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REDESIGN, PERFORMANCE EVALUATION AND IMPACT ANALYSIS OF 825KVAR AUTOMATIC POWER FACTOR CORRECTION (CASE STUDY IN AMHARA-PLASTIC- PIPE- FACTORY)

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BAHIR DAR, ETHIOPIA

October 25, 2017

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(CASE STUDY IN AMHARA-PLASTIC- PIPE- FACTORY)

Abraraw Addis Ambelu

A thesis submitted to the school of Research and Graduate Studies of Bahir Dar Institute of Technology, BDU in partial fulfillment of the requirements for the degree of master of science in the power system engineering in the faculty of electrical and computer engineering

Advisor Name:

Dr. Tassew Tadiwose

Bahirdar,Ethiopia

October 25, 2017

DECLARATION

I, the under signed, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can evoke penal action from the sources, which have not been properly cited or acknowledged.

Name of the student Abraraw Addis

Signature

Date of submission: August 29, 2017

Place: Bahir Dar

This thesis has been submitted for examination with my approval as a university advisor.

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THESIS APPROVAL SHEET

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ABSTRACT

The purpose of the study is to redesign, evaluate the performance and impact analysis of the 825 KVAR automatic power factor corrections, which is installed in Amhara Plastic Pipe Factory *with* the total transformer capacity of 4.45 MVA. The necessary reactive power for the capacitor bank calculated according to practical readings for equipment's information that printed on the nameplates, by using two calculation methods namely table of coefficient, Mathematical analysis and verified by Matlab /Simulink software. The researcher selected the power factor of the site from 0.84 to 0.98 because to see the effects up to the AC drive motor loads i.e. 0.97. The investigation shows that the factory total power factor correction capacity is 825KVAR. But this study ensures that the factory total need of power compensator is 1650 KVAR. The Mathematical analysis of the results prove that automatic power factor correction (APFC) significantly reduces the cost of electric power by the annual saving 2.15 million birr per year, it's payback period of the cost procurement by 1.23 years, the capacity increment by 16%, loss reduction by 14.29% & voltage raise increased by 1.8%. The main recommendation of the thesis is the factory has been to solve this problem will be adding additional 825 KVAR reactive powers for the new expansion of factory machines.

Key words: *APFC panels, Power factor correction. Power Factor Controller, Reactive power, plastic industry.*

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LIST OF ACRONYM & NOMENCLATURES

Acronyms

AC	Alternating current
APF	Amhara Plastic Pipe Factory
APFC	Automatic Power Factor Correction
ATS	Automatic transfer switch
CB	Capacitor Bank
DPF	Displacement power factor
EEP	Ethiopian Electric Power
EEU	Ethiopian Electric Utility
HDPE	High Density Poly Ethyline
IEEE	Institution of Electrical and Electronics Engineering
KVA	Kilo-Volt-Ampere
KVAR	Kilo Volt-Ampere-Reactive
KW	KiloWatt
KWH	KiloWatt-Hour
MVA	Mega Volt Ampere
PF	Power Factor
PFC	Power Factor controller
PQ	Power Quality
RMS	Root Mean Square
RVC	Relay Voltage Controller
UPVC	Un plasticized Poly Vinyl Chloride
TPF	True power factor

Nomenclatures

θ	Displacement phase angle
Ω	Ohm (unit of resistance)
A	Ampere
B	Circuit breaker
D	Diameter
F	Fuse
HZ	Hertz (cycles per second)
I	RMS Current
P	Real power
Q	Reactive power
Q acc	Reactive power accepter
Q cbr	Capacitor bank rated
R	Resistance
S	Apparent power
Tr	Transformer
V	Voltage
X_C	Capacitive reactance
X_L	Inductive reactance
Z	Impedance
P	Real Power
R	Resistor or resistance
L	Inductor
C	Capacitor
X	Reactance
Z	Impedance

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Electrical energy performance efficiency is of prime importance to industrial and commercial companies operating in today's competitive markets. Optimum use of plant and equipment is one of the main concerns that industry tries to balance with energy efficiency, for both economic and environmental reasons. As society becomes increasingly conscious of its impact on the environment, reduced energy consumption becomes more desirable, which, is an achievable goal for everyone. Through the use of measures such as power factor correction, electricity consumption is optimized, which ultimately leads to reduced energy consumption and reduced CO_2 greenhouse gas emissions. Within a cost conscious market, payback considerations are also important [1].

This thesis identifies the most appropriate application for power factor correction based on energy consumption, tariff metering, cost payback and redesign. Power factor correction is an appropriate means by which to improve the power quality of an installation [2].

Controlling application is dependent on the size and number of the motors being used at one time of the installation and the extent that power factor correction needs to be applied. This makes it difficult to balance the inductive and capacitive loads continuously. Wasted energy capacity, also known as poor power factor, is often overlooked. It can result in poor reliability, safety problem and higher energy costs. Generally, the goal of any factory is reducing the power factor, and keep them from penalty particularly minimizing the cost of electric power utility bill.

The opportunity exists to make a significant environmental contribution whilst simultaneously providing economic benefit. Currently, the effective capacitor bank as power factor correction device was produced as capacitor bank for industry/factory use.

This will correct power factor base capacitor concept as compensator reactive current in the three phase electric circuit. However, this device is less efficiency because the factory has a yearly expansion plan so that the present capacitor bank did not come up load change. During recent years, increasing attention has been paid to minimize the energy cost and inefficiency in electricity generation, transmission and distribution [3].

The thesis entitled "Performance evaluation and Impact analysis of 825 KVAR automatic power factor corrections" was developed to enable operation of capacitor bank to within a load change. The operation of capacitor bank was not able to operate base of current change according the increase or reduction load. Because the present system could not enough to detect load rating that changed, the operation inefficient and power factor correction not be optimum.

It is also very important to ensure that electricity is properly used. Because safety, reliability and stability of the industries power supply are the primary objective of any industry engaged in mass production. Among the measures that enable electricity use to be optimized, its performance evaluation, impacts analysis of the power factor of electrical systems is undoubtedly one of the most important.

APF plc is one of the main energy consuming factories that suffer from incredible high energy consumption. Due to high reactive power through the factory distribution networks and there is new expansions and rehabilitations through the previous 5 years. This study deals with the performance evaluation and impact analysis of power loss reduction of the factory through power factor improvement before and after capacitor bank.

1.2 Statement of the Problem,

In Amhara plastic pipe factory there is no power factor penalty throughout the last five years up to 2008 E.C. Even if it was the flourish period of time in production, profit and efficient use of the machines, there is new incidence occurred in the factory. The reactive power penalty bill was coming which was not coming in the last 5 years. The researcher was serving more than five years as a manager of maintenance work process. So that, the procurement finance manager requested the work process that to filter out EEU's a new penalty bill which is different from the normal tariff. The problem is shared by different organizations, the solutions is not yet come. A lot of questions come into my mind to know the reason of the punishment of this factory. In one hand the factory has a five year expansion strategic plan on the other hand EEU has a rule of penalty and rejection bellow 0.9 and 0.7 respectively.

The researcher has seen some hypothesis on range of power factor which is between of 0.7 to 0.8. This means that a 1MVA transformer can only supply 700 – 800 KW or the loads can draw only 70 - 80 useful Amps from a 100Amp supply. So, improving the power factor means supplying the necessary reactive power to getting on active power or reduces the amount of wasted power (reactive power).

- Even if there is 825KVAR capacitor panel the bank is not enough power factor compensator if the factory is running in full efficiency the new expansion and rehabilitation of machines. therefore this cause penalties and high monthly payment.[more than million birr per month and 0.5 million birr for penalty]
- Failure or malfunctioning of equipment results of a huge economic losses
- Nonlinear type loads in the same distribution line

So that the researcher wants to calculate the reactive power and comparing with the old APFC, calculate system capacity and calculate simple payback period. This thesis comes to highlight the importance and the need for the power loss reduction in the APF plc and the economic impacts of power factor correction of capacitor bank panels.

The researcher rationality of the study over the past years, power capacity systems have received considerably less attention devoted to upgrading automatic power factor correction capacitor bank panel.

The thesis will be answered the following questions;

1. What are the general methods to control capacitor banks?
2. What a new capacitor bankfor the expansion of the factory loads?
3. What is the method of power factor correction with the low cost an automatically controlled PFC unit that will bring the power factor to as near to 0.98?
4. Does the factory have sufficient capacity for future APFC requirements or expansion?
5. What is the implemented automatic capacitor bank verification analysis and forward the economic benefit that can be achieved for the factory (power saver)?

1.3 Objectives

1.3.1 General Objective

The general objective of this study is to make performance evaluation and impact analysis for high energy consumptions in industries, through a sustainable development of automatic system that corrects low power factor & decline power loss in Amahara plastic pipe factory plc.

1. 3.2. Specific Objectives

- To identify methods to control capacitor banks, designing for the expansion of power feeder system loads.
- To point out a method of power factor correction with the low cost and practical. i.e. to provide an automatically controlled PFC unit that will bring the power factor to as near to unity as practical (typically 0.98) and have sufficient capacity for future PFC requirements or expansion.
- To show the test of automatic capacitor bank verification to make analysis and forward the economic benefit that can be achieved for the factory (power saver).
- Identify reactive power factor problems in Amhara pipe factory PLC.
- Simulate the mitigation systems and observe the impact of the proposed solutions.

1.4 Scope of the Study

There have several scopes on achieving the objective mention and covered as much as the aspect of the thesis designs on finding the suitable method to be used. The study is primarily concerned to improve the power factor of the Amhara plastic pipe factory distribution network. It is obvious that, the most practical and economic power factor improvement device is shunt capacitor. Because there are considerable low losses and little maintenance as there are no rotating parts when capacitors are used as power factor correction method.

Thus, the scope of the study was covered

1. Identify reactive power factor problems in Amhara pipe factory PLC. and Evaluating the performance of old 825 KVAR power factor corrector
2. Electricity tariff savings, pay backs and Extra KVA periods could be calculated

3. Capacitive compensation does not change according to its maximum loads so it has to be automatic
4. New design for the new expansion lines.
5. Simulate the mitigation systems and observe the impact of the proposed solutions.

This thesis was developed to redesign, evaluate the performance, impacts analysis of the power factor according to load change.

The researcher were challenged on scarce of related materials, however, he used journals and other online materials instead. The study faces to struggle to get EEU present a company report like statistics, financial involvement, costing etc. regarding the topic or the opportunity. During the report, the researcher use some documents it had to be taken care of that the report does not contain any company confidential information and harm the organization in their strategic stance. The thesis was also limited to implementation of APFC; calculate the reactive values of transformers, harmonics etc.

1.5 Thesis Report Outline

Generally this thesis report is divided into six chapters, where it consists:

Chapter 1. Introduction: - is an overview of the thesis in whole, the problem statement; objective and scope of thesis is defined. The theses that will be done are based on the objectives and scopes that had been stated earlier.

Chapter 2. Literature Review: - presents the literature review of the performance and impact analysis of automatic power factor correction thesis. Studies on literature review helps in understanding the fundamental of the thesis. Main hardware component, software and calculation will be discussed in this chapter.

Chapter 3. Methodology :- will discuss about the methodology that shall adopted for this thesis work which basically defined the planning process flow and principles that is essential guide to produce a well planning thesis. Besides, selected approach or methodology will describe the activities that might be done in every stage.

Chapter 4. System description to over view total power need of the factory

Chapter 5. Results and Discussions: - will be discussed the thesis testing and result. Where the collected data from experimental work will be gathered before the analysis will be performed. The 5 final sections from this chapter are the discussion for the gathered data will be explained.

Chapter 6. Conclusion and Recommendation: - will conclude all the works that had been presented in previous chapter and all the results of the thesis. This is followed by recommendations for the future study work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature review that related to this study case will be identify and reviewed. Generally, these papers are related with the topic make performance evaluation and impact analysis of power factor correction by using capacitor bank. Power factor correction is an appropriate means by which to improve the power quality of an installation. These papers focus on the performance evaluation and impact analysis of capacitor bank that a purpose to get scientific information, analysis and study the weakness concept and method how to improve the present power factor panel and to design APFC for the new expansion is not addressed in the previous studies.

There are many researchers have been done in the power factor improvement in small factory. However, for the performance evaluation and impact analysis of reactive compensators is too small. The main gaps of these studies are not address the design, performance evaluation and impact analysis of 825 KVAR automatic power factor corrections in a complete manner.

Such as:-

[12] Adi Osama A. etal (2012) a case Study a switchgear factory was selected as a case study for before and after operating the Capacitor Bank that was installed at the MLTB. The study has limitations on load factor and future expansion rates. According to Osama etal (2011), focus on the electrical distribution network study in Kuwait has undergone several findings, which show the improvements over the years to ensure a higher capacity and efficient electricity service to all consumers. Such improvement permits a reduction in the size of switchgear, transformers and cables, which imply lower cost. In this regard the article presents a case study that shows the advantages of power factor correction for the electrical distribution network in Kuwait.

This thesis is different from Osama (2012); because this thesis deals on a performance evaluation and impact analysis of power loss reduction of the factory through power factor improvement before and after capacitor bank. However, Osman and Ahmed focus on the case study in this measured data is taken on the factory site before and after installing power factor correction capacitors.

But this thesis includes the redesign of APFC. The study of Osama and Ahmed are not incorporated. The researchers' data includes power factor, active power, reactive power, apparent power, and current. By improving the power factor of the site from 0.75 to 0.95, the KVA capacity of the distribution transformers (supplying the factory) increases by 21.05%.

The thesis shows, improving the power factor of the site from 0.84 to 0.98. The KVA capacity of the distribution transformers (supplying the factory) increases by 16%. Analyses of the results prove that APFC significantly reduces the cost of electric power production compared to these study similarly increases the capacity and efficiency of the electrical power system in APF.

The systems are available to produce reactive energy and improve the power factor. Particularly, shunt capacitors at the nearest point to the loads is a well-established approach to improve the power factor. Shunt capacitors are attractive because they are economical and easy to maintain. Not only that, but also they have no moving parts, unlike some other devices used for the same purpose

From the case study on the Switchgear Factory, it has been found that in order to have good performance for the electricity supply system, it is important to optimize the power factor between 0.9 and 0.95. This will eliminate waste in electrical energy and increase the output without the need to install additional transformers and cables. APF in distribution system will indeed release generation and transmission capacities. Moreover, due to tightly interconnected nature of the system, the exact benefit due to capacity release in these areas is quite difficult to compute. Capacity releases in generation and transmission levels is probably more relevant in compensation studies at these areas and hence are left out from the economic analysis of capacitors application in distribution system.

[21] Anant, Durga,Vijay (2014) The article identified the power factor correction of electrical loads is a problem common to all industrial companies. Earlier the power factor correction was done by adjusting the capacitive bank manually.

The article contends the automotive power factor correction using capacitive load banks is very efficient as it reduces the cost by decreasing the power drawn from the supply. As it operates automatically, manpower are not required and this Automated Power factor Correction using capacitive load banks can be used for the industries purpose is not include. It is bounded in the laboratory but my thesis is focus on in the industry.

However, this thesis argues in the industry area to automated Power factor Correction using capacitive load banks can be used for the industries. The automated power factor corrector (APFC) using capacitive load bank is helpful in providing the power factor correction. Proposed automated project involves measuring the power factor value from the load-using microcontroller. The design of this auto-adjustable power factor correction is to ensure the entire power system always preserving unity power factor. The software and hardware required to implement the suggested automatic power factor correction scheme are explained and its operation is described. In this study APFC thus helps to decrease the time taken to correct the power factor which helps to increase the efficiency but, Anant, Durga, vijay (2014) studied not embedded and limited in the laboratory.

[24] Ziana Bt Che Ros (2013) the main focus of this study is the technical losses that caused by the physical properties of components at transmission lines especially the MW loss and the Mvar loss. This thesis focused on the 9 Bus system analyses. Several studies have been conducted for this system which can be divided into two categories; the original setting (stable system) and the modified circuit for heavy loads setting where the loads capacity are increased to twice the value of the original setting. The purpose is to generate greater value of power losses.

This thesis and Ziana Bt Che Ros (2013) article are completely different. Ziana Bt Che Ros (2013) concept, idea and finding. The main limitation Ziana Bt Che Ros (2013) study is the simulations experiment assumed perfect simulation, Outside interference from other technologies are negligence, The values of the capacitor are randomly selected, The chosen bus to install the capacitor is based on the greatest losses shown by the power world simulator. This study focuses on that, nine Bus power grid system offered by the simulator tool. The systems then would be disturbed by introducing the heavy inductive load KVAr demand by doubling the size of the loads capacity at the selected Bus. The study will concentrate on the MW and Mvar Power Losses created at transmission lines.

[19]. S.O .Onohaebi etal. *a case study on medium scale industries*. April 2011 presented the power quality problems, issues, related international standard, and effect of power quality problem in different apparatuses in Industry and methods for its correction to improving the efficiency of electrical equipment by using power factor correction**.**

[25]. Bhogadi etal (2014) effort them is Automatic Power Factor Correction (APFC) Panels. The main limit of the study is very difficult to maintain consistent power factor by using fixed capacitors because the researcher need to be operated manually which may result in over voltages, saturation of transformers etc. that may lead to the interruption in the power supply of the distribution system. Similarly, both sides APFC Panels automatically varies according to the load requirements on the L.T side i.e. distribution side, which compensates the load requirements. Impact of automatic power factor correction panels (APFC) at L.T side of a transformer are discussed which are inductive in nature.

The impact of contactor switched automatic power factor panels at low tension side of transformer has been studied at rapidly varying and scattered loads. Automatic switching operation of the panel was observed to be satisfactory, thereby, eliminating the need for manual intervention. The target power factor was also improved much better (0.88 to ~0.99) almost unity when compared to its absence, thus reducing the effect of high power bills and heavy penalties from electricity boards.

[22].S. Khalid, B. Dwivedi, Presented the power quality problems, issues, related international standard, and effect of power quality problem in different apparatuses in Industry and methods for its correction**.**

[29]. Haider Muhamed (2014) Study and Analysis for the Effects of Power Factor Correction in Al-Najaf Cement Plant, The article emphasis on the effects of power factor on performance of the main motors, the electrical cables and transformers, which are used in an Al- Najaf cement plant, are discussed.

This research focuses on for future expansion and saving amount money and power. But this Haider Muhamed (2015) Study and Analysis focus on the calculations of reactive power for power factor correction has demonstrated several benefits such as: The total value of current which is drawn from the network is reduced with limits of (96.23A) to the equipment's which has been calculated, reduce the power rating of transformers, the reduction in the cross-sectional area of cables and decrease the losses of cables which is about (8.682 KW). The technical benefits of power factor correction are increasing the operational life for equipment's, which are host in the factory, and utilizing the complete active power. Regarding the economic benefits of analyzing the mentioned equipment's are the reduction of the cross sectional area of the used cables and the rated capacity of transformers and switchgears, this will have a great impact in cost reduction of these equipment's. But the researcher lacks the performance and impact analysis of for the factory.

But the researcher argues with the researcher, quality of electrical power plays an important factor in any industrial process, these factors relates to the economic and technical benefits. The cement industry used many of the miscellaneous equipment's, which are classifying as non-linear loads such as induction motors, transformers etc. The electrical equipment's are absorbing additional currents called "inductive reactive currents"; the effects of additional currents making electrical network inefficient, result of reducing the power factor. However, the low power factor will affect the increase the loads on the power station on the one hand and on the efficiency of the equipment's, capacity of transformer's, sizes of cables and capacity of switchgears on the other hand this in relation to the cement plant.

In this paper, the effects of low power factor on main motors, which use in AL-Najaf cement plant analyzed, such as raw material mill, cement mill and the clinker cooler. The necessary reactive power for the capacitor bank calculated according to practical readings for equipment's information that printed on the nameplates, by using two methods for calculation (the mathematical equations and table of factor K). The influence of power factor correction on the motors, transformers and sizes and losses of electrical cables calculated. The advantages of power factor correction are both similarly analyzed for economic and technical sides.

[21] Sapna and Vijay (2013) paper describes the improvement of power factor of an induction motor by using capacitor bank. the study shows when the power factor is improved, automatically energy will be saved A power factor is the goal of any electrical utility company since if the power factor is less than one, they have to supply more current to the user for a given amount of power use. In so doing they occur more line losses. Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. For industrial and mining applications, 3- phase AC induction motors are the prime movers for the vast majority of machines. It has been estimated that these motors consume 70% to 80% of all electricity in the world.[20]

The main differences of this thesis focus on centralize automatic reactive power compensation. But their study is decentralized type and Power factor correction is achieved by the addition of capacitors in parallel with the connected motor circuits and can be applied at the starter, or applied at the switchboard or distribution panel.

[18]. S. Osafehinti, etal (2013) Design and implementation of measuring and information system for analysis of power quality in compliance with EN 50160 in different points of power supply network.

[25] S.V Ravi Kumar and S.Siva Nagaraju worked on simulation of D-STATCOM and DVR in power systems. They described the techniques of correcting supply voltage sag, swell and interruptions in a distributed system. In their work they used DVR to inject voltage in series with the system voltage and D-STATCOM to inject current into the system to correct the voltage sag, swell and interruption. Finally they found that DVR provide relatively better voltage regulation capabilities and also observed that the capacity for power compensation of DVR and D-STATCOM depends on the rating of storage devices.

[15]. M. Thein , E. Ei Cho, “Improvement of Power Factor for Industrial Plant with Automatic Capacitor Bank”, Proceedings of World Academy of Science, Engineering and Technology, Vol. 32, P. 695 -701, ISSN 2070-3740, Aug. 2008. Design 200KVAr automatic capacitor panel by using circutor.

[48] Prakash sundaram1, Shimi S.L.2, Dr.S.Chatter ji3 published a paper entitled “Reduction in Harmonics in Marble Industry” on an industry found in India. After measuring the harmonic components of current, they found that the 5th harmonic content was beyond the IEEE limits, then design the harmonic filter. After installation of harmonic filter at Arihant Marble Industry, measurement were done again and found that 5th harmonic content was below IEEE limits. They are found shunt harmonic filters are economical way of mitigating harmonics.

CHAPTER THREE

METHODOLOGY

The methodological approach of this study is quantitative one. Which is describe number, percentage, graphs and charts etc? The design of the research is descriptive form of presentation. In this chapter, data have been collected and analyzed. After analysis of the data, mitigation solutions have been proposed. The collected data have been analyzed and the levels of the power factor correction have been compared to international standards. The schematic diagram of Amhara plastic pipe Factory PLC is shown in next chapter Figure 4.3. It has five transformers each for different section of loads.

Data have been collected from the load side of motors with respective ratings of 4450KVA (4.45MVA), 15/0.4KV and 5% impedance.

The factory has two sections:

- Old distribution system
- New expansion distribution system

The methodology consists of systematic study of methods that will have been applied within a discipline on the proposal title. On this thesis, the aspect of automatic power factor correction (APFC) is discussed as to find the technical on the objective achievement. Implementation of the "At Load" focus on performance, evaluation and impact analysis of Power Factor Correction for the industrial locations was relatively simple and involved the following steps:

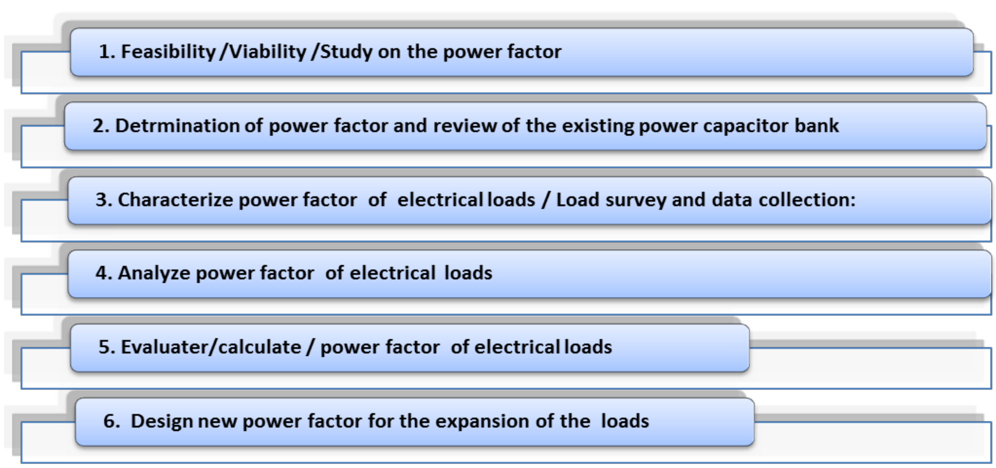

Figure (3.1) Thesis flow implementation of all the stages of research flow based on the following matters:

Feasibility Study on Power Factor: Literature review on theoretical background about the truth of power factor, others related study on mitigation plan and activities of low power factor of electrical load.

