lighting were 138,397.54 and their payback period is less than 6 months. By replacing standard (low efficiency) motors with energy efficient motor gives 49,482 KWh/year energy saving and cost saving of $1,484 per year as well as payback period of less than 10 years as analyzed by Motor Master software.

Key words: energy Audit, Energy Conservation, Energy conservation opportunities (ECOs), technical energy loss, ETAP

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NOMENCLATURES AND ABBREVIATIONS

2BF	Brothers Flour and Biscuit Factory
ABB	Asean Brown Boveri
AMI	Advanced metering infrastructure
AMR	Automatic meter reading
ANSI	American national standard
B	Bus
C	Cable
CB	Circuit Breaker
CCR	Central Control Room
CFL	Compact fluorescent lamp
DG	Distributed generation
DPCA	Distributed Power Coalition of America
DT	Distribution Transformer
ECMs	Energy Conservation measures
ECOs	Energy Conservation Opportunities
EEP	Ethiopian Electric Power
EEPCO	Ethiopian Electric Power Corporation
EEU	Ethiopian Electric Utility
ETAP	Electrical Transient Analyzer Program
ETB	Ethiopian Birr
HID	High-Intensity discharge
HVAC	Heating, ventilation and air-conditioning
IEC	International electro technical commission
JICA	Japan International cooperation Agency
LED	Light Emitting diode
LF	Load Factor
LLF	Loss Load Factor
LTC	Load Tap Changing
MD	Maximum Demand
MDB	Main Distribution Board
METEC	Metal Engineering Corporation
NEC	National Electric Code
OTI	Operation Technology, Inc.
PEA	Provincial Electricity Authority
PLED	Polymer light emitting diode
PQA	Power quality analyzer
SEEDT	Selecting Energy Efficient Distribution Transformers
TCF	Trillion Cubic Feet
THD	Total harmonic distortion
TNEB	Tamil Nadu Electricity Board
UGS	Underground Raceway Systems
UPS	Uninterruptable Power Supply

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Energy conservation is a most spoken subject in the world today. Every factory, industries, commercial complexes, offices, institutions, hospitals etc. are now totally dependent on electricity [1]. The demand and the cost of electricity are continuously increasing and availability is limited. Presently, the energy auditing is becoming more popular to cut down energy bill and reduce the recurring expenditures [2]. It attempts to balance the total energy inputs with its use and serves to identify the areas where wastage can be minimized if not totally eliminated. It also quantifies energy usage according to its discrete functions. Energy audit consists of several tasks which can be carried out depending on the type of the audit and the function of the audited facility [3]. It starts with a review of the historical data on energy consumption, which can be compiled from the electricity bills. Factory energy audit is an effective tool in defining and pursuing comprehensive energy management programme [4]. The energy management programme is a systematic on-going strategy for controlling a factory's energy consumption pattern. It is to reduce waste of energy and money to the minimum permitted by the climate the factory is located, its functions, occupancy schedules, and other factors. It establishes and maintains an efficient balance between a factory's annual functional energy requirements and its annual actual energy consumption.

As per the Energy Conservation Act, 2001, Energy audit is defined as the verification, monitoring and analysis of energy use including submission of technical report containing all the recommendations for improving energy efficiency with cost analysis and an action plan to reduce consumption [5]. A systematic approach, to monitor industrial energy consumption and to pin point source of wastage, is known as energy audit. Energy audit is an energy survey or an energy analysis of energy flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output(s), so that it is not confused with a financial audit [6].

Recent days, energy saving has become essential rather than electricity generation. In any factory, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. The energy demand is increasing because of the increasing population in the country from time to time. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists.

Electrical Energy Audit forms an integral part of an Industrial Energy Audit. It is one of the two main forms of energy that is being audited and accounted for during Energy Audit. For some of the Industries/factories which do not have Thermal Utilities an Energy Audit will only consist of Electrical Energy Audit, as that of 2BF.

Electrical Energy Audit involves Studying, Assessing, Measuring and Analyzing electrical utilities. In a typical Plant, the electrical utilities consist of

- Transformers
- Power Distribution System
- Metering and Monitoring System
- Motors
- Blowers/Fans
- Compressors
- Pumps
- Lighting, Etc.

The Energy Audit would 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 will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies etc. Energy auditing will not only save money but it also improves the quality of electrical energy supply. Most of the saving is possible with low investment, without affecting the manufacturing processes and quality [7].

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].

1.2 Statement of the Problem

Both electric utilities and end users of electric energy are becoming concerned about the energy/power loss and their main causes. The utility is concerned about the power loss or the energy losses until the meter of consumer and the loss behind the meter is the concern of the consumer. Brothers Flour and Biscuit Factory is one of the energy intensive consumer factories in our country as compared to commercial and the expenditure of the factory for electrical energy is high.

The Factory worker did not know their energy consumption patterns in well-defined manner by performing energy audit. This is due to:

- Lack of awareness for the factory workers about energy management,
- Lack of skilled human resource in energy management,
- The absence of enough measuring instruments for audit,
- Absence of energy audit team in the factories, etc.…

As a result of the above facts Brothers Flour and Biscuit Factory was selected, which has electrical energy related problems, to conduct energy audit. The walk-through observed problems (such as using energy inefficient equipment) in the factory also signify that it should conduct energy auditing. The owner of the factory is unable to know the monthly profit due to variation of electrical energy consumption for constant output.

This thesis investigates the electrical energy consumption patterns of the Brothers Flour and Biscuit Factory and analyses the efficiencies of the major energy consuming systems thereby identifying energy conservation opportunities.

1.3 Objectives

1.3.1 General Objective

The general objective of the research is to investigate the way energy is being used in Brothers Flour and Biscuit Factory, to identify energy conservation opportunities and come up with recommendations to minimize energy wastage without affecting production & quality.

1.3.2 Specific Objectives

The specific objectives of the thesis include:

- Understanding how energy is being used in Brothers Flour and Biscuit Factory
- Investigating energy conservation opportunities of the factory.

- Examining electrical energy consuming systems of the factory so the improvements can be quantified in terms of both energy and cost.
- Identifying and analyzing improved operational techniques and / or new equipment's that could substantially reduce energy and which ones are cost-effective
- Evaluating economic and technical practicability of opportunities and recommending the feasible measures
- Assessment of technical energy loss of 2BF distribution system components
- Determination of causes and effects of technical energy loss in the factory
- Recommendations for minimization of energy wastage without affecting production & quality.

1.4 Significance of the study

The energy audit in a factory is a feasibility study. For it not only serves to identify energy use among the various services and to identify opportunities for energy conservation [1], but it is also a crucial first step in establishing an energy management programme. The audit will produce the data on which such a programme is based. The study reveals to the owner, manager, or management team of Brothers Flour and Biscuit Factory or for any concerned body the alternatives available for reducing energy waste, the costs involved, and the benefits achievable from implementing those energy-conserving opportunities (ECOs).

1.5 Limitation of the study

In this study technical energy loss was assessed based on maximum power loss (simulation result at maximum demand), load factor and loss factor of power system components in the factory power distribution system. The load factor and loss factor were estimated from the measured power demand of each department based on the production operation period of each department. However, accurate assessment of technical energy loss requires accurate load factor and loss factor, and this needs accurate measurement of power demand for 24 hours, which is measured per hour interval. The main reasons were:

- Most of the ammeters, voltmeters, and watt meters installed in the control room of each department are not accurate which is observed during sample measurement and sum of them are already damaged. Hence, the only alternative was to measure load current of each department device.

- Measuring load current for 24 hours per hour interval for each equipment, which are installed far away from each other, was impossible by one person. At least it requires three people per department, to measure day and night demand per 24 hours accurately.

1.6 Methodology

Generally, the methodology employed under this study is presented according to the following steps.

1. Gathering data and analyzing it with preliminary audit, critical analysis of papers
2. Conducting introductory meetings, audit interview, walk through tour with relevant managers by establishing work relation with the factory management
3. Primary data of the power distribution system of the factory is gathered through personal interviews, measurement, telephone, and the available documents of the company
4. Analysis of lighting system and electric motor analysis with Motor Master + International software as well as bill analysis with bench mark have been done
5. Simulation of the model of the factory power distribution system is prepared using ETAP 12.6.0
6. Load flow analysis of the simulation is done numerically using ETAP
7. Load flow result of the simulation is compared to the standard
8. Technical energy loss of branch circuits is calculated and the result is compared to the ideal standard for loss in electrical power system (3-6%)
9. Cost of technical energy loss is estimated according to EEU tariff
10. Identifying energy conservation opportunities by:
    - ✓ Performing technical evaluation
    - ✓ Performing economic evaluation
    - ✓ Calculating payback periods for energy consuming equipment’s used in the factory
11. Investigation of motors and their data as well as ECOs (economic conservation opportunities with software) is done.

1.7 Organization of the thesis

This thesis contains 5 chapters which are organized as follows: -

Chapter one provides general introduction of the thesis, which highlights the background of thesis, statement of the problem, objectives of the thesis.

Chapter two describes about the factory as well as background theory and literature review of energy audit and technical electrical energy loss assessment.

Chapter three is about data collection and system modelling. Under this chapter data organization, system modelling and software used and analysis of different load of the factory are explained in detail. Major power consuming areas which have high energy saving opportunities are also discussed and technically and economically feasible energy conservation opportunities are summarized.

Chapter four presents simulation studies, analysis of results and discussions. In the last chapter, conclusions and recommendations of the research is presented. Finally, the references and appendices are presented at the end of the thesis.

CHAPTER TWO

ENERGY EFFICIRENCY TECHNOLOGIES AT BROTHERS FLOUR & BISCUIT FACTORY AND LITERATURE REVIEW

2.1 Brothers Flour and Biscuit Factory

Brother Flour & Biscuit Factory is a profit based company established in November 1992 E.C for the purpose of engaging mainly in the business of food processing, with the initial capital investment of 8,671,660 ETB on 700 sq.m land, The Company is owned by private shareholders and over seen by the general manager Mr. Mohamed Seid Ibrahim. The total area of the company is more than (30,000) Sq.m. at this time.

The latest Brother Flour & Biscuit Factory was equipped with modern biscuit manufacturing technology which was established in 2004 E.C.

- **Location**

2BF is found in Adama city. Adama, also known as Nazreth, is a city in central Ethiopia and the previous capital of the Oromia Region. Adama forms a special Zone of Oromia which have six sub cities and is surrounded by Misrak Shewa Zone. It is located at 08°32′29″N 39°16′08″E/ 8.54139°N 39.26889°E Latitude and Longitude respectively at an elevation of 1,712 meters (5,617 ft.), 99 Km, which is now reduced to around 84 Km on high way, Southeast of Addis Ababa along the main road to Harar. The city sits between the base of an escarpment to the west, and the Great Rift Valley to the east.

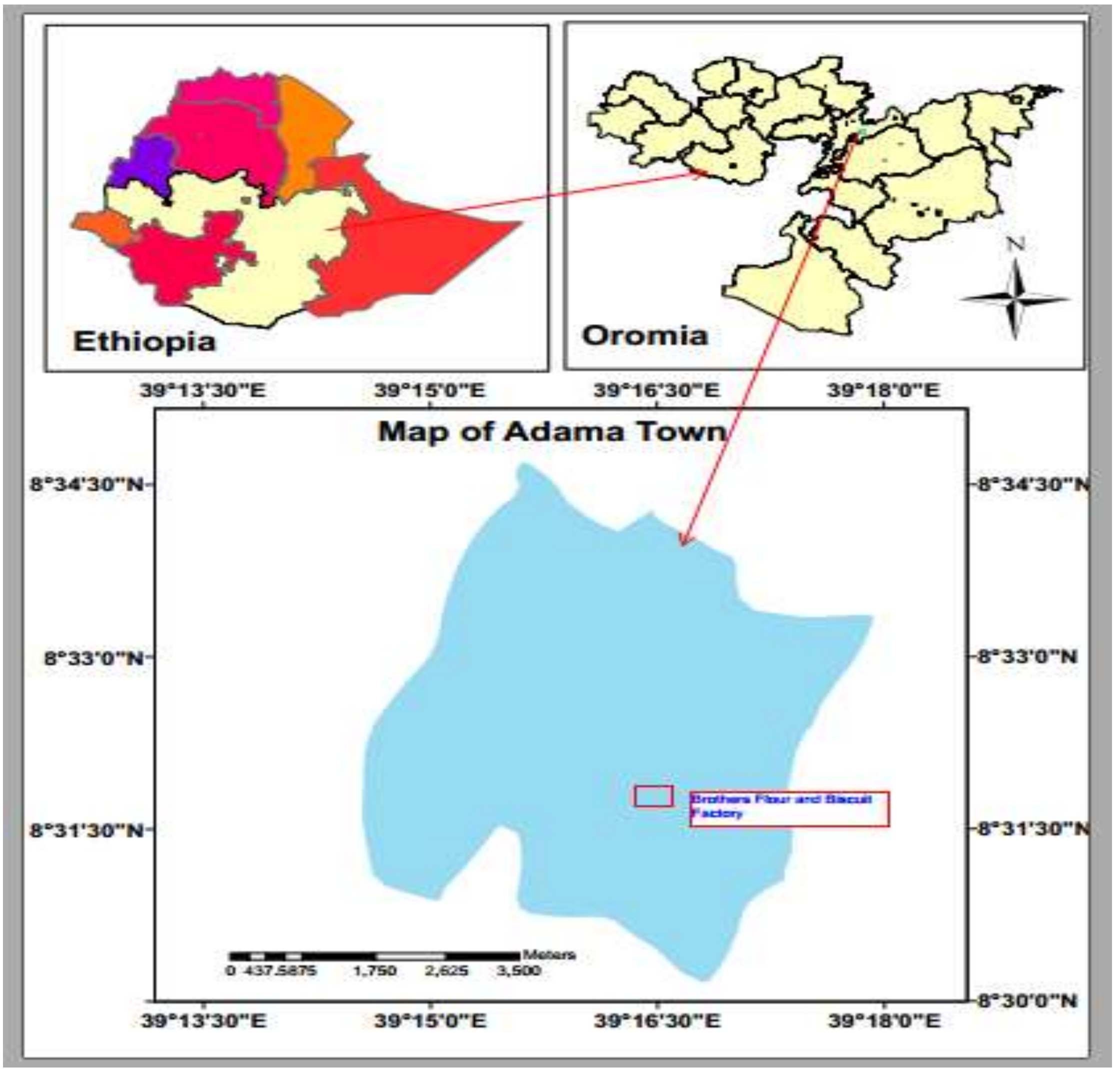

Figure 2-1 Location map of Adama town where 2BF is found

Climate

Adama lies in somewhat warm and lower badda dare Climate. Hence, it enjoys hot and dry weather for the greater part of the winter and warm and sunny climate in summer. Thus, the area is generally, known for its attractive weekends and summer resort release. References to its temperature points that Adama has a minimum annual temperature falling between 19^0 and 22^0C. Its yearly minimum rainfall is reported to be 760 mm.

Biscuit Production Process

The production process involves the following unit operations; receiving raw material, cleaning, storage, transferring through conveyors to intermediate storage, seed mixing, milling, packing, dough mixing, rotary molder (Hard dough), rotary cutter/laminator (Soft Dough), biscuit baking oven, cooling conveyor, stacking machine, and finally to biscuit packing machines.

All materials except flour are preparatory mixed in a certain cream mixer. Materials used at this stage are sugar, shortening, salt, millet jelly, glucose, starch etc. Materials premixed in the previous stage are put into the mixing machine with flow and undergone fermentation. Then the dough is rolled by laminator and the dough sheet is made and it is automatically punched in a molded design by a cutting machine.

Biscuit is then baked on a steel belt (or wire mesh belt) running in the oven for some minutes. The speed of the belt can be adjusted based on the kind of biscuit. After baking, biscuits are cooled on a cooling conveyor which is connected to oven. Finally, biscuits are stacked and then packed.

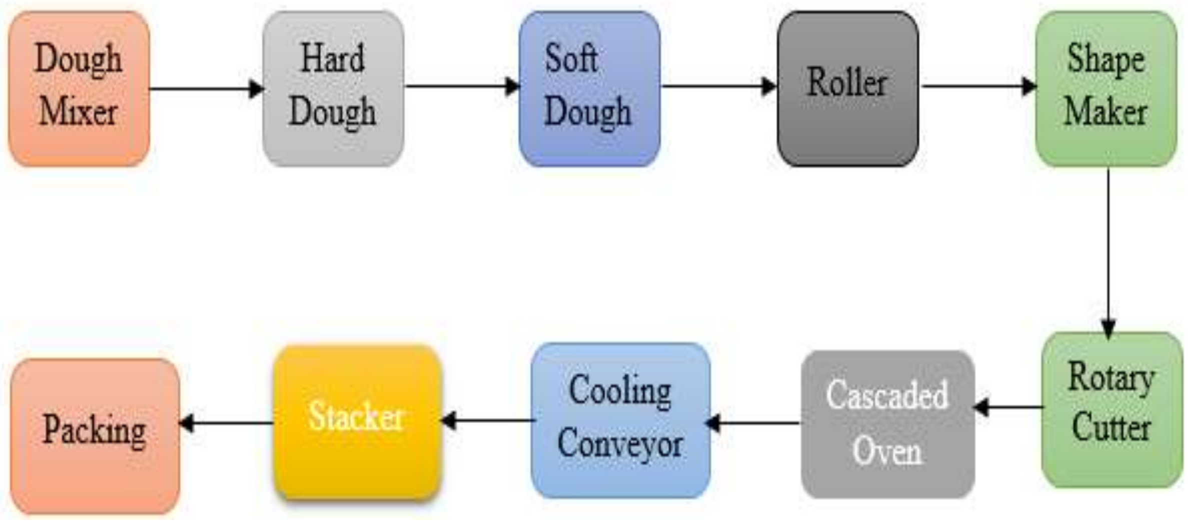

Figure 2-2 Biscuit baking process

There are around 60 ovens of 15KW each in one factory. Oven of 2 factories have intelligent controller. The milling, mixing, biscuit baking as well as packing are fully automated. The size of packaging range for flour is (50 & 100) KG and the packaging range for biscuit is 24.07 & 53.80 gram. In different part of the machine there is temperature control device, flow meters, control board, etc. most of them are digital devices and some of them have chart.

Organizational Structure

Everyone in the company has responsibility for the quality and safety of its work, to operate in conformance with requirements of the food safety management system. Moreover, particular responsibilities and authorities are assigned to managers for the effective operation of their departments. Specific responsibilities for each employee are indicated and communicated in the job description, work instruction and procedures as required. Figure 2-3 shows the factory organizational structure in block diagram.

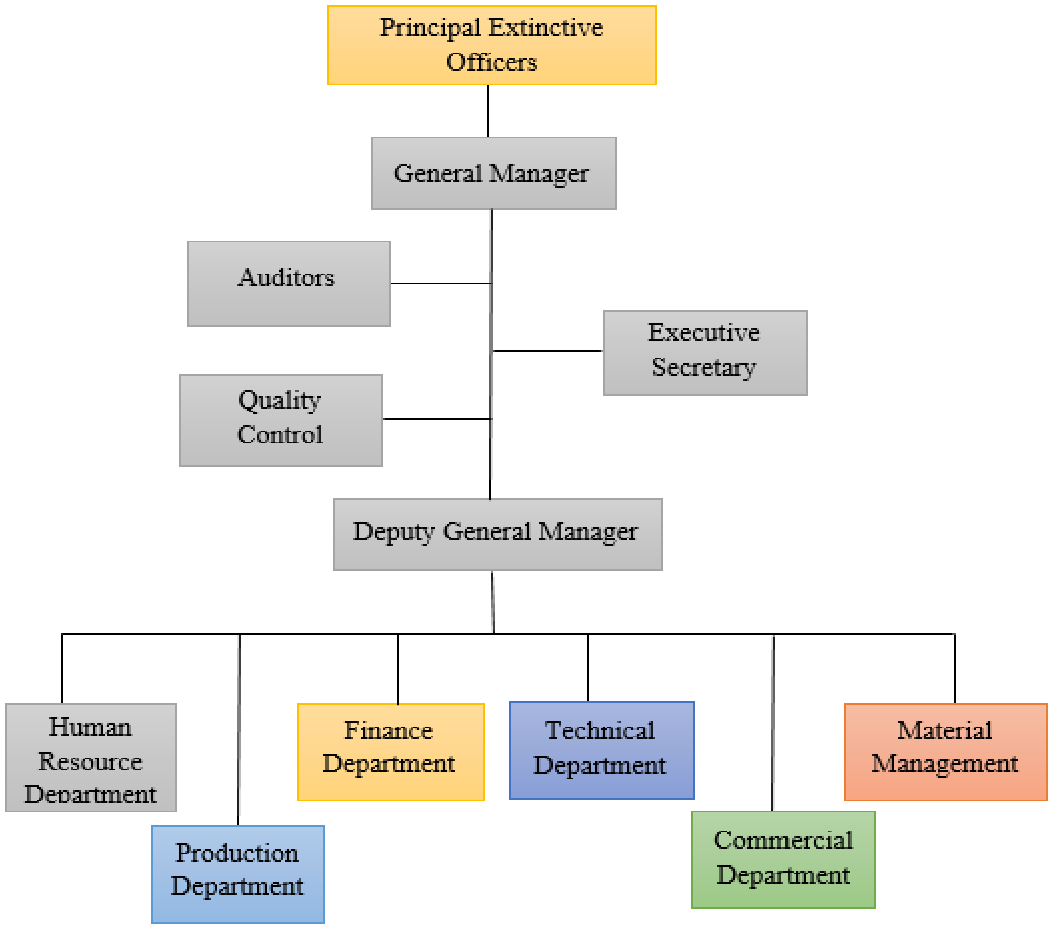

Figure 2-3 brother's flour and biscuit factory organization structure

Staff profile

Currently the factory has total number of more than 1800 workers, out of which:

- 800 are Permanent staff including the administrators which have total of around 45 professionals (15 Degree and 30 College Diploma), and
- 1000 are temporary workers and this number varies based on the day today activity of the factory

2BF have six departments, statistician and secretaries under General Manager. The six departments include: Total personnel service department, finance department, maintenance/electrical department, property section, Wheat Flour production department, and Biscuit production department. The distribution of the permanent workers in each department depends on the need of the factory. Temporary workers are needed with different number within each working day of the factory based on the activities performed in each section of the factory. Most of the time, more temporary workers are needed in Wheat Flour and Biscuit production sections.