1. Determine Power Factor of Electrical Load: Data collection through measurement the power factor of electrical load based on impedance belongs to an electrical load.
2. Characterize Power Factor of Electrical Load: Data of measured power factor is gathered and organized.
3. Analyze Power Factor of Electrical Load: Observe the result of characterization of power factor, then extract the related finding matters and identify the relationship between related Power Factor components of electrical load.
4. Evaluate Power Factor of Electrical Load: Justify the analysis on Power Factor Characteristics related component of electrical load.

3.1. Initial Inspection and Measurements

The first step: - The step focus on look at the equipment located on site. Certain types of equipment are likely sources of reactive power. Those include screw compressors, air conditioning equipment, machinery with fly wheels, and large blowers, among others.

***The second step*:-** is to take measurements at the service entrance of the facility over an extended period of several hours during the building's prime operating period to determine the reactive load and power factor of the facility.

The third step:- in the process is to take measurements at the interconnection point of obvious sources of the reactive load to determine each machines load characteristics and how much reactive power they are discharging onto the system.

The fourth Step:- involves calculating the size of the devices that need to be attached to each piece of equipment to correct the problem. To gather the required data for the study, This includes: interviews, survey, observation and voltage drop measurement. The secondary-data were obtained from the documents of the factory.

3.2. Assessment Procedure of Load Survey and Data Collection[29]

The Consideration of Amhara plastic pipe factory plc installations can provide valuable insight into the strategies and design principles of PFC that could be used to undertake the feasibility assessment. General aspects to consider include:

A) Location and type of PFC equipment

B) Previous supplier of PFC equipment and preferred configuration

C) Performance of existing PFC equipment including maintenance issues and downtime.

D) Equipment compatibility/suitability i.e. methods of controlling mechanisms of the capacitor bank for each equipments.

E) Checking the designed data and actual /practical/ collecting data's

(i) Check if required KVAR of capacitors are installed.

(ii) Check the type of capacitor installed is suitable for application or the capacitors are de-rated.

(iii) Check if the capacitors are permanently "ON". The capacitors are not switched off.

(iv) Load survey and data collection: then the load is not only active power under such condition the average power factor is found to be lower side.

(v) Check whether all the capacitors are operated in APFC depending upon the load operation.

(vi) Check whether the old capacitor bank APFC installed in the installation is working or not. Check the CT connection is taken from the main incomer side of transformer, after the fix compensation of transformer.

(vii) Check if the load demand in the system is increased.

(viii) Check if power transformer compensation is provided

3.3 Analysis and Testing of old Capacitor Bank

Using the single line diagram the load flow analysis will be done in order to determine the line parameters after the insertion of shunt capacitors by using mathlab soft ware. From the result of the analysis the power loss, voltage drop and the system capacitor bank will be determined. If the devices are properly sized, the power factor will have risen to the desired levels after installation. This will be confirmed by the data logger attached at the service entrance. Present study has been conducted on APFC panels with contactor type of switching mechanism. Rating of the panels was 825KVAR, 400V, 3-phase, star connected. To improve the power factor using APFC panels.

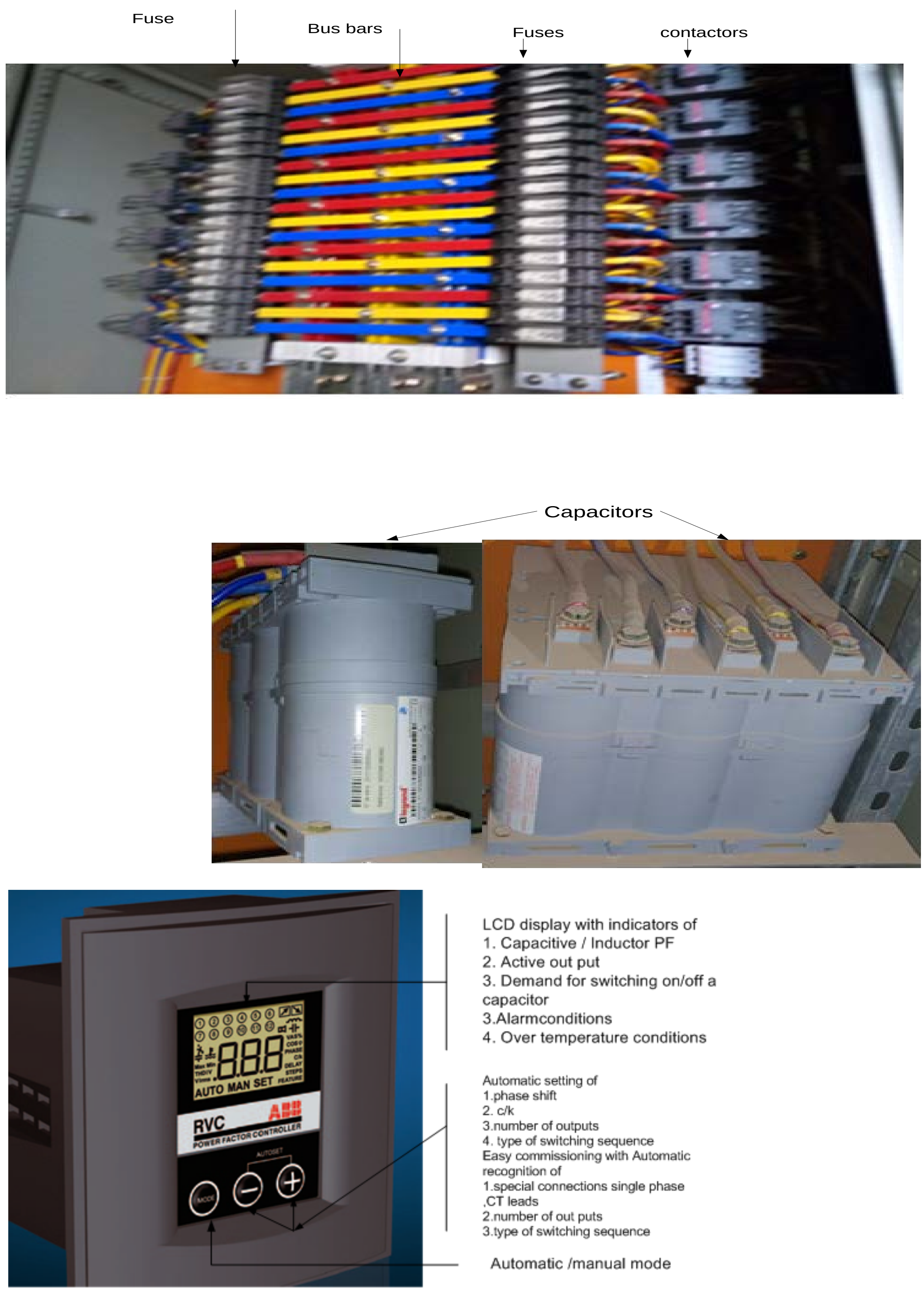

Figure 3. 2 825KVAR Automatic Power Factor correction (APFC) and Relay controller unit

3.4. Calculation of Reactive Power

In this paper, calculations of the required capacitor to improve the power factor are achieved on the main equipment's. There are two methods to calculate the necessary capacitor bank to obtain a defined power factor by using mathematical analysis and table of coefficient K (KVAR/KW) [4], [10].and for comparative evaluation of Calculations of Reactive Power for Motor, Calculations of Reactive Power for power cables.

3.5 Calculation of System Capacity

Power factor correction permits additional loads to be added and served by the existing system. In case if the transformers or cables get overloaded, improving the power factor will be the most economical way to reduce the current and therefore eliminate overload condition. The field's measurement show that the power factor have to improved from 0.84 to 0.98, and due to this improvement, the demand decreased and can be calculated using equation 1

$$S_{new} = \frac{\text{power factor inicial}}{\text{power factor final}} \text{ x } S_{sold} \quad (3.1)$$

3.6. Calculation Simple Payback Period

APFC system combined of Fixed Cost and Running Cost. The Fixed Cost of the installed capacitor with its accessories calculated. The Running Cost is the annual maintenance cost for this capacitor. However, for calculating the simple payback period, the fixed cost will be considered as total invested cost. Also, the life period for the capacitors is 15-20 years.

$$\text{Pay back period} = \frac{\text{Capital cost of capacitor}}{\text{Annual Saving}} \quad (3.2)$$

3.7. Mathematical Modeling and Designing

Each components of the distribution system will be modeled and designed according to the collecting data such as feeder line, transformers, capacitors bank, and loads. The analysis will be done to determine the line parameters based on the collected data and based on the result of the above

- The optimal size of shunt capacitor will be designed
- The optimal location of the capacitor bank will be determined

- Protection and controls of the automatic capacitor will be designed

Preparation of an Equipment Order and Acquisition of Correction Devices: The total size of the facility's KW load, its reactive load, and the facility power factor will determine which locations receive correction. To raise the power factor to 0.98 does not require correcting every piece of equipment in a building. After a certain point, there is a diminishing return to adding correction. The additional cost of the device and installation will not be justified by the return on investment. Smaller loads, in relation to other loads within the facility, will likely not need to be corrected in order to achieve a final power factor of 0.98.

CHAPTER FOUR

OVERVIEW OF THE FACTORY

4.1. Overview Amhara Plastic Pipe Factory PLC

The Amhara plastic pipe factory is one of the plastic multifunction manufacturing industry in the region. This is established in 2003 to become one of the top five leading plastic industries in east Africa. To produce and sale high quality products of UPVC, HDPE, and Geo membrane and constantly strive to meet customer needs and expectations, enhancing its market share all over the region and to be preferred company in domestic and export markets.

To produce the above products the factory has a power consumption of 2.85 MVA from two 800KVA & one 1250KVA step down transformers for UPVC, HDPE AND Geo membrane sheet machines and 1.6 MVA from two 800KVA step down transformers for green sheet and recycle machines. Totally 4.45 MVA power is delivered by north west district EEU from the high voltage side 15KV main air force distribution line but the low voltage distribution system of the factory has no enough power factor correction. Specially the green sheet factory power distribution system is installed separately from the first ATS (Automatic Ttransfer Switch) for this reason the researcher want to Evaluate the performance and impact analysis of shunt capacitor bank to contribute the reactive power management at the power distribution feeder of the factory by comparing the power triangle.

Figure 4. 1 Two 800KVA transformer

Figure 4. 2 Two 800KVA & one 1250KVA transformer

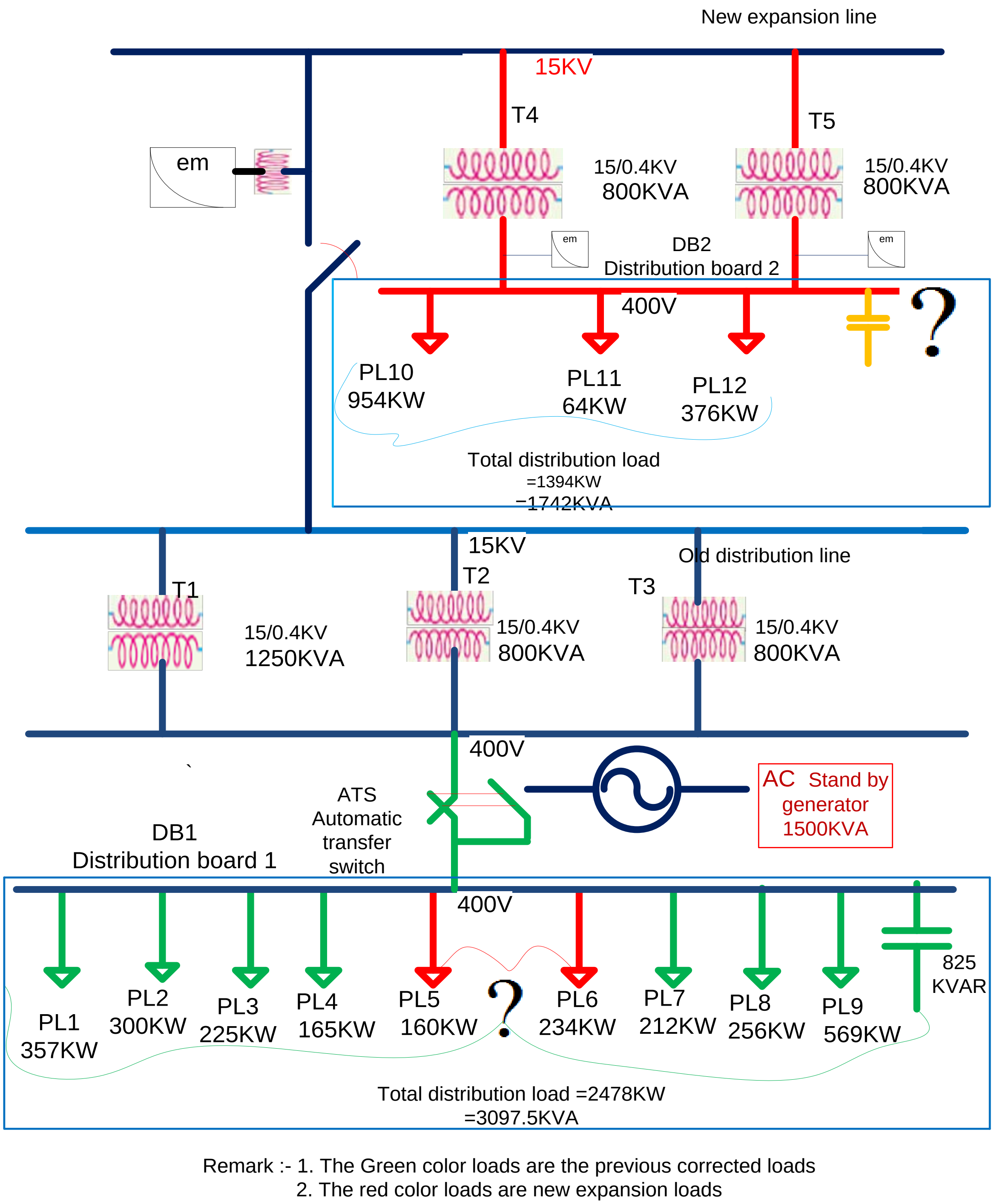

Figure 4. 3 single line diagram of the factory distribution system

4.1.2. APFC Viability or Feasibility Study

Provided below is a basic checklist for determining PFC feasibility:

A) Is there a KVA Demand Charge Tariff from the Network Provider against which savings?Can be made? According to the thought of the North West EEU retailed and bill work process assures that the corporation uses: - Minimum charge and Power factor tariff

Minimum charge:- customers whose power demand is greater than or equal to 20 KW with active- reactive meters may be charged additional minimum charge penalties. The charges will be effective if and only if both the power and energy consumptions are below 50 % of the highest maximum ones previously registered in the computer.[64]

$$\text{Minimum charge} = (P_{HMD} - P_{MD}) \times R \qquad (4.1)$$

where R rate birr/KW

P_{HMD} the highest maximum demand registered in the computer

P_{MD} the maximum demand of the billing month

Power factor tariff: - *The tariff in which power factor of the consumer's load is taken into Consideration is known as* power factor tariff. [63]In an A.C. system, power factor plays an important role. A low power factor increases the rating of station equipment and line losses. Therefore, a consumer having low power factor must be penalized.

The following are the important types of power factor tariff:

(*i*) KVA *maximum demand tariff:* It is a modified form of two-part tariff. In this case, the fixed charges are made on the basis of maximum demand in KVA and *not* in KW. As KVA is inversely proportional to power factor, therefore, a consumer having low power factor has to contribute more towards the fixed charges. This type of tariff has the advantage that it encourages the consumers to operate their appliances and machinery at improved power factor. [1]

(*ii*) *Sliding scale tariff*: This is also known as average power factor tariff. In this case, an average power factor, say 0·8 lagging, is taken as the reference. If the power factor of the consumer falls below this factor, suitable additional charges are made. On the other hand, if the power factor is above the reference, a discount is allowed to the consumer. [1]

(*iii*) *KW and KVAR tariff*: In this type, both active power (KW) and reactive power (KVAR) supplied are charged separately. A consumer having low power factor will draw more reactive power and hence shall have to pay more charges. [1]

B) Is there an opportunity for green house gas reductions?

If the power is generated from fuel it will decrease fuel or coal consumption So that the system is working in less fuel and coal. in addition CO_2 gas also decline.

C) Will the installation of PFC achieve construction cost savings?

Yes but we can check the market options

D) Is the payback period less than 5 yrs?

Even if there is no feasibility study on the previous capacitor bank there are so many literatures that proves the payback periods are less than 5 yrs.

E) Is there a suitable location for the installation of the PFC equipment?

Yes, there is free space in the power /transformer /house of the factory.

F) Is the installation suitable for PFC? Yes it is!

G) Is there an operational or commercial reason to install PFC that overrides the economic reasons? Yes in one case the rule and regulations of EEU and for the second case to safe the factory equipment.

4.2. Determine and Characterize Actual Power Factor and reactive power of the factory

4.2.1. Load Survey /Data Acquisition/

The main intent of this study is to evaluate and redesign an energy saving scheme for an industrial distribution network. This can be achieved by decreasing the network losses and improving the main electric load operation to a better efficiency level. The designed scheme is concerned with improving the power factor of the distribution network by adding shunt capacitors to the network at optimal size and location. Industrial power distribution networks encounters increase in power losses and increase in the type of load is accompanied with low power factor which leads to huge transfer of reactive power from the utility through the network.

The actual amount of power being used or dissipated in a circuit is called true power. Reactive loads such as inductors and capacitors make up what is called reactive power. The linear combination of true power and reactive power is called apparent power. Power system loads consist of resistive, inductive, and capacitive loads. Examples of resistive loads are incandescent lighting and electric heaters. Inductive loads are induction motors, transformers, and reactors and capacitive loads are capacitors, variable or fixed capacitor banks, motor starting capacitors, generators, and synchronous motors. Low power factor is not that much problem in domestic’s area but it becomes a problem in industry where multiple large motors are used so there is requirement to correct the power factor. Thus Power factor correction (PFC) is usually achieved by adding capacitive load to offset the inductive load present in the power system. There are many benefits to having power factor correction.

This paper studies the performance evaluation and effect of low power factor in Amhara plastic pipe factory electrical distribution systems from the economic and technical benefits point of view. For maximizing the benefits of power factor improvement at some industrial plants located at Bahir dar city, a sufficient study for the existing power system distribution including the power factor rates and the associated equipment have been done and the recommendations for improving the power factor to an acceptable rates are also established and presented.

Amhara plastic pipe factory was selected as a case study. The plant is fed at 11 KV from the distribution utility, installed capacity was 4450 KVA and the maximum demand active KW, KVAR reactive power and power factor of the company calculated in the table below.

Table (4.1) Total electrical load of the factory

Production lines	Resistive load 1 (unity)	AC drive loads (0.95-0.97)	Compensated loads	Motor (0.7-0.85)	Dc drives (0.4-0.75)	compressor , fans and pumps (0.75-0.8)	Pups for Spraying (0.6-0.65)	Non Compensated loads	Idle loads	load factor (2008 EC.)
UPVC line 1	80.38	9.9	90.28	97.16	110	35.75	37	356.69	13.5	4
UPVC line 2	44.83	9.9	54.73	92.23	110	24.25	33	300.71	13.5	7
UPVC line 3	27.68	6.25	33.93	94.11	55.022	15.9	33	224.61	7.25	11
UPVC line 4	12.5	46.15	58.65	92.11	0	11.15	16.9	165.31	13.5	1
HDPE line 5	8.99	35.8	44.79	9.235	75	9.65	33	159.67	12	12
HDPE line6	27.37	1.1	28.47	11.685	160	12.48	33	233.63	12	12
HDPE line 7	27.13	23.4	50.53	11.25	110.022	19.25	33	212.06	12	12
HDPE line 8	15	60.4	75.4	89.35	55.022	15.45	33	256.222	12	12
Geo membrane 9	73.85	70	143.85	32.9	352.47	27.95	33	568.82	221.35	9
Green sheet 10	117	780.4	897.4	41.1	15.4	5.75	0	953.65	6	0
Flat hose 11	4	56.4	60.4	5.335	0	0	1	63.735	3	0
Accessories 12	16	33.35	49.35	639.95	0	7.5	5.5	375.825	326.47	3
Total	**454.73**	**1133.05**	**1587.78**	**1089.1**	**1027.54**	**332.385**	**285.9**	**3870.96**	**431.22**	**60%**

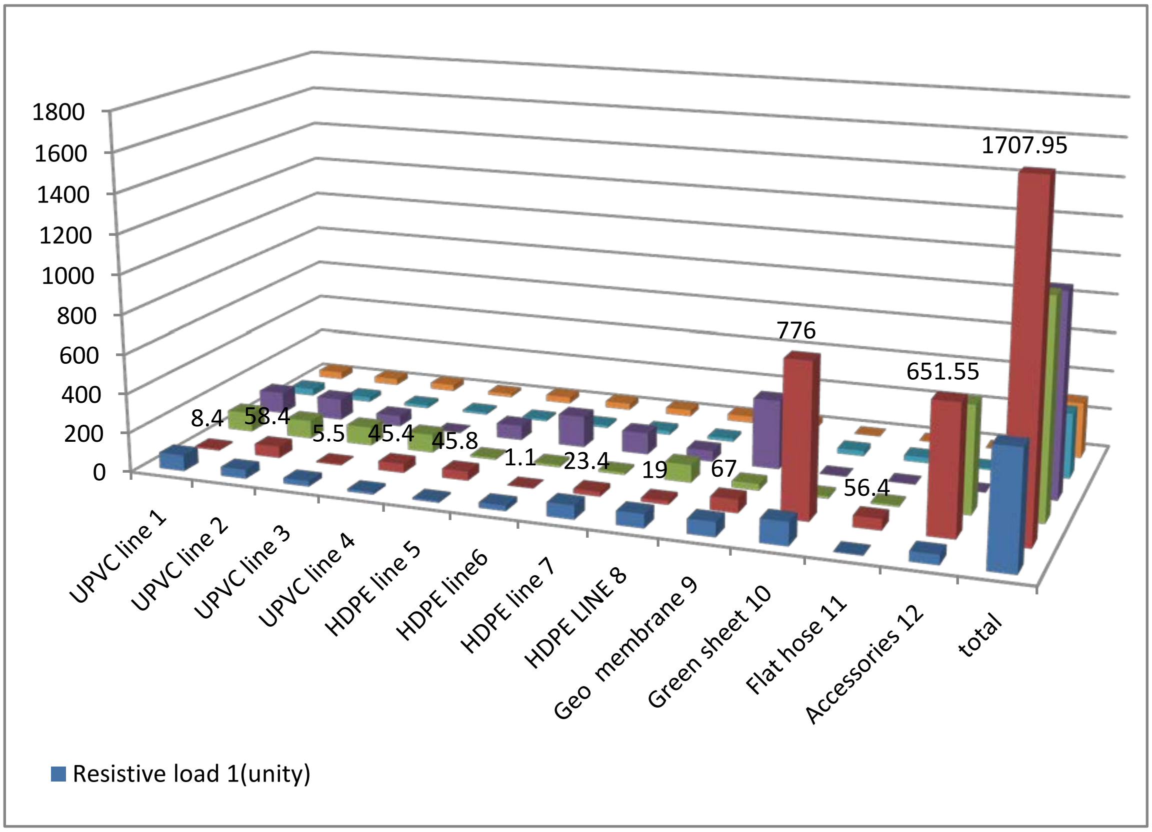

Figure (4. 4) Load Distribution of in each Production Line

Table (4. 2) squeezed factory load

Production lines	Resistive load 1(unity)	AC drive loads 0.97	Motor 0.85	Dc drives 0.7	compressor ,fans and pumps 0.8	Pups for Spraying 0.65	IDLE loads 0.85	Sub Total With idle loads	Sub Total Without idle loads
KW	454.73	1133.1	1089.	1027.5	332.3	285.9	431.2	4753.9	4322.7
KVA	454.73	1168.1	1281.3	1468	415.5	440	507.2	5734.8	5227.6
KW x 0.85	386.5	963.1	925.70	873.40	282.53	243.01	366.5	3917.26	3674.24
KVA x 0.85	328.5	992.9	1089.1	1247.8	353.17	374	431.1	4759.47	4385.47
KVAR	0	241	573.8	891.17	212	284.3	227	2703.26	2394.21

The maximum demand of active power P= *3675*KW,

Reactive power Q =*2394* KVAR and

$$\text{Power factor } (\text{Pf}) = \frac{\text{KW}}{\text{KV}} \tag{4. 2}$$

$$\text{Power factor } (\text{Pf}) = \frac{\text{KW}}{\text{KV}} = \frac{3674.245}{4385.47} = 83.78\% = 84\%$$

The annual consumption was 16,096,500 KWh per year *and the tariff applied was 0.5778 birr/KWh with transformer ratio or multiplying factor of 4500.*

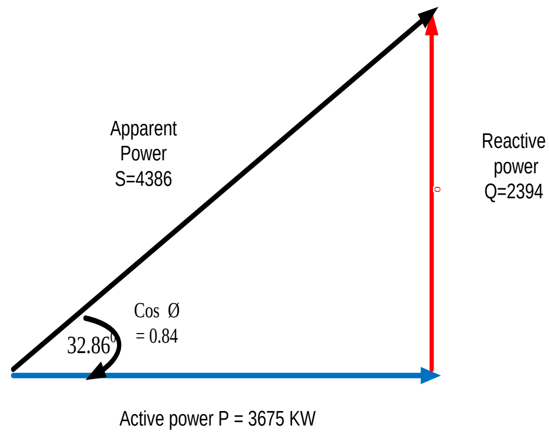

Figure (4.5) Power Triangle

The maximum demand of active power is 3675KW, the Reactive power of the factory 2394 KVAR and power factor Pf=3674.245/KW/4385.47KV apparent power of the data. so that the power factor of the factory becomes approximately 84%. The annual consumption was 16,096,500 KWh per year and at the normal tariff applied was 0.5778 birr/KWh with transformer ratio or multiplying factor of 4500.

$$\text{KVAR} = \text{KW x K KVAR} = \text{KW x K} \tag{4. 3}$$

CHAPTER FIVE

RESULT AND DISCUSSION

In this chapter, the investigations of the study presented in line with specific objectives and research question. i.e calculations of the required capacitor to improve the power factor are achieved on the main equipment's. The case study in this paper covered the following points:

1. Reactive power (KVAR) and power factor (PF) measurements.
2. Demand load (KW) VS power factor improvement rates estimation.
3. Power cost establishment VS power factor improvement rates.
4. Capacitive KVAR required estimation.
5. Power factor correction system cost (PFC)
6. Payback period and annual gross return estimation VS power factor improvement rates.
7. Deciding the optimum power factor.

5.1 Calculations of Capacitor Bank

There are two methods to calculate the necessary capacitor bank to obtain a defined power factor by using

1. Table of coefficient K ($\frac{KVAR}{KW}$) and
2. Mathematical analysis [4, 21,46].

Method 1. Table of coefficient K (KVAR/KW)

A plant has a 4,450 KVA transformer operating full of capacity. The present power factor is 84%, so the actual working power available is 3675 KW. From the table 4.8. by using KW multiplier to raise the power factor from 0.84 to 0.98 therefore Ratio of needed power capacity calculated from the table which is stated at the appendices table A1. is K=0.443 KW coefficient thus needed capacities. by using (4. 4)

KVAR = KW x K KVAR = KW x K = 3675 x 0.443 =**1628.025** KVAR (4. 5)

Method 2. Mathematical analysis

Before Correction:

Demand of $KVA = \frac{KW}{Pf} = \frac{3675}{0.84} = 4375 KVA$ (5.1)

$KVA^2 = KW^2 + KVAR^2$ (5.2)

KVAR of system = √ ($KVA^2 – KW^2$) (5.3)

KVAR of system = $\sqrt{KVA^2 + KW^2} = \sqrt{(4{,}375^2 - 3675^2)}$ = 2,374 KVAR

It is desired to increase production, a better solution would be to improve the power factor and release enough capacity to accommodate the increased load. If want to improve power factor from 84% to 98%.

After correction:

Maximum Demand of $KVA = \frac{KW}{Pf} = \frac{3675}{0.98} = 3750$ KVA (5.4)

$KVA^2 = KW^2 + KVAR^2$ (5.5)

KVAR of system = $\sqrt{KVA^2 - KW^2}$ (5.6)

$= \sqrt{3{,}750^2 - 3675^2}$ = 746.24 KVAR

After power factor correction, maximum demand decrease almost (2,374 - 746.24) KVAR 1610 KVA. So, we should design a power improvement plant for1610.5KVAR. (Use 1650 KVAR)

To conclude the above discussion the current data using either KW multiplier or data analysis method to raise the power factor from 0.84 to 0.98, therefore the equipment of needed reactive power compensation is 1628.025 KVAR. The company has only 825 KVAR. So that it should be add new 825 KVAR capacitor panel is necessary to increase the productivity of the factory.

This thesis is different from Osama and Ahmed (2012) findings the power factor of the site from 0.75 to 0.95, the KVA capacity of the distribution transformers (supplying the factory) increases by 21.05%. But my finding shows, improving the power factor of the site from 0.84 to 0.98. The KVA capacity of the distribution transformers (supplying the factory) increases by 16%. Analyses of the results prove that APFC significantly reduces the cost of electric power production compared to these study similarly increases the capacity and efficiency of the electrical power system in APF. Osama and Ahmed (2012) study is not consider the load factor. The reason of getting a different point reflects in load factor considerations. So, Osama and Ahmed (2012) had not seen maintenances, preparation time, internal and external failures load factor.

5.2. Calculation of Discharge Resistor for Capacitor

Size of Capacitor Bank=1650 KVAR Leading KVAR supplied by each Phase

= KVAR/No of Phase

$$\text{Size of Capacitor Bank}=\frac{\text{KVAR}}{\text{no.of phases}}=\frac{\text{KVAR}}{\text{No of Phase}} \quad (5.7)$$

$$=\frac{1650\ \text{KVAR}}{3}= 550\text{KVAr/Phase}$$

$$\text{Capacitor Charging Current (Ic)}=\frac{(\frac{\text{KVAR}}{\text{Phase}}\text{x1000})}{\text{Volt}} \quad (5.8)$$

$$\text{Capacitor Charging Current (Ic)}=\frac{(\frac{\text{KVAR}}{\text{Phase}}\text{x1000})}{\text{Volt}}=\frac{(550*1000)}{(\frac{415}{\sqrt{3}})}=138.3\text{Amp}$$

$$\text{Capacitance of Capacitor (Xc)} = 2\ \text{x}\pi\text{x f x V} \quad (5.9)$$

$$= 2\ x\ 3.14\ \text{x f x V}$$

$$=2 \text{ x } 3.14 \text{ x } 50 \text{ x } (415/\sqrt{3})$$

$$=75362$$

$$\text{Capacitance of Capacitor (C)= KVAR / } (2\ \text{x}\pi x\text{fxV}^2) \text{ in microfarad} \quad (5.10)$$

$$\text{Capacitance of Capacitor (C)}=\frac{\text{KVAR}}{(2\ \text{x}\pi x\text{fxV}^2)}=138.3 \text{ in microfarad}$$

$$\text{Capacitor Charging Current } I_C = \frac{QC}{V}=\frac{117375}{75362}= 21.89 \quad (5.11)$$

$$\text{Capacitance of Capacitor (C)} =\frac{\text{Ic}}{\text{Xc}}=\frac{138.3}{75362}=1835\mu\text{F} \quad (5.12)$$

Required Capacity of Capacitor in KVAR= C x (2 Π f V^2) (5.13)

= 21.89*75362=1649674.18KVAR= 1650

$$\text{Capacitor Charging Current IC} = \frac{Q_C}{V}$$

$$\text{Capacitor Charging Current IC} = \frac{Q_C}{V} \quad (5.14)$$

$$\text{Capacitor Charging Current IC} = \frac{Q_C}{V} = \frac{1650*1000}{(1.73*415)} = 577.3A$$

$$\text{Capacitance of CapacitorXC} = \frac{V}{Ic}$$

$$\text{Capacitance of CapacitorXC} = \frac{V}{Ic} = \frac{\sqrt{3}\ x415}{577.3\ A} = 1.245\ \mu f \quad (5.15)$$

$$\text{Capacitance of Capacitor C} = \frac{1}{(2\ \Pi\ x\ f\ x\ X_C)} \quad (5.16)$$

$$\text{Capacitance of Capacitor C} = \frac{1}{(2\ \Pi\ x\ f\ x\ X_C)} = \frac{1}{2*3.14*50*1.245} = 2558\mu F$$

Remark 2 As a result *24 No's of Capacitors are Required and the total Size of Capacitor Bank is 1650 KVAR.*

Capacitors will be discharge by discharging resistors.

After the capacitor is disconnected from the source of supply, discharge resistors are required for discharging each unit within 3 min to 75 V or less from initial nominal peak voltage (according IEC-standard 60831).

Discharge resistors have to be connected directly to the capacitors. There shall be no switch, fuse cut-out or any other isolating device between the capacitor unit and the discharge resistors.

$$\text{Max. Discharge resistance Value (Star Connection)} = \frac{C_t}{C_n\ x\ Log(U_n\ x\frac{\sqrt{2}}{D_v})} \quad (5.17)$$

Where C_t =Capacitor Discharge Time (sec)

C_n=Capacitance Farad.

U_n = Line Voltage

D_v=Capacitor Discharge voltage.

$$\text{Maximum Discharge resistance} = \frac{60}{((1835\mu F/1000000) \times \log(415 \times \frac{\sqrt{2}}{50})} = 83\Omega\ K$$

5.3 Sizes Protection of Capacitor Bank [6]

When connected to the main supply, this unit contains dangerous voltages, which may be fatal. The main isolating switch for this unit may be behind the door or mounted on the main switchboard, identify this before attempting to work on this unit. Ensure all power is off and waitat least 5 minutes. Check for all the presence of power with a reliable meter before touching any conductors. Proper operation of capacitor bank is very important issue. One needs to bear in mind, that capacitor bank switching can cause many unwanted phenomena. According to the standards, the capacitor bank can be disconnected when:

- Increased voltage across capacitor bank terminals. In some cases, increased voltage is permissible as far as it does not exceed 110% of rated voltage
- Current value is greater than 130% of rated current of capacitor bank
- phase currents asymmetry no more than 5% for star and 10% for delta connection, referring to the phase current in the phase that is the most loaded
- ambient temperature is higher than the one determined in the technical documentation
- capacitor deformation
- sparking on capacitors` terminals and other issues that may cause the problems during operation

The short circuit protection of the capacitors is provided by the switch dis connectors. For the capacitors the fuse link rated current should be 1.6 time of the rated reactive current of the capacitor.

$$\text{The rated reactive current of the capacitor } (I_n) = \frac{\sqrt{3Q_n}}{U_n} \qquad (5.18)$$

Where Un rated voltage of the mains,

Q, rated power of the capacitor at rated mains voltage.

Not only capacitors should be protected against short circuit, but the whole capacitor bank as well. Usually, in the switchgear from which the CB is supplied, there is an additional circuit breaker for the capacitor bank. Its value should be selected as:

- Standard capacitor bank: 1.36xI_n
- Overrated capacitor bank: 1.50xI_n
- Capacitor bank with reactors (n=4.3): 1.21xI_n

The next important issue is to provide proper section of the wires and conductors, which has to be able to withstand at least 1.5 of the nominal reactive current. One needs to remember, that the control and cooling circuits also need protection. It is provided by the fuse links with rated current of 6A in compliance with technical documentation of PFR.

- Size of HRC Fuse for Capacitor Bank Protection:

  Size of the fuse =165% to 200% of Capacitor Charging current.

  Size of the fuse=2×*138.3*Amp

  Size of the fuse=276.6Amp approximately 300A

- Size of Circuit Breaker for Capacitor Protection:

  Size of the Circuit Breaker =135% to 150% of Capacitor Charging current.

  Size of the Circuit Breaker=1.5×*138.3* Amp

  Size of the Circuit Breaker=207.45 Amp

- Thermal relay setting between 1.3 and 1.5 of Capacitor Charging current.

  Thermal relay setting of C.B=1.5×*138.3* Amp

  Thermal relay setting of C.B=207.45 Amp

  Magnetic relay setting between 5 and 10 of Capacitor Charging current.

  Magnetic relay setting of C.B=10×*138.3* Amp

  Magnetic relay setting of C.B=1383Amp

- Sizing of cables for capacitor Connection:

  Capacitors can withstand a permanent over current of 30% + tolerance of 10% on capacitor Current.

  Cables size for Capacitor Connection= 1.3 x1.1 x nominal capacitor Current

  Cables size for Capacitor Connection = 1.43 x nominal capacitor Current

  Cables size for Capacitor Connection=1.43×*138.3* Amp

  Cables size for Capacitor Connection=197.77 Amp

5.4 Annual Cost /Tariff/ Calculation

Before going to calculation the EEU uses different tariff systems [65]

Power factor tariff: - *The tariff in which power factor of the consumer's load is taken into consideration is known as* power factor tariff. In an A.C. system, power factor plays an important role. A low power factor increases the rating of station equipment and line losses. Therefore, a consumer having low power factor must be penalized. The following are the important types of power factor tariff:

A) **KVA maximum demand tariff*:* -** It is a modified form of two-part tariff. In this case, the fixed charges are made on the basis of maximum demand in KVA and *not* in KW. As KVA is inversely proportional to power factor, therefore, a consumer having low power factor has to contribute more towards the fixed charges. This type of tariff has the advantage that it encourages the consumers to operate their appliances and machinery at improved power factor.

B) **Sliding scale tariff***:* - This is also known as average power factor tariff. In this case, an average power factor, say 0·8 lagging, is taken as the reference. If the power factor of the consumer falls below this factor, suitable additional charges are made. On the other hand, if the power factor is above the reference, a discount is allowed to the consumer.

C) **KW and KVAR Tariff: -** In this type, both active power (KW) and reactive power (KVAR) supplied are charged separately. A consumer having low power factor will draw more reactive power and hence shall have to pay more charges.

Maximum demand: - It is the greatest demand of load on the power station during a given period. Load factor the ratio of the area under the load curve to the total area of rectangle in which it is contained gives the load factor.

Load factor $=\frac{\text{Average load}}{\text{Max.demand}} = \frac{\text{Average load } 24}{\text{Max.demand } 24}$

$$= \frac{\text{Area (in kWh) under daily load curve}}{\text{Total areaof rectangle in which the load curve is contained}}$$

Load factor $= \frac{\text{Average load}}{\text{Max .demand}} = \frac{\text{Average load 24}}{\text{Max .demand 24}}$ (4.19)

Average load. *The average of loads occurring on the power station in a given period* (*day or month or year*) *is known as* average load *or* average demand.

Load factor. *The ratio of average load to the maximum demand during a given period is Known as* load factor *i.e*.

Load factor $= \frac{\text{average load}}{\text{maximum demand}}$ (5.20)

It is the ratio of maximum demand on the power station to its connected load

Demand factor $= \frac{\text{maximum demand}}{\text{connected load}}$ (5.21)

According to EEP tariff

- power factor tariff system and have the following

PF surcharge = (cosø₁ - cosø₂) P_{max} R

$PF_{surcharge} = (\cos\phi_1 - \cos\phi_2)\, P_{max}\, R$ (4.22)

Where $\cos\phi_1 = \cos\left(\tan^{-1} \frac{\Delta W r}{\Delta W a}\right)$

ΔWr = monthly consumed reactive energy

ΔWa = monthly consumed active energy

- Minimum charge (below 50% the highest maximum demand

$P = (P_{HMD} - P_{MD})R$ (5.23)

Where P_{HMD} the highest maximum demand registered in the computer

P_{MD} the maximum demand of the billing month /year

R rate birr/KW which vary in accordance to the utility tariff systems

- ***Annual cost before correction***
  - Max. KVA demand = 3675/0.84 = 5208.33 KVA
  - KVA demand charges = (5208.33 x 56.04)=291,874.8 birr

    [Consider ,1KVA= 56.04Tx] Units

- Units/energy/ consumed/year = Max. demand × L.F. × Hours in a year

Units/energy/ consumed/year = Max. demand × L.F. × Hours in a year (5.24)

= (3675) *(0.5) *(8760) KWH = 16,096,500 KWh per year

- Energy charges/year = 0.5778x16,096,500) KWH birr

[Consider, 1KWH=0.5778birr]

= 11,641,514.4birr

- Total annual cost /Annual bill/ = Max. demand charges + Energy charges

Units/energy/ consumed/year = Max. demand × L.F. × Hours in a year (5.25)

= (291,874.8 +11,641,514.4) = 11,933,389.2

But if improve power factor up to 0.98

- ***Annual cost after p.f correction***

Max. KVA demand = 3675/0.98 = 3750 KVA

Units /energy/consumed/year = 3750 *0.5*8760(hours) = 16,425,000 KWh

Energy charges/year = (0.5778*16,425,000) [Consider, 1KWh=0.5778birr]

= 9,490,365 birr

Total annual cost = (291,874.8 +9,490,365) = 9,782,239.8 birr

- **Annual Saving**

Annual Saving =*Annual cost before correction-Annual cost after correction*

Annual Saving =Annual cost before correction-Annual cost after correction (5.26)

Annual Saving = (11,933,389.2– 9,782,239.8) = 2,151,149.4 birr

- **Pay Back Period:**

Payback Period= Capital Cost of Capacitor / Annual Saving (5.27)

Payback Period= Capital Cost of Capacitor / Annual Saving

Payback Period= 2,650,000 / 2,151,149.4

Payback Period =1. 231 Years

To summarize the above point of the finding show that APFC significantly reduces the cost of electric power by the annual saving of 2.15 million birr its payback period of 1.23 year for the cost procurement and the capacity increment, loss reduction & voltage raise increased by 16%, 14.29% and 1.8% consecutively.

5.5. Importance of PFI

Power factor improvement plant is very important for a power station to reduce the losses. Different type of electrical equipment is installing in a power factor improvement plant. PFI is installing in large power station, industrial substation, indoor substation etc. The important of PFI for the below:

Benefit 1 - Reduce Utility Power Bills

In areas where a KVA demand clause or some other form of low power factor penalty is incorporated in the electric utility's power rate structure, removing system KVAR improves the power factor; reduce power bills by reducing the KVA. Most utility bills are influenced by KVAR usage[25]

Annual Saving = *Annual cost before correction- Annual cost after correction*

Annual Saving = Annual cost before correction- Annual cost after correction (5.28)

Annual Saving = (11,933,389.2– 9,782,239.8) = 2,151,149.4 birr

Monthly reduction bill =179,262.45 birr

Daily reduction bill = 5,975.415 birr

Hourly reduction bill = 248.98 birr

Benefit 2 – Increase System Capacity

The power factor improvement releases system capacity and permits additional loads (motors, lighting, etc.) to be added without overloading the system. In a typical system with a 0.84 PF, only 3675 KW of productive power is available out of 4375 KVA installed. By correcting the system to unity (1.0 PF), the KW = KVA. Now the corrected system will support 4375 KW, versus the 3675 KW at the 0.84 PF uncorrected condition; an increase of 700 KW of productive power. This is achieved by adding capacitors which furnish the necessary magnetizing current for induction motors and transformers. Capacitors reduce the current drawn from the power supply; less current means lesser load on transformers and feeder circuits. Power factor correction through devices such as capacitors can avoid an investment in more expensive transformers, switchgear and cable, otherwise required to serve additional load. The Figure below shows the empirical relationship of system capacity vs. power factor. From the Figure one can see that improving power factor from 0.84 to 0 .98 shall release approximately 16% system capacity respectively.

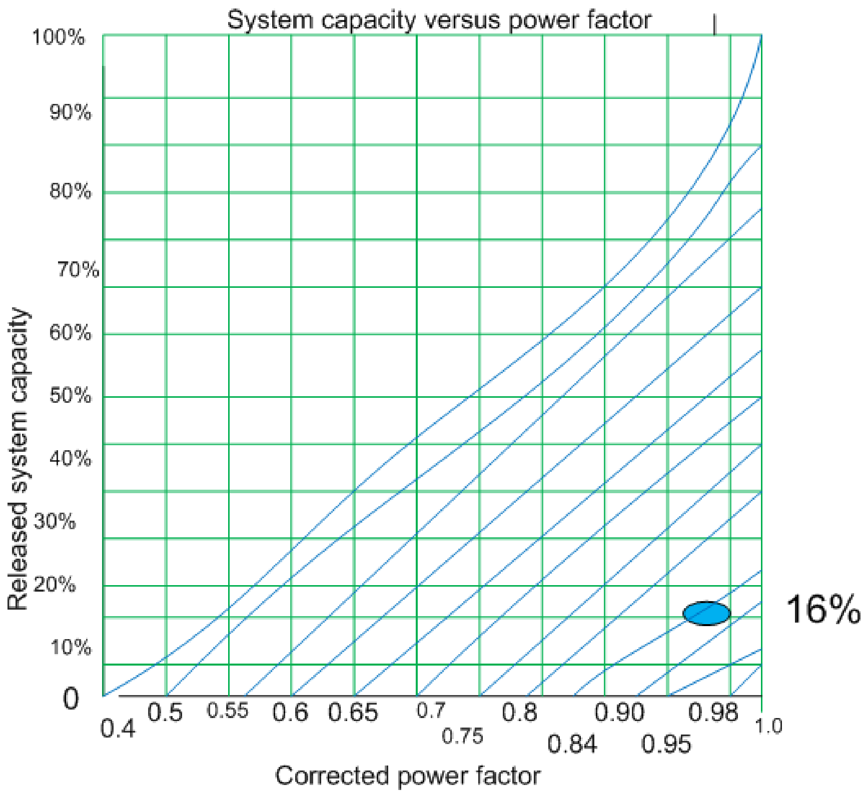

Figure (5. 1) System capacity vs. Power Factor

Benefit 3 - Improve System Operating Characteristics (Gain Voltage)

A good power factor (0.98) provides a "stiffer" voltage, typically a 1-2% voltage rise can be expected when power factor is brought to +\-0.98. Excessive voltage drops can make your motors sluggish, and cause them to overheat. Low voltage also interferes with lighting, the proper application of motor controls and electrical and electronic instruments. Motor performance is improved and so is production. [25]

An estimate of voltage rise from the improved power factor with the installation of power capacitors can be made using following equation:

$$\%\text{ of Voltage Rise} = \frac{\text{KVAR of capacitor x\% Impedance of transformer}}{\text{KVA of the transformer}} \quad (4.29)$$

= (2394*5)/4450 =2.69%

= (1650*5)/4450 =1.8%

But now they actually installed is 825 so that % of Voltage Rise= (825*5)/4450 =0.9%

Benefit 4 - Improve System Operating Characteristics (Reduce Line Losses) Improving power factor at the load points shall relieve the system of transmitting reactive current. Less current shall mean lower losses in the distribution system of the facility since losses are proportional to the square of the current (I^2R). Therefore, fewer kilowatt-hours need to be purchased from the utility. [25]

An estimate of reduction of power losses can be made using following equation:

$$\%\ \text{Reduction of Power Losses} = 100 - 100\left(\frac{\text{original power factor}}{\text{Improve power factor}}\right) \tag{4.30}$$

$$\%\ \text{Reduction of Power Losses} = 100 - 100\left(\frac{\text{original power factor}}{\text{Improve power factor}}\right)$$

$$=100 - 100\left(\frac{84}{98}\right) = 14.29\%$$

The above findings shows the annual saving of 2.15 million birr its payback period of 1.23 year for the cost procurement and the capacity increment, loss reduction & voltage raise increased by 16%, 14.29% and 1.8% consecutively.

5.6. Designing Additional Capacitor Bank for the Expansion

The most important standards, that were used during design process was:

a) Polish standard PN–EN 61921:2005 "Capacitors, Capacitor banks, Power factor, Low-voltage equipment, Electric control equipment, Control equipment, Switchgear, Marking, Installation, Electrical safety, Design, Rated voltage, Environment (working), Compatibility, Electrical components, Electrical equipment, Electromagnetic compatibility" [17]

b) Standard IEC 60831-2 Shunt power capacitors of the self-healing type for a.c. systems having a rated voltage up to and including 1000 V - Part 2: Ageing test, self healing test and destruction test.

c) Polish standard PN – EN 61921:2005 describes the general requirements for the capacitor bank.

The most important of them are listed below:

- **Access** to the particular elements within the capacitor bank should be easy, so that there is no problem to replace an element in case of failure

- Index of protection depends of the place of the installation of a capacitor bank. If the capacitor bank is to be placed in the same place as the main switchgear or utility room next to it, IP 20 is enough.
- **Section construction –** in a device for reactive power compensation particular sections can be determined, placing them in separate partitions or within the same cubicle.
- **Marking** each capacitor bank has to have nameplate, which contains information about: manufacturer, identification number, date of manufacture, rated power in [KVAR], rated voltage in [V], min and max ambient temperature, index of protection, short circuit strength in [A]

5.6.1. Determining Capacitor Requirements

When deciding which type of capacitor installation best meets weight the advantages and disadvantages of each and consider several plant variables, including load type, load constancy, Load capacity, and motor starting method.