Operating Hours

The factory operates throughout the year with three shifts 8 hours operating times for each shift.

- Morning shift from 6:00 AM to 2:00 PM
- Afternoon shift from 2:00 PM to 10:00 PM and
- The last which is Night shift is from 10:00 PM to 6:00 AM

Depending on the availability of the product, if there is sufficient product, some of the machines may not be in operation on Sunday once a week.

Utilities

The factory depends on the following utility systems: -

i. Electricity utility systems: The factory uses electricity for lighting and to run electrical appliances (such as pumps motors, flour milling motor, oven, air compressor fans, mixer, conveyor, laminator, computers, etc.). So, the factory should have the necessary source of electricity utility systems.

ii. Water distribution utility systems: The factory consumes too much water. The source of much amount of water used in 2BF is ground water in the factory compound and some amount is from Adama town water utility distribution system. Therefore, to have these functions the factories presence of water distribution utility systems is required.

Additionally, the factory has three 250KVA standby diesel generators which are used during power interruption for some critical loads. This generator only supplies loads connected to the transformer named T3 & T4, T5 & T6 and T7 & T8. The factory has a total connected load of about 4.608MVA as obtained from the factory's data.

Major energy consuming equipment's

Major energy consuming equipment's in 2BF are motors. Here motors which have rated power greater than 1HP are taken as major energy consuming equipment.

- Cream mixer
- Dough mixing machine
- Laminator
- Cutting machine
- Rotary molding machine
- Steel belt Oven

- Cooling conveyor
- 3-step cooling conveyor
- Stacking machine
- Wire cut attachment
- Oil spray machine
- Revolving salt duster

Factory supply

Power is supplied from Adama distribution substation which supplies the factory distribution system through 15KV overhead transmission line. The factory consists of nine distribution transformers, which is shown in figure 2-4.

The factory is classified into different departments and sections in consideration to its vast size and process. The departments are generally named as production departments, electrical departments, and supporting facilities. Inside the production department also there are different departments which are assigned according to the production process undertaken. And, all the departments have their own control room with appropriate protective devices, controllers and fault or history indicators in collaboration with CCR (central control room). Power is distributed to different departments and each department has its own distribution transformer. Currently the factory is on the erection process to expand the factory. Simplified one-line diagram of the factory is given below and the load labelled 1 to 6 are the load on each transformer at which their value is specified in chapter 3.

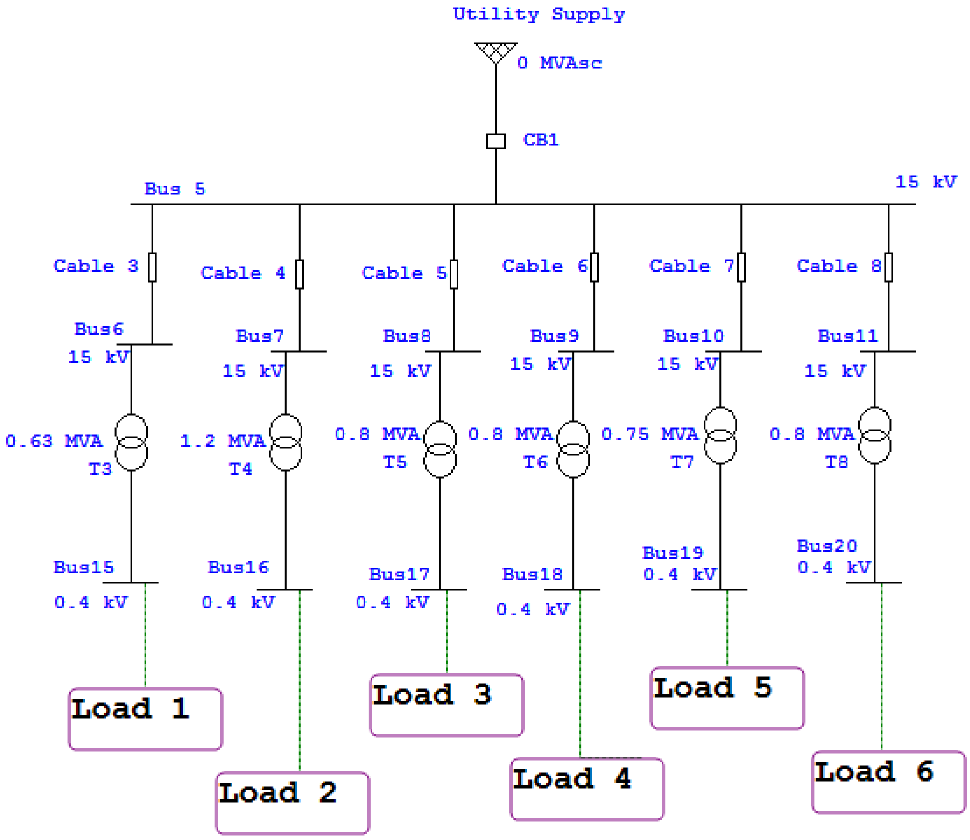

Figure 2-4 Simplified single line diagram of power distribution system of the factory

2.2 Energy Security Systems and Energy Auditing

Energy is an overpowering need of any society. It plays an important role in the national security of any given country as a fuel to power the economic engine. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities and as a scarce resource it has been an underlying cause of political conflicts and wars. Energy security is a term for an association between national security and the availability of natural energy resources. It refers to the uninterrupted availability of energy sources at an affordable price. Long-term energy security is linked to timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance. Currently, long term measures are being considered in the world to increase energy security by reducing dependence on any one source of imported energy, exploiting native fossil fuel or renewable energy resources, increasing the number of suppliers, and reducing overall demand through energy conservation measures. In addition to the security problem, the gathering and use of energy resources can also be harmful to local ecosystems and may have global outcomes. When producing electrical energy from the conventional energy resources through the traditional processes, the greenhouse gases leak into the atmosphere, which are very harmful to the environment. With these concerns countries have been researching new methods of creating electricity in a clean way [9].

Types of Energy Audit

Energy audit is the basic to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use and assists to identify all the energy streams in a facility. It is the process of assessing the way energy is being used and possibly wasted in industries, factories, energy consuming systems, machines, etc… and if there is wastage, it takes corrective measures to diminish the wastage. Minimization of energy wastage is done by finding better way of meeting the energy demand. Saving money on energy bills is attractive to business, industries and individuals alike. Customers, whose energy bills use up a large part of their income and especially those customers whose energy bills represent a substantial fraction of their company's operating costs, have a strong inspiration to initiate and continue an ongoing energy cost control program. Energy audit is sometimes called an energy survey or an energy analysis, so that, it is not in a weak position (hampered) with the negative connotation of an audit. Energy Audit can be classified into two types.

1. Preliminary Audit [11] [12]: It is a relatively quick exercise to:
   - Establish energy consumption in the organization
   - Estimate the scope for saving
   - Identify the most likely and the easiest areas for attention
   - Identify immediate (especially no- or low-cost) improvements or savings
   - Set a "bench mark" (reference point)
   - Identify areas for more detailed study or measurement
   - Preliminary energy audit uses existing, or easily obtained data.

The preliminary audit alternatively called a simple audit, screening audit or walk-through audit which is the simplest and quickest type of audit. It involves slight interviews with site operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and identify glaring areas of energy waste or wastefulness.

2. Detailed Audit [12] [13]: -A wide-ranging audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit provides the most accurate estimate of energy savings and costs. It considers all the equipment’s that use existing energy in the factory and performs energy cost saving calculations.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of present operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges.
This type of audit will be able to identify all energy conservation measures which are suitable for the facility given in operating parameters. A detailed financial analysis is executed for each measure based on detailed implementation cost estimates (site-specific operating cost savings, and the customer's investment criteria).

Energy Efficiency

Efficient energy use, or simply called energy efficiency, is the goal of efforts made to reduce the amount of energy required to provide products and to attain the same level of services. Improvements in energy efficiency are most often achieved by adopting a more efficient technology or production process. Reducing energy use reduces energy costs and may result in a financial cost saving to consumers if the energy savings offset any additional costs of implementing an energy efficient technology. Energy efficiency is also seen to have a national security benefit because it can be used to reduce the level of energy imports from foreign countries and may slow down the rate at which domestic energy resources are depleted. As more electricity is used, fossil-fueled power plants not only generate more electricity, but also more pollution. Therefore, reducing energy use is also seen as a key solution to the problem of reducing emissions [10].

Power and Energy Losses

Power system losses are the difference in the amount of energy or power that is required to be delivered to a system to supply the customer’s energy or power needs and the power or energy practical used by customers.

1. Power losses, defined in kW or MW create a need for the provision of additional capacity to be installed on the system over and above that required to meet the system demand.
2. Energy Losses, defined in kWh or MWh, is the integral of the power losses with respect to time and represents the amount of additional energy that needs to be purchased.

Energy losses associated with a distribution system can be classified as follows [14]:

1) Technical Losses - losses associated with the electrical system
    - Series losses which are proportional to the square of the current and to the resistance of the circuit elements and
    - Shunt losses due the excitation losses in transformers and rotating machines, as well as leakage currents in cables
2) Non-technical (economical) losses - losses associated with unidentified and uncollected revenue. This covers matters such as illegal connections, meter tampering, metering errors, errors in estimating unmetered supplies, errors in invoicing and revenue collection.

The technical loss is the component of distribution system losses that is inherent in the electrical equipment, devices and conductors used in the physical delivery of electric energy. It includes the Load and No-Load (or Fixed) losses in the following [15]:

- Sub-transmission Lines;
- Substation Power Transformers;
- Primary Distribution Lines;
- Distribution Transformers;
- Secondary Distribution Lines;
- Service Drops;
- Voltage Regulators;
- Capacitors;
- Reactors; and
- All other electrical equipment necessary for the operation of the Distribution System.

This research focuses on distribution transformers, and secondary distribution lines technical energy loss for 2BF power distribution system.

Technical losses represent 6-8% of the cost of generated electricity and 25% of the cost to deliver the electricity to the customer [14]. Transformer losses in distribution network are also considered as copper losses due to the internal impedance of the transformer coils and the core losses. Transformers connected to the energy distribution network are connected permanently to the power supply system; therefore, the no- load losses of the transformer must be taken in to consideration.

2.3 Basic Energy Efficiency Principles and Technologies

During the design and development process, energy efficient buildings must have a comprehensive, integrated outlook that seeks to reduce loads. Although a single technique cannot achieve a significant energy reduction, combined techniques could do it. So many combinations should be assessed.

- **Climate and Site**

The basic principle of building climatic design focuses on the building's response to the natural environment and how to gain the maximum benefit from the local climatic conditions. A building's location and surroundings play a key role in regulating its temperature and illumination.

The six important aspects of architectural planning which will affect thermal and energy performance of buildings are site selection, layout, shape, spacing, orientation and mutual relationship. When faced with unfavorable climatic conditions, optimal siting and site design may solve all or part of the problems. Site elements to be considered include topography (slopes, valleys, hills and their surface conditions), vegetation (plant types, mass, texture) and built forms (surrounding buildings and structures). For example, trees, landscaping, and hills can provide shade and block wind. In cooler climates, designing buildings with south-facing windows increases the amount of sun entering the building, minimizing energy use by maximizing passive solar heating. Tight building design, including energy-efficient windows, well-sealed doors, and additional thermal insulation of walls, basement slabs, and foundations can reduce heat loss by 25 to 50 percent [17].

- **Building Envelope**

Elements of the building envelope are exterior walls, windows, roof, underground slab and foundation. And the three factors determining the heat flow across the building envelope are temperature differential, area of the building exposed and heat transmission value of the exposed area [18].

Glazing must be selected for optimal performance. Glass on south, east and west facades should be highly protective against solar heat gain, except glazing that is protected by shading devices or south-facing glazing being used for passive solar heating. Glass on north facades can be clear or lightly tinted. Consider fritted and spectrally selective glazing, tuned to use and orientation on south, east or west elevations.

To minimize heating, and cooling loads, effective insulation should be provided by optimally insulating the building envelope. Avoid thermal bridging in metal-framed assemblies through exterior wall, roof and floor details and components. Avoid irregular exterior building shapes, which increase surface area, resulting in unwanted heat loss.

Air and moisture in the building envelope should be controlled by detailing the building envelope to minimize infiltration and to prevent moisture build-up within the walls due to condensation. Ensure that all internal sources of humidity are properly ventilated.

- **Efficient Lighting Systems**

Energy efficient lighting system should ensure that illumination is not excessive and switching is provided to turn off unnecessary light. Also, take advantage of day-lighting opportunities whenever possible. The use of techniques to bring sunlight into buildings and the efficiency of artificial lighting system can contribute to saving energy. Efficient lighting system that utilizes both natural and electric sources can also provide a comfortable yet visually interesting environment for the occupants. Lighting systems introduce heat into the space and increase building cooling loads. Because lighting systems significantly impact a building's operating cost and energy performance, options for the lighting systems should be evaluated before considering strategies for a low-energy HVAC system. Therefore, to reduce the need for artificial lighting, minimize the total primary energy consumption and energy costs, daylighting techniques are the first daytime solution to employ. Efficient daylighting design should consider sky conditions, site environment, building space and form, glazing systems. By comparing different energy efficiency lamps: ***Fluorescent Lamps****:* are about 3 to 5 times as efficient as standard incandescent lamps and can last about 10 to 20 times longer. To gain the most efficiency, use current and proven equipment technology and install fluorescent luminaires in places where they can be integrated with the architecture, available daylight, and switching or dimming controls [9] [17]. Compact fluorescent lamps (CFLs) are often used as a simple substitute for incandescent lamps due to their significantly longer life and better energy efficiency. Due to their small size, CFL lamps are used in recessed Luminaires, wall and ceiling mounted fixtures, and even track lighting and task lighting. The diffuse nature of the fluorescent lamp makes the CFL lamp a good choice for down lighting and wall lighting. Compact fluorescents have a typical life of about 8,000 hours [23].

High-Intensity Discharge Lamps (HID): are still one of the best performing and most efficient lamps for lighting large areas or great distances. Metal halide (white light) lamps are replacing high pressure sodium lamps in many outdoor applications because white light sources can be 2 to 30 times more effective in peripheral visual detection than yellow-orange sources like high pressure sodium. Typically, HID lamps do not work well with occupancy sensors because most HID lamps take a long time to start each time they are switched off. Special ballasts are available that allow the lights to be step-dimmed to 50% (or another level). These ballasts could be used with occupancy sensors and the lights would be automatically dimmed to a set level when the room is unoccupied [10] [17].

Incandescent Lamps*:* are still used for specialty lighting, where the warm color, controlled brightness, instant-on, and dimming capabilities of these sources is needed. However, because of their lower energy efficiency and shorter lamp life, incandescent lamps should be used carefully for lighting of specific features. Incandescent bulbs have a typical life of 1,000 hours [10] [17].

Light Emitting Diodes, LED Lamps: is a solid-state lamp that uses light-emitting diodes (LEDs) as the source of light. High power light-emitting diodes with higher lumen output are making it possible to replace other lamps with LED lamps. LED lamps can be made interchangeable with other types of lamps. LED lamps offer long service life and high 6energy efficiency, but initial costs are higher than those of fluorescent lamps. LED lamps are used for both general and special-purpose lighting. Compared to fluorescent bulbs, advantages claimed for LED light bulbs are that they turn on instantly, and that lifetime is unaffected by cycling on and off, so that they are well suited for light fixtures where bulbs are often turned on and off. A LED lamp can be made dimmable over a wide range. Many LED lamps have become available as replacements for screw-in incandescent or compact fluorescent light bulbs, ranging from low-power 5–40 watt incandescent bulbs, through conventional replacement bulbs for 60 watt incandescent bulbs (typically requiring about 6 watts of power), and higher wattage bulbs, e.g., a 13-16 watt LED bulb which is about as bright as a 100W incandescent [22]. These bulbs are more power-efficient than compact fluorescent bulbs and offer lifespan of 30,000 or more hours, reduced operated at a higher temperature than specified. LED light bulb can be expected to last 25–30 years under normal use. The higher purchase cost than other types may be more than offset by savings in energy and maintenance [10] [17].

Fluorescent Ballasts: The efficiency of fluorescent tubes with modern electronic ballasts and compact fluorescents commonly ranges from 50 to 67lum/w. Most compact fluorescents rated at 13 W or more with integral electronic ballasts achieve about 60lum/w, which is comparable to the LED bulb [17].

- Rapid start ballasts: offer a long lamp life at a reasonable cost. They have been used for years with lighting controls to provide energy savings.
- Instant start ballasts: have higher efficiency than rapid start ballasts, but lamp life is shorter, especially when the frequency of starts is increased due to the use of controls. They are often used where energy savings is the primary goal and lights are on continuously for very long periods of time.
- Program rapid start ballasts: are the best to use for energy efficiency and long lamp life. These ballasts are slightly more expensive than standard rapid start ballasts, but use a "gentler" starting method so that frequent starting lessens the reduction in rated lamp life.
- Dimming electronic ballasts: for linear fluorescent lamps usually fall into two categories. The first type has a dimming range of 5% or 10% up to 100% light output and is generally the least expensive. This ballast is commonly used when the lowest light levels are not needed, or to achieve energy savings by dimming the lights when there is plentiful daylight. The second type of ballast often referred to as an "architectural dimming ballast," is more expensive and has a dimming range of 1% to 100% light output. This ballast is used in situations where lower light levels are desired.
- Electronic high-intensity discharge ballasts (HID): for metal halide lamps are now available for most lamps up to 150 watts. These ballasts should improve lamp performance and offer a limited range of dimming to achieve some energy savings.

Efficient electric lighting controls are used in lighting design to achieve a high quality energy efficient lighting system. They are used as part of an efficient lighting system that integrates daylight and electric light sources to provide a comfortable and visually interesting environment for the occupants of a space. Electric lighting controls can be incorporated with daylighting to provide flexibility and energy savings. Specifying a daylight-integrated lighting control system gives the occupants control of the lighting while providing appropriate lighting levels. Lighting controls [17] [21]:

- Provide multi-zone switching for multiple use spaces by properly zoning lighting circuits and switches to optimize energy-efficient operation
- Provide multi-level switching for multiple use spaces through multi-level controls
- Incorporate time clock or energy management system controls

When electric lighting controls are used properly, energy will be saved and the life of lamps and ballasts can be extended. Lighting controls will help reduce energy by:

- Reducing the number of hours per year that the lights are on
- Allowing occupants to use controls to lower light levels and save energy
- Reducing the amount of power used during the peak demand period by automatically dimming lights or turning them off when they are not needed
- Reducing internal heat gains by cutting down lighting use, which allows for reduced
- HVAC system size and a reduction in the building's cooling needs

Efficient Electrical Equipment

Other industrial systems that consume energy include electrical appliances, motors, pumps, compressor, oven, etc... Modern energy-efficient appliances use significantly less energy than older conventional model appliances. In addition to this, the replacement of old appliances is one of the most efficient global measures to reduce emissions of greenhouse gases.

Many countries identify energy-efficient appliances using energy input labeling. Appliance consumer products meeting independent energy efficiency testing and receiving Eco-label certification marks for reduced electrical-'natural-gas' consumption and product manufacturing carbon emission labels are preferred for use in Low-energy buildings. The eco label certification marks of Energy Star and EKO-energy are examples.

2.4 Literature Review

Literature referred in carrying out this thesis work are guidelines, books, articles, publications, website and research papers mostly published in international journals have been reviewed and appropriate strategies and methodologies were adopted. The notes given under this chapter are taken from these sources.

2.4.1 Electrical energy Auditing

Malkiat Singh [25] presents his idea about industrial energy management. As there was a different industry, the demand for the energy is also variable (different), across the world with the growing technique and innovation in the field of energy has proved the path for achieving energy efficiency. It conveys us to look forward to more renewable resources present around us and with the managed approach of renewable energy source with the audit a more cost effective and efficient energy technology can be achieved. Along with this one also had to make changes in the installation process. Figure 2-5 shows the comparison of power consumption between Fluorescent tube with copper choke and Fluorescent tube with electronics choke.

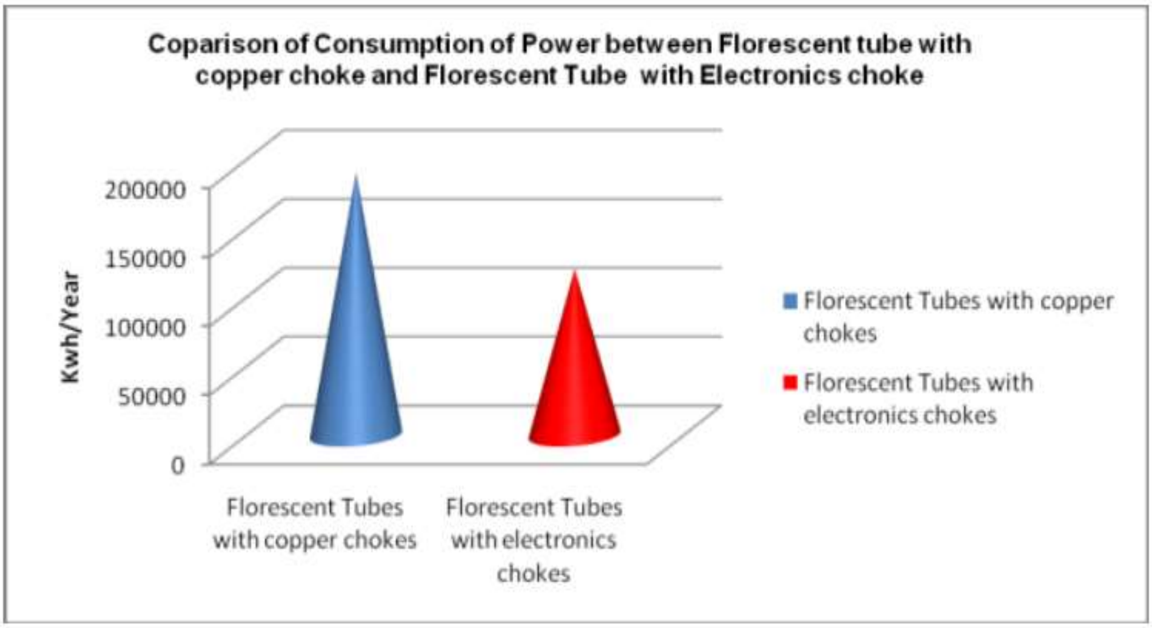

Figure 2-5 Comparison between Tubes light with copper choke

It indicates that the Fluorescent tubes with copper chokes consume more energy than fluorescent tubes with electronics chokes.