A. Load type

If the plant consist of many large motors, 50 Hp and above, it is usually economical to install one capacitor per motor and switch the capacitor and motor together. If the plant has many small motors, ½ to 25 hp, group motors and install one capacitor at a control point in the distribution system. The best solution per plants with large and small motor is to use both types of capacitor installation. Most of the motors are used in Amhara Plastic Pipe Factory are soft starting and synchronized for line operation so that it consists AC/DC drive reactor, and motor.

B. Load Size

Facilities with large loads benefit from a combination of individual load, group load and banks of fixed and automatically-switched capacitor units. A small facility may need only one capacitor as the control board. Sometimes, only an isolated trouble spot requires power factor correction. This may be the case if the plant has welding machines, induction heaters or dc drives. If a particular feeder serving low power factor load is connected, it may raise overall plant power factor enough that additional capacitors are unnecessary

C. Load Constancy

If the plant operates around the clock and has a constant load demand, fixed capacitors offer the greatest economy. If lead is determined by eight-hour shift five day a week, switched units are wanted more to decrease capacitance during times of reduced load.

D. Load capacity

If the feeder or transformers are overloaded, or if additional load is added to already load lines, correction needs at the load if the facility has surplus amperage, the capacitor banks are installed at main feeders. If load varied a great deal, automatic switching is probably the solution.

Typical Locations for Power Capacitors (Where/ What Type to Install)

The sitting of the capacitors, does to some extent, depends on whether each piece of equipment e.g. a motor, or a transformer, is being individually corrected or the installation as a whole or part is being corrected as a block generally known as bulk or group connection. In the first case the capacitor and the load motor, transformer etc. are as close together as possible; in the second case the capacitor is located at some convenient point in the system, such as distributions.

Before power capacitors can be placed, the physical location of the utility meter should be determined since all power capacitors must be installed "downstream" of the meter.

There are three basic locations for Power Capacitors:

1. Individual capacitor installation at the level of each machine

- Load side of the AC motor, commonly referred to as "at the load" or "motor switched"

2. Group or bank installation

- Small motors operating from a common starter
- Load side of the utility transformer on the distribution bus
- Bank installation at Feeders, Sub-stations, or Transformers Load side of the AC motor, commonly referred to as "at the load" or "motor switched"

3. Mixed installation, at both the individual and group level

e) How to Switch Capacitors Separately

The switching device should be sized to exceed the capacitor nominal current as follows:

- Magnetic breakers: 135%1

- Fusible switches: 165%
- Molded case breakers: 150%

f) Automatic Switching and Size of capacitor bank

Capacitors are rated in KVAR. Common sizes are 1, 2, 3, 4, 5, 6, 7, 8, 10/12/15/20 and 25 KVAR at 415 or 440V alternating current, 3 phase, 50 Hz. Usually more than one capacitor is required give the desired degree of power factor correction. Groups of

capacitors are factory assembled in various configurations. Standard capacitor ratings are designed for 50 or 60Hz operation. When operated at less than nameplate frequency of 50 or 60Hz, the actual KVAR attained will be less than rated KVAR. If the operating voltage is less than the rated voltage, a reduction in the nameplate KVAR will be realized. The following equation defines the relation:

$$KVAR = 2x\Pi xfCE^{2}X10^{-3.} \quad (4.31)$$

KVAR=2x3.14 xfCE2X10^{-3}.

Π=3.1416

f=Hz

C=μ F

E=KV

g) Advantages and disadvantages of the methods of PFC

Once all PFC methods were discussed in previous section, one can focus on advantages and drawbacks of each one.

h) Classification of capacitor based compensation equipment

- Supplying voltage [4]
  - Low Voltage: up to 1kV
  - Medium Voltage: up to 30kV
  - High Voltage: above 110 kV
  - The highest voltage: above 110kV
- Frequency
  - frequency of supplying network (50Hz or 60Hz)
  - higher than network frequency (i.e. induction furnaces)
- Phase Number
  - mono phase

    - multiphase
- Control Method
    - Manual
    - switching by hand
    - automatically switched
    - auto - controlled
- Protection against higher Order Harmonics
    - without reactors
    - detuned filters
    - passive filters of higher order harmonics
- Environmental conditions
    - Overhead
    - Internal
    - External
- Special environmental conditions
    - very high/low temperature, high humidity
    - mains
    - dust
    - chemicals

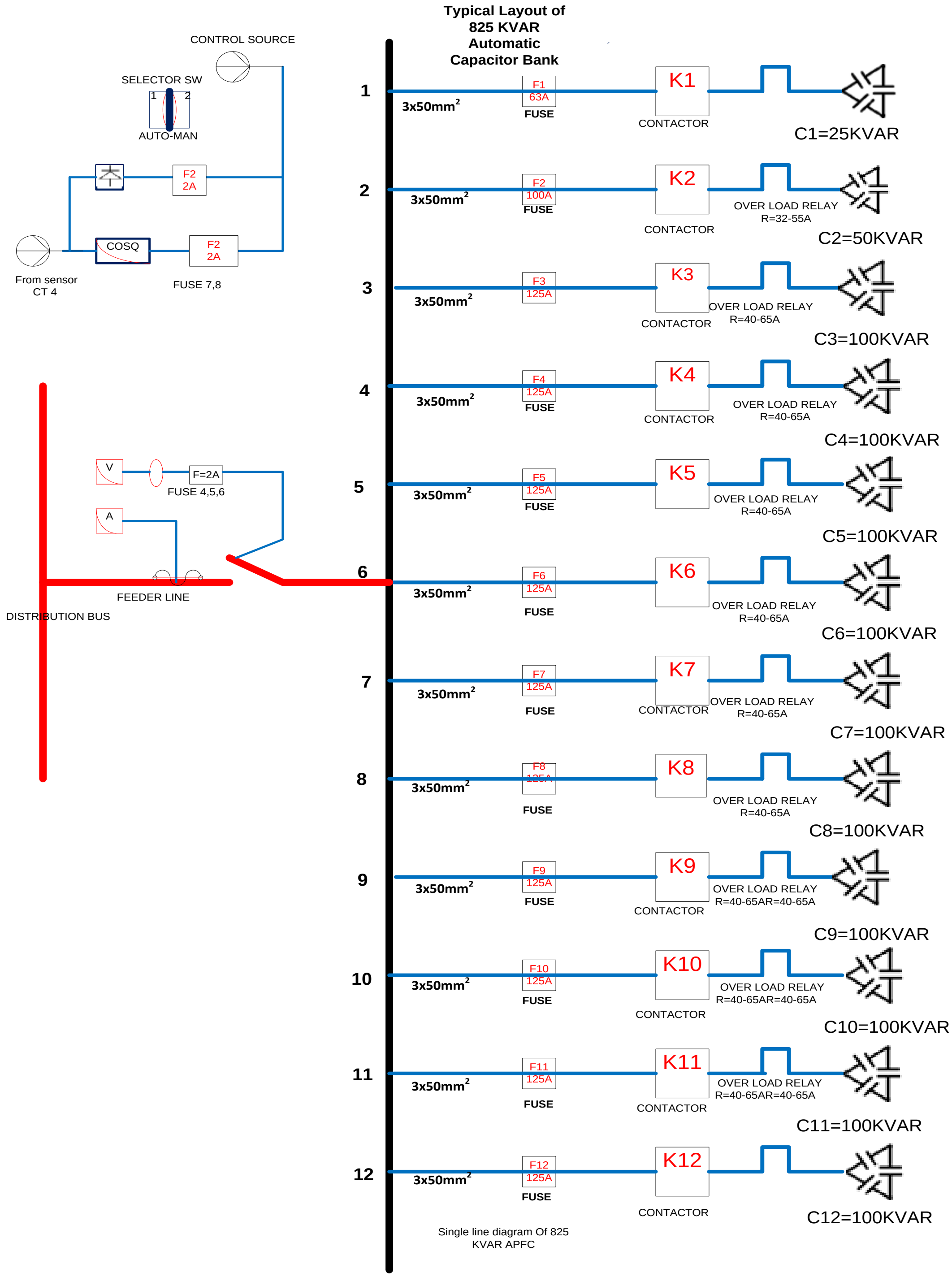

Figure (5. 2) Single Line Diagram of Capacitor Bank

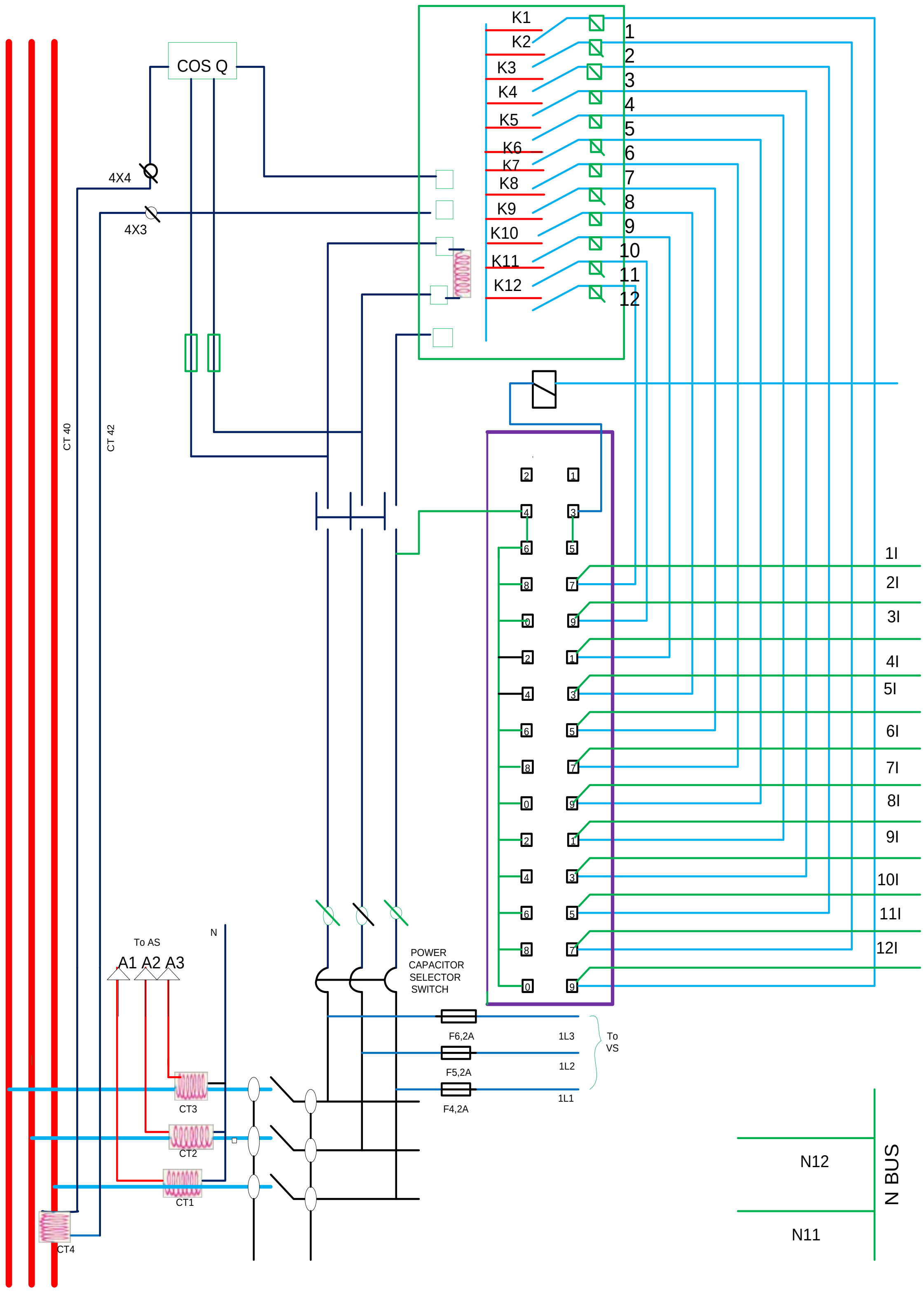

Figure (5. 3) Main Control Circuit Diagram of 825 KVAR Automatic Capacitor Bank

5.6.3. Automatic Switching of Capacitors[8]

Case 1. By using RVC / Relay Voltage Controller

Automatic switching of capacitors is an ideal method of obtaining the full electrical and financial benefits from a capacitor installation. Automatic power factor correction is a micro processor controlled system designed to continuously regulate the power factor to the specified levels by adjusting the amount of KVAR in relation to the variations in load. The system consists of a capacitor banks subdivided into a number of equal steps, each step being controlled by a multistep relay and air break contactors connected to the main bus bars. Each capacitor bank incorporates multiple single-phase cells that are wired in a delta connection for three-phase operation. Step to switch to achieve the target power factor with the least switching operations. The target value of the power factor is adjustable. The operation is controlled by load current (CT) according to the power factor, which is determined by the demand to control on/off the capacitors. During initial switch-on, the unit self-checks the current and voltage connections and, if incorrect, displays a fault signal. The value of each stage can be programmed in manually or if a 'self-current' CT is fitted, the unit steps through the stages and memorizes the capacitive reactive power of each stage (learning mode). The unit can then select which / where contactor switching is used; a delay is programmed in to allow previously energized capacitors to discharge before being reconnected. Where thyristor switching is employed, this delay is not necessary as the switching takes place at zero volts.

The auto-control of the capacitor banks ensures that over-correction will not occur.

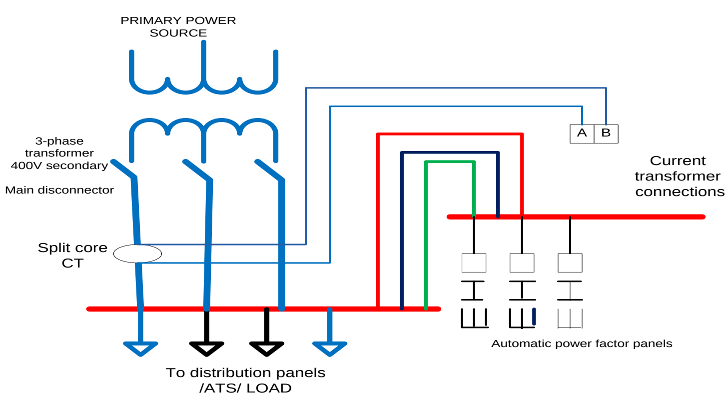

Figure (5. 4) Completely automatic power factor correction system.

The number of stages installed is usually a compromise between the technical requirements and cost. Studies indicate that the resulting benefits, economies and convenience of automatic system far outweighing the initial cost. The power factor controller can be programmed with many additional features. To protect the capacitors, the regulators are equipped with an automatic shutdown facility in the event of excess voltage or excess harmonics. A contact for a remote alarm may be included with programmable delay time. The regulators should have digital display of PF, current, volts, active power, reactive power, network harmonics and KVAR required to achieving target power factor. [25]

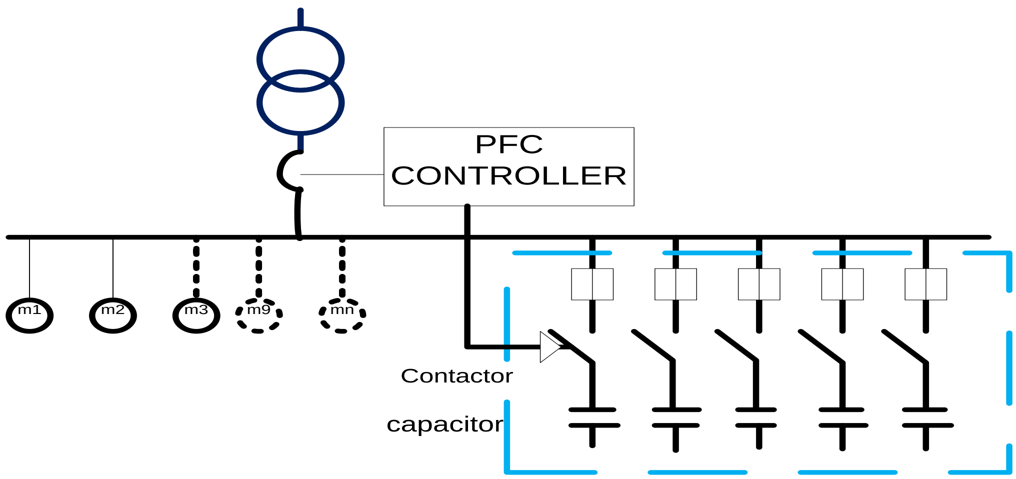

Figure (5. 5) Standard power factor correction

Step to switch to achieve the target power factor with the least switching operations. The target value of the power factor is adjustable. The operation is controlled by load current (CT) according to the power factor, which is determined by the demand to control on/off the capacitors. During initial switch-on, the unit self-checks the current and voltage connections and, if incorrect, displays a fault signal. The value of each stage can be programmed in manually or if a 'self-current' CT is fitted, the unit steps through the stages and memorizes the capacitive reactive power of each stage (learning mode). The unit can then select which / where contactor switching is used, a delay is programmed in to allow previously energized capacitors to discharge before being reconnected. Where thyristor switching is employed, this delay is not necessary as the switching takes place at zero volts.

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The principle of operation

Power factor regulators take action every time when one of the following parameters changes:

- Power factor
- Reactive power
- Reactive current
- Voltage value

Each PFR is equipped with the following units and elements [3]:

i) Measuring unit which measures the value that is assumed to be the principle of operation of the PFR and compares it to the value set by the user. If the actual value of the variable is higher than the set one, the unit sends the impulse to the time unit.

ii) Time unit is distinguishing whether the change of the measured value is big enough to take an action, such as switching the capacitor. In other words, the time unit helps to avoid unnecessary switching. Moreover, it allows to discharge the capacitor before it`s switched one more time. The delay can last from few seconds up to the few minutes

iii) Final control element sends the impulse which will cause the contactor of particular capacitor to switch on, according to the programmed algorithm. In some cases, if the value that is being measured is oscillating between the values set by the user, there is a probability that the PFR could send unnecessary impulses to the apparatus. In order to avoid this, there is a parameter referred to as the zone of insensitivity.

Nowadays, all of PFR are advanced electronic devices, where all the measurements, decisions making and control is performed by the microprocessor.

Power factor regulators keeps measuring the reactive power level in the network where capacitor bank is installed, as well as determines the network behavior. The Aron`s circuit is applied as a measuring scheme which checks the current level in one out of three phases. The voltage measurement is made on two other phases. The results of the measurement are being analyzed by the microprocessor. In next step, it calculates what the actual power level at the mains is, and makes decision whether switch the capacitor bank section or no, referring to the algorithm defined by the user. [8]

The measuring circuit is very accurate. PFR is able to control reactive power level, even if the secondary current of CT is as small as 40mA. Therefore, light load or wrongly selected CT does not affect the efficiency of reactive power compensation. Moreover, the regulation process can be adopted taking into account network behavior as well as dynamics of reactive power changes. Thanks of it, one out of the three available measuring characteristics of PFR can be used, what makes the PFR more universal and effective. [8]

Data processing algorithms and measuring method offered by the PFR, ensures, that the device will be properly operating even if supplying current and voltage is strongly distorted by the higher order harmonics. [8]

- One can distinguish following basic parameters of the power factor regulators:
  - ✓ Number of outputs
  - ✓ Nominal voltage, current and frequency
  - ✓ Range of the load fluctuation
  - ✓ Insensitivity zone Q/n
  - ✓ Control range of no compensated reactive power
  - ✓ Time of operation of the contactors

The Q/n parameter decides about the sensitivity of the regulator. It has to be set taking into account the capacitor with the lowest rated power and the ration of current transformer. The parameter % Q/n decides about the reactive power that will not be compensated referring to the capacitor on the first stage of the capacitor bank. Increasing the value of this parameter one will cause offset of the respond threshold value of the PFR. In result, the accuracy of compensation will decrease. The mentioned setting decides about the characteristic of operation of power factor regulator. Choosing the proper setting one can adjust the characteristic, so that it will allow for the desired level of the reactive power compensation.

Case 2. By using **Circutor[57][58]**

circutor's "computer" regulators can be used to monitor existing load curves accurately, whereby the cos θ is guaranteed to reach the programmed values. The whole range of computer regulators is based on **circutor's FCP** system (Fast Computerized Program), offering a set of unique performance features [15]

- Minimization of the number of switching operations, increasing the working life of the components in the capacitor bank.
- Increase in the unit's response time, thus achieving greater energy savings. Anti oscillation system, preventing unwanted capacitor connections and disconnections. Optimum regulation, thanks to the accurate information about the status of network parameters and the anti-oscillation system, guaranteeing that the installation load curve can be monitored accurately and the objective cos θ can be attained.

Case 3. By using **"Magic" power factor regulator**

The state-of-the-art regulators of the MAGIC Series have been designed to offer simple and efficient regulation features. The whole range of computer regulators is based on CIRCUTOR's FCP system (Fast Computerized Program), offering a set of unique performance features. In addition to the FCP system, its main features are as follows [15]:

- High precision regulation.
- Configure ration of parameters in run _ time, with no need to disconnect the unit
- Digital programming and handling
- 4 alarm levels: low load levels, no connection of the transformer, incorrect phase
- Connection, over compensation, lack of compensation
- LCD Display with three digits to display the following: cos ø installation, number of steps connection, inductive or capacitive load, alarms.

The computer MAGIC regulator is ideal to compensate unbalanced installations where the ease or programming, robustness and accuracy are vital requirements. Its programming system is simple and intuitive, making it very easy for the user to install and maintain it [15].

Case 4. By using **Computer D[8]**

The computer d series offers the user a very simple and safe installation, thanks to its top performance features and its ease of installation. Thanks to its FCP technology, the computer d series attains the objective cos θ with the minimum number of switching operations, increasing the working life of capacitors. [15]

Other important features:

- It enables the rotation of phases, in order to configure the regulator independently from the phase where the CT is installed
- Ammeter function
- Measurement of THD *(I)*
- Alarms: Harmonic distortion, lack of compensation, overcompensation, loss of current or voltage signal
- Optional RS-485 communications
- Manual connection and disconnection of steps
- Voltage-free alarm relay.

Case 5. By using **RMB-10 Power factor[8]**

The PFR manufactured by Elektromontex company is very often used by the major companies offering automatic capacitor bank. Offered power factor regulators can have different dimensions or output number. The company can also provide the power factor regulator dedicated for the thyristor capacitor banks. [16]

Features:

- Overcompensation blocking function
- Measurement of RMS value of current and voltage
- Wide range of voltage measurement
- Current input sensitivity
- Separated current input
- Ease of programming/setting
- 6 or 12 relay outputs
- Minimized power consumption
- Voltage drop detection

Case 6. By using **RMB-10 Power factor**

Moreover, the software within the regulator is basing on the fast digital signal processing as well as many switching algorithms. There is a function that does not allow switch capacitor on, until it is totally discharged. The switching operation is optimized, so that the desired power factor value is reached in relatively short time. The power factor regulator can display on the LCD information such as current cosø, current voltage THD in percent, voltage and current higher order harmonics and many others. It also provides the alarms about too low power of the capacitor bank, to small current value, to high THD level, as well as wrong connection of PFR.[16]

5.6.4. Number and type of capacitors

Once coefficient M was calculated as well as the total power of the capacitors that needs to be installed, one may consider how many capacitors should be selected. At this point, it is important to match the capacitor which will be the first one in the series. However, before it happens, the "series of type" has to be explained. Power factor regulators are manufactured with 6 or 12 outputs. It means that maximum 6 or 12 power capacitors can be switched on or off. Let`s take a closer look at the series below:

a) 1:1:1:1:1:1....

b) 1:2:2:2:2:4....

5.7 Applications

Automatic systems, rather than fixed capacitors, should be applied where any of the following

Conditions occur:

- Electric utility rates include KVA demand billing or a power factor penalty clause.
- The facility is experiencing KVA capacity problems causing overheating of system components resulting in increased operating costs and KW usage.
- The facility is not able to maintain a desired power factor window, especially when extreme fluctuating loads are present.
- Sustained leading power factor problems are experienced when the electric distribution system is lightly loaded[31]

5.8. Analytical Results and Discussions

Improvement of power factor makes the utility companies get rid from the power losses while the consumers are free from low power factor penalty charges.

By installing suitably sized power capacitors into the circuit the Power Factor is improved and the value becomes nearer to 0.84 to 0.98, thus, capacitor banks used for power factor correction reduce losses and increases the efficiency of the power system and also increases stability. By using this APFC system the efficiency of the system is highly increased.

The maximum demand of active power P= *3675*KW,

Reactive power Q =*2394* KVAR and

Power factor Pf=KW/KVA= 3674.245/4385.47 =83.78% ≅ 84%

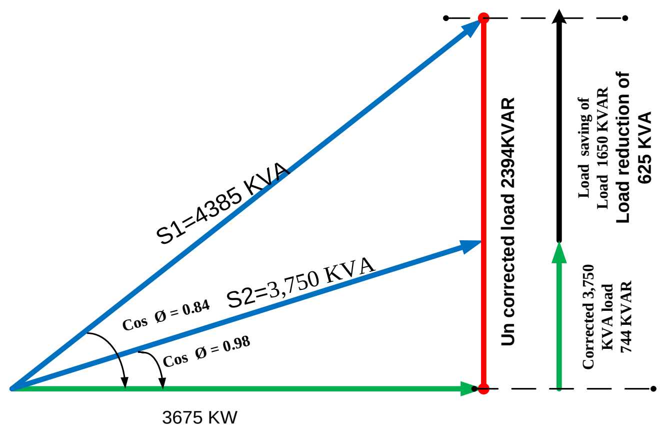

Figure (5. 6) Power triangle diagram

5.9. Power sim (PSIM) Software

PSIM provides an ultimate simulation environment for power conversion and control. It is mainly designed for power electronics, motor drives, analog and digital control, magnetic and dynamic system studies. It enables fast simulation and it is quite user-friendly. The PSIM simulation environment includes the PSIM Circuit Schematic, the Simulation engine and the SIMVIEW for viewing and analyzing the waveforms. The PSIM schematic program is highly interactive and user-friendly in building the circuit as well as editing it.

The PSIM software has been used for carrying out all the simulations and analysis of the waveforms so obtained in the thesis.

5.10 Simulation Results

Firstly, simulations are done using simple circuit networks for different reactive power value of shunt capacitors. For all the RLC load has been used and the position of the capacitive load has been shuffled to observe the variations in the input and output voltages and currents and the value of distortions present in them.

Further, improvement of power factor is taken care of in the subsequent circuits where feedback loops are employed using analog circuits. Hence, we are finally concerned with PFC using Analog circuits.

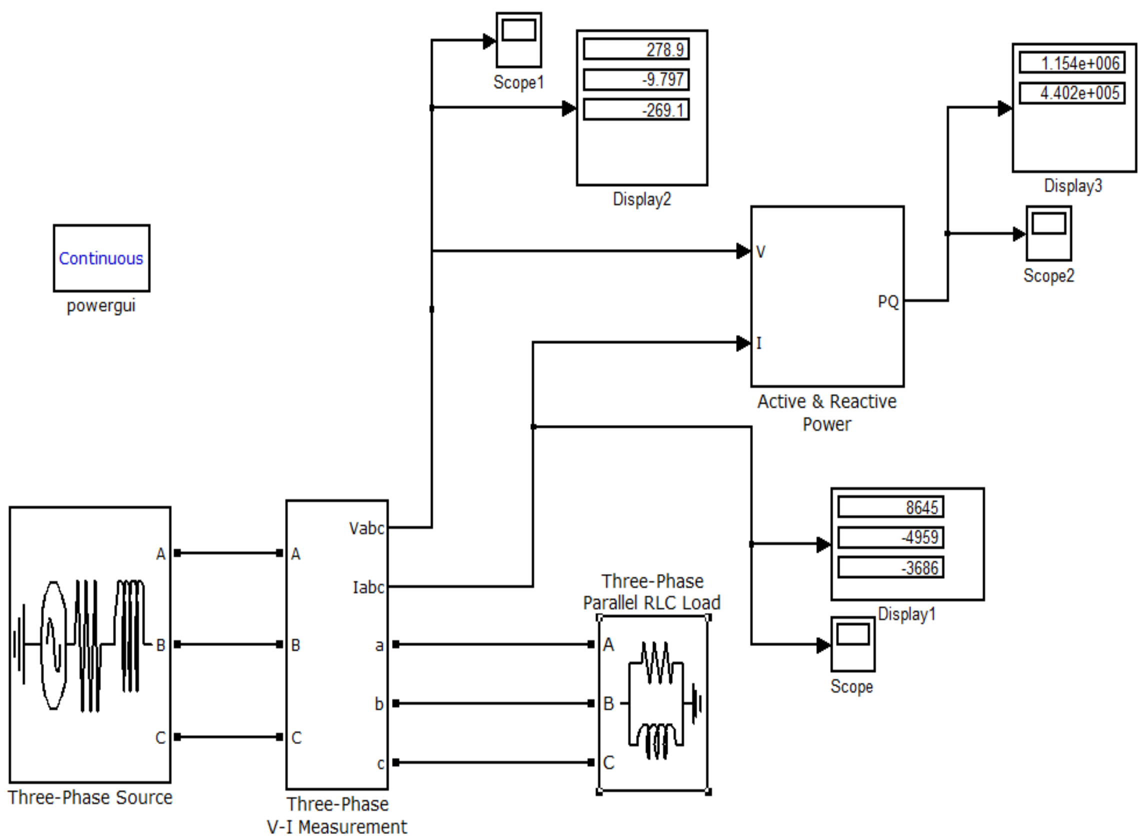

Figure (5. 7) Three phase Circuit model without capacitive load

Active and reactive power before APFC capacitor panel Using Simulink toolbar and its respective library, a sequence of models can be created to meet the requirements. This show as Active Power 1154 KW + 440.2KVAR

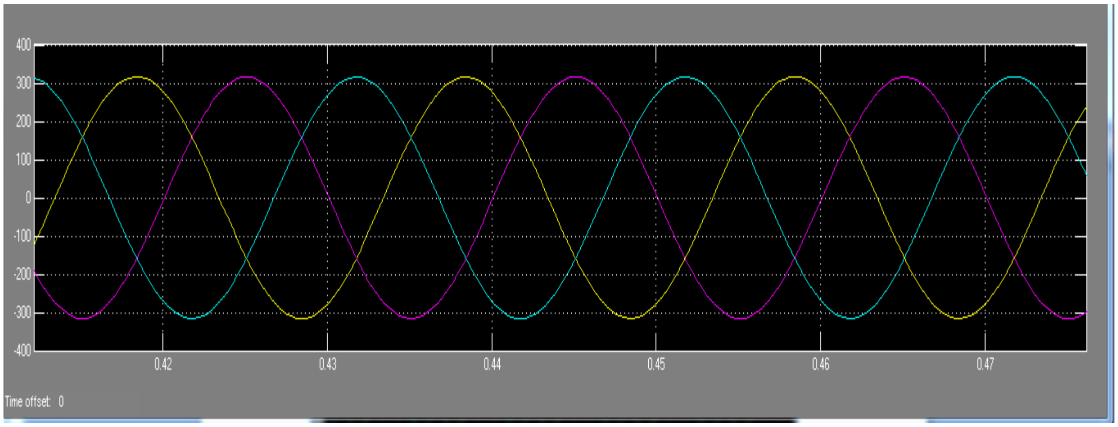

Figure (5. 8) simulation result of three phase voltage without capacitive load

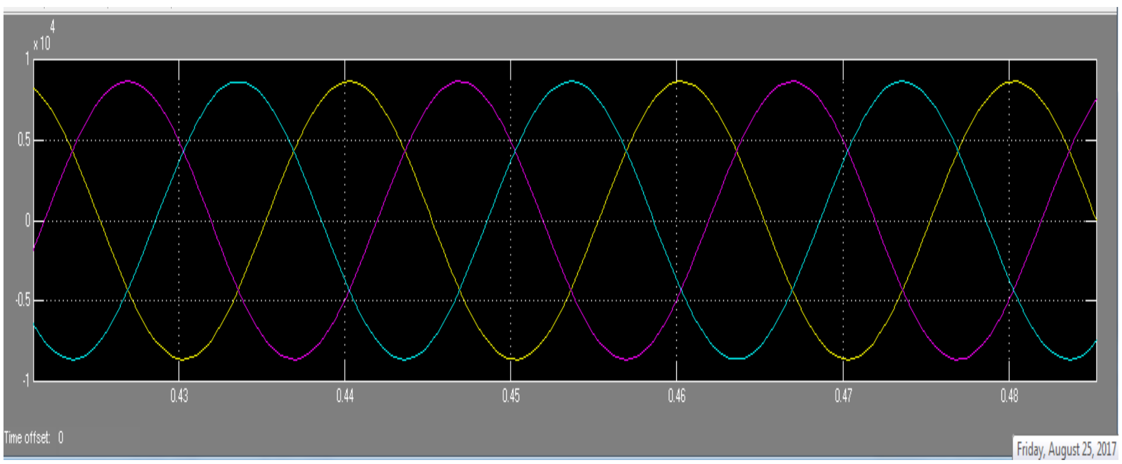

Figure (5. 9) Simulation result of current without capacitive load

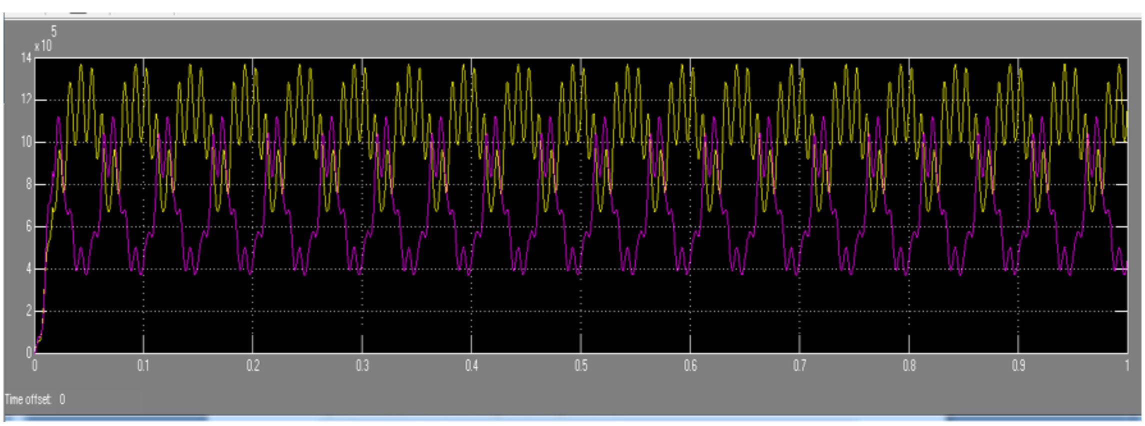

Figure (5. 10) Simulation results of PQ power at no capacitive reactive compensation when we see the above figure Voltage source Vrms=400V, frequency 50 Hz, Active power 3,675KW, Capacitive Reactive power 0 KVAR. And as a result yellow color shows active power and purple color shows reactive power; In addition the three phase voltage and current of ABC are shown by colors Yellow, Purple, and **B**lue.

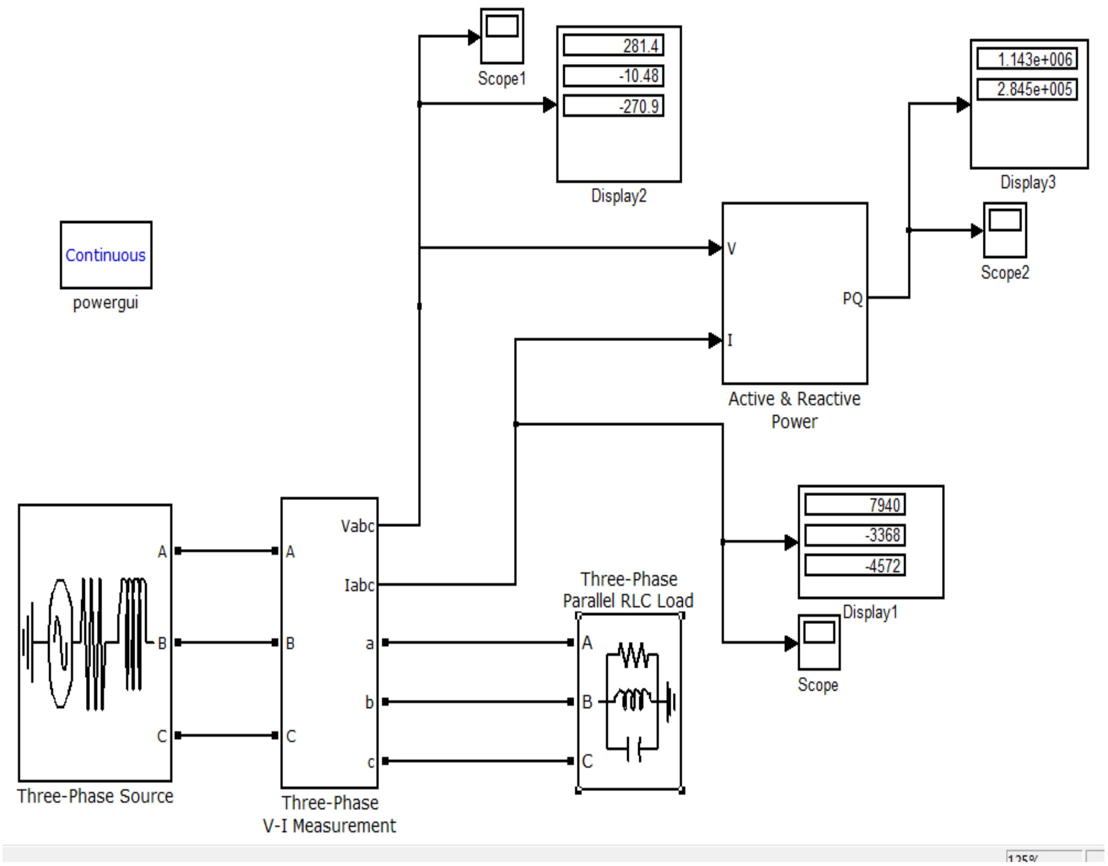

Figure (5. 11) Three phase Circuit model with 825 KVAR capacitive load

Active and reactive power after 825 KVAR capacitive load Using Simulink toolbar and its respective library, a sequence of models can be created to meet the requirements.

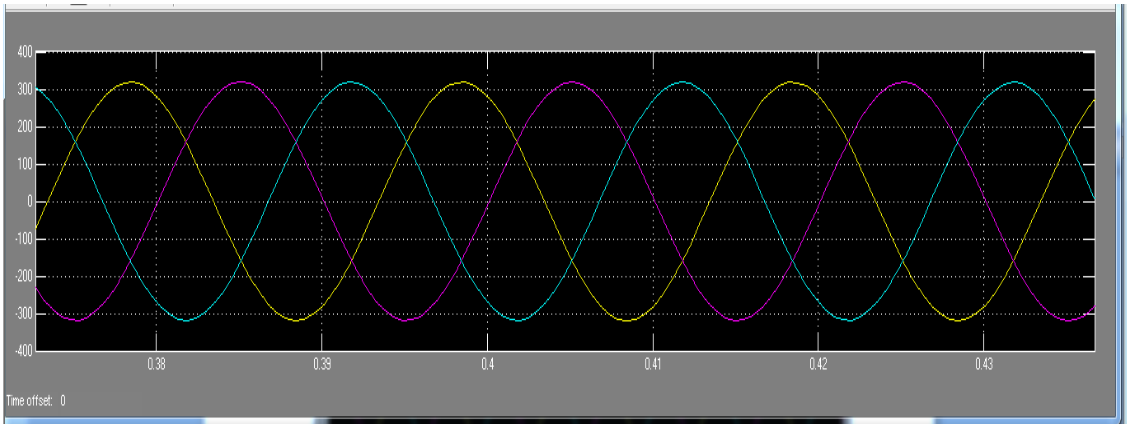

Figure (5. 12) Simulation result of three phase voltage with 825 KVAR capacitive load

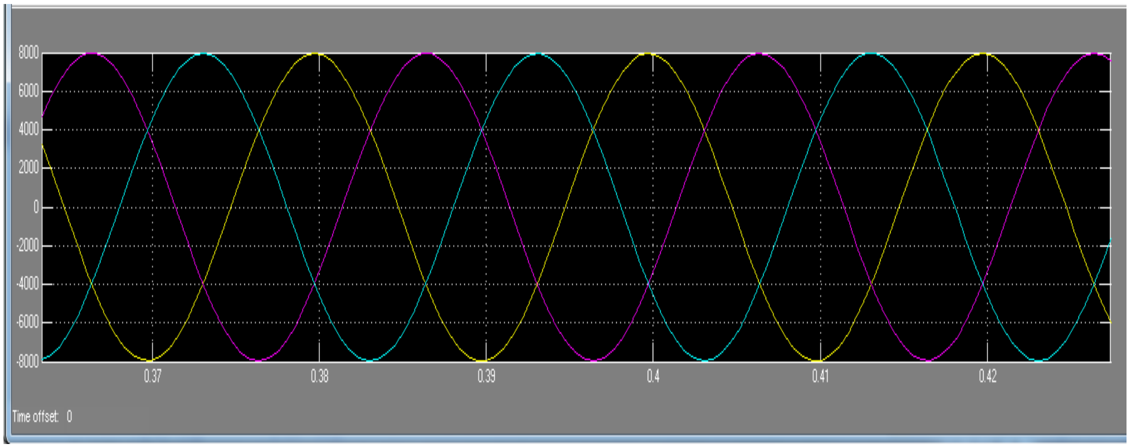

Figure (5. 13) Simulation result three phase of current with 825 KVAR capacitive load

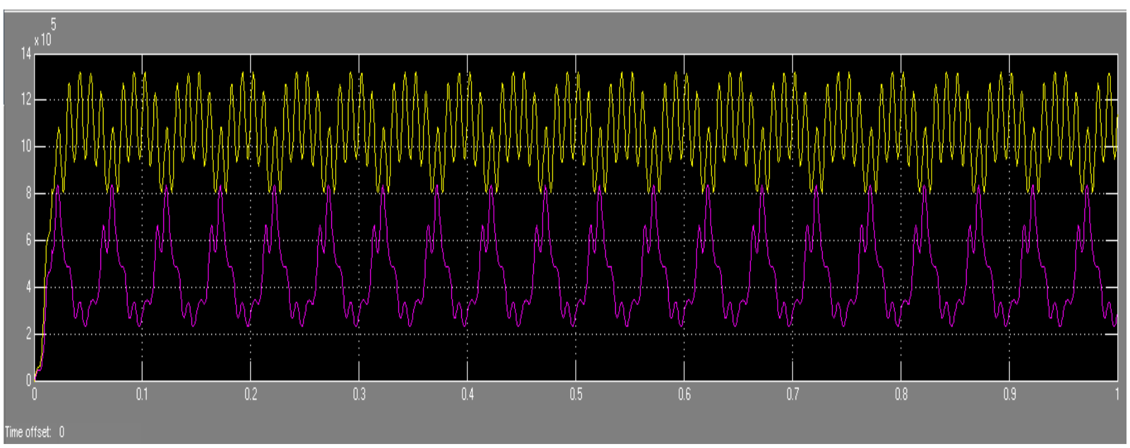

Figure (5. 14) Simulation results of three phase PQ power at 825 KVAR capacitive reactive compensation.

It is a Voltage source Vrms=400V, frequency 50 Hz, Active power 3,675KW, Reactive power 825 KVAR. And as a result yellow color shows active power and purple color shows reactive power In addition the three phase voltage and current of ABC are shown by colors Yellow, Purple, and **B**lue.

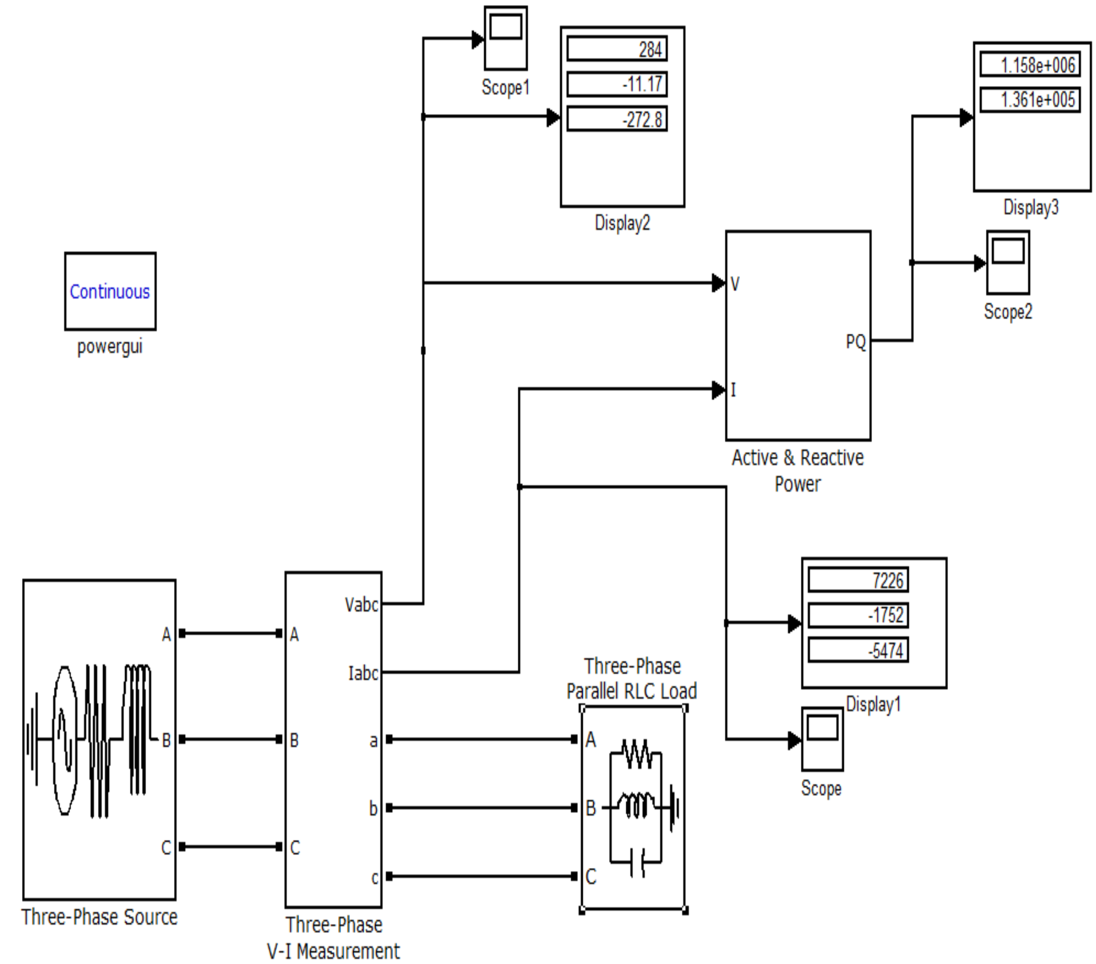

Figure (5. 15) Three phase Circuit model with 1650 capacitive load

circuits that show Active and reactive power after 1650 KVAR capacitive load Using Simulink toolbar and its respective library, a sequence of models can be created to meet the requirements.