Mehul Kumar [26] this paper deals with energy conservation and its value in developing the economy of one country. As considering materially, the standard of the living in any economy is evaluated by the expense of the energy used per capita. As with the growing population a huge exploitation of energy can be seen on the earth's resources.

He concluded that the energy audit type is one of types which add completeness to the energy conservation. In present scenario apart from the industrial point of view most of the common peoples are wasting huge amount of power (energy) by different methods in their homes, shops, etc. due to lack of awareness. Also the consumer has to look at the more efficient techniques and machineries towards the renewable energy resources. This research paper will help the owner to know the status of the factory through energy audit analyzed by ETAP software.

Mukesh k saini [1] in this paper the author state about the industrial development in India and provide recommendation for industry energy audit. He considered as an electrical energy consumption by industries is about 60 percent of the total energy consumption. The industrial development in the country is progressing at a fast pace, due to the increase in the number of industries the gap between demand and supply of electricity is also increasing day by day and to solve this problem author suggest that doing the energy audit for all industries on regular bases as the best solution. The energy audit will determine energy wastage and losses and provide techniques and ways to minimize the losses. The energy consumption techniques suggested by the energy audit will not only minimize the losses but also reduce monthly electricity bill. In general, this paper suggests ways and means to conduct an energy audit in industry.

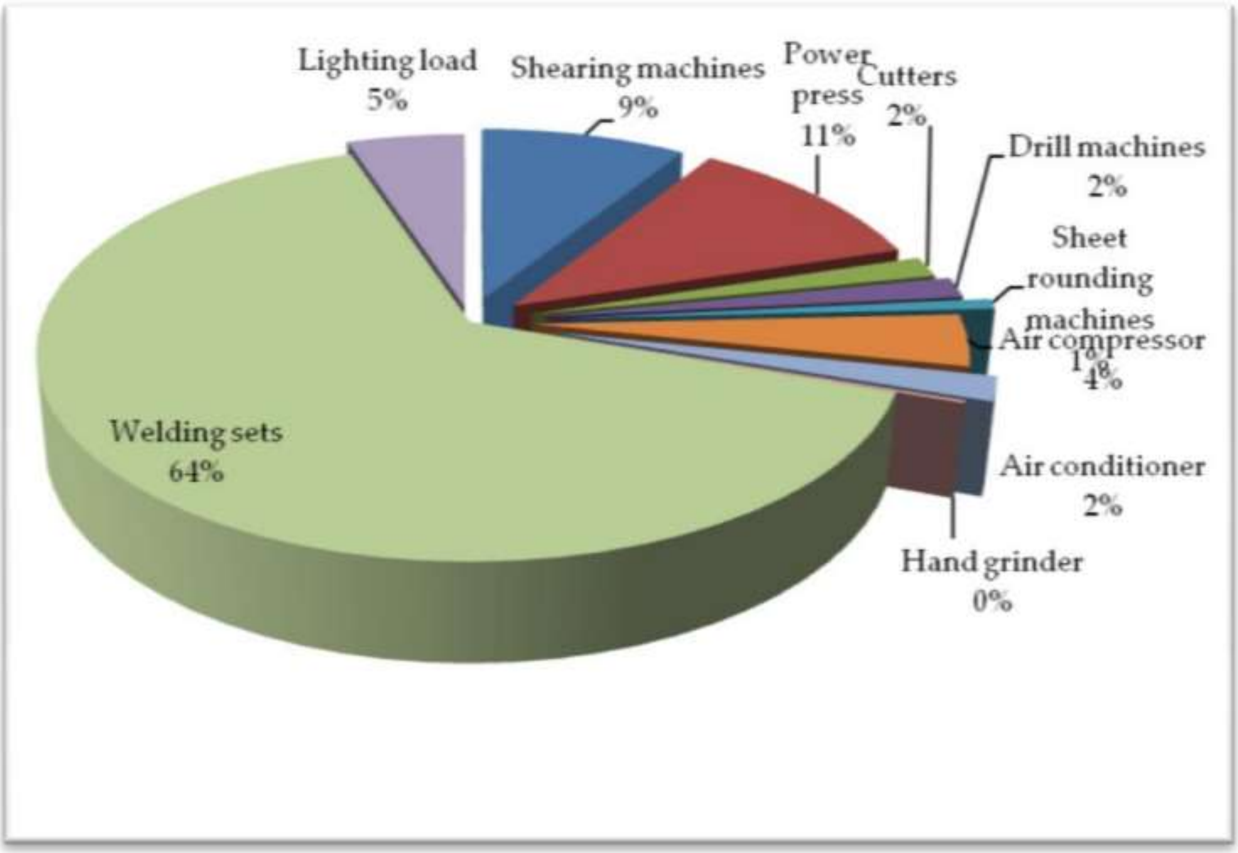

Figure 2-6 Equipment Wise Energy Consumption

This paper focuses light on the advantages of the conventional energy sources and its loss-less power generation every growing economy is mainly using the resources available on the earth and hot conserving the energy by innovation techniques. As electrical equipment, transmission also creates loss. A huge loss in the industries and at domestic level is existed because of the harmonics and distortion present which distorts the sinusoidal waveform.

The authors [27] Mario E. Berges & Etal says Non-intrusive load monitoring is an idea for reducing the power consumption and operation schedule or individual load in a building through measurement of voltage and current. There are many opportunities reducing electricity consumption in building. Energy audit is used as one way to obtain accurate and objective element to save energy. Two typical type of meter are used in this work to monitor the data through AMR (Automatic meter reading) & AMI (advanced metering infrastructure). In this AMI will save meter reader cost and AMR facilitate the demand response. The plug level technology is introduced for residential electricity monitoring. The authors contrast with this & show its advantages and disadvantages. The plug load meter is used to measure a single appliance. This meter is connected to any electric outlet or more appliances can be plugged into meter. Recommendation for improving the technology and energy efficiency is executed in this work. The resulting difference in energy estimates for the 5.5 days of the experiment was 14.8% with the non-intrusive load monitoring system underestimating the actual consumption by 2.29 kWh, the plug level meter is measured 15.48 kWh, whereas the non-intrusive load monitoring algorithms predicted 13.19 kWh.

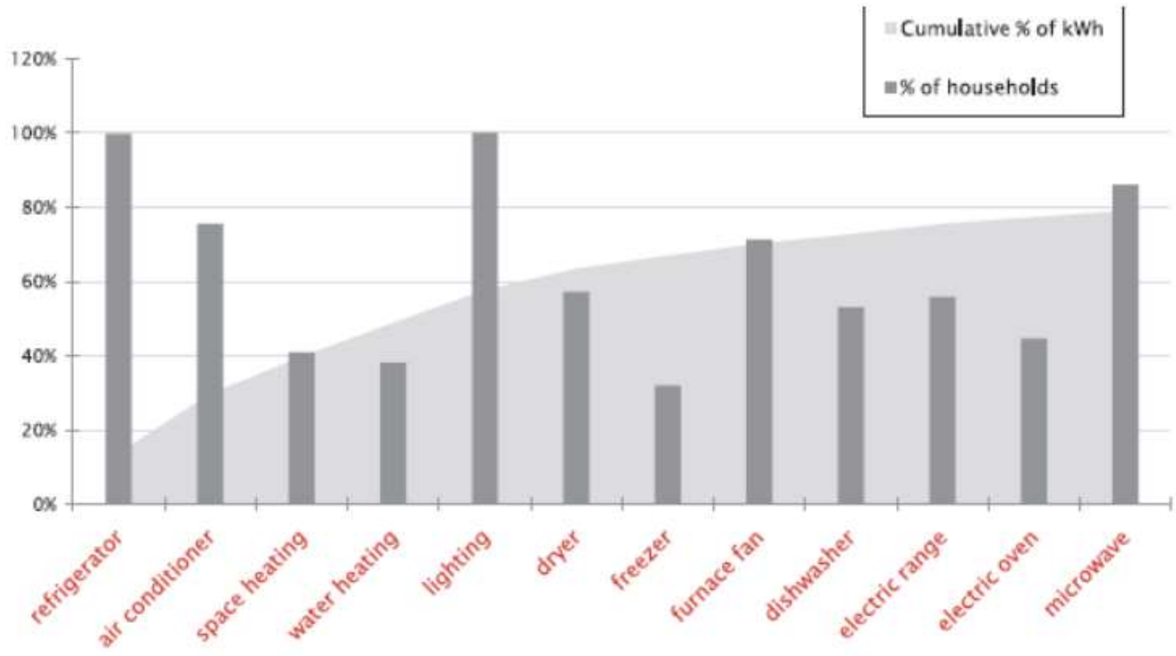

Figure 2-7 Percentage of household graph

The author [29] Michael Lubliner says about the past, present & future direction of energy audit of residential single family. In the paper the main aim is conducting audit for national institute of standards and technology. The purpose is to measure energy use and energy saving associate with short term energy and long term energy which is related to repairs, retrofit, remodeling for a single family house. Repair remodeling is one of the ways to save the energy. Utility billing analysis to improve the efficiency of energy in residential single family housing is another way. The need for the observation of utility billing data analysis is the current reality. The author was report the past, present & future direction of energy audit in single family houses for heating & ventilating air conditioning for industries. The residential or domestic energy audit research will improve the energy efficiency. The author’s use the round robin auditing to improve energy auditing and retrofit practices. Finally, the author feedback from round robin to helps ensure that house owner get comparatively consistent, reliable, repeatable & useful recommendation from home performance contracting industry.

Tony botkin [29] presented testing and inspecting process and to identify and disclose deficiency in the energy efficiency of the property at the time of the inspection. In the paper the author introduced three section used to energy efficiency of home. These are: -

- Current performance,
- Infrared report and
- Home energy retro-fit.

In the first section current performance list components of the house and the energy consumption as well as detail about the air tightness limits. In the second section infrared report photo performing insulation and other prominent items identified by the infrared camera. The third section is Home energy retro-fit is used improvements & their potential energy savings. Acting on the energy retrofit recommendation will make four home more comfortable more valuable and more affordable. Tony bodkin explains the current performance by making of annual consumption load, heating cost and cooling cost graph. And his Infrared report is by using of snap shot. Finally, the author concluded showing the energy retrofit table in that table individual & total annual savings are based on whole package.

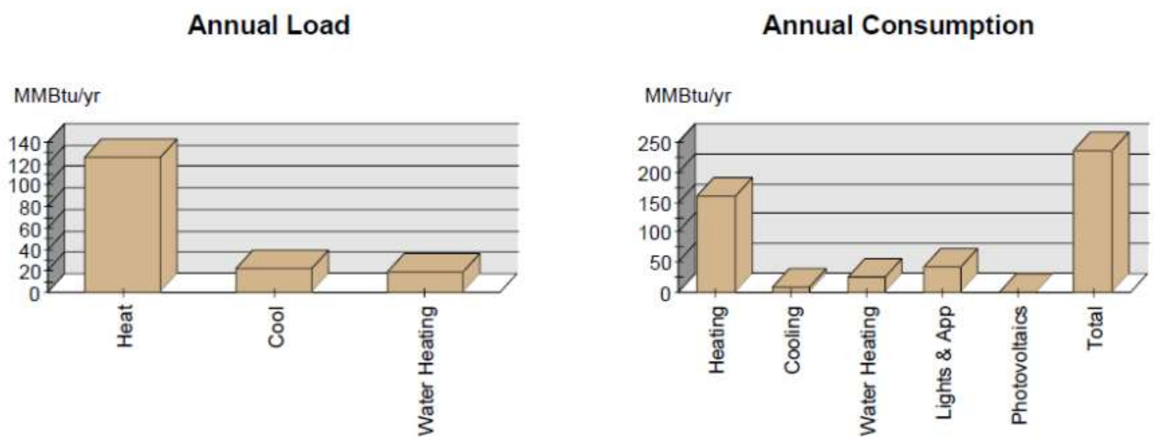

Figure 2-8 Annual loads and annual consumption chart

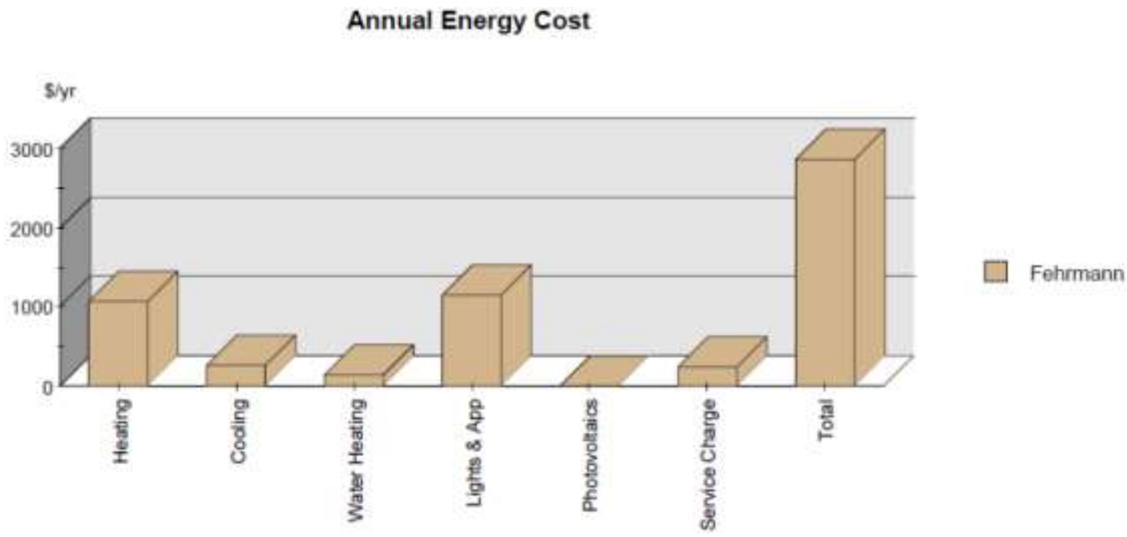

Figure 2-9 Annual cost for energy chart

Bhansali, V.K [31] describes that the gap between supply and demand of energy is continuously increasing despite huge outlay for energy sector since independence. Further, the burning of fossil fuel is resulting in greenhouse gases which are detrimental to the environment. The gap between supply and demand of energy can be bridged with the help of energy conservation which may be considered as a new source of energy which is benign and environment friendly. The energy conservation is cost effective with a short payback period and modest investment. There is a good scope of energy conservation in various sectors, viz., industry, agriculture, transport and domestic. The energy audit can unearth huge profits to the industry. The industrial sector has failed to take full advantage of many financial incentives provided by the government to encourage energy conservation strategies. The planners have started appreciating the role and significance of energy conservation in future energy scenario of India. However, the achievements so far are far from satisfactory. It is imperative to develop energy conservation as a mass movement.

2.4.2 Technical Loss Assessment

Betrianis et al [32] have employed simulation method to study technical energy loss of distribution system. Their paper is presented as follows.

One best method to see a system is to make a model and do simulation. Model is a representation of a system. Through model, it can be easier to forecast and control the changing of each element system. Electricity distribution is also a system. Losses are general problem that exist in a distribution network system. But with the right methods, specifically technical energy losses can be reduced in order to increase the efficiency. By making model of the distribution network, the value of technical energy losses in the whole network as well as in every line can be observed. Simulation can also be used to see all losses reduction alternatives. By comparing results from each alternative, the best alternative, which gives best result can be decided and implemented. To make a good simulation, it needs a model based on real condition. So the model can represent real condition. [32] has done their research in distribution station, a distribution station which has operated since 1970s, and it focus on low voltage network and counts only technical energy losses.

For constructing the model, [32] used Simulink software which is packaged with Matlab ver. 6.5.1. In Simulink, subsystem construction is possible. So, [32] constructs the main model simply by using subsystems, and places complicated formulas on those subsystems. This simplifies their main model. In model construction, there are three main subsystems, [32] employs: pole subsystems, cable sub-systems, and station subsystems.

According to [32] the present model, simulation displays varied total energy and total losses. But in short, total average energy which comes out from the station is 4,831.345 kWh per day with average daily losses as big as 203.4023 kWh. In means losses are 4.21 % from total energy. Finally, seven alternatives are used to minimize the average daily losses; seven of them employ replacing distribution lines with high loss.

Narong Mungkung *et al* [33], which have been one of the best literatures this study refers, were really crucial for this study. It has been helpful in simplifying the methodology used to assess the technical loss. Their paper presents the techniques used to assess power loss and calculates technical energy loss provided in different power system equipments. [33], first uses PSS/Adept program to find maximum power loss by simulating a model and then mathematically calculate the technical energy loss provided in different power system components as follows:

Transmission Line Losses (kWh) = Loss Factor * Line Losses * period.

When

Loss Factor = $0.33LF + 0.67LF^2$ ………………………………………………….. (2.1)

Load Factor (LF) $= \dfrac{Averageload}{Peakload} = \dfrac{KW_{AVe}}{KW_{Peak}}$ ……………………………………….. (2.2)

Power Transformer Losses included two types:

- No Load Losses are losses which occurred at core of transformer. The core losses are ensured from current which causes magnetic flux in core of transformer, when it is energized. Core losses are constant value at constant voltage.
- Load Losses are losses which are occurred at winding of transformer. At the beginning this loss was known by Copper losses but this time since transformer are also using aluminum instead of copper, winding loss is the appropriate name.

Power Transformer Losses = Winding Losses + No Load Losses.

When

No Load Losses

Core losses from test report of manufacturer or Provincial Electricity Authority (PEA) standard.

Winding Losses $= \frac{MVA^2{}_{Peak}}{MVA^2{}_{Rated}} * LoadLosses * LossFactor$ ……………………….… (2.3)

Load Losses = Copper losses from Test Report of manufacturer.

Loss Factor $= 0.2LF + 0.8LF^2$ ……………………..…………………….………...…. (2.4)

Distribution line losses = Loss Factor * Line Losses * period

When

Loss Factor = $0.33LF + 0.67LF^2$ ………………………….….…………………. (2.5)

Load Factor (LF) from eqn. (2.2)

Distribution Transformer Losses = Winding Losses + No Load Losses

When

No Load Losses from Provincial Electricity Authority (PEA) standard

Winding Losses from eqn. (2.3)

Load Losses from PEA standard

Loss Factor from eqn. (2.4)

According to [33], technical energy loss due to transmission lines, power transformers, distribution lines, and low voltage transformers and distribution lines was totally 42,201.675 MWH.

Marina Yusoff *et al* [34], in their research on TNB distribution system technical loss assessment, have employed a simplified approach for estimating technical loss based on load profile and feeder characteristics; such as length, peak demand to installed capacity ratio, and load distribution profile. The developed methodology is implemented in spread sheets format, which is simple and user friendly. It requires minimum set of input data, while giving reasonably accurate results. The approach is tested on a real TNB distribution network and the results were reasonably accurate. Additionally, the spread sheet developed based on the methodology could also be used to perform various energy auditing exercises.

The proposed approach of [34] for their study is peak power loss functions of medium voltage feeders of different characteristics (variation in feeder length, peak demand, and load distribution profile) are first established through network simulation using PSS Adept software. Subsequently, technical losses for each medium voltage feeder are estimated based on user input peak demand, load factor, and feeder length. An analytical expression incorporating weight-age factors, calculated by taking the ratio of energy flow through each feeder against the total energy supplied to the system is used to estimate technical losses contributed by the respective medium voltage network. Technical losses in distribution transformers are estimated based on empirical formulas of no load and full load loss scaled by capacity factors. For low voltage network, its technical losses level is primarily influenced by its percentage loading, besides load factor and network type (overhead or underground).

Bo Yang *et al* [35] has developed four feeder models representing typical urban, suburban, semi-rural and rural feeders, which are used as a platform to examine the breakdown of technical losses in distribution systems. Two attributes are evaluated to illuminate the characteristics of technical losses, peak power loss and yearly energy loss. Power losses are analyzed assuming system loading at close to its thermal limit and are summarized for each system level, i.e. main feeder (three phase), laterals, distribution transformers, secondary mains, and service drops.

CHAPTER THREE

DATA COLLECTION AND SYSTEM MODELLING

3.1 Data Collection

The methodology employed under this study to assess technical energy loss is to develop a system model. The model is developed from the one-line diagrams, the electrical equipment data (transformers, cables, machines, etc.), the utility system characteristics, and the loading information. The result is a database that should include the following elements:

- Representation of the utility system supplying the facility.
- Transformers (ratings and nameplate impedances).
- Cable data (resistance, reactance, capacitance)
- Load data for each bus/boards (kW, kvar, and kVA).

The first part of the process is to gather data on the system. This involves finding circuit diagrams, information on transformers, cables, motors etc. and finally the load size in (kVA, Kvar, KW) and type of loads. In addition, bills and all energy consumption data of the factory were collected.

One-line diagram is prepared to simplify the circuit so that data can be easily gathered from the practical network of the factory and modelled by ETAP 12.6.0. All the bus bar, transformer, motor, and load ID’S are created just for this study. And the detail data’s of the components in the network is given according to this ID’S. The prepared one-line diagram is given in figure 3-1.