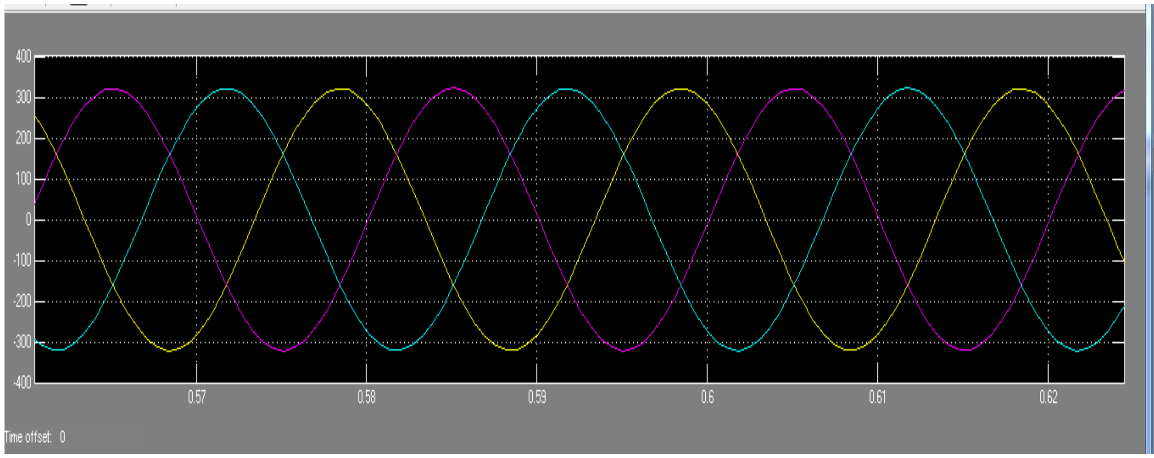

Figure (5. 16) simulation result of RMS voltage with 1650 KVAR capacitive load

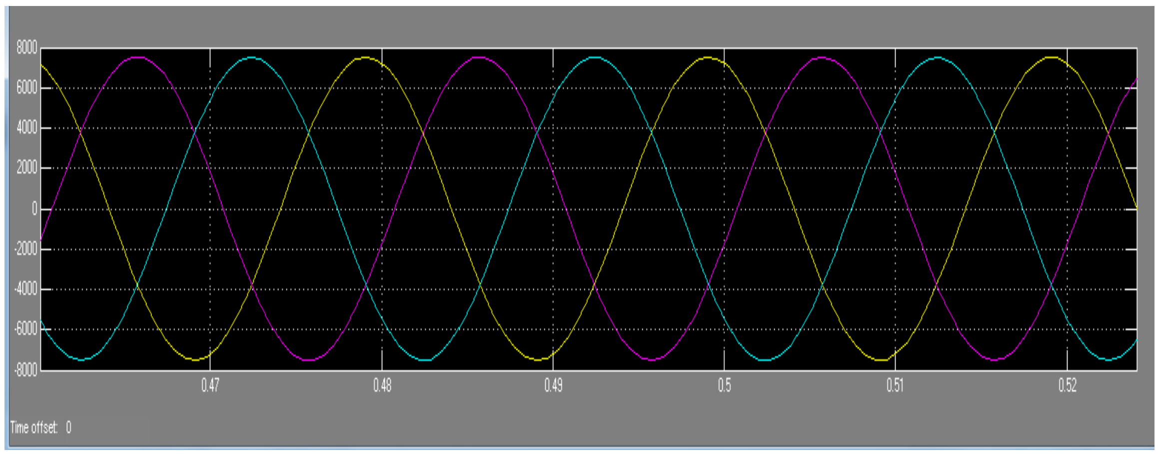

Figure (5. 17) simulation result of current with 825 KVAR capacitive load

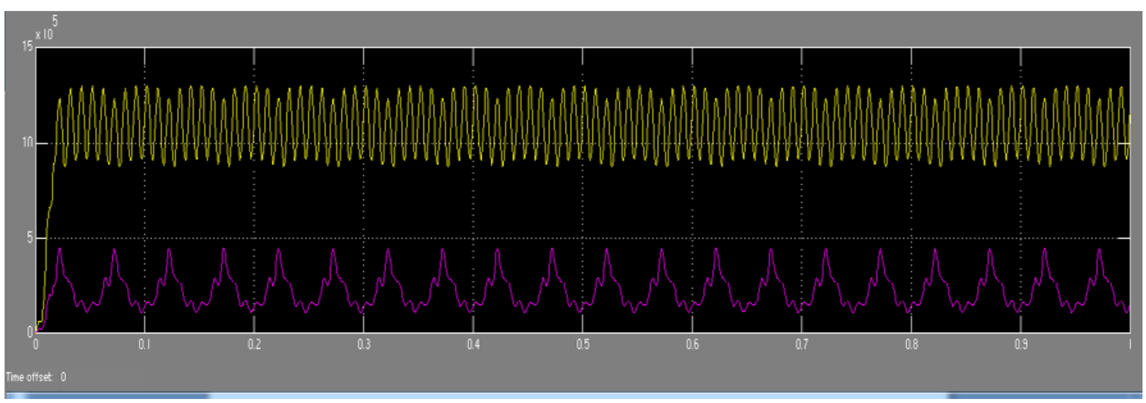

Figure (5. 18) The simulation results of PQ power at 1650 KVAR capacitive compensation

It is Voltage source Vrms=400V, frequency 50 Hz, Active power 3,675KW, Reactive power 1650KVAR. And as a result yellow color shows active power and purple color shows reactive power; In addition the three phase voltage and current of ABC are shown by colors Yellow, Purple, and **B**lue.

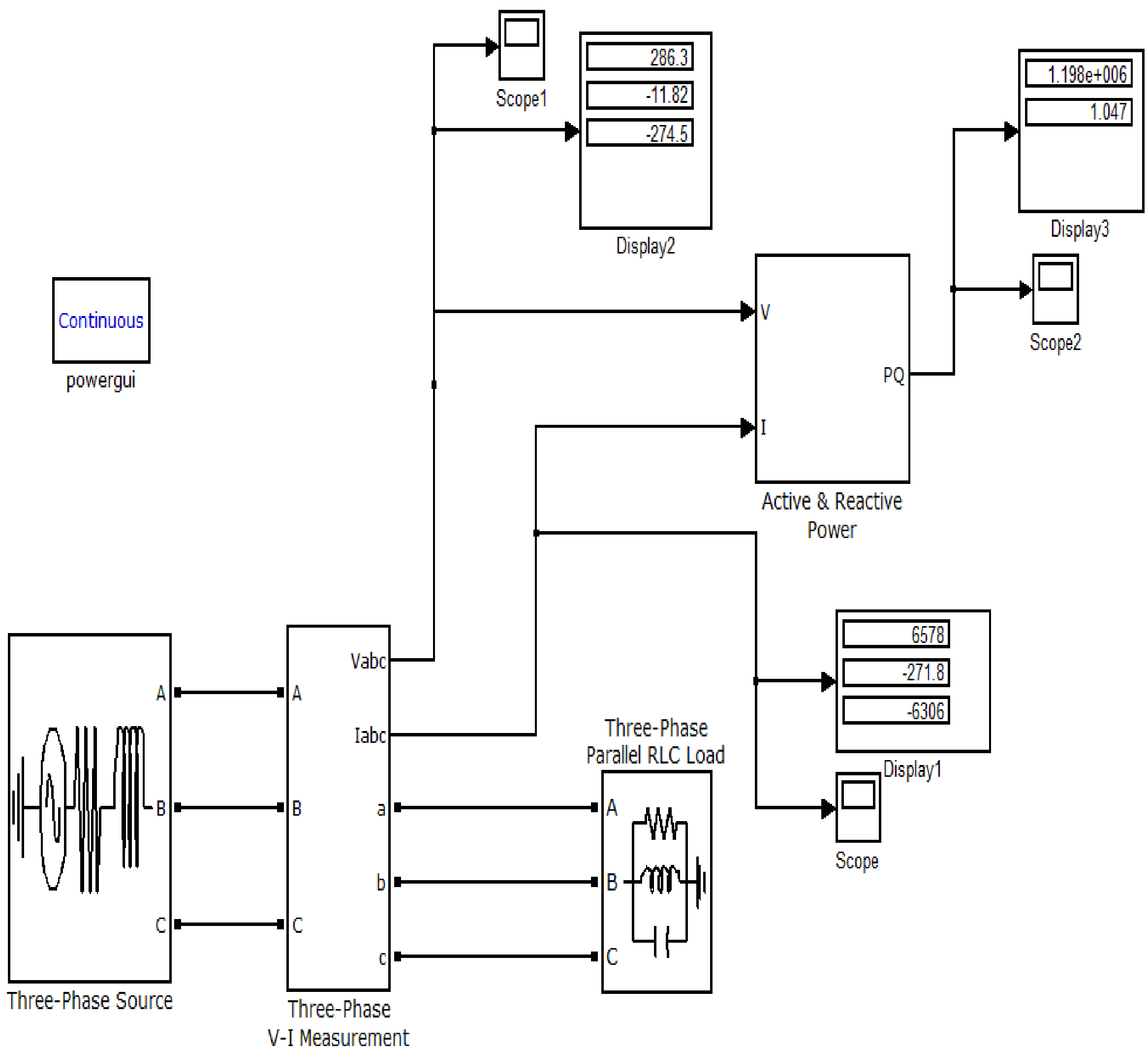

Figure (5. 19) circuits that show Active and reactive power after 2394 KVAR capacitive load

Using Simulink toolbar and its respective library, a sequence of models can be created to meet the requirements

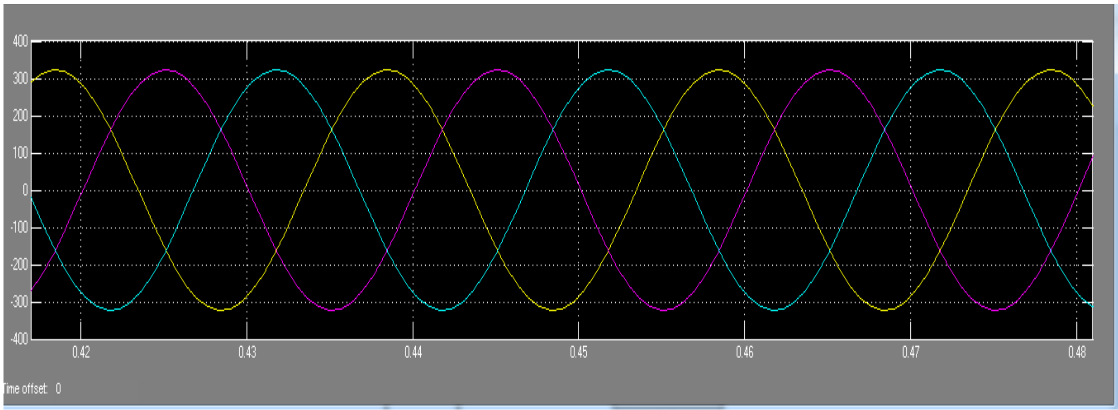

Figure (5. 20) simulation result of RMS voltage with 2394 KVAR capacitive load

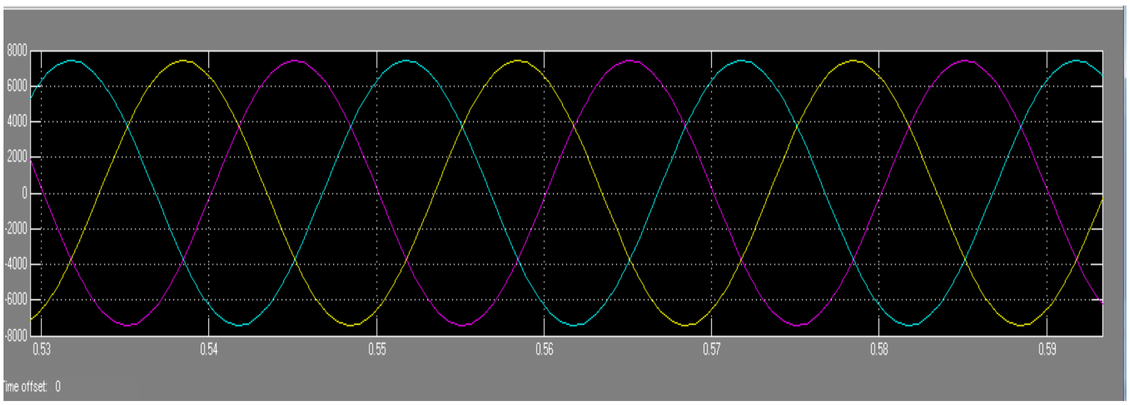

Figure (5. 21) simulation result of RMS current with 2394 KVAR capacitive load

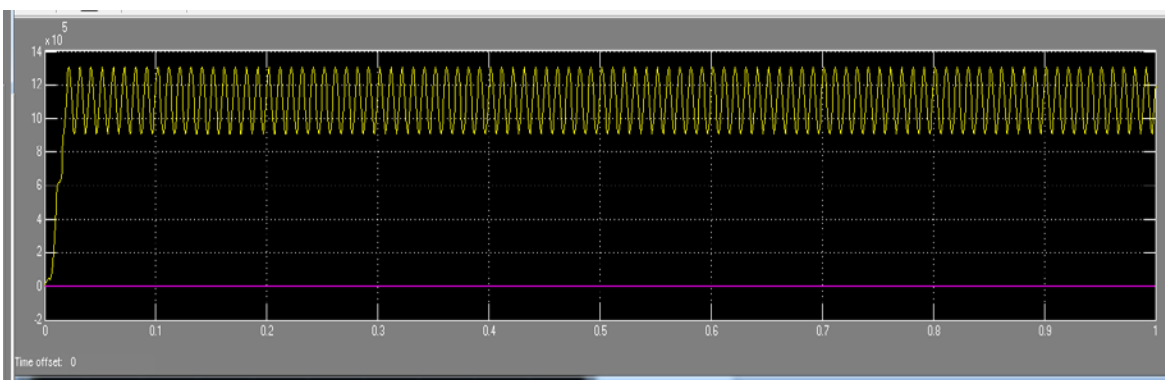

Figure (5 22) the simulation results of PQ power at 2394 KVAR capacitive compensation

It shows the value of PQ simulation result at Voltage source Vrms=400V, frequency 50 Hz, Active power 3,675KW, 2394 KVAR Reactive power. And as a result yellow color shows active power and purple color shows reactive power

Summary: - simulation result of wave form of voltage, current and active and reactive power of Amhara Plastic Pipe factory machineries at 0 KVAR, 825KVAR, 1650KVAR, and 2394 VAR is showed. It has been discussed that the reactive power compensation have been not significant compared the calculated value and even if the voltage and current value of the diagram are seam to similar there is variations. This simulations also verify that the power factor of the factory from 0.84 to 0.98 from this the factory reactive power compensation need is 2394 at full load working.

CHAPTER SIX

6. Conclusion, Recommendation, and Future work

This study was conducted on the 'Redesign, Performance evaluation and Impact analysis of 825 KVAR automatic power factor correction''. Based on the information obtained through data collecting; the researcher analyzed the data by using a quantitative data analyzed method. First and foremost, the researchers found that with the APFC significantly reduces the cost of electric power by the annual saving of 2.15 million birr per year, its payback period of 1.23 year for the cost procurement and the capacity increment, loss reduction & voltage raise increased by 16%, 14.29% and 1.8% consecutively. Finally the researcher based on the finding of the study came up with the following conclusion and recommendation. In this chapter, after useful recommendations are forwarded the main areas of future work are suggested.

6.1 Conclusion

The factory has a power consumption of 2.85 MVA from two 800KVA & one 1250KVA step down transformers for UPVC, HDPE AND Geo membrane sheet machines and 1.6 MVA from two 800KVA step down transformers for green sheet and recycles machines. Totally 4.45 MVA power is delivered by north west district EEU from the high voltage side 15KV main air force distribution line but the low voltage distribution system of the factory has no enough power factor correction. Especially the green sheet factory power distribution system is installed separately from the first ATS /automatic transfer switch/ for this reason we want to evaluate the performance and impact analysis of shunt capacitor bank to contribute the reactive power management at the power distribution feeder of the factory by comparing the power triangle.

The maximum demand of active power is 3675KW, the Reactive power of the factory 2394 KVAR and power factor Pf=KW/KVA= 3674.245/ apparent power of the data 4385.47. So that the power factor of the factory becomes approximately 84%. The annual consumption was 16,096,500 KWh per year and at the normal tariff applied was 0.5778 birr/KWh with current transformer ratio or multiplying factor of 4500.

The current data using either KW multiplier or data analysis method to raise the power factor from 0.84 to 0.98, therefore the equipment of needed reactive power compensation is 1628.025 KVAR. The company has only 825 KVAR. so that it should be add new 825 KVAR capacitor panel is necessary. A plant has a 4,450 KVA transformer operating near capacity. The present power factor is 84%, so the actual working power available is 3675 KW.

The investigation show that APFC significantly reduces the cost of electric power by the annual saving of 2.15 million birr its payback period of 1.23 year for the cost procurement and the capacity increment, loss reduction & voltage raise increased by 16%, 14.29% and 1.8% consecutively.

The study also provides a new power expansion design reduces of electricity cost via half million and save money on utility costs and 350 extra KVA available from the existing supply. The design too helps to reduce of power 7 % (I^2R) losses in transformers and feeder equipment. More over to extended equipment life concluded reduced electrical burden on cables and electrical components over obtaining extra electrical system capacity available from the existing supply. The simulation result demonstrates that Amhara plastic pipe factory (APF) should be including reactive power compensator to decrease (I^2R) losses in transformers and feeder line loads.

6.2 Recommendations

This study shows that with the 'Design, Performance evaluation and Impact analysis of 825KVAr automatic power factor correction'. From this point of view the researcher recommended the following points;

- Factories need to assess at least monthly the reactive power energy meter reading. To protect the organization unplanned costs or penalty. This helps to improve the factory power compensation and to protect the organization status of profitability.
- According to this thesis, Amhara pipe factory had been used 825 KVAR, however it is not sufficient. So that, the reactive power cost penalty influenced over the company. So, at least monthly the reactive power
- The study ensures that the factory total need of power compensator is 1650 KVAR. According to the character of the machine and the last five years load factor study demonstrate that the old capacitor panel 825KVAR is not sufficient power to compensate the total load of the factory working in a full capacity. So, the factory has to solve this problem by adding additional 825 KVAR reactive power expansions. As a result the factory can be increasing its value of 825KVAR to 1650KVAR.
- Improvement of power factor makes the utility companies get rid from the power losses while the consumers are free from low power factor penalty charges.
- After power factor correction the loads need less current. Hence, annual saving of the factory can be more i.e. **1,075,574.7** birr per .
- The factory can implement practically and install additional 825 KVAR power factor compensator to increase the efficiency of the factory distribution net work.

6.3 Future Research Work

The following areas are the issues that need to be further studied. There are four expected thesis ideas where the work can really continue.

Firstly, according to the installation of EEU unfortunately if they can connecting in ring system rather than radial and the factory expansion places determined i.e. some machines are putting temporarily till to finalized there ware house near to the work shop or at the eastern side of the power house. So that it will explored further better solutions that can be carried on the factory distribution board. In addition to, the researcher can do their own research in the following cases.

Case1: Putting the two power factor panels conjugate it by Alienation techniques.

Case 2: Can putting individual compensation by estimating the five year strategic plan

- Secondly effects of harmonic due to the electronic equipment in Amhara pipe factory
- thirdly energy management systems as case study in Amhara plastic pipe factory
- fourthly, investigating other approaches described at the introduction. This will lead to other system models and objective functions, and will span the scope of the problem, which can embrace questions that could emerge in the future. Adaptation of the optimization method to the particularities of the network and the constraints is another aspect in this field.

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Appendices

Appendix A

Table A 1 Table of Coefficient **[4]**

Factor K (kvar/kW)

	final cosφ												
initial cosφ	0.80	0.85	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1
0.60	0.583	0.714	0.849	0.878	0.907	0.938	0.970	1.005	1.042	1.083	1.130	1.191	1.333
0.61	0.549	0.679	0.815	0.843	0.873	0.904	0.936	0.970	1.007	1.048	1.096	1.157	1.299
0.62	0.515	0.646	0.781	0.810	0.839	0.870	0.903	0.937	0.974	1.01 5	1.062	1.123	1.265
0.63	0.483	0.613	0.748	0.777	0.807	0.837	0.870	0.904	0.941	0.982	1.030	1.090	1.233
0.64	0.451	0.581	0.716	0.745	0.775	0.805	0.838	0.872	0.909	0.950	0.998	1.058	1.201
0.65	0.419	0.549	0.685	0.714	0.743	0.774	0.806	0.840	0.877	0.919	0.966	1.027	1.169
0.66	0.388	0.519	0.654	0.683	0.712	0.743	0.775	0.810	0.847	0.888	0.935	0.996	1.138
0.67	0.358	0.488	0.624	0.652	0.682	0.713	0.745	0.779	0.816	0.857	0.905	0.966	1.108
0.68	0.328	0.459	0.594	0.623	0.652	0.683	0.715	0.750	0.787	0.828	0.875	0.936	1.078
0.69	0.299	0.429	0.565	0.593	0.623	0.654	0.686	0.720	0.757	0.798	0.846	0.907	1.049
0.70	0.270	0.400	0.536	0.565	0.594	0.625	0.657	0.692	0.729	0.770	0.817	0.878	1.020
0.71	0.242	0.372	0.508	0.536	0.566	0.597	0.629	0.663	0.700	0.741	0.789	0.849	0.992
0.72	0.214	0.344	0.480	0.508	0.538	0.569	0.601	0.635	0.672	0.713	0.761	0.821	0.964
0.73	0.186	0.316	0.452	0.481	0.510	0.541	0.573	0.608	0.645	0.686	0.733	0.794	0.936
0.74	0.159	0.289	0.425	0.453	0.483	0.514	0.546	0.580	0.617	0.658	0.706	0.766	0.909
0.75	0.132	0.262	0.398	0.426	0.456	0.487	0.519	0.553	0.590	0.631	0.679	0.739	0.882
0.76	0.105	0.235	0.371	0.400	0.429	0.460	0.492	0.526	0.563	0.605	0.652	0.713	0.855
0.77	0.079	0.209	0.344	0.373	0.403	0.433	0.466	0.500	0.537	0.578	0.626	0.686	0.829
0.78	0.052	0.183	0.318	0.347	0.376	0.407	0.439	0.474	0.511	0.552	0.599	0.660	0.802
0.79	0.026	0.156	0.292	0.320	0.350	0.381	0.413	0.447	0.484	0.525	0.573	0.634	0.776
0.80		0.130	0.266	0.294	0.324	0.355	0.387	0.421	0.458	0.499	0.547	0.608	0.750
0.81		0.104	0.240	0.268	0.298	0.329	0.361	0.395	0.432	0.473	0.521	0.581	0.724
0.82		0.078	0.214	0.242	0.272	0.303	0.335	0.369	0.406	0.447	0.495	0.556	0.698
0.83		0.052	0.188	0.216	0.246	0.277	0.309	0.343	0.380	0.421	0.469	0.530	0.672
0.84		0.026	0.162	0.190	0.220	0.251	0.283	0.317	0.354	0.395	0.443	0.503	0.646
0.85			0.135	0.164	0.194	0.225	0.257	0.291	0.328	0.369	0.417	0.477	0.620
0.86			0.109	0.138	0.167	0.198	0.230	0.265	0.302	0.343	0.390	0.451	0.593
0.87			0.082	0.111	0.141	0.172	0.204	0.238	0.275	0.316	0.364	0.424	0.567
0.88			0.055	0.084	0.114	0.145	0.177	0.211	0.248	0.289	0.337	0.397	0.540
0.89			0.028	0.057	0.086	0.117	0.149	0.184	0.221	0.262	0.309	0.370	0.512
0.90				0.029	0.058	0.089	0.121	0.156	0.193	0.234	0.281	0.342	0.484

Table A 2 Table show the motor power factor under load condition **[5]**

Motor Load Factor Power Factor		
Unloaded	**17%**	
1/4 Loaded	**55%**	
½ Loaded	**73%**	
¾ Loaded	**80%**	
Fully Loaded	**84%**	
Overloaded	**(25%) 86%**	

Table A 3 Typical un-improve power factor by Equipment **[2]**

	Equipment Power Factor	**Power factor**
	Air Compressor & Pumps (external Motors)	**75-80**

	Hermetic Motors (compressors)	**50-80**
	Arc Welding	**35-60**
	Resistance Welding	**40-60**
	Machining	**40-65**
	Arc Furnaces	**75-90**
	Induction Furnaces (60Hz)	**100**
	Standard Stamping	**60-70**
	High Speed Stamping	**45-60**
	Spraying	**60-65**
	Industrial Heating With resistance, as in ovens or dryers, the power factor is often closed to	**100%.**
	Welding Electric arc welders generally have a low power factor, around Other types of machinery or equipment those are likely to have a low power factor include	**60%.**

Table A 4 Shows the typical power factors of some electrical equipment [4]

	Load	**power factor**
	Transformers (no load condition)	**0.1÷0.15**
	Motor	**0.7÷0.85**
	Metal working apparatuses: **- Arc welding** **- Arc welding compensated** **- Resistance welding:** **-Arc melting furnace**	 **0.35÷0.6** **0.7÷0.8** **0.4÷0.6** **0.75÷0.9**
	Fluorescent lamps **-compensated** **-uncompensated**	 **0.9** **0.4÷0.6**
	AC DC converters	**0.6÷0.95**
	DC drives	**0.4÷0.75**

	AC drives	**0.95÷0.97**
	Resistive load	**1**

Table A 5 Shows the variation of the transmissible power for MV/LV three-phase transformers as a function of the cos φ of the load [60] **[63][3]**

Power of the transformer[KVA]	**Power of the transformer[KW][cos φ]**					
	0.5	**0.6**	**0.7**	**0.8**	**0.9**	**1**
63	**32**	**38**	**44**	**50**	**57**	**63**
100	**50**	**60**	**70**	**80**	**90**	**100**
160	**80**	**96**	**112**	**128**	**144**	**160**
125	**63**	**75**	**88**	**100**	**113**	**125**
200	**100**	**120**	**140**	**160**	**180**	**200**
250	**125**	**150**	**175**	**200**	**225**	**250**
315	**185**	**189**	**221**	**252**	**284**	**315**
400	**200**	**240**	**280**	**320**	**360**	**400**
630	**315**	**378**	**441**	**504**	**567**	**630**
800	**400**	**480**	**560**	**640**	**720**	**800**
1000	**500**	**600**	**700**	**800**	**900**	**1000**
1250	**625**	**750**	**875**	**1000**	**1125**	**1250**

Table A 6 Current carrying capacity I0 of copper single-core cables on perforated tray **[2][4]**

S [mm2]	**Cu I [A]**	
	XLPE/EPR	**PVC**
25	**141**	**114**
35	**176**	**143**
50	**216**	**174**
70	**279**	**225**
95	**342**	**275**

120	**400**	**321**
150	**464**	**372**
185	**533**	**427**
240	**634**	**507**
300	**736**	**587**
500	**998**	**789**
630	**1151**	**905**

Table A7 maximum compensation of reactive energy (KVAR) at the terminals of LV asynchronous motors **[2]**

Maximum compensation of reactive energy (KVAR)[60]				
LV motor nominal power (KW)	**Number of pairs of poles**			
	1		**3**	**4**
22	**6**	**8**	**9**	**10**
30	**7.5**	**10**	**11**	**12.5**
37	**9**	**11**	**12.5**	**16**
45	**11**	**13**	**14**	**17**
55	**13**	**17**	**18**	**21**
75	**17**	**22**	**25**	**28**
90	**20**	**25**	**25**	**30**
110	**24**	**29**	**33**	**37**
132	**31**	**36**	**38**	**43**
160	**35**	**41**	**44**	**52**
200	**43**	**47**	**53**	**61**
250	**52**	**57**	**63**	**71**
280	**57**	**63**	**70**	**79**
355	**67**	**76**	**86**	**98**
400	**78**	**82**	**97**	**106**
450	**87**	**93**	**107**	**117**

Appendix B **Data of each Production Line [64]**

Table B 1 Load survey of Production Line one: D400, D450, D500, D560, D630

No.	**Location**	***Nxwxn***	**Load Type**						
			KVA)	**Resistive load power**	***compensated* (KW)**	***Non compensated***	**3-phase Amper**	**1-phase Amper**	**Power Factor**

				(KW)		(KW)	e (A)	e (A)	
MIXER MACHINE									
1.	**Hot mixer motor**	**1x47/67**				**67**	**120**		
2.	**Cold mixer motor**	**1x11x1**				**11**	**22.5**		**0.84**
3.	**Sucker Motor**	**1x2.2x1**				**2.2**	**5.6**		**0.81**
EXTRUSSION MACHINE									
4.	**Feed motor**	**1x1.5x1**			**1.5**		**3.7**		
5.	**Extruder main DC motor**	**1x110x1**				**110**	**275**		**0.79**
6.	**Main DC motor cooling fan**	**1x3x1**				**3**	**6.4**		**0.87**
7.	**Barrel cooling Fans 5 consecutive**	**5x0.55x1**				**2.75**	**6.75**		
8.	**barrel Heaters- 1 (ø375x215)**	**1x3.75x1**		**3.75**				**7.5**	
9.	**barrel Heaters- 2 (ø340x390**	**1x10x1**		**10**				**20**	
10.	**barrel Heaters - 3 (ø340x380**	**1x10x1**		**10**				**20**	
11.	**barrel Heaters- 4 (ø340x320**	**1x8.5x1**		**8.5**				**17**	
12.	**barrel Heaters- 5 (ø280x260**	**1x5.3x1**		**5.3**				**10.6**	
13.	**barrel Heaters- 6 ø280x240**	**1x5.3x1**		**5.3**				**10.6**	
14.	**Die -core Heaters- (220x160)x1pcs**	**1x2.5x1**		**2.5**				**5**	
MOLD (DIE) MACHINE									
15.	**Die -Heaters-1- (ø 450x136)x1 pcs**	**1x3.6x1**		**3.6**				**7.2**	
16.	**Die -Heaters-2,3,- (ø 730x110)x4**	**2x1.5x4**		**12**				**24**	
17.	**Die -Heaters-4,5,6, - (ø 850x125)x2**	**3x3.8x2**		**22.8**				**45.6**	
18.	**Die -Heaters-7,8- (ø 1040x170)x2**	**2x6.4x2**		**25.6**				**51.2**	
19.	**Die -Heaters--9-(ø 1040x120)x2pcs**	**1x4.5x2**		**9**				**18**	
20.	**Die -Heaters-10,11- (ø 910x150)x2**	**2x5x2**		**20**				**40**	
21.	**Die -Heaters- 12- (ø 720x123)x1 pcs**	**1x5.6x1**		**5.6**				**11.2**	
22.	**Die -Heaters-13-(ø 660x235)x4 pcs**	**1x2.8x4**		**11.2**				**22.4**	
23.	**Die -Heaters-14- (ø 910x150)x2 pcs**	**1x5x2**		**10**				**20**	
24.	**Die -Heaters-15- (ø 710x230)x4 pcs**	**1x3x4**		**12**				**24**	
25.	**Die -Heaters-16- (ø 475x300)x4 pcs**	**1x2.6x4**		**10.4**				**20.4**	
26.	**Die -Heaters-17,18- (ø 570x260)x4**	**2x2.7x4**		**21.6**				**43.2**	
VACUUM TANK MACHINE									
27.	**Vacuum pump motor 2pcs**	**7.5x2**				**15**	**24**		
28.	**Water pump motor 2pcs**	**7.5x2**				**15**	**30**		**0.88**
29.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE 1&2									
30.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
31.	**2nd cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
	HALL OFF MACHINE								
32.	**Hall Off AC motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
33.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
34.	**Cutter feed & retract x1 pcs**	**1.1**				**1.1**	**2.2**		**0.78**
35.	**Cutter -rotation x1 pcs**	**3**				**3**	**6.8**		**0.87**
36.	**Cutter- revolution x1 pcs**	**4**			**4**		**8**		
BELLING MACHINE 1&2									
37.	**Heater rode**	**8x2x2**		**32**				**64**	
38.	**Pipe puller**	**2x2.2x1**				**8.8**	**17.6**		
39.	**Fro and back rotation**	**2x0.35x1**				**0.7**	**1.15**		
40.	**Oil pump motor**	**2x7.5x1**				**15**	**15**		
41.	**Pipe rotation motor**	**4x0.09x**				**0.36**	**0.72**		
Sub Total load				**241.15/3**	**9.9**	**278.41**	**604.28**	**481.9**	
Total load		**358.69 =80.38**							
Speed variable load(feeder, dc motor		**110**							
compensated (heaters,+ ac drives		**80.38 +9.9=90.28**							
Idle loads(pump1/2of belling) No.30,32		**11+1+1.5=13.5**							
Variable loads(mixer, sucker, cutter), fan, vacuum, &cooling pump, haul off)		**67+11+ 2.2+3+2.75+15+11+1.1+3+8.8+0.7+15+0.36 =140.91**							

Table B 2 Load survey of Production Line two: D250, D280, D315, D355,D400

No.	**Location**	***Nxwxn***	**Load Type**						
			KV	**Resistive load**	***compensated***	**Non compen**	**3-phase**	**1-phase**	**Power Factor**

			A	power (KW)	*(KW)*	sated (KW)	Ampere (A)	Ampere (A)	
MIXER MACHINE									
1.	**Hot mixer motor**	**(47/67KW)**				**67**	**120**		
2.	**Cold mixer motor**	**11**				**11**	**22.5**		**0.84**
3.	**Sucker Motor**	**2.2**				**2.2**	**5.6**		**0.81**
EXTRUSSION MACHINE									
4.	**Feed motor**				**1.5**		**3.7**		
5.	**Extruder main DC motor**					**110**	**275**		**0.79**
6.	**Main motor cooling fan**					**3**	**6.4**		**0.87**
7.	**Barrel cooling Fans 5 consecutive 1.35A**	**5x0.55x1**				**2.75**	**6.75**		
8.	**barrel Heaters- 1 (ø375x215)**	**1x3.75x1**		**3.75**				**7.5**	
9.	**barrel Heaters- 2 (ø340x390**	**1x10x1**		**10**				**20**	
10.	**barrel Heaters - 3 (ø340x380**	**1x10x1**		**10**				**20**	
11.	**barrel Heaters- 4 (ø340x320**	**1x8.5x1**		**8.5**				**17**	
12.	**barrel Heaters- 5 (ø280x260**	**1x5.3x1**		**5.3**				**10.6**	
13.	**barrel Heaters- 6 ø280x240**	**1x5.3x1**		**5.3**				**10.6**	
14.	**Die -core Heaters- (220x160)x1pcs**	**1x2.5x1**		**2.5**				**5**	
MOLD (DIE) MACHINE									
15.	**Die -Heaters-1- (ø 390x130)x1 pcs**	**1x3.5x1**		**3.5**				**7.2**	
16.	**Die -Heaters-2,3- (ø 740x232)x4 p**	**1x4.8x2**		**9.6**				**24**	
17.	**Die -Heaters-4- (ø 740x100)x2 pcs**	**2x6.2x2**		**24.8**				**45.6**	
18.	**Die -Heaters-5- (ø 620x130)x2 pcs**	**1x5.8x2**		**11.6**				**51.2**	
19.	**Die -Heaters-6- (ø320x152)x4pcs**	**1x3.5x4**		**14**				**18**	
20.	**Die -Heaters-7- (ø 470x140)x4pcs**	**2x4.8x4**		**19.2**				**40**	
VACUUM TANK MACHINE									
21.	**Vacuum pump motor 2pcs**	**5.5x2**				**11**	**22.2**		
22.	**Water pump motor 2pcs**	**5.5x2**				**11**	**30**		**0.88**
23.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
24.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
25.	**2nd cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
HALL OFF MACHINE									
26.	**Hall Off AC motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
27.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
28.	**Cutter feed & retract**	**1x1.1**				**1.1**	**2.2**		**0.78**
29.	**Cutter -rotation**	**1x3**				**3**	**6.8**		**0.87**
30.	**Cutter- revolution AC motor**	**1x4**			**4**		**8**		
BELLING MACHINE									
31.	**Heater rode**	**4 x1.5**		**6**				**12**	
32.	**Pipe puller**	**1x2.2**				**4.4**			
33.	**Fro and back rotation**	**1x0.35**				**0.35**	**1.12**		
34.	**Oil pump motor**	**1x7.5**				**7.5**	**15**		
35.	**Pipe rotation motor**	**2x0.09**				**0.18**	**0.64**		
Sub Total				**134.5/3 =44.83**	**9.9**	**257.98**	**873.47**	**288.7**	
Total		**308.713**							
Speed variable load dc motor		**110**							
compensated (heaters, ac drives)		**44.83 +9.9=54.73**							
Idle loads pump1/2of belling		**11+1.5=12.5**							
Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off		**67+11+ 2.2+3+2.75+11+11+1.1+3+4.4+0.35+7.5+0.18 =124.48**							

Table B 3 Load survey of Production Line three: D75, D90,D110, D125, D140, D160, D180,D200,D225, D250

No.	**Location**	**Nxwxn**	**Load Type**						
			(K	**Resistive load**	**Compensate**	**Non Compe**	**3-phase**	**1-phase**	**Power Factor**

			VA	power (KW)	d(KW)	nsated(KW)	Ampere (A)	Ampere (A)	
MIXER MACHINE									
1.	**Hot mixer motor**	**(47/67KW)**				**67**	**120**		
2.	**Cold mixer motor**	**11**				**11**	**22.5**		**0.84**
3.	**Sucker Motor**	**2.2**				**2.2**	**5.6**		**0.81**
EXTRUSSION MACHINE									
4.	**Feed motor**				**0.75**		**2.03**		
5.	**Extruder main DC motor**					**55**	**275**		**0.79**
6.	**Taco generator**					**0.022**	**0.2**		
7.	**Main motor cooling fan**					**1.1**	**2.6**		**0.84**
8.	**Barrel cooling Fans 3 consecutive 1.2A**	**3x0.55x1**				**2.75**	**3.6**		
9.	**Barrel Heaters- 1 (ø320x300)**	**1x5x1**		**5**				**7.5**	
10.	**Barrel Heaters- 2 (ø290x390)**	**1x10x1**		**10**				**20**	
11.	**Barrel Heaters - 3 (ø260x380)**	**1x10x1**		**10**				**20**	
12.	**Barrel Heaters- 4 (ø240x320)**	**1x8.5x1**		**8.5**				**17**	
13.	**Die -core Heaters- (210x160)x1pcs**	**1x2x1**		**2**				**5**	
MOLD (DIE) MACHINE									
14.	**Die -Heaters-1- (ø 330x115) x1**	**1x2.6x1**		**2.6**				**7.2**	
15.	**Die -Heaters-2- (ø 520x120) x1**	**1x4.5x1**		**12**				**24**	
16.	**Die -Heaters-3- (ø 520x65)x1 pcs**	**1x2.4x1**		**2.4**				**45.6**	
17.	**Die -Heaters-, 4- (ø 520x175)x1**	**1x6.5x1**		**6.5**				**51.2**	
18.	**Die -Heaters -,5-(ø 436x95)x1pcs**	**1x4.5x1**		**4.5**				**18**	
19.	**Die -Heaters-,6,7- (ø 310x110)x2**	**2x2.5x1**		**5**				**40**	
20.	**Die -Heaters-8- (ø 150x135)x1 pcs**	**1x1.4x1**		**1.4**				**11.2**	
21.	**Die -Heaters-9-(ø 296x80)x1pcs**	**1x1.6x1**		**1.6**				**22.4**	
22.	**Die -Heaters-10- (ø 95x150)x1 pcs**	**1x0.65x1**		**0.65**				**20**	
23.	**Die -Heaters-11- (ø 296x80)x1 pcs**	**1x1.6x1**		**1.6**				**24**	
24.	**Die -Heaters-12- (ø 296x40)x1 pcs**	**1x0.8x1**		**0.8**				**20.4**	
25.	**Die-Heaters-13- (ø 296x110)x1pcs**	**1x2.5x1**		**2.5**				**43.2**	
VACUUM TANK MACHINE									
26.	**Vacuum pump motor 1pcs**	**4**				**4**	**8.2**		**0.88**
27.	**Vacuum screw 1pcs**	**0.37**				**0.37**	**1.12**		
28.	**Water pump motor 1pcs**	**5.5**				**5.5**	**10.9**		**0.88**
29.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
30.	**1st cooling Water pump motor 1**	**5.5**				**5.5**	**11.1**		**0.88**
31.	**2nd cooling Water pump motor 1**	**5.5**				**5.5**	**11.1**		**0.88**
HALL OFF MACHINE									
32.	**Hall Off AC motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
33.	**Haul off adjuster 1pcs**	**0.75**				**0.75**	**1.9**		**0.75**
CUTTER MACHINE									
34.	**Cutter feed & retract**	**0.35**				**0.35**	**1.12**		**0.78**
35.	**Cutter -rotation**	**1.5**				**1.5**	**3.67**		**0.87**
36.	**Cutter- revolution**	**1.5**			**1.5**		**3.7**		
BELLING MACHINE 1&2									
37.	**Heater rode**	**4x1.5**		**6**				**12**	
38.	**Tow/Pipe puller motor**	**1x2.2**				**4.4**			
39.	**Oil pump motor 1pcs**	**1.5**				**1.5**	**3.7**		
40.	**Fro and back rotation motor 1pcs**	**1x0.09**				**0.18**	**0.64**		
41.	**Pipe rotation motor 1pcs**	**2x0.09**				**0.18**	**0.64**		
Sub total				**83.05/3 =27.68**	**6.25**	**168.752**	**499.72**	**408.7**	
Total		**202.713**							
Speed variable load feeder, dc motor		**55**							
compensated (heaters, ac drives)		**27.68 +5.5=33.18**							
Idle loads pump1/2of belling		**5.5+0.75=6.25**							
Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off		**67+11+ 2.2+1.1+2.75+4+0.37+5.5+5.5+0.35+1.5+4.4+1.5+0.18+0.18 =107.53**							

Table B 4 Load survey of Production Line four:D16,D20,D32,D40,D50,D63,D75

No.	**Location**	***Nxwxn***		**Load Type**					
			(KVA)	**Resistive load power**	***Compensated (KW)***	***Non Compensated***	**3-phase Amper**	**1-phase Amper**	**Power Facto**

				(KW)		*(KW)*	e (A)	e (A)	r
	MIXER MACHINE								
1.	**Hot mixer motor**	**47/67**				**67**	**120**		
2.	**Cold mixer motor**	**11**				**11**	**22.5**		**0.84**
3.	**Sucker Motor**	**2.2**				**2.2**	**4.7**		**0.81**
	EXTRUSSION MACHINE								
4.	**Barrel cooling Fans 3 consecutive 1.35A**	**3x0.55x1**				**1.65**	**3.3**		
5.	**Feed motor**	**0.75**			**0.75**		**2.03**		
6.	**Extruder main AC motor**	**37**			**37**			**75**	**0.79**
7.	**Barrel Heaters- 1 (ø265x290) 1pcs**	**1x4.5x1**		**4.5**				**10**	
8.	**Barrel Heaters- 2 (ø230x160) 1pcs**	**1x4x1**		**4**				**8.4**	
9.	**Barrel Heaters - 3 (ø230x245) 1pcs**	**1x5x1**		**5**				**11**	
10.	**Barrel Heaters- 4 (ø190x240) 1pcs**	**1x4x1**		**4**				**8.4**	
11.	**Die -core Heaters- (220x120) 1pcs**	**1x2x1**		**2**				**5**	
MOLD (DIE) MACHINE									
12.	**Die -Heaters -1- (ø 210x120)x1 pcs**	**1x2x1**		**2**				**4.2**	
13.	**Die -Heaters -2, 3- (ø 215x115)x1 pcs**	**2x3.4x1**		**6.8**				**13.8**	
14.	**Die -Heaters -4,5,- (ø 80x65)x1 pcs**	**2x0.4x1**		**1.8**				**45.6**	
15.	**Die -Heaters - 6, 7- (ø176x106)x1 pcs**	**2x0.3x1**		**0.6**				**51.2**	
16.	**Die -Heaters -8,9- (ø 196x80)x1pcs**	**2x1.1x1**		**2.2**				**18**	
17.	**Die -Heaters-10,11- (ø 196x100)x1 pcs**	**2x1.3x1**		**2.6**				**40**	
VACUUM TANK MACHINE									
18.	**Vacuum pump motor 1pcs**	**4x2**				**8**	**16.4**		
19.	**Water pump motor 1pcs**	**2.2x2**				**4.4**	**9.4**		**0.88**
20.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
21.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
22.	**2nd cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
HALL OFF MACHINE									
23.	**Hall Off motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
24.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
25.	**Cutter feed & retract**	**1x1.1**				**1.1**	**2.2**		**0.78**
26.	**Cutter -rotation**	**1x3**				**3**	**6.8**		**0.87**
27.	**Cutter- revolution**	**1x4**			**4**		**8**		
BELLING MACHINE									
28.	**Tow/ Pipe puller motor**	**1x2.2**				**4.4**			
29.	**Heater rode**	**4x0.5**		**2**				**4**	
30.	**Oil pump motor**	**1.5**				**1.5**	**3.7**		
31.	**Fro and back rotation motor 1pcs**	**1x0.09**				**0.18**	**0.64**		
32.	**Pipe rotation motor 1pcs**	**2x0.09**				**0.18**	**0.64**		
	Subtotal			**37.5/3 =12.5**	**46.15**	**116.06**	**259.17**	**294.6**	
	Total	**182.2**							
	compensated (heaters, ac drives)	**12.5.5+46.15=58.7**							
	Idle loads pump1/2of belling	**1+5.5+0.75 = 7.25**							
	Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off	**67+11+ 2.2+1.65+8+4.4+11+1,1+3+4.4+1.5+0.18+0.18 =116.25**							

Table B 5 Load survey of Production Line five:D16,D20,D32,D40,D50,D63,D75

No.	**Location**	***Nxwxn***	**Load Type**						
			KVA	**Resistive load Active power**	***Compensated (KW)***	***Non Compensated (KW)***	**3-phase Ampere (A)**	**1-phase Ampere (A)**	**Power Factor**

				(KW)					
MIXER MACHINE									
2.	**Stripper main motor 1pcs**	**0.55**				**0.55**	**1.15**		
3.	**Stripper fan motor 1pcs**	**0.085**				**0.085**	**0.19**		
4.	**Stripper heater 4pcs**	**0.18**		**0.72**			**1.5**		
EXTRUSSION MACHINE									
4.	**Auto loader /Feed motor**	**3**				**3**	**6**		**0.81**
5.	**Extruder main DC motor**	**75**				**75**	**188**		**0.79**
6.	**Main DC motor cooling fan**				**3**		**6.4**		**0.87**
7.	**Barrel cooling Fans 4 consecutive 1.35A**	**4x0.55x1**				**2.25**	**6.75**		
8.	**Barrel Heaters- 1,2,3,4 (ø160x350)**	**4x3.5x1**		**14**				**28**	
9.	**Die -core Heaters- (120x80)x1pcs**	**1x0.8x1**		**0.8**				**1.6**	
MOLD (DIE) MACHINE									
10.	**Die -Heaters-1,2- (ø 220x45) x2pcs**	**2x0.95**		**1.9**				**4**	
11.	**Die -Heaters-3- (ø 110x55) x1 pcs**	**1x0.65**		**0.65**				**1.5**	
12.	**Die -Heaters-4- (ø 180x45)x1 pcs**	**1x0.7x1**		**0.7**				**1.5**	
13.	**Die -Heaters-4,5,6- (ø 280x130)x3**	**3x2.8x1**		**7.4**				**15**	
14.	**Die -Heaters -5-(ø 120x80)x1pcs**	**1x0.8x1**		**0.8**				**1.6**	
VACUUM TANK MACHINE									
15.	**Vacuum pump motor 2pcs**	**2.2x2**				**4.4**	**8.8**		**0.88**
16.	**Water pump motor 2pcs**	**5.5x2**				**11**	**24**		
17.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
18.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
HALL OFF MACHINE									
19.	**Hall Off AC motor 4pcs**	**4x2.2**			**8.8**		**18**		
20.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
21.	**Cutter feed & retract motor**	**1.1**				**1.1**	**2.2**		**0.78**
22.	**Cutter -rotation motor**	**3**				**3**	**6.8**		**0.87**
23.	**Cutter- revolution AC motor**	**4**			**4**		**8**		
WINDER MACHINE									
24.	**Winder motor**	**2x5.5**			**11**		**22.2**		
Subtotal				**26.97/3=9**	**26.8**	**82.85**	**348.45**	**53.2**	
Total		**149.685**							
Speed variable load feeder, dc motor		**75**							
compensated (heaters, ac drives)		**9+ 3+8.8+4+11 =35.8**							
Idle loads pump1/2of belling		**11+1=12**							
Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off		**0.55+0.085+3+2.25+4.4+11+1.5+1.1+3 =26.885**							

Table B 6 Load survey of Production Line six: D90, D110, D125, D140, D160, D180, D200, D225, D250, D280, D315