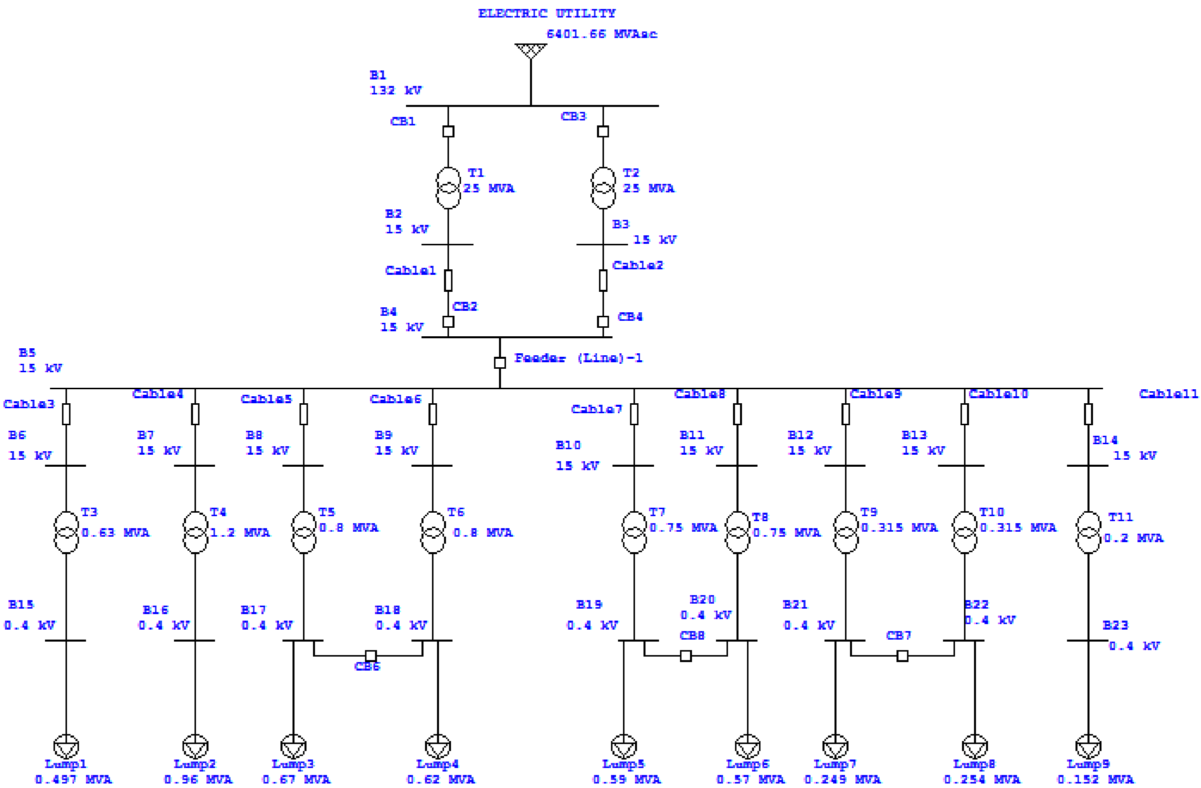

Figure 3-1 Prepared one-line diagram

Finally, the summary of the data gathered for transformers, cables, motors and loads is given below.

Most of the data's used to model the distribution transformers are gathered from the name plate of the transformers except the X/R which is typically selected by ETAP depending on the percentage impedance of the transformer. In addition to this, no load and on load loss data for the distribution transformers are gathered from the SEEDT (Selecting Energy Efficient Distribution Transformers) [39], ABB distribution transformers manufacturer data and EEPCO for distribution transformers and it is used to calculate transformer technical loss. All the name plate data's, including the no load and on load data's used, are given in Table 3-1 and 3-2

Table 3-1 Name plate data of distribution transformers

Transformer Name	Used at	Manufacturer	Power Rating (KVA)	Percent Impedance (%Z)	Vector Group
T3	Biscuit No.1	ABB	630	5.9	Dyn11
T4	Biscuit No.2	ABB	1200	6.53	Dyn11
T5	Biscuit No.3	ABB	800	5.97	Dyn11
T6	Biscuit No.3	ABB	800	5.97	Dyn11
T7	Biscuit No.4	CEEG	750	5.72	Dyn11
T8	Biscuit No.4	CEEG	750	5.72	Dyn11
T9	Flour No.1	India	315	4.0	Dyn5
T10	Flour No.2	India	315	4.0	Dyn5
T11	Flour No.3	Italy (Zennaro)	200	4.0	Dyn5

Table 3-2 No load, on load and Taping, data of distribution transformers

Transformer Name	Used at	No. of taping	Min. Voltage tap [KV]	Max. Voltage tap [KV]	Fixed tap Voltage [KV]	No load loss [KW]	On load loss [KW]
T3	Biscuit No.1	9	14.25	15.75	15	1.2	6.75
T4	Biscuit No.2	9	14.25	15.75	15	2.1	13
T5	Biscuit No.3	9	14.25	15.75	15	1.5	12
T6	Biscuit No.3	9	14.25	15.75	15	1.5	12
T7	Biscuit No.4	9	14.25	15.75	15	1.3	8.5
T8	Biscuit No.4	9	14.25	15.75	15	1.3	8.5
T9	Flour No.1	5	14.25	15.75	15	0.52	3.9
T10	Flour No.2	5	14.25	15.75	15	0.52	3.9
T11	Flour No.3	5	14.25	15.75	15	0.34	2.5

Most of the loads of the factory are electric motor loads. All motor data are gathered from the name plate, through interview with the factory worker and by taking their measurement as it was shown in Table 3-3. They are connected to the load bus bar according to the measured demand at the distribution transformer secondary not according to their name plate value. Because they are too many to consider them separately. So the best solution is to measure their demand in sum at the department distribution transformers secondary including other loads and use lumped load option of ETAP 12.6.0.

Table 3-3 Measured and name plate motor data of biscuit factory

Name of Motor	Name plate data						Measured Data			
	Type	Rated Voltage V(V)	Speed (RPM)	Current (A)	Power (KW)	Power Factor	Voltage V(v)	Current I(A)	Power P(KW)	Power factor
Air Compressor (*2)	GA11F	380	1420	23	11	0.88	378.6	18.51	8.23	0.83
Horizontal mixer (*2)	TR750	400	3560	135	65	0.87	400.9	117.9	48.31	0.86
Pri Mixer	JM Gola	400	1410	5.7	1.5	0.79	392.6	4.93	1.34	0.77
Pri Mixer pressure control	Mlk Mul	400	2900	32	15	0.88	388.2	28.91	10.52	0.83
Sugar Mill	M200L A	400	3560	52.7	36	0.9	393.6	46.75	31.91	0.84
Sugar Conveyor	M1100	380	1450	4.65	2.2	0.81	379.4	3.52	1.63	0.73
Sugar Mixer	EF100L B.4	400	1430	6.5	3	0.82	394.2	4.81	1.91	0.77
Invert pump	1752J	415	935	5.1	2.2	0.87	402.3	4.82	1.78	0.81
Dough load unload	M3A RF	400	1430	4.9	2.2	0.78	392.4	4.27	1.95	0.71
Palm Oil(Cream) Mixer	M200	400	1430	25	12	0.85	391.1	21.83	10.56	0.74
Laminator 1	KAZ87	380	1460	14.3	4	0.83	380.2	11.43	3.24	0.77
Laminator 2	KAZ87	380	1460	14.3	4	0.82	380.6	11.14	3.31	0.74
Laminator 3	KAZ97	380	1420	2.55	1.1	0.79	380.8	2.31	0.82	0.71
Laminator 4	KAZ87	380	1430	5.45	1.5	0.77	379.4	4.21	1.12	0.70
Oven	11-21-014	400	-	1.43	935	-	368	2.15	924	0.89
Biscuit Conveyor (*10)	SF 47	380	1420	2.5	1.1	0.92	372	2.2	1.12	0.87
Packing(*4)	EPL 22	380	-	25	22	0.88	374.3	23.5	19	0.85
Water pump	PS6	220	-	3.5	1.5	0.87	205	2.8	1.24	0.83
Total					1195.2					

The cable data are gathered from the factory documentation [39] and electric cables handbook [40]. Since the contribution of underground cables to the technical loss depends on the resistance, reactance, capacitance and length of the cables accurate data are required. So the exact length is taken from the cable list documentation of the factory; and the exact resistance, reactance and capacitance from the electric cables handbook according to its specification because it is not in the cable list documentation. Cable data are given in Table 3-4.

Table 3-4 Collected cable data

Cable ID	Connected Bus ID		Length [Km]	R [Ω]	X [Ω]	Y [S]
	From	To				
Cable 1	B2	B4	0.012	0.004	0.001	0.00000118
Cable 2	B3	B4	0.012	0.004	0.001	0.00000118
Cable 3	B5	B6	0.084	0.029	0.009	0.0000084
Cable 4	B5	B7	0.250	0.014	0.023	0.00005
Cable 5	B5	B8	0.072	0.025	0.008	0.0000072
Cable 6	B5	B9	0.072	0.025	0.008	0.0000072
Cable7	B5	B10	0.450	0.185	0.047	0.000003
Cable8	B5	B11	0.450	0.185	0.047	0.000003
Cable 9	B5	B12	0.311	0.106	0.033	0.0000311
Cable 10	B5	B13	0.311	0.106	0.033	0.0000311
Cable 11	B5	B14	0.077	0.026	0.008	0.0000077

For this research clump on ammeter is used for direct measurement of load current, which is taken at each load. The same load current is considered for each phase because the system is balanced. It is also assumed that the measured current is fundamental frequency current; losses due to harmonic currents are not considered. Technical loss of a distribution system varies as the load demand connected to it varies. As the given factory have consistent period of operation load varies slightly. So, consideration of the whole day demand or load duration curve of the distribution system is not required to assess technical energy loss. Load duration curve for Brothers Flour and Biscuit factory is not available, so the consumption of power for each individual department is measured, considering process of production interval.

The overall peak power demand of 2BF power distribution is 3.924MW and 2.364Mvar at utility entrance according to EEU peak power demand data.

3.2 Software Description and Model Development

In this research two softwares are used for selecting a proper electric motor in terms of efficiency, cost effectiveness & energy saving potential and technical energy loss assessment.

Motor master + International software

Motor Master + International software supports motor management functions at commercial and institutional facilities, water supply and wastewater treatment systems, irrigation districts and medium sized and large industrial facilities. Designed for utility auditors, energy managers, and plant or consulting engineers, International Motor Selection and Savings Analysis (IMSSA) Software supports motor and motor systems improvement planning through identifying the most efficient action for a given repair or motor purchase decision. IMSSA can be used to compute the energy and demand savings associated with purchase of a new EFF1 instead of a standard EFF3 or Improved Efficiency EFF2 motor model or evaluate the cost-effectiveness of replacing a failed or operable EFF3 motor with an EFF1 motor [47]. Input and output data for the software is shown in Table 3-5.

Table 3-5 input and output field data measurements for analysis saving potential of electric motor

Input for existing motors (Existing Data)	Input for energy efficient motors (Software catalogue)	Output parameters
-Power rating (KW) -Loading (%) -Efficiency (%) -Nameplate speed (rpm) -Voltage rating (v)	-Power rating (KW) -Loading (%) -Efficiency (%) -Nameplate speed (rpm) -Voltage rating (v) -Purchase price	-Energy -Demand savings and -simple Payback period

ETAP 12.6.0 software

ETAP 12.6.0 is used as software for this study. Operation Technology, Inc (OTI) is the developer of the ETAP enterprise solution for the simulation and analysis of electrical power systems using offline as well as real-time data. Operation Technology, Inc. is a full spectrum analytical engineering firm specializing in the planning, design, analysis, operation, training, and computer simulation of power systems.

Table 3-6 Required load flow calculation data

Bus Data	1. Nominal kV 2. %V & Angle (when initial condition is set to use bus voltage) 3. Load diversity factor(when the loading option is set use DF)
Branch Data	1. Branch Z, R, X or X/R values and units, tolerance, and temperature, if applicable 2. Cable and Transmission line, length, and units 3. Transformer rated KV, and KVA/MVA, tap, and LTC settings 4. Impedance base KV and base KVA/MVA
Power Grid Data	1. Operating mode (Swing, Voltage control, Mvar control or pf control) 2. Nominal/Rated KV 3. %V and angle for Swing mode 4. %V, MW loading, and Mvar limits (Q max and Q min) for Voltage control mode 5. MW and Mvar loading for Mvar control mode.
Induction Motor Data	1. Rated KW/HP and KV 2. Power factors and efficiencies at 100%, 75%, and 50% loadings. 3. % of loading and loading category ID 4. Equipment cable data.
Static Load Data	1. Static load ID 2. Rated KVA/MVA and KV 3. Power factor 4. % loading and loading category ID 5. Equipment cable data
Lumped Load Data	1. Load ID 2. Rated KV, KVA/MVA, power factor, and % motor load 3. % loading and loading category ID

The full version of ETAP is integrated with all calculation modules such as Load Flow, Short-Circuit, Transient Stability, DC load flow, Optimal Capacitor Placement, Harmonic Analysis, Protective Device Coordination, UGS, and ETAP Real-Time etc. Newton-Raphson, Fast–decoupled, and Accelerated Gauss-Seidel are the three load flow solution methods available. The Newton-Raphson method is recommended for use with any system as a first choice after few Gauss-Seidel iterations to establish a set of bus voltage initial values. It uses ANSI or IEC standard; so for a new project it is mandatory to select ANSI or IEC standard first. For this study load flow modules are used to estimate technical energy loss. Required load flow calculation data for buses, branch, Power grid, static load and lumped load data are given in Table 3-6.

3.2.1 Constructing the Model

Power Grid

The power grid is used as swing bus and the following data's are used as an input.

Short circuit current, rated KV and X/R are data of the transmission line from Adama substation, which is the input for the power transformer primary, it is taken from EEP. The others are calculated as follows based on the given data:

Step1. Calculate the source impedance [42]

%Z source = (Z source ohms / %Z transformer base) x 100 ………………...……….(3.1)

Where,

Z source ohms = (KV L-L) 2 / (MVA short circuit) ………………...………..……… (3.2)

%Z transformer = (KV $_{L-L}$)^2/ (MVA transformer) …………………………..…..……(3.3)

Finally, %Z source = (MVA transformers / MVA short circuit) x 100

MVA short circuit = √3 x KV_{L-L} X $I_{Short\ circuit}$ ……….………..…………………….(3.4)

MVA short circuit =√3 x 132 KV X 28 KA = 6,401.7 MVA

%Z transformer and MVA transformer are 10.05%, 25MVA

%Z source = (25MVA) / (6401.7MVA)

Z source = 0.0039 Ω

%Z source at 100 MVA base can be calculated as follows

$$\%Z\ source = Z\ source\ Ohms \times \frac{100\text{MVA}}{MVAtransformer}$$

$$\%Z\ source = 0.0039\ \Omega \times \frac{100\text{MVA}}{25MVA}$$

%Z source = 0.016

Considering X/R 4.35, ETAP 12.6.0 immediately calculates %R and %X using the relation: $\%Z = \sqrt{(\%X^2 + \%R^2)}$

And the zero sequence % R and % X are typically selected by ETAP.

Table 3-7 Input data required by the power grid

Rated KV	Short Circuit MVA	X/R	Short Circuit Current in KA	Short Circuit Impedance at 100MVA		
				Sequence	%R	%X
132	6401.7	4.35	28	Positive	0.34997	1.52239
				Negative	0.34997	1.52239
				Zero	0.51618	2.24538

To construct the model of transformer ETAP uses the nameplate value as input. Therefore, the data's given in Table 3-1 and 3-2 are the main data's used to construct the model of distribution transformers. Since the value of X/R ratio is not given in the name plate, the ETAP software typically selects the value considering short circuit impedance of the transformer to be modelled. ETAP has three options for phase shift case, those are standard positive sequence, standard negative sequence and special (angle of the phase shift is selected), since the vector group data is available accordingly phase shift angle is selected. Even though all of the transformers used has tapping option at their primary side for voltage regulation, only some of the transformers tapping option is practically used by Brother biscuit and flour factory automatically according to the load variation. ETAP has the option of automatic LTC (load tap changing) to regulate bus voltage at 100% of nominal voltage using transformer LTCs and the following data from the name plate are analyzed to use the option.

- Max. tap voltage, Min. tap voltage
- Step voltage between each tap, and number of tapping

Considering the fixed tap voltage (rated voltage), % Max. Tap, %Min. tap, and % step voltage is calculated as follows:

$$\% \text{ Max. Tap} = \frac{Max.tap * 100}{RatedVoltage}$$

$$\% \text{ Min. tap} = \frac{Min.tap * 100}{RatedVoltage}$$

% Step voltage = $\frac{StepVoltage*100}{RatedVoltage}$

ETAP has two options to construct load model, which are lumped and Static load options. First, MW, MVar and MVA equivalent of the load current measured is calculated considering V_{L-L} and 0.91 power factor at MDB, measured power factor for 2BF distribution system is 0.91 at MDB. Next depending on the type of loads available, motor or static loads, load models are selected. Static load is selected for loads, which are stationary and lumped load for loads, which are mixture of both motor and static load. Under the lumped load option, the mixture of motor and static load is identified in percent. For this study, lumped load option is selected because the composition of motor is more than 85%. Since peak power loss of each branch component is required, peak load current is selected from the measured load current to calculate the MVA rating of lumped loads.

3.2.2 Technical Loss Estimation

The methodology used in this study to estimate the overall technical loss of the factory distribution system detail calculation is shown below:

1. Distribution Line Technical Losses

- The feeder current (Im) at maximum demand is measured (MD)
- Network model of the whole industrial distribution system is prepared using ETAP 12.6.0.
- Load flow is carried out for the network model maximum demand connected at each load bus bar and power loss at maximum demand is determined (KW loss @ MD).
- Load Factor (LF) of the distribution feeder is determined using equation 3.6.
- The Load Loss Factor (LLF) is calculated using the empirical formula [42]

$$LLF = 0.2 * LF + 0.8 * LF^2 \quad \ldots\ldots(3.5)$$

When

$$\text{Load Factor (LF)} = \frac{AverageLoad(KW_{avg})}{PeakLoad(KW_{peak})} \quad \ldots\ldots(3.6)$$

- The annual technical loss for the distribution feeder is calculated using the formula below:

Annual technical energy loss for distribution feeder = (KW loss) * LLF * 8760......(3.7)

where

8760= 24 hours * 365 days

- Total annual technical loss for all distribution feeders can then be calculated by summing the annual loss for each individual distribution feeder.

2. Distribution Transformer Technical Loss

- MD (maximum demand) of transformers is measured.
- Typical copper losses (L_{CU}) of the transformers at their nameplate rating are determined from ABB technical data catalogue and European distribution transformer loss standard.
- Copper loss (L_{Cm}) is calculated for the distribution transformers at MD using the following empirical formula:

  $L_{Cm} = L_{CU} * (MD / \text{Transformer Nameplate Rating})^2$ ………………….……(3.8)

- The load factor (LF) of the distribution transformer is estimated.
- The load loss factor (LLF) is calculated using the empirical formula given below:

  $LLF = 0.2 * LF + 0.8 * LF^2$

  Average copper loss (LC) for the distribution transformer is calculated as follows:

  $LC = L_{CM} * LLF$……………………………………………………….....(3.9)

- Iron losses (L_I) for the distribution transformers are added.
- Total annual loss of the distribution transformer is calculated as follows:

  Total annual technical loss for distribution transformers = $(LC + L_I) * 8760$….(3.10)

- Total technical losses for all distribution transformers can then be calculated by summing the annual technical loss for each individual distribution transformer.

3.3 Major causes of energy loss and saving opportunities in 2BF

Based on the walk-through audit conducted in the factory as well as information from the collected data, the major power consuming areas which have high energy saving opportunities are lightings, rewound motors, electrical networks, and air compressors. Energy efficiency improvements for the factory refers to a reduction in the energy usage for a given energy service (production, lighting, etc.). Energy efficiency is a matter of individual behavior and rationale of energy consumers. Avoiding excessive consumption of energy or choosing the most appropriate equipment to reduce the cost of the energy contribute to decrease individual energy consumption without affecting individual welfare and production.

There are different opportunities to improve energy efficiency of 2BF by maintaining or enhancing productivity. Improving energy efficiency at the factory was approached from several directions. First, the factory uses energy for different equipment's which require regular maintenance, good operation and replacement when necessary. Thus, a critical element of the factory energy management involves the efficient control of cross-cutting equipment that powers the production processes of a factory. Second and equally important area is the proper and efficient operation of the processes. Process optimization and ensuring the most productive technologies are keys to realize energy saving in a factory's Operation.

3.3.1 Analysis of Lighting Systems

Lighting system analysis of the factory was done by comparing the existing lighting system with appropriate illumination (standard lux) level for various sections of the factory, which may reduce the energy use and cost throughout the entire factory.

For the purpose of analyzing existing lighting systems of the factory, it is necessary to consider & determine the:

- total number of lamps and power rating which was installed in each section
- Area of each room measured in square meter.
- Operating hours of each lamps
- Standard illumination required or illumination of specific working stations and
- Total lumen output and illumination produced by the existing lamp installed in the room

Table 3-8 Luminous Intensity and Life time of Various Lamps

No.	Types of lamps	Luminous Intensity [Lumens/watt]	Relative Efficiency based on HPS	Lamp Life [hrs]
1	Incandescent	8-18	19%	1000-2000
2	Tungsten-Halogen Lamps	80-100	77%	2000-4000
3	High Pressure Hg Vapour lamps	50-60	46%	16,000-24,000
4	Fluorescent tube	65-85	65%	5000
5	LED Lights	70-120	92%	50,000-100,000
6	High Pressure Sodium	75-130	100%	24,000
7	Low Pressure Sodium	100-200	100% plus	24,000
8	Compact Fluorescent Lam	30-60	46%	7,000-10,000

The luminous intensity of various lamps and the standard illumination required in various working stations are given in Table 3-7 and 3-8 respectively.

Various terms and definitions are used to quantify light, light source, etc. They are luminous flux, luminous intensity, illumination, luminance, etc.

Table 3-9 Illumination required in various working station

No.	Working station	Average Illumination required [Lux=lumens/m^2]
1	Office	500
2	Workshops	200-750
3	General Store	300
4	Baking Rooms	500-1000
5	Flour Mill	600-1000
6	Garage	500

The key descriptions and discussions of the results of the lighting data of Table 3-8 are given below.

The following relation shows detail calculation about the lighting used.

Total Power=P_{each} *Number of Lamps ………….……..……………......…. (3.11)

Total luminous o/put of lamps=Number of Lamps *Lo.………………..… (3.12)

IP=TL/RA …….…………………………………...………..……………. (3.13)

where

P_{each} – is power of each lamp

Lo – is the luminous output of each fluorescent lamp which is 85 lumens/watt obtained from Table 3-7

RA – Area of each room [m^2]

IP –illumination produced in each section by Installed lamps expressed in lux (1 lux ~1lumens/m^2).

OH – Operating hours per day

LR – The lamps required for proper illumination which is used to analyze energy wastes due to improper illumination. Number of lamps required with the same ratings at the factory can be calculated as: -

LR=(IR/IP) *NL ………………………………………………………………… (3.14)

Table 3-10 Lighting data summary

No.	Section	NL	TP (KW)	TL [Lumen]	RA [m^2]	IP [Lumn/m^2]	LR	OH [hr.]	EU [KWh] /day	ER [KWh] /day	ED [KWH] /day
1	Administration building	76	3.040	258400	340	760	50	8	24.32	16.00	8.32
2	Guard	8	0.480	5760	32	180	8	24	11.52	11.52	0.00
3	Biscuit Store	92	3.680	312800	600	521.3	88	24	88.32	88.48	3.84
4	Biscuit Baking room	162	6.480	550800	800	688.5	236	24	155.52	226.56	-71.04
5	Raw material store	40	1.600	136000	300	453.3	26	24	38.4	24.96	13.44
6	Flour store	96	3.840	326400	520	627.7	46	8	30.72	14.72	16.00
7	Garage	38	1.520	129200	240	538.3	36	8	12.16	11.52	0.64
8	Flour mill	360	1.440	1224000	600	2040	176	24	345.60	168.96	176.64
9	Biscuit Baking room 4	25	6.250	812500	320	2539	10	24	150.00	60.00	90.00
10	General store	22	0.880	74800	150	498.7	16	8	7.04	5.12	1.92
11	Wheat store	70	2.800	238000	750	317.3	66	24	67.20	63.36	3.84
12	Bran store	30	1.200	102000	200	510	18	24	28.80	17.28	11.52
13	Workshops	22	0.880	74800	128	584.4	28	8	7.04	8.96	-1.92
14	Maintenance	16	0.640	54400	118	461.0	10	8	5.12	3.20	1.92
15	Time keeper	4	0.160	13600	36	377.8	4	24	3.84	3.84	0.00
16	Packing and transport	26	1.040	88400	240	368.3	36	16	16.64	23.04	-6.40
17	Rest Room	16	0.960	11520	36	320	16	16	15.36	15.36	0.00
Total		1103	49.85				872		1007.6	758.88	248.72

where

IR= is the illumination required in each room which is 500 Lux for office from Table 3-7 and this figure is compared with the lux produced in each office. The lamp required (LR) are calculated for each section and compared with number of lamps (NL) currently installed. Energy utilization (EU) for the lighting systems can be calculated using equation below and compared with the energy required (ER) after a proper illumination as shown in table. Energy difference (ED) shows the difference between energy utilization and the energy required after proper illumination.

$EU=NL*P_{each}$ ……..…………………………………………….………..…...…. (3.15)

$ER=LR*P_{each}$………………..…………………………………….….……….. (3.16)

ED=EU-ER …………...…………………………..…………………………… (3.17)

The lighting data of each department of the factory is collected and analyzed in Table 3-9. Currently a total of 1103 lamps which consists of 1054 fluorescent, 24 incandescent, and 25 high pressure sodium lamps are installed with 40 W, 60 W and 250 W power ratings respectively. Total installed capacity of the lighting system is about 49.85 KW and a daily energy consumption of 1,007.6 kWh. The actual lamps required in the factory should be 838 fluorescents, 24 incandescent, and 10 high pressure sodium lamps. Therefore, there is a significant energy differences (ED) between the energy utilization (EU) due to unnecessary installed lamps and the energy required (ER). The result shows 248.72 KWh daily energy loss which gives 90,782.8 KWh per year due to lighting systems in the factory.

3.3.2 Energy Conservation opportunities in Lighting System

As it was discussed above, there is a chance to conserve energy within this lighting system. Inventorying existing lighting, identifying deficiencies, evaluating improvements, and listing these improvements to guide the retrofit are all most easily done with a Table, such as a spreadsheet, which lists all spaces in a building. The space-by-space approach may seem like it is extra effort, but it typically makes the evaluation and recommendations go faster, with better results and more energy savings. Without space-by-space evaluations, opportunities are missed, and confusion arises when proceeding from evaluation/audit to installation. Therefore, it is essential to examine whether the light source is utilized in the most efficient way and take energy saving measures. Energy saving opportunities of the lighting system that should be implemented in the factory have been discussed below.

- **Lighting Controls**

Lights can be shut off during non-working hours manually or by automatic controls, such as occupancy sensors that turn off lights in unoccupied areas, spaces that have intermittent occupancy, such as conference rooms and storage areas.

Occupancy sensors can save up to 10-20% of facility lighting energy use. System Manual controls can be used in conjunction with automatic controls to save additional energy in smaller areas. One of the easiest measures is to install switches to allow occupants to control lights. It is also important to make employees aware of the importance of turning off lights in other lighting controls include daylight controls for indoor and outdoor lights, which adjust the intensity of electrical lighting based on the availability of daylight [44].

- **Task Lighting**

Task lighting denotes providing the required illuminance only in the actual area where the task is being performed, while the general illuminance of the shop floor or office is kept at a lower level; e.g. Machine mounted lamps or Table lamps. Energy saving takes place because good task lighting can be attained with low wattage lamps. If the concept of task lighting is implemented, it can reduce the number of general lighting fixtures, reduce the wattage of lamps, save considerable energy and provide better illumination and also provide visually attractive atmosphere. In some engineering industries, task lighting on machines is provided with CFLs. Even in offices, localized Table lighting with CFLs may be preferred instead of providing a large number of fluorescent tube lights of uniform general lighting [43].

- **Use of Natural Day Lighting**

Day lighting is the effective use of natural light in order to minimize the need for artificial light in buildings. Increasing daylight levels within a rooms can reduce electrical lighting loads. Effective day lighting system may provide evenly dispersed light without creating heat gains. Day lighting differs from other energy conserving measures because its features are integral to the architecture of a building, and so it is applied primarily to new buildings and incorporated at the design stage. However, existing buildings can be cost-effectively refitted with day lighting systems. Various day lighting systems are available on the market; some of which can be supplied as kits to retrofit an existing building. Day lighting can be combined with lighting controls to maximize its benefits. Because of its variability, day lighting is usually combined with artificial lighting to provide the necessary illumination on cloudy days or after dark. Day lighting technologies include properly placed and shaded windows, atria, angular or traditional (flat) roof lights, clerestories, light shelves, and light ducts. Clerestories, light shelves, and light ducts utilize angles of the sun and redirect light with walls or reflectors.

Not all parts of a facility may be suitable for the application of day lighting. Day lighting is most appropriate for those areas that are used in daytime hours by people. In office spaces, day lighting may save between 30 and 70%. The savings will vary widely depending the facility and buildings. Some problems associated with day lighting in industrial buildings have been identified due to the structure of the building. Various companies offer day lighting technologies. Day lighting systems will have a payback period of around 4 years, although shorter paybacks have been achieved [43].

- **Lighting Maintenance**

Maintenance is basic to lighting efficiency. The light levels decrease through time because of aging lamps and dirt on fixtures, lamps and room surfaces. These factors can reduce total illumination by 50 percent or more, while lights continue drawing full power.

The following basic and simple maintenance suggestions can help prevent this.

-Replace lenses if they appear yellow.

-Make fixtures, lamps and lenses clean every 6 to 24 months by wiping off the dust.

-Clean or repaint small rooms every year and larger rooms every 2 to 3 years. Dirt collects on surfaces, which reduces the amount of light they reflect [43].

- **Installation improvement of the System**

There must be sufficient and suitable illumination for varieties of operation in the factory. The illumination required for various operations and the luminous intensity of various lamps are given in Table 3-7 and 3-8. As explained above, currently, there are 1103 lighting points installed in the factory all fitted with 40W fluorescent lamps, 60W incandescent lamps and 250W High pressure sodium lamps. In certain work station segments the illumination is not significant and additional lamps need to be installed to bring the appropriate brightness. On the other hand, there is more than sufficient illumination in the other work station indicating possibility of reducing the number of lamps installed in these work stations. After the appropriate illumination has been checked, only 872 lamps or 838 fluorescent lamps of 40W ratings, 24 incandescent lamps of 60W ratings and 10 high pressure sodium lamps of 250W ratings would be required. This results in total reduction of 231 lamps which is equivalent to 12.374 KW of power. It also results in energy saving of 90,782.8 KWh per year and in money savings of 37,093.95 Ethiopian Birr annually. The analysis of lighting lamps has done through comprising of the existing illumination level at the specific area of the factory with the standards of illumination (see Table 3-9 lighting data summary), the saving potential of lighting systems from illumination level improvement.

Incandescent lamp replacement with CFL

The existing incandescent lamps which have 60W power rating can be replaced by energy efficient compact florescent lamps (CFL) with 18W power ratings. The cost of the replacement lamp is determined about $2.7(74.25 ETB) more than the 60W lamp which was $1.25(34.375) [50]. The new lamp is a direct screw in replacement and no change is needed in the fixture. Labor cost is assumed to be the same to install either lamp. Energy saving is realized in replacement of incandescent lamps with CFL because the luminous intensity of CFL is better than that of the incandescent lamp as it can be seen in Table 3.7. The benefits or cost savings can be calculated as:

Power saving (PS):

PS = total power of incandescent lamp – total power of CFL

$= (LR_{incandescent} * P_{each}/1000) - (LR_{CFL} * P_{each}/1000)$

$= [(24*60) - (24*18)]/1000 = 24*(60-18)/1000$

= 1.008 KW

Energy Saving (ES):

ES =PS*(NL*OH) =1.008 KW (8*24hrs/day + 16*16hrs/day) *365 days/year

= 1.008 KW* (192+256) *365 days/year

=164,828.16 KWh/year

Ethiopian Birr Saving (ETB Saving):

ETB/year Saving = ES*Tariff Rate= 164,828.16 kwh/year * 0.4086 birr/KWh = 67,348.79

Payback period (SPP): The SPP for an ECO is found by taking the initial cost and dividing it by the annual savings.

SPP= 24*74.25/ETB Saving = (24*74.25 ETB)/67,348.79 ETB/year

=0.0266 years

This would be considered an extremely cost effective ECO. Therefore, it is recommended that the existing incandescent lamps should be replaced by CFL to get saving of 67,348.79 ETB/year with SPP of 0.0266years.

Replacing T-12 Tubes with T-8 Tubes

In many industries including 2BF T-12 tube florescent lamps have been used. Quite simply, "T" which stands for *tubular* is the diameter of the tube in the lamp. A T-12 tube refers to the diameter in 1/8-inch increment (T-12 means 12/8 inch or 3.8 cm diameter tubes). The initial output and energy consumption of these lights is high. These also have extremely poor efficiency, lamp life, lumen depreciation, and colour rendering index. Because of these maintenance and energy costs of T-12 tubes are high. Replacing T-12(old and inefficient) lamps with T-8 (smaller diameter) lamps approximately doubles the efficiency of the former, the narrower the lamp the more efficient it will be. Also, T-8 tubes generally last 60% longer than T-12 tubes, which lead to savings in maintenance costs. Typical energy savings from the replacement of a T-12 lamp by a T-8 lamp are around 30% and also 20% more expensive in cost [46]. As it has been discussed earlier, there are 1103 lamps currently installed in the factory indicating that there are 1054 T-12 fluorescent tubes. After the corrected installation, however, only 838 lighting points would be required.

Replacing these 838 T-12 lamp tubes with T-8 lamps tubes is given by:

Power saving (PS):

PS = (0.3*LR*P_{each})/1000 = (0.3*838*40)/1000

= 10.056 KW

Energy Saving (ES):

ES = (0.3*ER*365 days/year) = 0.3*758.91 KWh/day*365 days /year

=83,100.65 KWh/year

Ethiopian Birr Saving (ETB Saving):

ETB Saving=ES*Tariff Rate= 83,100.65 kwh/year*0.4086 birr/KWh = 33,954.9 ETB/year

Simple Payback period (SPP)= $\frac{0.2*65*838}{33{,}954.9}$ 0.321 years, or about 4 months. This would be considered an extremely cost effective ECO.

3.3.3 Analysis of Electric Motors

Brothers biscuit and flour factory uses a vast number of electric motors. These are used to drive many different machines. The motors consume more than 75% of electrical energy in the factory. By improving the efficiencies of these motors or by replacing with energy efficient motors 5% to 15% of electrical energy can be saved.

The efficiency of a motor can be defined as “the ratio of a motor’s useful mechanical power output to its total electrical power input.”

$$\eta = \frac{0.746 * hp * Load}{P_i} \qquad (3.18)$$

where

η = Efficiency as operated in %

Hp = Nameplate rated horsepower

Load = Output power as a % of rated power

P_i= Three-phase power in KW

Motors convert electrical energy to mechanical energy to serve a certain load. In this process, Energy is lost as shown in Figure 3-2. Manufacturers design motors to operate at a 50-100% load. But once the load drops below 50% the efficiency decreases rapidly.

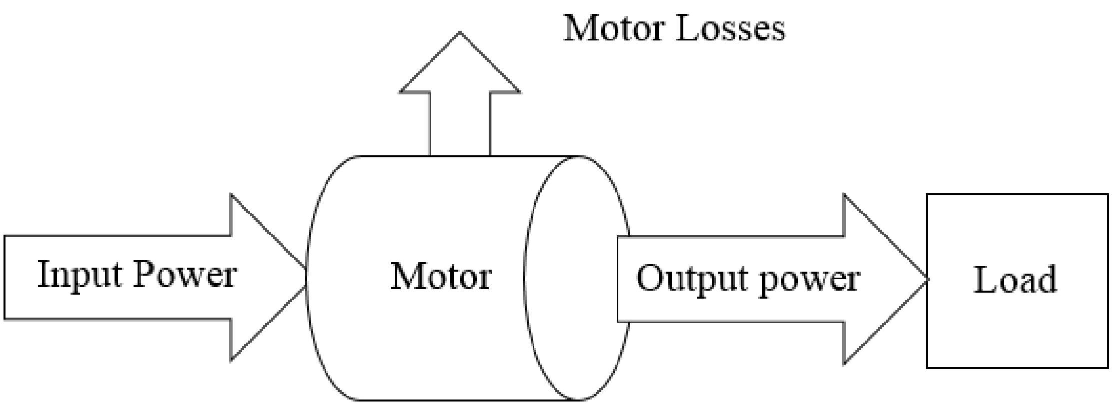

Figure 3-2 motor losses

Many motors of different power ratings are currently in operation in the factory. Most of these motors are old, rewound and not regularly maintained. At present the motor technology is improved. Energy efficient motors are being designed to transfer the input energy to the shaft very efficiently. Efficient motors also tend to have a better relative performance at part load, which is of increased benefit for applications with variable load requirements. In this regard there is a high opportunity to save energy in the factory. High motor efficiencies and power factor close to 1 are desirable for an efficient operation and for keeping costs down of the entire plant and not just the motor. For this reason, it is useful to determine both the load and efficiency when assessing a motor's performance [19].

The primary factors affecting motor efficiency are:

- Speed: - high-speed motors tend to be more efficient
- The size of the motor: - larger motor rate capacity tends to be more efficient.
- Type of enclosure: - open enclosures tend to be more efficient
- Design classification: -lower slip motors tend to be more efficient
- Size of the air gap between the rotor and the stator:-Large air gaps tend to maximize efficiency at the expense of power factor, while small air gaps slightly compromise efficiency while significantly improving power factor.
- Rewinding of motor can reduce its efficiency

- Temperature Totally-enclosed fan-cooled (TEFC) motors are more efficient than screen protected drip-proof (SPDP) motors.
- Motor load:- generally motors operating below 75% of full load relatively reduces their efficiency and with operating below 50% totally inefficient.
- Age: - New motors are more efficient than old one.

3.3.4 Energy conservation Opportunities in Electric Motors

When planning to improve the efficiency of the motor system in a factory shown in Table 3-3, a system approach incorporating pumps, compressors, and funs must be used in order to attain optimal savings and performance. Consideration with respect to energy use and energy saving opportunities for a motor system are discussed below.

i. Replacing Standard Motors with Energy Efficient Motors

High efficiency motors have been designed specifically to increase operating efficiency when compared to standard motors. Design improvements focus on reducing intrinsic (fixed and variable) motor losses.

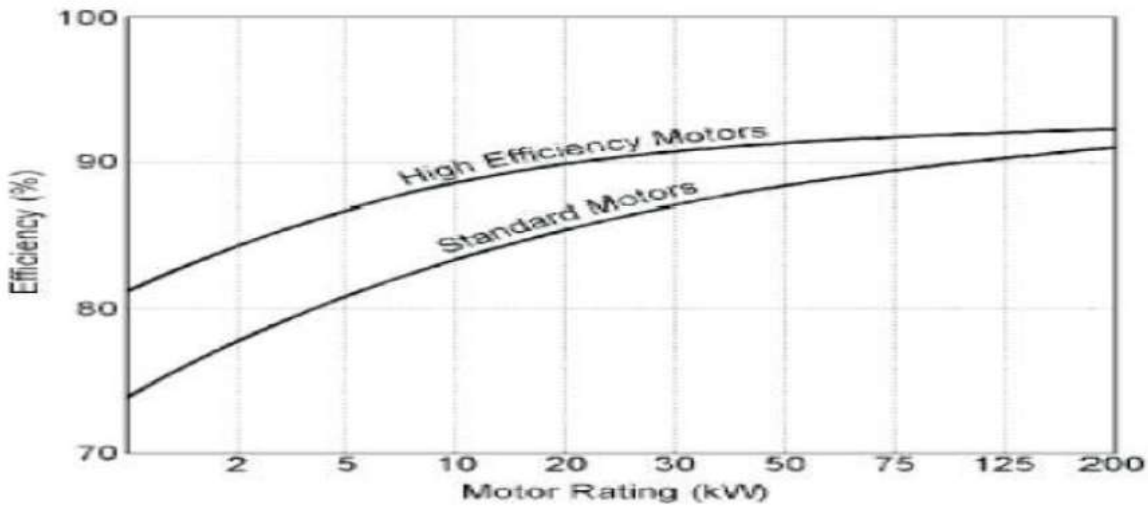

Figure 3-3 Standard vs. high efficiency motors (for typical 3- phase Induction Motors)

Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller fan, etc. They cover a wide range of ratings and the full load efficiencies. Energy efficient motors are higher from 3 to 7 % of standard efficiency motors as shown in figure 3-3.

However, high efficiency motors typically cost 30% more than standard motors, the decreased electricity usage can offset the higher capital costs in a short time. An industrial motor can use electricity worth about four times its capital cost annually. Changing to high efficiency models yields larger efficiency improvements and percentage cost savings in the small motor sizes, but greater absolute cost savings in the large sizes. Larger motors are often rewound, not replaced, when they malfunction. Rewinding is initially less expensive than purchasing a new motor, but ultimately costs more because of degraded efficiency. The efficiency of a rewound motor is typically about 2% below that of a new standard motor [22].

An energy efficient motor replacement can always be found in the same frame size and with comparable starting torque and locked rotor current as the existing motor. High motor efficiencies and power factor close to one are desirable for an efficient operation and for keeping costs down of the entire plant. However, as a result of the modifications to improve performance, the costs of energy efficient motors are higher than those of standard motors.

The higher cost will often be paid back rapidly in saved operating costs, particularly in new applications or end-of-life motor replacements. But replacing existing motors that have not reached the end of their useful life with energy efficient motors may not always be financially feasible, and therefore it is recommended to only replace these with energy efficiency motors when they fail [22].

ii. Replacing Under Loaded Motors with Proper Sized Motors

Probably the most common practice contributing to less motor efficiency is that of under loading. Under loading results in lower efficiency, power factor and higher than necessary first cost for the motor and related control equipment.

Under loading increases motor losses and reduces motor efficiency and the power factor. Under-loading is the most common cause of inefficiencies for several reasons:

- Equipment manufacturers tend to use a large safety factor when selecting the motor.
- Equipment is often under-utilized. For example, machine tool equipment manufacturers provide for a motor rated for the full capacity load of the equipment. In practice, the user may rarely need this full capacity, resulting in under-loaded operation most of the time.

- Large motors are selected to enable the output to be maintained at the desired level even when input voltages are abnormally low.
- Large motor is selected for applications requiring a high starting torque but where a smaller motor that is designed for high torque would have been more suitable.

Motor size should be selected based on a careful evaluation of the load. But when replacing an oversized motor with a smaller motor, it is also important to consider the potential efficiency gain. Larger motors namely have inherently higher rated efficiencies than smaller motors. Therefore, the replacement of motors operating at 60 – 70% of capacity or higher is generally not recommended. If the plant's motor operates under 50% of full rated load, it considers to replace large, partially loaded motors with smaller, full loaded motors either from company catalog / new energy efficient motor.

iii. Rewinding

It is common practice in industry/factory to rewind burnt motors. The number of rewound motors in some industries exceeds 40% of the total number of motors. Careful rewinding can sometimes maintain motor efficiency at previous levels, but in most cases results in efficiency losses. Rewinding can be affected by a number of factors that contribute to deteriorated motor efficiency. Such as: - winding and slot design, winding material, insulation performance, and operating temperature. For example, when heat is applied to strip old windings the insulation between laminations can be damaged, thereby increasing eddy current losses. A change in the air gap may affect power factor and output torque [44].

Rewinding is a common practice in 2BF. However, there are some problems in the process, removing the old winding, selecting wires of appropriate size, slot size design and rewinding the motors more than one times as well as manual way of winding which affects the insulation level. All these have an impact on the efficiency of the rewound motor. However, if proper measures are taken, the motor efficiency can be maintained after rewinding.

iv. Improving maintenance

The purposes of motor maintenance are to prolong motor life and to prevent a motor failure. Motor maintenance measures can be categorized as either preventive or predictive. Preventative measures, the purpose of which is to prevent unexpected downtime of motors, include electrical consideration, voltage imbalance minimization, load consideration, and motor ventilation, alignment, and lubrication. The purpose of predictive motor maintenance is to observe on going motor temperature, vibration, and other operating data to identify when it becomes necessary to overhaul or replace a motor before failure occurs. The savings associated with an on-going motor maintenance program are significant, and could range from 2% to 30% of total motor system energy use [8].

The maintenance condition of the motors in 2BF is poor because, there is no a regular schedule for measuring the line voltages and currents to check the line imbalance and loading conditions of the motors. They do not inspect motors regularly for wear in bearings and housings (to reduce frictional losses) and for dirt/dust in motor ventilating ducts (to ensure proper heat dissipation). Although more motors do have their own ventilating fun for cooling, there are some motors which do not have fun for ventilation. The installed AC conditioning systems do not work is some section of the factory. Also Appropriately Lubrication is not done according to the manufacturer's recommendations. Thus a proper on going motor maintenance program should be applied to save energy from 2% to 30% of the motor use.

v. Analyzing electric motors of 2BF with software

Motor master + international software is used in this work to evaluate the performance of the existing motors with the energy efficient motors. The loading, efficiency, nameplate speed (RPM), voltage rating (V) and power rating (KW) are the inputs of the software which are taken from the existing motors at 2BF and the specifications for the energy efficient motors are taken from the Motor master + international software catalogue. These values are selected in such a way to improve the loadings of the existing operation. The output parameters of the software are: Energy and demand savings, money savings and a simple payback period.

For example, if we evaluate the air compressor pump driver motor of 11 KW which exist in 2BF to the energy efficient motor model from the software catalogue, the following outcome will be obtained as a sample outputs.

Table 3-11 Under load operating electric motor of 2BF

Name of Motor	Name plate data						Measured Data			Loading (%)
	Current (A)	Voltage V(V)	Power Factor	Power (KW)	Speed (RPM)	Effi. (%)	Current I(A)	Voltage V(v)	Power P(KW)	
Mixer water feed pump	10.9	380	0.87	7.5	2930	71.0	7.47	379.7	2.32	30.9
Cooler water feed pump	20	380	0.88	5.5	2910	74.0	12.45	219.6	2.71	49.3
Air compressor pump	14.3	400	0.88	11	3000	65.0	7.61	400.9	4.62	42
Belt Conveyor	23	400	0.97	22	1500	75.0	15.9	384	10.2	46.36
Submersible water pump	30	400	0.9	30	1500	79.0	18.6	365	8.75	35.7
Hydrant pump	67	380	0.92	110	1480	82.0	56.7	377	33.1	30.1

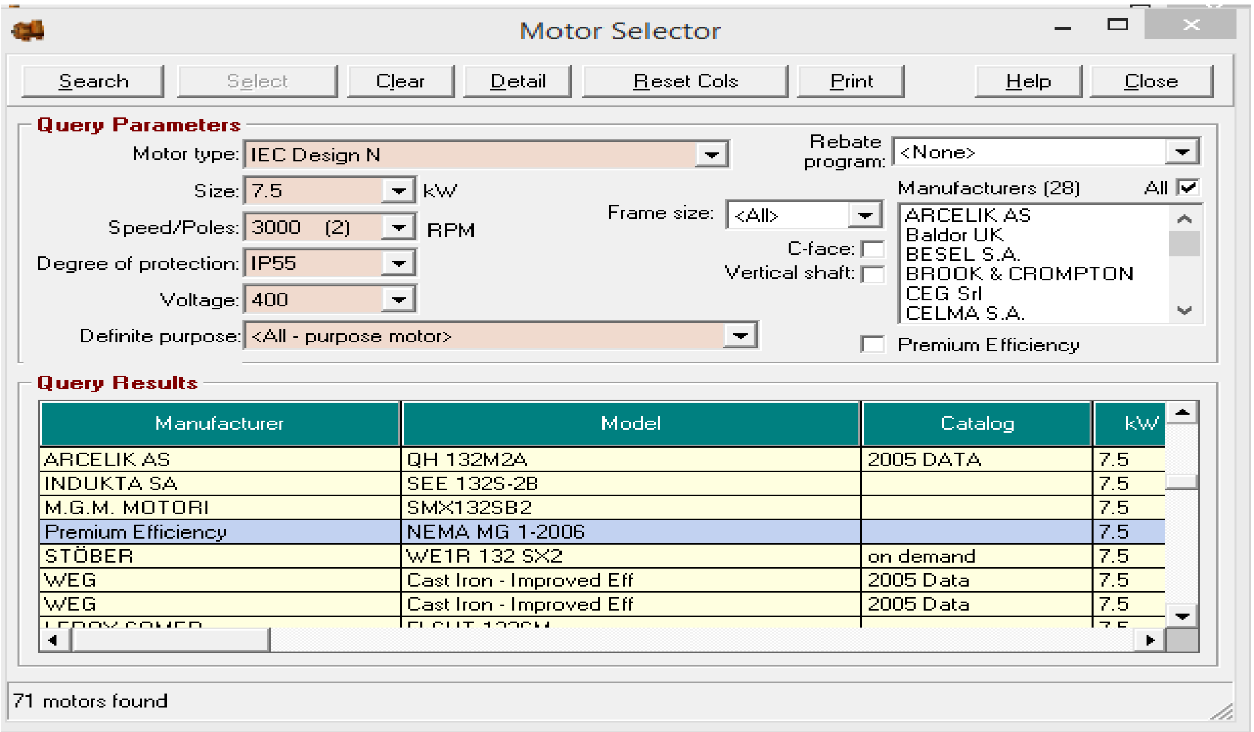

Figure 3-4 Motor selection from MotorMaster catalog

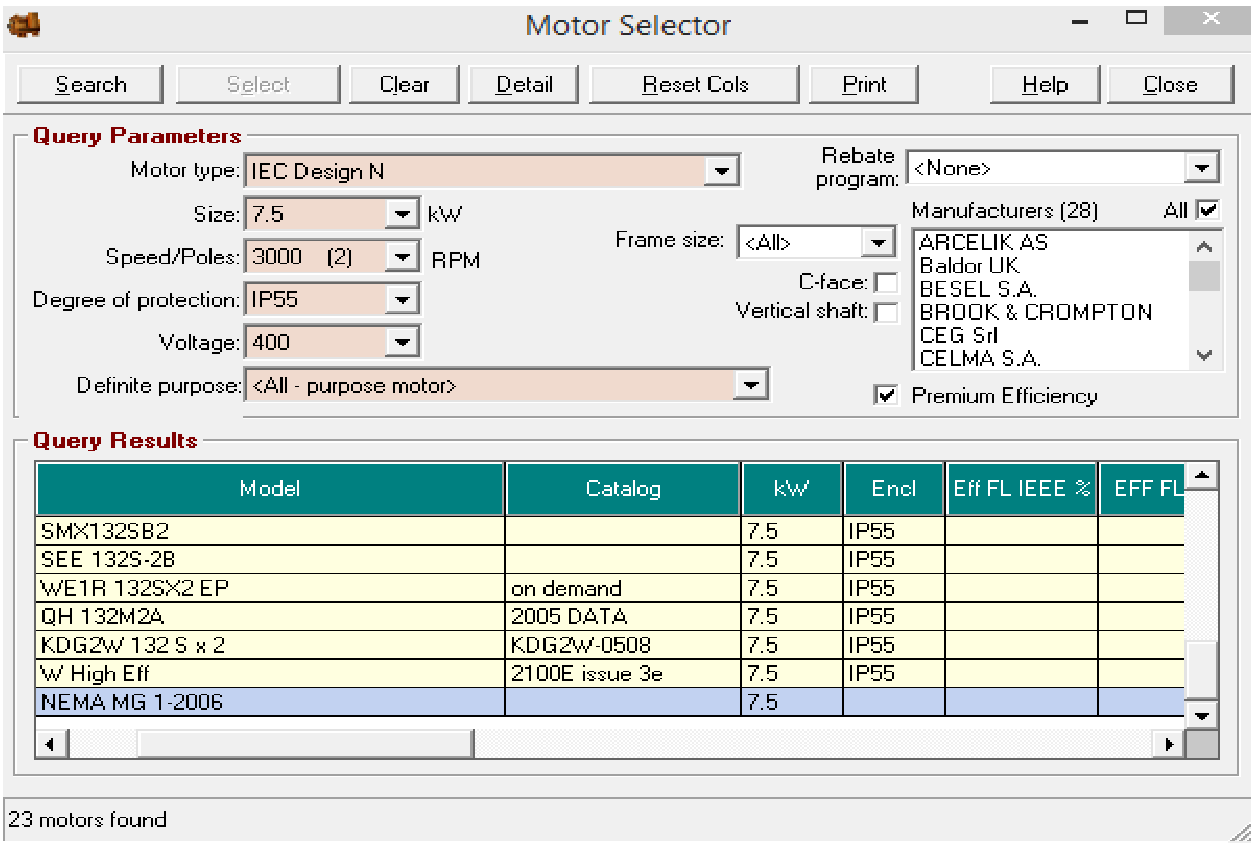

Figure 3-5 Energy Efficient motor selection from MotorMaster catalog

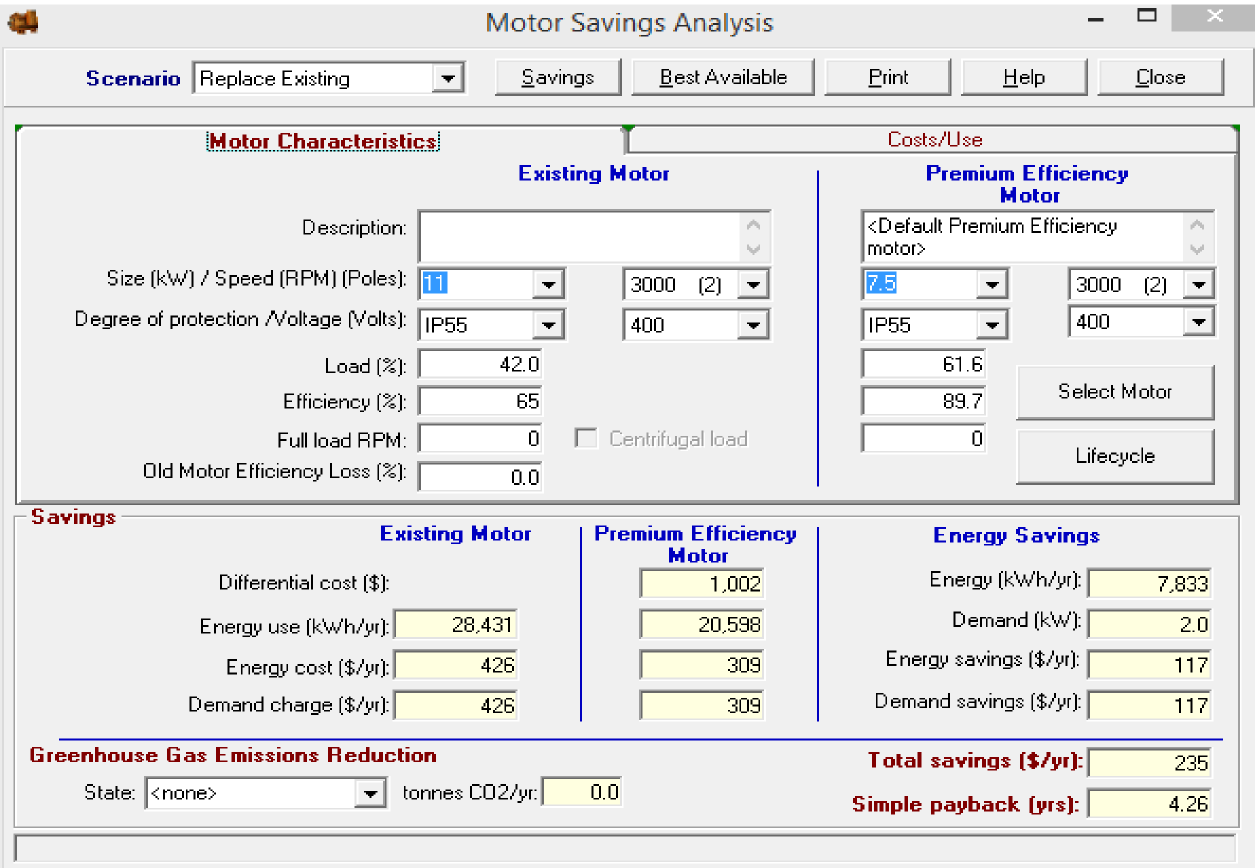

Figure 3-6 Motor Saving Analysis as compared to the standard existing motor

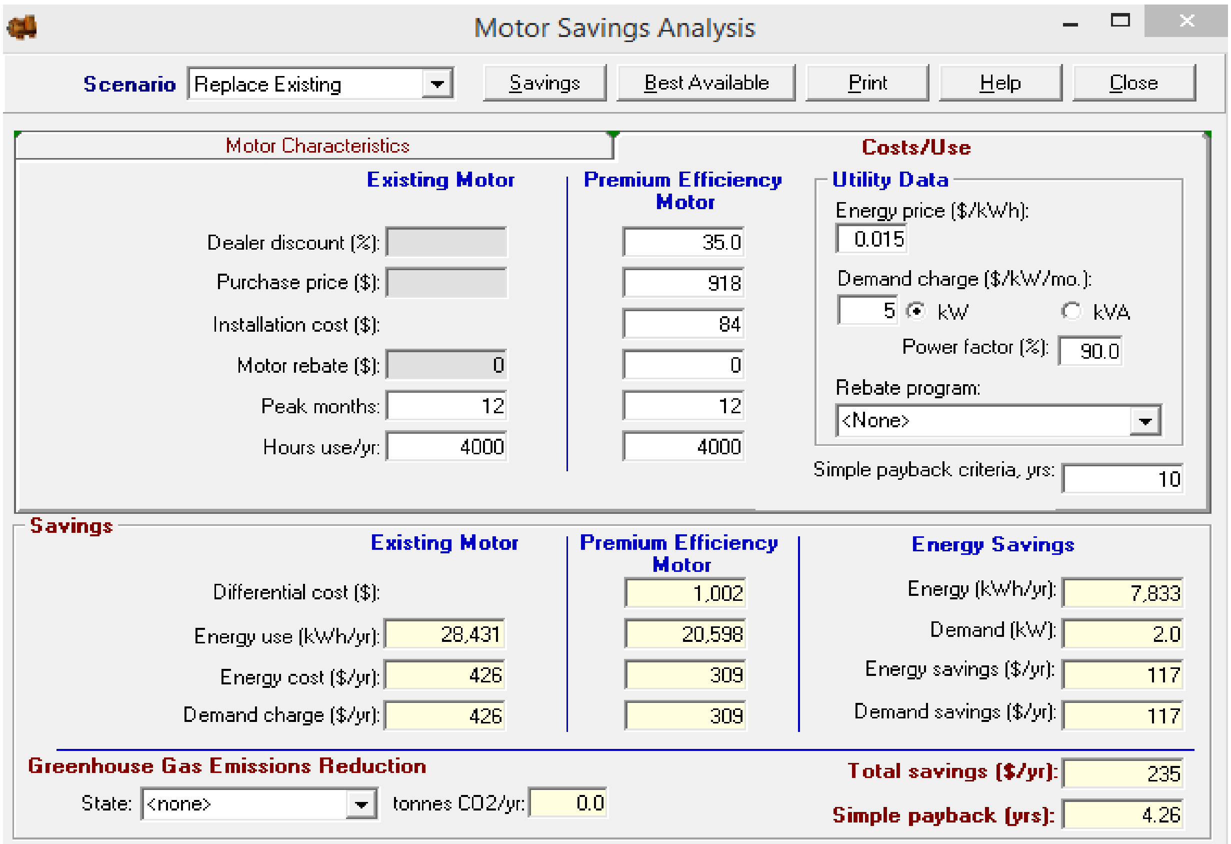

Figure 3-7 Utility Costs/Use data

A short payback period investment cost required to buy the energy efficient motors was effective. From the energy analysis summarized in figure 3-6, an energy efficient motor for air compressor pump requires 918 dollars to purchase, 84 dollars for the installation. But these costs will be back after 4.26 years with an energy savings of 7,833 Kwh per year and money saving of 235 dollars/year with contribution of CO_2 reduction. This is due to replacement of under load motors with proper sized motors and standard electric motors with energy efficient electric motors. Therefore, this method should be implemented in the factory to use electric energy more efficiently. Table 3-11 shows summarized potential of energy and cost saving of proper sized motors and energy efficient motors as compare with the existing inefficient electric motors of the factory.

Table 3-12 Electric motors improvment with replacement of under loaded operating motors with proper sized motors.

No.	Existing Motor			Replaced Efficient Motor			Energy Cost $/year	Energy Saving KWh/year	Money Saving $/year	Payback Period in years
	KW	Loading (%)	$\eta(\%)$	KW	Loading (%)	$\eta(\%)$				
1	7.5	30.9	71	5.5	42.1	84.9	164	2,135	64	7.65
2	5.5	49.3	74	5.5	49.3	87.7	186	2,287	69	7.14
3	11	42	65	7.5	61.6	89.7	309	7,833	235	4.26
4	22	46.36	75	15	68.0	91.9	666	10,014	300	5.26
5	30	35.7	79	18.5	57.9	92.0	698	7,672	230	8.64
6	110	30.1	82.0	75	44.1	93.3	2,130	19,541	586	9.82
Total								49,482	1,484	

Table 3-11 shows the Motor master + international software result of replacing standard motor with energy efficient motor which shows 49,482 KWh/year energy saving and $1,484 per year cost saving.

3.3.5 Electrical energy bill analysis

Electrical energy was used for the production of biscuit and flour in 2BF. So the factory pays cost for this energy source. Bills and energy consumption data of the factory is listed within the factory logbook for many years. From these only 12-months (from September 1st 2008 E.C to August 31st 2008 E.C) of two units' data regarding the factory consumption of electricity, and produced Flour and Biscuit are presented in appendix and used in the analysis [Appendix A].

The energy bills show that the factory paid more than 18 million birr for the selected audit year (from September 2008 E.C to August 2008 E.C). Therefore, the bill analysis is necessarily dependent on the paid money to the used energy by the factory.

The collected electricity consumption pattern is processed into monthly factory paid energy intensity. Based on the voltage consumption and number of phases, 2BF use three phases and medium voltage line, used in the factory, cost of electricity varies. The data collected shows that as the factory used the medium voltage of 15KV, a tariff with flat equivalent rate of 0.4086 per KWh is applied. But if the factory uses only three phases, a tariff with flat equivalent rate of 0.5778 per KWh is incurred. Monthly electricity cost is given by:

Table 3-13 Monthly electricity cost of 2BF

Billing period [2008 E.C]	Total production of biscuit [KG]	Total production of flour [Quintal]	Cost of electricity [ETB]
September	1,396,920.04	8,370.46	1,829,277.12
October	772,995.51	9,158.21	1,233,948.08
November	864,295.81	9,888.50	1,362,480.00
December	966,976.42	7,740.31	1,361,584.86
January	1,087,935.43	10,157.25	1,602,864.06
February	997,171.24	8,924.55	1,450,267.93
March	910,899.72	9,268.61	1,379,467.56
April	867,834.36	9,152.05	1,330,003.42
May	963,846.77	20,151.70	1,966,324.84
June	692,870.78	9,601.68	1,174,261.97
July	1,194,172.19	8,832.00	1,645,889.63
August	1,284,081.72	8,754.66	1,733,450.43
Total	12,000,000.00	120,000.00	18,069,819.90

Monthly Electricity Cost [ETB] = Electricity charge [ETB/KWh] *Monthly used electricity[KWh]…………………………………………………………………... (3.19)

So, with this formula Monthly electricity cost can be calculated or directly read from the factory logbook and tabulated as shown in Table 3-12.

- **Monthly Energy Intensity Consumption Pattern of 2BF**

Monthly energy intensity consumption of the factory is defined as an average monthly energy needed to produce one kilogram of biscuit and flour which are given by the following equations.

Monthly electric energy intensity of biscuit = $\frac{MonthlyElectricityUsed[KWh]}{MonthlyBiscuit\,Produced[Kg]}$ ……...(3.20)

Monthly electric energy intensity of flour = $\frac{MonthlyElectricityUsed[KWh]}{MonthlyFlour\,Produced[Kg]}$ …....…(3.21)

Substituting data from [appendix A] in equation 3.20 and 3.21 gives the value given in Table 3-13.

Table 3-14 Monthly electricity energy intensities of 2BF

Billing period [2008 E.C]	Monthly electricity used for biscuit [KWh]	Monthly electricity used for flour [KWh]	Electric Energy Intensity of biscuit [KJ/KG]	Electric Energy Intensity of flour [KJ/Quintal]
September	1,665,000.00	1,451,250.00	1.191908	173.3775256
October	1,822,500.00	796,500.00	2.357711	86.97110867
November	1,968,750.00	884,250.00	2.277866	89.42208182
December	1,541,250.00	999,000.00	1.593886	129.0645147
January	2,025,000.00	1,127,250.00	1.861324	110.9798022
February	1,777,500.00	1,032,750.00	1.782542	115.7201106
March	1,845,000.00	938,250.00	2.02547	101.228753
April	1,822,500.00	891,000.00	2.100055	97.35522788
May	2,171,250.00	992,250.00	2.252692	49.23901694
June	1,901,250.00	708,750.00	2.744018	73.81519098
July	1,755,000.00	1,235,250.00	1.469637	139.8607627
August	1,743,750.00	600,750.00	1.357974	68.62059978

where 1 Quintal =100Kg

3.3.6 Electric energy intensity comparisons of 2BF with Benchmarks

The energy intensities of benchmark factories which produce biscuit and flour at greater amount and had so far good practices of biscuit and flour production at efficient use of energy are included. By taking the average values of electric energy intensity consumption patterns at national level, Table 3-14 provide data of 5 benchmark countries [Zambia, China, Vietnam, Tanzania, Ghana].

The comparison is energy intensities of 2BF and the benchmarks. It can be seen that there is a significant difference between the energy intensities of the 2BF and the benchmarks. From the twelve months' electric energy intensity analysis of 2BF, we can see that the ranges are from 1.191908 to 2.744018 KWh/Kg of biscuit and 0.49239 to 1.733775 KWh/Kg of flour with an average monthly intensity of 1.92 and 1.03 respectively. The following Table shows the difference in energy intensity of 2BF with the benchmarks. Table 3-14 shows the difference in energy intensity of 2BF with the benchmarks.

Discussion of the results

It can be seen from the analysis of the energy intensity of 2BF, there is a substantial difference between the electric energy intensity of 2BF as compared to the selected benchmarks. This shows that there is a chance for improving the energy utilization of the factory.

Table 3-15 Energy intensity comparison with benchmarks

Benchmarking Countries	Average EEI [KJ/KG of biscuit]	Average EEI [KJ/KG of flour]	Difference in EEI flour of 2BF and benchmarks [%]	Difference in EEI biscuit of 2BF and benchmarks [%]
Zambia	1.35	0.87	0.16	0.57
China	1.52	0.94	0.09	0.4
Vietnam	1.68	0.81	0.22	0.24
Tanzania	1.74	0.83	0.2	0.18
Ghana	1.38	0.88	0.15	0.54

The following calculation shows clearly how much the company is spending for energy which was not essential.

- Annual Average production of biscuit and flour is 12,000,000.00 Kg/year each
- Cost of electricity for 3 phase input line = 0.5778 ETB/KWh

  Cost of electricity for 15KV input line = 0.4086 ETB/KWh

- Difference in electric energy intensity

  For flour = 0.22 KWh/Kg [with Vietnam] & For biscuit= 0.57 KWh/Kg [with Zambia]

- Annual cost of biscuit factory due to inefficient use of electric energy

  = electric consumption in KWh * cost of electricity.

  =energy intensity[KWh/Kg] *production[Kg/year] * cost of electricity [ETB/KWh]

  =0.57 KWh/Kg*12,000,000.00 Kg/year * 0.4086 ETB/KWh= 2,794,824 ETB/year.

- Annual cost of flour factory due to inefficient use of electric energy

  =electric consumption in KWh * cost of electricity.

  =energy intensity[KWh/Kg] * production[Kg/year] * cost of electricity[ETB/KWh)

  =0.22 KWh/Kg* 12,000,000.00 Kg/year* 0.5778 ETB/KWh= 1,525,392 ETB/year.

Total Annual cost of the factory due to inefficient use of electric energy

= Cost for biscuit + Cost for flour= 4,320,216 ETB/year.

So, from the data analysis the factory losses 31% and 22% of total energy for biscuit and flour respectively which is due to inefficient electrical energy consumption. This cost is in comparison with the benchmark countries. However, the benchmarks have their own limitation, it is a relative indication of ineffectiveness of the factory in energy utilization. Therefore, the factory can conduct energy audit on its major energy consuming devices to identify the basic energy loss.

CHAPTER FOUR

SIMULATION STUDIES AND ANALYSIS OF RESULTS

4.1 Power Distribution System Simulation Results

First, simulation results of the factory power distribution system are presented, discussed and compared to the available standard for possible loss in electrical equipment. Next annual technical energy loss of the factory power distribution system is determined and the result is discussed. Moreover, cost of the energy loss is estimated based on EEU billing tariff.

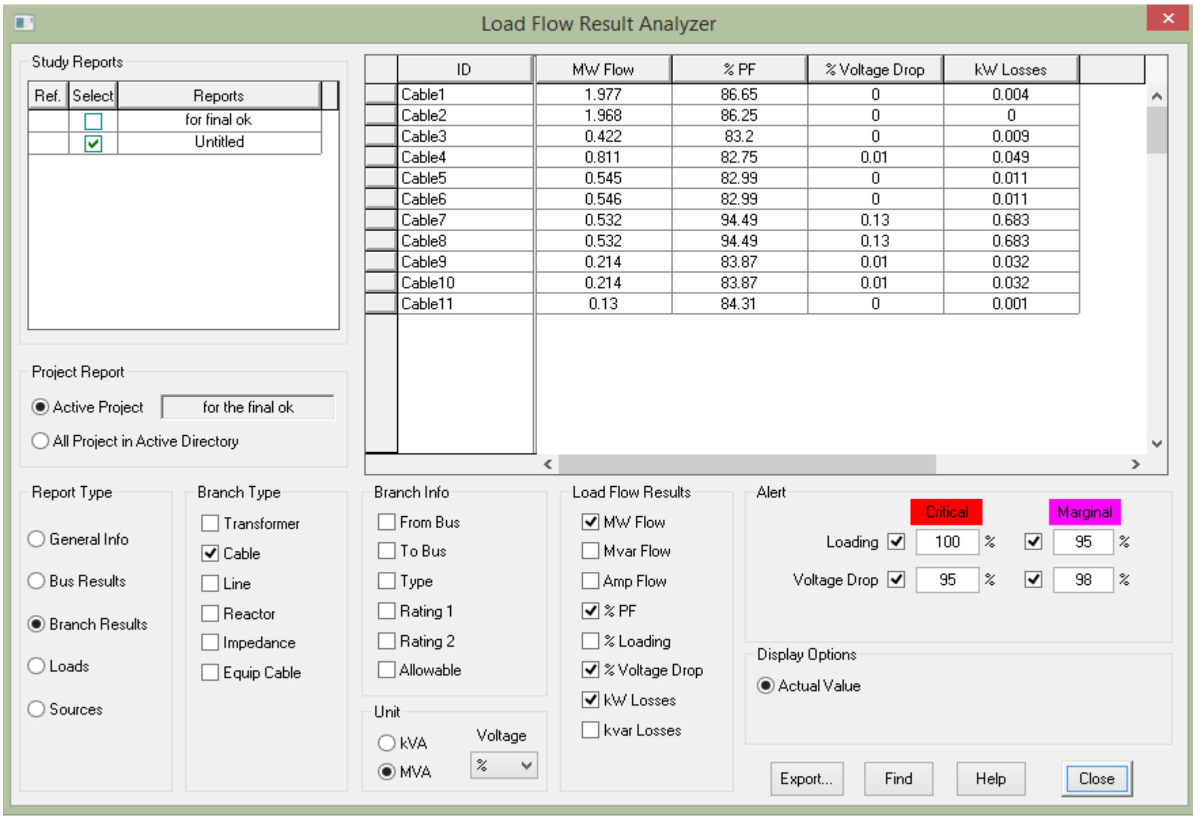

Figure 4-1 Simulation results of distribution cables

Here results, which are essential for estimating technical energy loss and comparison of the power distribution system and its components with standard for possible loss in electrical equipment and electric system are presented.

In Table 4-1 power flow, Power loss, voltage drop, power factor of simulated results of distribution cables, which are important for this study, are shown.

In 2nd column maximum active power flow through each cable of the power distribution system is shown. The simulated active power flow result through each cable is maximum, because during modelling of the power distribution system load connected at each load bus bar is the measured peak demand at MDB of each department. On the next column power factor of the maximum apparent power flow through each cable shows how much the reactive component of the current through each cable is minimized. So that, decision can be taken over the option of loss minimization by minimizing reactive component of current flow through distribution cables. At this point, there is no option to minimize power loss by controlling the active component of the current, since it is determined by the electrical energy utilized by the load connected. At the fourth column, simulated voltage drop result of distribution cables expressed in percentage of the voltage at sending end bus bar is shown. Reactive power flow affects both power loss and voltage drop of the distribution cables, therefore, when we think to minimize power loss of distribution cables by controlling reactive power flow voltage drop should be considered. Simulated power loss result of the distribution cables is shown in the remaining two columns in KW and expressed in percentage of maximum power flow through each cable. This is the most critical result of the simulation because; it decides the technical energy loss and efficiency of the distribution cables. Generally, based on maximum power loss result, load factor and loss factor average technical energy loss of the distribution cables is calculated. Moreover, before technical energy loss minimization of cables is considered; simulated maximum power loss result is compared to standard for possible loss of cables at maximum load.

Comparison of power loss and voltage drop between distribution cables shown in figure 4-1 is not based on the maximum power loss or voltage drop of the cables; it is based on power loss and voltage drop expressed in percentage of their maximum power flow and voltage at the sending end bus bar. For example, the power loss of Cable 7 and 8 is greater than Cable 9 however, when it is compared to the power loss expressed in percentage of maximum power flow through each cable, power loss of Cable 9 is greater than Cable 7 and 8. From figure 4-1 we can easily understand that power loss and voltage drop are proportional. According to the simulated result even though, the power loss of each distribution cable is within the standard for possible loss in cables at maximum load, (1-4% loss of maximum load), care should be given to cable 7 and cable 8 as they have high power loss and voltage drop as compared to others.

Table 4-1 Simulation results of distribution cables

Branch Circuit	Connected Bus ID		Power Flow @MD	Power Factor	Voltage Drop	Power Loss @MD	Power loss at MD
ID	From	To	MW	%	%	KW	%
Cable 1	B2	B4	1.977	86.65	0	0.004	0.0002
Cable 2	B3	B4	1.968	86.25	0	0	0
Cable 3	B5	B6	0.422	83.2	0	0.009	0.002133
Cable 4	B5	B7	0.811	82.75	0.01	0.049	0.006042
Cable 5	B5	B8	0.545	82.99	0	0.011	0.002018
Cable 6	B5	B9	0.546	82.99	0	0.011	0.002018
Cable 7	B5	B10	0.532	94.49	0.13	0.683	0.128383
Cable 8	B5	B11	0.532	94.49	0.13	0.683	0.128383
Cable 9	B5	B12	0.214	83.87	0.01	0.032	0.014953
Cable 10	B5	B13	0.214	83.87	0.01	0.032	0.014953
Cable 11	B5	B14	0.131	84.31	0	0.001	0.000763
					Total Loss	1.515	

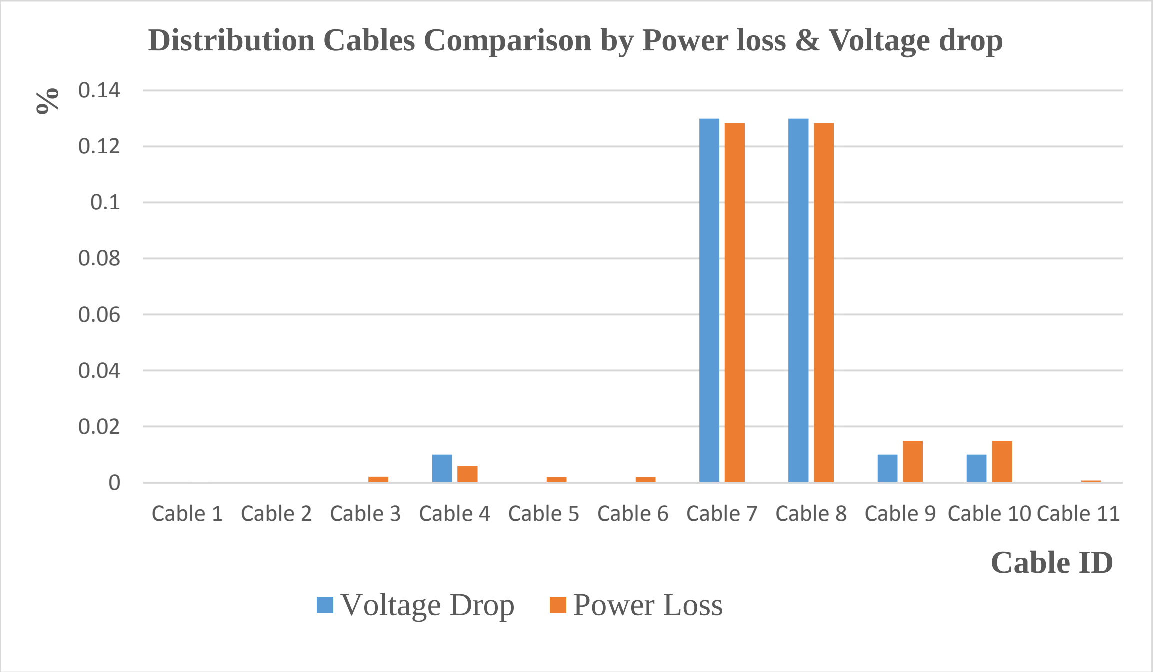

Figure 4-2 Comparison between distribution cables by Voltage drop and Power loss

Table 4-2 Simulation results of distribution transformers

Branch Circuit	Connected Bus ID		Power Flow at MD	Rated S	Power Loss at MD	Voltage Drop	Power Loss
ID	From	To	MW	MVA	KW	%	%
T1	B1	B2	1.978	25	1.056	0.5	0.053
T2	B1	B3	1.969	25	0.891	0.5	0.543
T3	B6	B15	0.422	0.63	5.954	3.49	1.411
T4	B7	B16	0.81	1.2	7.358	3.51	0.9084
T5	B8	B17	0.545	0.8	5.542	3.34	1.017
T6	B9	B18	0.546	0.8	5.545	3.34	1.016
T7	B10	B19	0.531	0.75	5.977	2.3	1.126
T8	B11	B20	0.531	0.75	5.977	2.3	1.126
T9	B12	B21	0.214	0.315	2.567	2.5	1.200
T10	B13	B22	0.214	0.315	2.567	2.5	1.200
T11	B14	B23	0.12	0.2	2.26	2.6	1.88
Total Loss					45.694		

In Table 4-2 power flow, power loss and voltage drop simulated results of distribution transformer at maximum demand are shown. These results are important for this study. The first column shows the maximum active power flow at the primary bus bar of the transformers. When it is compared to the rating of distribution transformers given in the next column considering power factor of the load connected, it is below the rating.

According to NEC (National Electric code) the rating of transformers should be 1.25 times the maximum demand. There for according to the simulated result, all of the transformers fulfil this condition. It is maximum value for the same reason given for distribution cables. In the next column maximum power loss of each transformer were shown, this value is vital for determining average technical energy loss due to transformers and comparing the loss of transformers to the standard for possible loss in transformers at maximum load. In the column 2nd from the last, simulated maximum voltage drop result is shown, this result is important for the same reason given for distribution cables. Simulated power factor result is not shown in Table 4-2 because, it is already shown for distribution cables which supply the distribution transformer, reactive power management option for power loss or technical energy loss minimization can be decided based on that result.

Figure 4-3 shows comparison between transformers depending on the power loss and voltage drop expressed in percentage of maximum power flow and primary voltage. When we observe on the result it is clear that power loss and voltage drops are proportional for the factory power distribution system. Based on the simulation result, power loss of every transformer is within the standard for possible loss in transformer at maximum load which is (0.4-1.9%) [7]. However, care should be given to the transformers with high power loss.

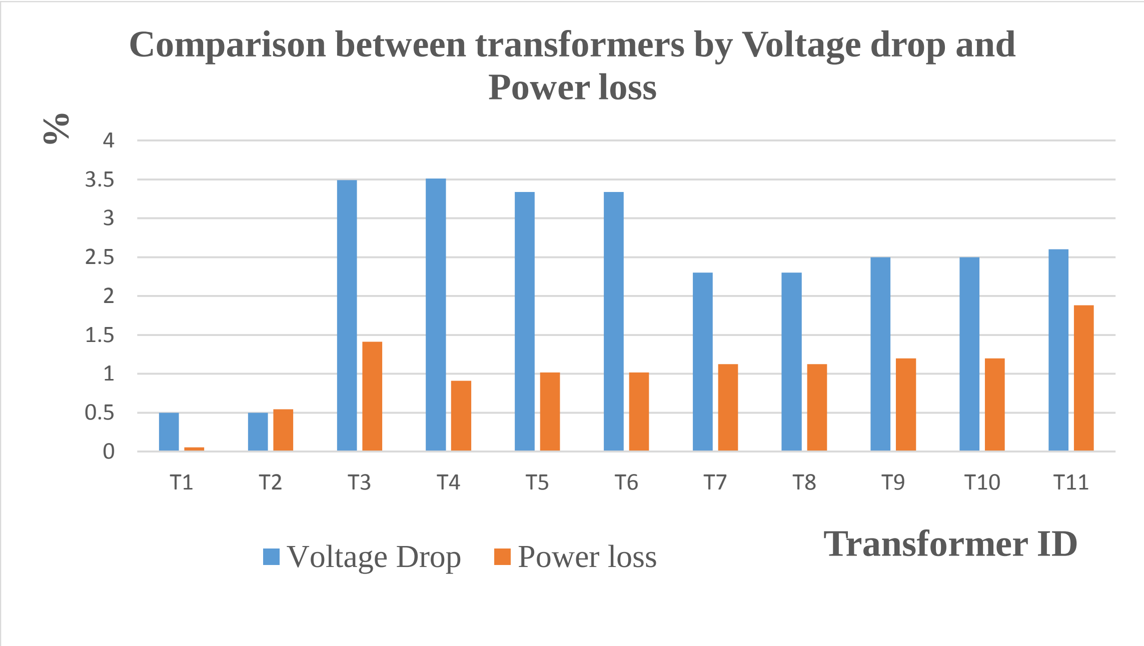

Figure 4-3 Comparison between Transformers by power loss and voltage drop

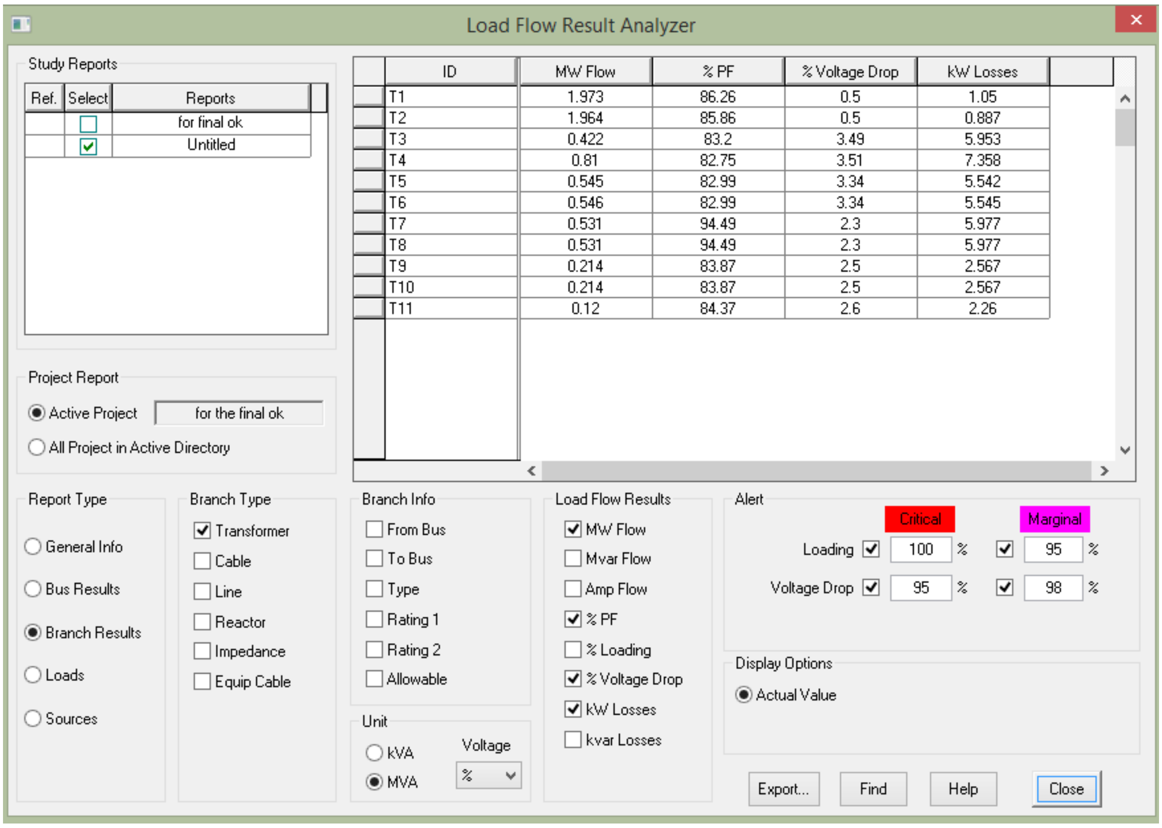

Figure 4-4 Simulation results of distribution transformers

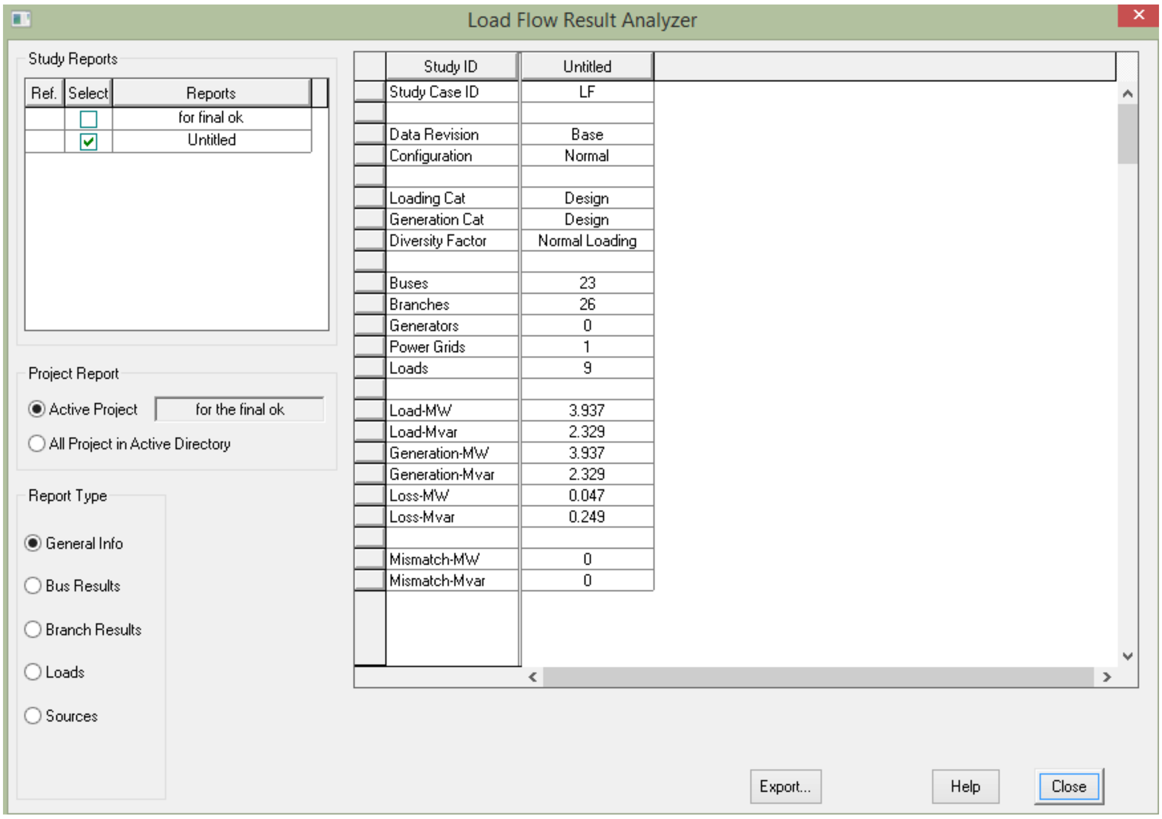

Figure 4-5 General simulation results of the factory power distribution System

When the simulated overall peak demand of active and reactive power result is compared to the overall peak power demand of the factory according to EEU (3.924MW, 2.364Mvar), it is approximately similar. This shows the measurement of power demand taken at each department secondary transformer is good enough. This result is important for comparing the technical energy loss of each distribution system components to the total demand of the factory. The other important simulated result is the overall power factor of the power distribution system of the factory at the swing bus. This result gives information to what extent we can manage or control the overall reactive power to decrease technical energy loss or power loss of the factory. The last important result is simulated overall maximum power loss result of the factory power distribution system. This result is compared to the ideal loss standard for power system, before technical energy loss minimization options are considered. From the result shown in figure 4-3 it is clear that the overall power loss of the distribution system for 2BF at maximum demand is only 1.2% of the overall simulated maximum power demand of the distribution system. And this is within the ideal standard for losses in an electric system, which is 3 to 6% [7].

4.2 Analysis of Technical Energy Loss

A spread sheet is prepared according to the methodology and sample examples already discussed in chapter three of this paper, to determine average annual technical energy loss of the distribution cables and distribution transformers. The spread sheet detail used to calculate technical energy loss is attached under the appendix B.

Table 4-3 Annual technical energy loss of distribution cables

Branch Circuit	Measured maximum Demand	Simulated Max. Power loss	Simulated Power Factor	Estimated Annual Technical Energy Loss	Estimated Annual Technical Energy Loss
ID	MW	KW	%	MWH	%
Cable 1	-	0.004	86.65	-	-
Cable 2	-	0	86.25	-	-
Cable 3	0.43942	0.009	83.2	0.049551292	0.001287
Cable 4	0.81856	0.049	82.75	0.345169723	0.004814
Cable 5	0.55155	0.011	82.99	0.070314432	0.001455
Cable 6	0.55254	0.011	82.99	0.070360177	0.001454
Cable 7	0.53091	0.683	94.49	4.747330674	0.102076
Cable 8	0.53091	0.683	94.49	4.747330674	0.102076
Cable 9	0.24512	0.032	83.87	0.190622496	0.008878
Cable 10	0.24512	0.032	83.87	0.190622496	0.008878
Cable 11	0.15273	0.001	84.31	0.004586338	0.000343
Total Loss		1.515		10.4158883	

Table 4-4 Annual technical energy loss of distribution transformers

Branch Circuit	Rated S	Simulated max. power loss	Maximum load demand	Calculated copper loss	Estimated annual technical energy loss	Estimated annual technical energy loss
ID	MVA	KW	MW	KW	MWH	%
T1	25	1.056	-	-	-	-
T2	25	0.891	-	-	-	-
T3	0.63	5.954	0.421	3.96551438	32.34492895	0.591722
T4	1.2	7.358	0.809	7.30464497	69.85196485	0.73833
T5	0.8	5.542	0.544	4.87894525	42.57529655	0.639499
T6	0.8	5.545	0.545	4.89647582	42.70771872	0.641488
T7	0.75	5.977	0.53	7.23648513	73.25473088	1.161446
T8	0.75	5.977	0.53	7.23648513	73.25473088	1.161446
T9	0.315	2.567	0.213	2.62430158	21.56242671	0.661684
T10	0.315	2.567	0.213	2.62430158	21.56242671	0.661684
T11	0.2	2.26	0.13	1.75777473	11.53541916	0.470296
Total Loss		45.694		42.5249286	388.6496434	

In Table 4-3 simulated power loss, and estimated annual technical energy loss of each distribution cables of 2BF power distribution system are shown. In addition, measured peak demand and average annual technical energy loss expressed in percentage of the average annual energy demand of each distribution cable is shown for discussion purpose. Simulated power loss and power factor shown in column three and four have been already discussed under the discussions section of simulation result. However, they are repeated here to discuss their relationship with average annual technical energy loss. The direct relationship was shown between simulated power losses and estimated average annual technical energy loss and this proofs that for minimizing technical energy loss, power loss should be minimized. And the relationship between power factor of the apparent power flow through the cables and annual technical energy loss of the cables justifies whether reactive power management is possible or not for minimizing technical energy loss of distribution cables. The estimated average annual technical energy loss in the sixth column indicates that the loss of each individual distribution cable is within the ideal standard for losses in power systems (3-6%). In addition, power loss of each distribution cable at maximum demand is compared with the standard power loss at maximum demand for energy efficient cables (1-4% loss of maximum load) at the previous discussion of the simulation result and the loss of the cables was below the standard. The following points are the main reason for the low technical energy loss in the distribution cables:

- The length of the distribution cables is very short, the longest cable is 0.45 KM
- All of the distribution cables peak demand is below the design capacity of the cables
- The power factor of power distribution system is compensated at each department control room by capacitor banks. Because of this, the power factor of the apparent power flow through these cables are above 90% for most of them.

In Table 4-4, simulated power loss, calculated copper loss and estimated annual average technical energy loss of distribution transformers are shown. In addition, the rating value and measured peak demand of the transformers is given in Table 4-4 for discussion purpose. Simulated power loss of the transformers is already discussed in simulation result discussions in the previous subtitle but it is repeated here to discuss its relationship with calculated copper loss and average annual technical energy loss. The relationship between maximum power loss and calculated copper loss shows that they are similar; this indicates the typical value selected for on load and no load loss of transformers is good enough. The other thing is the relationship between power loss and average annual technical energy loss and the result in Table 4-4 shows they are directly related. Estimated average annual technical energy loss expressed in percentage of annual average energy demand of each transformer at the last column shows, distribution transformer is very small. When it is compared to the standard loss in power systems (3-6%), it is with in the standard. In addition to this, the simulated maximum power loss of the transformers is compared to the standard for possible loss at transformers in maximum load, (0.4-1.9), it is with in the standard. The main reason for this low technical energy loss of the transformers is the measured maximum demand of all of the transformers, which is below their rating as it is shown in result Table 4-4.

The overall average annual technical energy loss of 2BF power distribution system is summarized using Table 4-5.

The result shows contribution of distribution cables, and distribution transformers to total annual technical energy loss of the factory power distribution system.

The contribution of distribution transformers to the total technical energy loss of the factory power distribution is dominant as it is shown in the summary result, so focus should be given to it to minimize the overall loss. The total estimated annual technical energy loss of the factory is about 1.2% of the factory simulated total active power demand, which is obtained from the simulated maximum active power demand of the factory and load factor obtained from the measured data, and when it is compared to the standard loss for power system, which is 3-6 %, the overall loss is within the standard.

4.3 Cost Estimation of Technical Energy loss

At this point cost of average annual technical energy loss for 2BF power distribution system is estimated according to EEU billing tariff. EEU billing tariff for Industrial sectors is presented as follows: -

- 380V input line low voltage customer pay 0.5778 cents/KWH
- 15 KV input line high voltage industries pay 0.4086 cents/KWH
- 132KV input line high voltage industries pay 0.3805cents/KWH
- The power factor penalty for high voltage industries is 68.369 birr/0.01pf, if the power factor is less than 0.9.

__Table 4-5 Estimated cost of annual technical energy loss__

Branch Circuit Name	Estimated annual technical energy loss [MWH]	Cost estimation [ETB/Year]
Distribution cables	10.4158883	4,255.932
Distribution transformers	388.6496434	158,802.2
Total	399.0655317	163,058.2

The cost estimation result shown in Table 4-5 describes that the factory total expenditure for annual technical energy loss is about 163,058.2 ETB/year. And the expenditure for the technical energy loss due to distribution transformers, which is 158,802.2 ETB/year, is very high in comparison to the expenditures due to distribution cables. Even though the overall annual technical energy loss of the factory is within the ideal standard for loss in power system; the expenditure for the loss is significant. Therefore, cost wise technical energy loss minimization technique should be applied to the power system of the factory, especially for technical energy loss due to transformers.

CHAPTER FIVE

CONCLUSIONS, RECOMMENDATIONS AND FUTURE WORK

5.1 Conclusions

Electrical energy is used in Brothers Biscuit and Flour Factory as a common power source for all types of load in the factory. They use electric energy inefficiently, since attention is not given toward their energy utilization and energy efficiency. This implies a lot of avoidable expenditure on energy due to inefficient use.

Based on the walk-through audit conducted in the factory as well as information from the collected data, the major power consuming areas which have high energy saving opportunities are lighting systems, rewound motors, electrical networks and air compressors. This study may help them for analyzing the progress of their energy utilization and energy efficiency, especially on their electric motor and lighting system. And also helps them on how they can get the energy efficiency improvement opportunities (technologies and measures) to improve the system.

Analysis of bills

As the result of data analysis the factory loses 31% and 22% of total energy for biscuit and flour respectively which is due to inefficient electrical energy consumption and pays a total of 4,320,216 ETB/year. This cost is in comparison with the benchmarks. However, the benchmarks have their own limitation in energy utilization, it is a relative indication of ineffectiveness of the factory in energy utilization. By improving the energy efficiency system of the factory considerable amount of energy can be saved and it also leads to have clean environment. So, the factory can conduct energy audit on its major energy consuming devices to identify the basic energy losses. This helps the factory to find out energy conservation opportunities and take the energy conservation measures.

Analysis of lighting system

- By lighting installation improvement energy saving of 248.72 KWH per day which gives around 90,782.8 KWH per year is obtained with money saving of 37,093.85 ETB/year.
- By replacing old type of T-12 fluorescent tube with T-8 fluorescent tube 83,100.65 KWH/year energy is saved with 33,954.9 ETB/year money saving as well as

simple payback period of less than 6 months.

- The factory also uses low efficiency incandescent lamp of 60W rating. Replacing 60W incandescent lamp with 18W Compact fluorescent lamp (CFL) gives 164,828.16 KWH/year energy saving which corresponds to money saving of 67,348.79 ETB/year. Again the payback period is less than 6 months. In general, it has energy saving of around 338.711MWh per year with 138,397.54 ETB saving.

Analysis of electric motors

Brothers biscuit and flour factory uses a vast number of relatively small electric motors. These are used to drive many different machines. The motors consume more than 75% of electrical energy in the factory. By improving the efficiencies of these motors or by replacing with energy efficient motors 5% to 15% of electrical energy can be saved with short payback period. Even if rewinding different types of motor have low initial cost, its running cost with short period of time can buy the new motor or energy efficient motor. So care should be taken while rewinding the motor. And replacing under loaded motor can have significant saving.

On the other hand, there are no rigid rules governing motor selection and the savings potential needs to be evaluated on a case-by-case basis. As the result of the analysis, this factory uses electric motor operated inefficient due to under load operation and low efficiency of rating, thus needs to improve their energy efficiency.

Using motor master+ international software, it has been seen that replacing 11 KW of the existing pump motor with a 7.5 KW energy efficient motor can bring energy savings of 7,833 KWh per year and money savings of 235 dollars per year with 4.26 years' payback periods. Also, replacing standard motor with energy efficient motor shows 49,482 KWh/year energy saving and $1,484 per year cost saving.

In general, when you buy new types of motor for replacement it is better to be with professional person in that area and refer Motor master + international software catalog. From these measures, the factory should have a clear image of its energy handling practice and take all the possible measures to become energy efficient and competent biscuit manufacturer industry.

In this thesis technical energy loss assessment of brothers' biscuit and flour factory power distribution system has also been studied. Technical energy losses, which are dissipated in the form of heat, occurred naturally in power system components such as distribution lines, transformers etc.; mainly this is due to the current flow and resistance of the power system components. For this study, load current is measured at the MDB or secondary of distribution transformers of each department, model of the power distribution system of the factory is simulated, technical energy loss of each branch circuit is calculated and its cost is estimated based on EEU billing tariff. Modelling, simulation and numerical solution of the load flow for the factory power distribution system has been done using ETAP 12.6.0. For numerical solution of brothers' biscuit and flour factory power distribution system load flow analysis; Newton- Raphson solution method was employed and according to the result report of ETAP 12.6.0, 99 maximum iterations has done and 0.0001 precision is achieving to obtain the final load flow solution. Load flow analysis result of the factory power distribution system presented in chapter five has been compared with the standard for loss in electrical equipments at maximum load taken from "Development of Building Regulations and Guidelines to Achieve Energy Efficiency in Bangalore City" [33] and the overall maximum power loss with the ideal standard power loss of power systems 3-6% [32]. And the maximum power loss result of each branch circuit and maximum overall power loss of the power distribution system of the factory has been with in the standard considered. But the contribution of distribution transformers for the technical energy loss is high when compared to distribution cables.

For estimating the average annual technical energy loss of the factory power distribution system; load factor and loss factor of the power distribution system estimated from the measured power demand data were employed. More over a spread sheet is prepared in excel to calculate average technical energy loss according to empirical formulas presented in chapter three. The average annual technical energy loss of the factory power distribution system is estimated around 1.2% of the simulated average annual demand. And when it is compared to the ideal standard for loss in power system (3-6%) it is with in the standard.

5.2 Recommendations

This thesis recommended major ECMs from the conducted detail electrical energy audit for different system units and energy conservation measures so as to help the factory reduce its energy cost.

The factory's managers & their staffs' also gives low attention on how their energy uses efficiently, which is a means of most successful and cost-effective way of bringing optimum energy consumption. Thus, upgrading the efficiency of new technologies alone cannot achieve optimal savings, but when combined with a strong energy management program such as good operational and maintenance practices, day to day follow-up on their energy utilization and efficiency can lead to significant savings. The government also gives low attention to check whether the amount of energy presently being generated is efficiently used and give awareness of energy conservation especially for the industry sectors of the country. Thus, the government should involve with a technical and financial expenditure of improving energy efficiency of industries. Especially on:

- creating awareness on general management of the industry on use of their energy efficiently without investment
- Implement the cost effective measures (especially for lighting system) with investing such as to optimization system

5.3 Suggestions for Future Work

To study the technical energy loss and power quality problem of Brother biscuit and flour factory power supply distribution due to harmonic component of the load current, it is suggested that wave shapes of the voltage and current may be further investigated for THD_V and THD_i using power quality analyzer (PQA) and effects of these harmonics on power and power factor may be analyzed.

- The factory is in the process of expansion to increase its production. Therefore, complete technical energy loss assessment of the expanded factory may be carried out.
- The high cost or capital intensive measures may be further investigated and detailed audit and analysis carried out.

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APPENDIX A: Electric Energy bill of 2BF

Table A-1: Energy bill of 12 months for one energy meter among 6 of 2BF that produces different types biscuit which categorized in high voltage industry@15KV line input

Month	Year	Consumption KWh/KVA	Block Rate	Monthly charge(Birr)	Service charge (Birr)	Power factor (Birr)	Total (Birr)
September	2008	333,000.00	0.4086	136.063.80	54.01	546.18	136,663.99
October	2008	364,500.00	0.4086	148,934.70	54.01	536.85	149,525.56
November	2008	393,750.00	0.4086	160,886.25	54.01	508.59	161,448.85
December	2008	308,250.00	0.4086	125,950.95	54.01	370.66	126,375.62
January	2008	405,000.00	0.4086	165,483.00	54.01	299.81	165,836.82
February	2008	355,500.00	0.4086	145,257.30	54.01	399.25	145,710.56
March	2008	369,000.00	0.4086	150,773.40	54.01	500.61	151,328.02
April	2008	364,500.00	0.4086	148,934.70	54.01	436.23	149,424.94
May	2008	434,250.00	0.4086	177,434.55	54.01	198.95	329,015.53
June	2008	380,250.00	0.4086	155,370.15	54.01	1,341.88	156,766.04
July	2008	351,000.00	0.4086	143,418.60	54.01	726.85	144,199.46
August	2008	348,750.00	0.4086	142,499.25	54.01	383.50	142,936.76
Total							1,959,232.15

Table A-2: 12 months' bill of 1 energy meter among 3 of the factory that produces wheat flour which categorized in Industrial (low voltage industry)

Month	Year	Consumption KWh/KVA	Block Rate	Monthly charge(Birr)	Service charge (Birr)	Power factor (Birr)	Total (Birr)
September	2008	483750.00	0.5778	279510.75	53.7	4292.71	283,857.03
October	2008	265500.00	0.5778	153405.90	53.7	3614.81	157,074.28
November	2008	294750.00	0.5778	170306.55	53.7	5266.57	175,626.69
December	2008	333000.00	0.5778	192407.40	53.7	4030.63	196,491.60
January	2008	375750.00	0.5778	217108.35	53.7	3908.80	221,070.72
February	2008	344250.00	0.5778	198907.65	53.7	3666.03	202,627.25
March	2008	312750.00	0.5778	180706.95	53.7	4336.18	185,096.70
April	2008	297000.00	0.5778	171606.60	53.7	4685.55	176,345.72
May	2008	330750.00	0.5778	191107.35	53.7	4694.73	195,855.65
June	2008	236250.00	0.5778	136505.25	53.7	4233.95	140,792.77
July	2008	411750.00	0.5778	237909.15	53.7	4695.53	242,658.25
August	2008	200250.00	0.5778	115704.45	53.7	4377.24	260,928.03
Total							2,438,424.69

Source: brother's flour and biscuit factory catalog

APPENDIX B: Spread Sheet of technical energy loss

Table B-1 Spread sheet prepared on excels to calculate annual technical energy loss of distribution transformers model

Branch Circuit ID	Connected bus ID		Rated S	Simulated power loss		Simul. VD	Peak load demand	Average load	Calculated copper loss	Typical copper loss at I rated	No load Loss	Load factor	Loss factor	Calculated annual technical energy loss
	From	To		KW	Kvar	%	MW	MW	KW	KW	KW			MWH
T3	B6	B15	0.63	5.995	23.741	3.5	0.43942	0.33841	3.96551438	6.75	1.2	0.77	0.62850446	32.34492895
T4	B7	B16	1.2	7.409	52.591	3.53	0.81856	0.72471	7.30464497	13	2.1	0.89	0.80414156	69.85196485
T5	B8	B17	0.8	5.581	32.314	3.35	0.55155	0.46231	4.87894525	8.5	1.3	0.84	0.7297056	42.57529655
T6	B9	B18	0.8	5.584	32.329	3.35	0.55254	0.46331	4.89647582	8.5	1.3	0.84	0.73018034	42.70771872
T7	B10	B19	0.75	6.018	23.829	2.31	0.53	0.51458	7.23648513	12	1.5	0.97	0.94830737	73.25473088
T8	B11	B20	0.75	6.018	23.829	2.31	0.53	0.51458	7.23648513	12	1.5	0.97	0.94830737	73.25473088
T9	B12	B21	0.315	2.585	7.987	2.51	0.23514	0.19863	2.62430158	3.9	0.52	0.84	0.73980226	21.56242671
T10	B13	B22	0.315	2.585	7.987	2.51	0.23514	0.19863	2.62430158	3.9	0.52	0.84	0.73980226	21.56242671
T11	B14	B23	0.2	2.69	4.035	2.84	0.15261	0.10954	1.75777473	2.5	0.34	0.72	0.55571892	11.53541916
Total				**44.465**	**208.642**					**71.05**	**10.28**			**388.6496434**

Table B-2 Spread sheet prepared on excels to calculate annual technical energy loss of distribution cables

Branch Circuit ID	Connected Bus ID From	Connected Bus ID To	Simulated P.loss @MD KW	Simulated P.loss @MD Kvar	I flow A	P. F %	V.Drop %	Peak P.D MW	Average P.D MW	Load factor	Loss factor	Calculated annual technical loss MWH	Annual technical loss %
Cable 1	B2	B4	0.015	0.004	177.1	86.43	0	4.0235	3.5869	0.8914875	0.8140975	0.10697241	1.009335627
Cable 3	B5	B6	0.009	0.003	19.68	83.18	0	0.43942	0.33841	0.7701288	0.6285045	0.049551292	0.467540035
Cable 4	B5	B7	0.05	0.082	38.03	82.73	0.01	0.81856	0.72471	0.8853474	0.8041416	0.345169723	3.323306837
Cable 5	B5	B8	0.012	0.012	25.51	82.97	0	0.55155	0.46231	0.8382014	0.7297056	0.070314432	0.723763795
Cable 6	B5	B9	0.012	0.004	25.52	82.97	0	0.55254	0.46331	0.8385094	0.7301803	0.070360177	0.724234666
Cable 7	B5	B10	0.683	0.236	21.85	94.48	0.13	0.53091	0.46652	0.8787177	0.7934593	4.747330674	45.05565836
Cable 8	B5	B11	0.683	0.236	21.85	94.48	0.13	0.53091	0.46652	0.8787177	0.7934593	4.747330674	45.05565836
Cable 9	B5	B12	0.032	0.01	9.896	83.86	0.01	0.24512	0.19742	0.8054014	0.6800175	0.190622496	1.798614023
Cable 10	B5	B13	0.032	0.01	9.896	83.86	0.01	0.24512	0.19742	0.8054014	0.6800175	0.190622496	1.798614023
Cable 11	B5	B14	0.001	0	5.993	84.3	0	0.15273	0.10593	0.6935769	0.5235545	0.004586338	0.043274279
Total loss			1.515	0.597								10.4158883	100