			Load Type						
No.	**Location**	***Nxwx***		**Resistive**	***Compe***	***Non***	**3-**	**1-**	**Power**

		n	***KVA)***	**load Active power (KW)**	***nsated (KW)***	***Compensated (KW)***	**phase Ampere (A)**	**phase Ampere (A)**	**Factor**
MIXER MACHINE									
42.	**Mixer motor 1pcs**	**3**				**3**	**6**		
43.	**Stripper main motor 1pcs**	**1.1**				**1.1**	**2.5**		
44.	**Stripper fan motor 1pcs**	**0.085**				**0.085**	**0.19**		
45.	**Stripper heater 4pcs**	**0.18**		**0.72**				**1.5**	
EXTRUSSION MACHINE									
46.	**Autoloader motor**					**1.5**	**3.7**		
47.	**Extruder main DC motor**					**160**	**397**		**0.79**
48.	**Main motor cooling fan**					**3**	**6.4**		**0.87**
49.	**Barrel cooling Fans 4 consecutive 1.4A**	**4x0.37x1**				**1.48**	**5.6**		
50.	**Barrel Heaters- 1 (ø160x565) 1**	**1x8.5x4**		**34**				**70**	
51.	**Die -core Heaters- (120x80)x2pcs**	**1x0.8x2**		**1.6**				**3.2**	
MOLD (DIE) MACHINE									
52.	**Die -Heaters-1- (ø 245x110)x1 pcs**	**1x2.4x1**		**2.4**				**5**	
53.	**Die -Heaters-2,3,- (ø 330x75)x2 pcs**	**2x2.4x2**		**9.6**				**24**	
54.	**Die -Heaters-4,5,6, - (ø 530x75)x1**	**3x2.15x2**		**13**				**26**	
55.	**Die -Heaters-7,8- (ø 400x75)x2 pcs**	**2x1.4x2**		**9.6**				**19.2**	
56.	**Die -Heaters-9-(ø 510x110)x2pcs**	**1x2.75x2**		**4.5**				**9**	
57.	**Die -Heaters-10,11- (ø 410x80)x2**	**2x1.3x2**		**5.2**				**10.4**	
58.	**Die -Heaters- 12- (ø 430x80)x1 pcs**	**1x1.5x1**		**1.5**				**3**	
VACUUM TANK MACHINE									
59.	**Vacuum pump motor 2pcs**	**4x2**				**8**	**16**		**0.88**
60.	**Water pump motor 2pcs**	**5.5x2**				**11**	**24**		
61.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
62.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
63.	**2nd cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
HALL OFF MACHINE									
64.	**Hall Off motor 4pcs**	**4x2.2**			**8.8**		**17**		
65.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
66.	**Cutter feed & retract**	**1.5**				**1.5**	**3**		**0.78**
67.	**Cutter -rotation**	**3**				**3**	**6**		**0.87**
68.	**Cutter- revolution**	**1.1**			**1.1**		**2.6**		
Subtotal				**82.12/3 =27.37**	**9.9**	**225.965**	**538.45**	**171.3**	
Total		**259.7**							
Speed variable load feeder, dc motor		**160**							
compensated (heaters, ac drives)		**27.37+8.8 +1.1=37.27**							
Idle loads pump1/2of belling		**11+1=12**							
Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off		**3+1.1+0.85+5+3+1.48+8+11+11+1.5+1.5+3 =50.43**							

Table B 7 Load survey of Production Line seven: D75, D90, D110, D125, D140, D160, D180, D200, D225, and D250

No.	**Location**	***Nxwxn***	**Load Type**						
			(	**Resistiv**	***Compe***	***Non***	**3-**	**1-**	**Power**

			K V A)	e load Active power (Kw)	*nsated (KW)*	*Compe nsated (KW)*	phase Ampere (A)	phase Ampere (A)	Factor
MIXER MACHINE									
1.	**Mixer motor 1pcs**	**1x3x1**				**3**	**6**		
2.	**Stripper main motor 1pcs**	**1x1.1x1**				**1.1**	**2.5**		
3.	**Stripper fan motor 1pcs**	**1x0.085x1**				**0.085**	**0.19**		
4.	**Stripper heater 4pcs**	**1x0.18x1**		**0.72**				**1.5**	
EXTRUSSION MACHINE									
5.	**Feed motor**	**1x1.5x1**				**1.5**	**3.7**		
6.	**Extruder main DC motor**	**1x110x1**				**110**	**275**		**0.79**
7.	**Taco generator**	**0.022x1**				**0.022**	**0.2**		
8.	**Main motor cooling fan**	**1x3x1**				**3**	**6.4**		**0.87**
9.	**Barrel cooling Fans 5 consecutive 1.35A**	**5x0.55x1**				**2.75**	**6.75**		
10.	**Barrel Heaters- 1 (ø160x565) 1**	**1x8.5x4**		**34**				**70**	
11.	**Die -core Heaters- (120x80)x2pcs**	**1x0.8x2**		**1.6**				**3.2**	
MOLD (DIE) MACHINE									
12.	**Die -Heaters-1- (ø 245x110)x1 pcs**	**1x2.4x1**		**2.4**				**5**	
13.	**Die -Heaters-2,3,- (ø 330x75)x2 pcs**	**2x2.4x2**		**9.6**				**24**	
14.	**Die -Heaters-4,5,6, - (ø 530x75)x1**	**3x2.15x2**		**13**				**26**	
15.	**Die -Heaters-7,8- (ø 400x75)x2 pcs**	**2x1.4x2**		**9.6**				**19.2**	
16.	**Die -Heaters-9-(ø 510x110)x2pcs**	**1x2.75x2**		**4.5**				**9**	
17.	**Die -Heaters-10,11- (ø 410x80)x2**	**2x1.3x2**		**5.2**				**10.4**	
18.	**Die -Heaters- 12- (ø 430x80)x1 pcs**	**1x1.5x1**		**1.5**				**3**	
VACUUM TANK MACHINE									
19.	**Vacuum pump motor 2pcs**	**4x2**				**8**	**16**		
20.	**Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
21.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
22.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
23.	**2nd cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
HALL OFF MACHINE									
24.	**Hall Off motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
25.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
26.	**Cutter feed & retract**	**0.35**				**0.35**	**1.12**		**0.78**
27.	**Cutter -rotation**					**3**	**6.8**		**0.87**
28.	**Cutter- revolution AC motor**	**4**			**4**		**8**		
WINDER MACHINE									
29.	**AC Winder**	**2x7.5x1**			**15**		**30**		**0.84**
	Subtotal			**81.4./3=27.13**	**23.4**	**168.027**	**445.22**	**417.9**	
	Total	**201.83**							
	Speed variable load feeder, dc motor	**110**							
	compensated (heaters, ac drives)	**27.13+ 23.4 =32.4**							
	Idle loads pump1/2of belling	**11+1=12**							
	Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off	**3+1.1+0.85+1.5+2.75+1.48+8+11+11+1.5+1.5+0.35+3 =47.43**							

Table B 8 Load survey of Production Line eight: D16, D20, D30, D40, D50, D63, D75

			Load Type						
No.	**Location**	***Nxwxn***	*(*	**Resistive**	***Compens***	***Non***	**Ampe**		**Power**

			K V A)	load Active power (KW)	*ated (KW)*	*Compe nsated (KW)*	re (A)		Factor
	MIXER MACHINE								
1.	**mixer motor**					**1.1**	**22.5**		**0.84**
2.	**Sucker Motor**					**2.2**	**5.6**		**0.81**
	EXTRUSSION MACHINE								
3.	**Feed motor**					**1.5**	**3.7**		
4.	**Extruder main AC motor**				**37**		**74**		**0.79**
5.	**Main motor cooling fan**				**3**		**6.4**		**0.87**
6.	**Barrel cooling Fans 5 consecutive 1.35A**	**5x0.55x1**				**2.75**	**6.75**		
7.	**Barrel Heaters- 1 (ø160x565) 1**	**1x2.2x4**		**8.8**				**17**	
8.	**Die -core Heaters- (120x80)x2pcs**	**1x0.8x2**		**1.6**				**3.2**	
9.	***MOLD (DIE) MACHINE***								
10.	**Die -Heaters-1- (ø 245x110)x1 pcs**	**1x2.4x1**		**2.4**				**5**	
11.	**Die -Heaters-2,3,- (ø 330x75)x2 pcs**	**2x2.4x2**		**9.6**				**24**	
12.	**Die -Heaters-4,5,6, - (ø 530x75)x1**	**3x2.15x2**		**13**				**26**	
13.	**Die -Heaters-7,8- (ø 400x75)x2 pcs**	**2x1.4x2**		**9.6**				**19.2**	
VACUUM TANK MACHINE									
14.	**Vacuum pump motor 2pcs**	**5.5X1**				**5.5**	**24**		
15.	**Water pump motor 2pcs**	**1X5.5**				**5.5**	**30**		**0.88**
16.	**Vacuum screw motor**	**1x1**				**1**	**2**		
COOLING TANK MACHINE									
17.	**1st cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
18.	**2nd cooling Water pump motor 2pcs**	**5.5x2**				**11**	**22.2**		**0.88**
HALL OFF MACHINE									
19.	**Hall Off motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
20.	**Haul off adjuster**	**2x0.75**				**1.5**	**4.06**		**0.75**
CUTTER MACHINE									
21.	**Cutter feed & retract**					**1.1**	**2.2**		**0.78**
22.	**Cutter -rotation**					**3**	**6.8**		**0.87**
23.	**Cutter- revolution**				**4**		**8**		
WINDING MACHINE									
24.	***Winder***	***2x7.5x1***			***15***		***30***		***0.84***
	Subtotal			**45/3=15**	**60.4**	**35.15**	**589.81**	**417.9**	
	Total	**122.55**							
	compensated (heaters, ac drives)	**15+ 60.4 =75.4**							
	Idle loads pump1/2of belling	**11+1=12**							
	Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off	**1.1+2.2+1.5+2.75+5.5+5.5+11+1.5+1.1+3 =35.15**							

Table B 9 Load survey of Production Line nine: Geo membrane 0.5 mm up to 2 mm

No.	**Location**	***Nxwxn N=repetitio***		**Load Type** Resistive	***Compe***	***Non***	**3-**	**1-**	**Power**

		n W=wattage n=no.Of w/circle	*(KVA)*	**load power (KW)**	*nsated (KW)*	*Compensated (KW)*	**phase Ampere (A)**	**phase Ampere (A)**	**Factor**
MIXER MACHINE									
1.	**1 Mixer motor 1**	**1x4x1**				**4**	**8**		**0.87**
2.	**Sucker Motor 1**	**1x2.2x1**				**3**	**6**		**0.88**
3.	**Blower AC motor 1,2**	**2x18.5x1**			**37**		**71**		**0.9**
4.	**Blower AC motor 1**	**1x30x1**			**30**		**56.9**		**0.9**
5.	***EXTRUSSION MACHINE***								
6.	**Extruder main DC motor 1**	**1x315x1**				**315**	**630**		**0.87**
7.	**Main DC motor fan**	**1x3x1**			**3**		**6**		**0.87**
8.	**Hydraulic Oil pump**	**1x3x1**				**3**	**6**		
9.	**Gear box Oil pump**	**1x3x1**				**3**	**6**		
10.	**Barrel cooling Fans 9 consecutive 1.5A**	**9x0.75x1**				**6.75**	**13.5**		
11.	**Barrel cooling Fans 2 consecutive 1.35A**	**2x0.55x1**				**2.7**	**6.75**		
12.	**barrel Heaters -1- (ø375x215)**	**11x8.5x1**		**3.75**				**7.5**	
13.	**barrel Heaters -2- (ø340x390)**	**2x5.8x1**		**10**				**20**	
MOLD (DIE) MACHINE									
14.	**Die lip-Heaters-1- (ø 1865x85)x12pcs**	**12x1x1**		**12**				**24**	
15.	**Die shell - Heaters-2,3,- (ø 1865x70)x4pcs**	**12x1.5x2**		**36**				**72**	
16.	**Die base bottom-Heaters-4, (ø1 850x98)x12pcs**	**12x1x1**		**12**				**24**	
17.	**Die bottom -Heaters-7,8- (ø 1830x ø 1500x170)x12**	**12x2x1**		**24**				**48**	
18.	**Die bottom -Heaters-7,8- (ø 1060x ø x400)x12pcs**	**12x2x1**		**24**				**48**	
19.	**Die - neck-Heaters-9-(ø 1040x120)x2pcs**	**1x4.5x2**		**9**				**18**	
20.	**Die-neck-Heaters-10,11- (ø 910x150)x2pcs**	**2x5x2**		**20**				**40**	
21.	**Adapter -Heaters- 12- (ø 720x123)x1pcs**	**1x5.6x1**		**5.6**				**11.2**	
22.	**Adapter -Heaters-13-(ø 660x235)x4 pcs**	**1x2.8x4**		**11.2**				**22.4**	
23.	**Adapter -Heaters-14- (ø 910x150)x2 pcs**	**1x5x2**		**10**				**20**	
24.	**Feeder-Heaters-15- (ø 710x230)x4 pcs**	**1x3x4**		**12**				**24**	
25.	**Feeder-Heaters-16- (ø 475x300)x4 pcs**	**1x2.6x4**		**10.4**				**20.4**	
26.	**Die -Heaters-17,18- (ø 570x260)x4 pcs**	**2x2.7x4**		**21.6**				**43.2**	
HALL OFF MACHINE									
27.	**Hall Off up stair DC motor 2pcs**	**2x11x1**				**22**	**44**		**0.75**
28.	**Hall Off DC motor Taco generator**	**2x0.022**				**0.044**	**0.1**		
29.	**Haul off adjuster**	**8x2.2x1**				**17.6**	**35.2**		**0.75**
30.	**Adjuster**	**3x0.55x1**				**1.75**	**3.55**		**0.78**
WINDING MACHINE									
31.	**Winder A&B DC motor**	**2x7.5x1**				**15**	**30**		**0.84**
32.	**Winder DC motor fun**	**2x0.18x1**				**0.36**	**0.72**		
33.	**Winder A&B DC motor Taco generator**	**2x0.022**				**0.044**	**0.1**		
34.	**Roller rotation**	**1x0.55x1**				**0.55**	**1.15**		**0.84**
35.	**Rewinder**	**2x1.5x1**				**3**	**6**		
Subtotal				**221.55/3 =73.85**	**70**	**400.798**	**930.97**	**442.7**	
Total		**<u>524.63</u>**							
Speed variable load feeder, dc motor		**315**							
compensated (heaters, ac drives)		**73.85+70 =143.85**							
Idle loads pump1/2of belling		**17.6+1.75=18.35**							
Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off		**4+3+3+3+6.75+2.7+22+15+0.36+0.55 =47.43**							

Table B 10 Production Line ten: Green sheet 0.1 mm up 0.5 to mm

			Load Type

No.	Location	*Nxwxn*	*Apparent Power (KVA)*	Resistive load Acpower (KW)	*Compensated (KW)*	*Non Compensated (KW)*	3-phase Ampere (A)	1-phase Ampere (A)	
	MIXER MACHINE								
1. 1	**Mixer motor 1,2,3**	3x3x1				9	18		0.87
2.	**Sucker Motor 1,2,3**	3x2.2x1				6.6	6		0.88
3.	**Blower motor 1,2**	2x22x1			44		88		0.9
4.	**Blower motor 1**	1x37x1			37		74		0.9
	EXTRUSSION MACHINE								
5.	**Extruder main AC motor 1,2**	2x200x1			400		800		0.87
6.	**Extruder main AC motor 1**	1x280x1			280		560		0.87
7.	**Barrel cooling Fans 5 consecutive 1.3A**	29x0.75x1				2.75	6.75		
8.	**barrel Heaters- 1 (ø375x215)**	1x3.75x1		3.75				7.5	
9.	**barrel Heaters- 2 (ø340x390)**	1x10x1		10				20	
	MOLD (DIE) MACHINE								
10.	**Die lip-Heaters-1÷18- (ø 2090x85)x18pcs**	18x1x1		18				36	
11.	**Die shell - Heaters-1÷54- (ø 2000x150)x54**	54x1.5x1		81				162	
12.	**Die bottom-Heaters-1÷18-(ø1985x98)x18**	18x1x1		18				36	
13.	**Die bottom -Heaters-1÷12-(ø 1965x ø 1465x250)x12**	12x3x1		3.6				7.2	
14.	**Die - neck-Heaters-1,2-(ø 814x55)x2pcs**	1x2.2x2		4.4				18	
15.	**Die -Heaters-1÷4- (ø 984x90)x2pcs**	4x4x1		8				16	
16.	**Die -Heaters-1÷4- (ø 750x ø 550x200)x4pcs**	4x1.5x1		6				12	
17.	**Die -Heaters-1÷4- (ø 880x ø 450x250)x4pcs**	4x2x1		8				16	
18.	**Die -Heaters-1÷4- (ø 1530x110)x4pcs**	4x1.5x1		6				12	
19.	**Die -Heaters-1÷4- (ø 1530x110)x4pcs**	4x2x1		8				16	
20.	**Die -Heaters-1 - (ø 340x185)x1 pcs**	1x1.6x1		1.6				3.2	
21.	**Adapter -Heaters -1- (ø 120x200)x6pcs**	6x2x1		12				24	
22.	**Adapter -Heaters-1-(ø 160x160)x3 pcs**	3x2x1		6				12	
23.	**Adapter -Heaters-1- (ø 100x100)x1**	1x0.8x1		0.8				1.6	
24.	**Feeder-Heaters-1- (ø 216x100)x1 pcs**	1x1.6x1		1.6				3.2	
25.	**Feeder-Heaters-1- (ø 350x156)x1 pcs**	1x3.2x1		6.4				12.8	
26.	**Feeder-Heaters-1- (ø 360x50)x2x3 pcs**	6x0.7x1		4.2				8.4	
27.	**Feeder-Heaters-1- (ø 360x60)x2x3**	6x0.85x1		5.1				10.2	
28.	**Feeder -Heaters-1- (ø 206x350)x18**	18x3.4x1		61.2				122.4	
29.	**Feeder-Heaters-1- (ø 250x350)x8 pcs**	8x8.2x1		65.6				131.2	
30.	**Feeder-Heaters-1- (ø 250x250)x2 pcs**	2x5.9x1		11.8				23.6	
	HALL OFF MACHINE								
31.	**Hall Off AC motor 4pcs**	4x1.1			4.4		10.4		
32.	**Haul off adjuster**	8x0.75				6	12		0.75
	WINDING MACHINE								
33.	**Winder AC motor**	2x7.5x1			15		30		0.84
34.	**Roller**	1x2.2x1				22	45		0.84
35.	**Winder A&B DC motor**	2x7.5x1				15	30		0.84
36.	**Winder DC motor fun**	2x0.18x1				0.36	0.72		
37.	**Winder A&B DC motor Taco generator**	2x0.022				0.044	0.1		
38.	**Roller rotation**	1x0.55x1				0.55	1.15		0.84
39.		Rewinder	2x1.5 x1			3	6		
	Subtotal			351.05/3	780.4	59.26	1677.18	717.3	
	Total	962.66		=117					
	Speed variable load feeder, dc motor	0							
	compensated (heaters, ac drives)	44+37+400+280+4.4+15=780.4 +117=							
	Idle loads pump1/2of belling	6							
	Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off	9+6.6+2.75+22+15+0.36+0.55+3=59.26							

Table B 11 Load survey of Production Line eleven: Flat hose

No.	Location	*Nxwxn*	Load Type						
			KVA	Resistive load power (KW)	*Compensated (KW)*	*Non Compensated (KW)*	Ampere (A)		Power Factor
EXTRUSSION MACHINE									
25.	**Material sucker/ Feed motor**					**0.18**	**0.4**		
26.	**Material heater blower motor**	**0.155**				**0.155**	**0.3**		
27.	**Extruder main AC motor**	**37**			**37**		**72**		**0.79**
28.	**Main motor cooling fan**	**3**				**3**	**6.4**		**0.87**
29.	**Barrel cooling Fans 4 consecutive 1.35A**	**4x0.25x1**				**1**	**2.15**		
30.	**Barrel Heaters- 1 (ø375x215) 12 pcs**	**12x0.4x1**		**4.8**				**9.6**	
31.	**Barrel screen Heaters- 2 (ø340x390)**	**4x0.3x1**		**1.2**				**20**	
32.	**Material Heaters - 3 (ø340x380**	**1x4x1**		**4**				**8**	
33.	**Fiber adjuster motor**	**2x1.5**				**3**	**6**		
MOLD (DIE) MACHINE									
34.	**Die -Heaters-1- (ø 450x136)x1 pcs**	**1x4x2**		**8**			**8**		
35.	**Die -Heaters-2,3,- (ø 730x110)x4 pcs**	**2x2.4x1**		**2.4**			**4.8**		
WEAVING MACHINE									
36.	***Weaving* motor 4pcs**	**4x1.1**			**4.4**		**10.4**		
COOLING TANK MACHINE									
37.	**1st cooling Water pump motor 2pcs**	**1x1**				**1**	**2**		**0.88**
WINDING MACHINE									
38.	**Winder motor**	**2x7.5x1**			**1**		**30**		**0.84**
39.	**Roller**	**1x1x1**				**1**	**45**		**0.84**
Subtotal				**12/3**	**56.4**	**6.335**	**233.91**	**37.6**	
Total		**49.4**							
Speed variable load feeder, dc motor		**0**							
compensated (heaters, ac drives)		**37+4.4+1=42.4+4=46.4**							
Idle loads pump1/2of belling		**3**							
Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off		**0.18+0.155+3+1+1+1=6.335**							

Table B 12 Production Line twelve: Accessories and Recycle machines

No.	Location	*Nxwxn*	Load Type						
			KVA	Resistive load Active power (KW)	*Compensated (KW)*	*Non Compensated (KW)*	3-phase Ampere (A)	1-phase Ampere (A)	Power Factor
	COMPRESSOR MACHINE								
1. 1	Compressor motor 1,2	2x55x1				110	220		0.87
2.	Compressor fan Motor 1,2	2x2.2x1				4.4	8.8		0.88
	CHILLER MACHINE								
3.	Factory Inlet pump motor 1,2,3	3x11x1				33	66		0. 78
4.	Condenser inlet pump motor 1,2,3	3x7.5x1				22.5	45		0. 78
5.	cooling tower inlet pump motor 1.2,3	3x5x1				15	30		
6.	cooling tower fan motor 1.2,3	3x3x1				9	18		
	CRUSHER MACHINE								
7.	UPVC hammer crusher main motor	1x45x1				45	90		
8.	UPVC hammer crusher oil pump	1x3x1				3	6		
9.	UPVC crusher 1,2	2x55x1				110	220		
10.	UPVC Fine crusher/miller/ 1	1x45x1				45	90		
11.	Fine crusher/miller/ oil pump	1x2.2x1				2.2	4.4		
12.	Miller blower	1x5.5x1				5.5	11		
13.	Milling /pulverizer/ 1,2	2x37x1				74	150		
14.	Milling blower 1,2	2x4x1				8	16		
15.	HDPE hammer crusher main motor	1x55x1				55	110		
16.	HDPE hammer crusher oil pump	1x3x1				3	6		
17.	HDPE belt conveyer	1x2.2x1				2.2	5		
18.	HDPE crusher 1	1x75x1				75	150		
19.	HDPE crusher adjuster	1x0.55x1				0.55	1.2		
20.	HDPE crusher screw conveyer 1,2,3,4	4x2.2x1				8.8	18		
21.	HDPE crusher washing	4x2.2x1				8.8	18		
22.	HDPE crusher dewater	1x5.5x1				5.5	12.1		
23.	HDPE crusher blower	1x7.5x1				7.5	14.5		0.89
24.	Shower heaters 8pcs	8x3		24				48	
25.	Dryer heaters 8pcs	8x3		24				48	
26.	Factory lighting	100x1			100		200		
	Subtotal			48/3	100/3	652.95	1507.2	96	
	Total	<u>**605.85**</u>							
	Speed variable load feeder, dc motor	0							
	compensated (heaters, ac drives)	33.35+16=49.35							
	Idle loads pump1/2of belling	302.95							
	Variable loads mixer, sucker, cutter, fan, vacuum, &cooling pump, haul off	110+4.4+33+22.5+15+9+45+3+110+45+2.2+55+3+2.2+75+0.55+8.8+5.5+7.5= 556.65							

Table B 13 Manipulated data 1

	Resistive load 1phase	Compensated	Motor	Fans	Dc drives	compressor and pumps	Pups for Spraying	Sub total
	Compensated		**Not compensated**					
	1	0.95÷0.97	0.7÷0.85	0.75÷0.8	0.4÷0.75	0.75÷0.80	0.60÷0.65	Cos φ
1	*241.15*	*8.4*	*97.16*	*5.75*	*110*	*30*	*37*	*279.91*
2	*134.5*	*8.4*	*92.23*	*5.75*	*110*	*18.5*	*33*	*259.48*
3	*83.05*	*5.5*	*94.11*	*3.85*	*55.022*	*12.5*	*33*	*198.482*
4	*37.5*	*45.4*	*92.11*	*1.65*	*0*	*9.5*	*16.9*	*120.16*
5	*26.97*	*45.8*	*9.235*	*5.25*	*75*	*4.4*	*33*	*126.885*
6	*82.12*	*1.1*	*11.685*	*4.48*	*160*	*8*	*33*	*217.165*
7	*209.15*	*23.4*	*11.255*	*5.75*	*110.022*	*8*	*33*	*168.027*
8	*209.15*	*19*	*89.35*	*2.95*	*55.022*	*12.5*	*33*	*192.822*
9	*221.55*	*67*	*32.9*	*9.45*	*352.47*	*18.5*	*33*	*446.32*
10	*351.05*	*776*	*12*	*2.75*	*0*	*23.5*	*0*	*38.25*
11	*10*	*56.4*	*7.18*	*4.155*	*0*	*23.5*	*1*	*35.835*
12	*148*	*651.55*	*539.85*	*27*	*0*	*84.7*	*0*	*651.55*
total	*1754.19=*	*1707.95*	*1089.065*	*78.785*	*1027.536*	*253.6*	*285.9*	*2734.886*

Table B14. Manipulated data 2

	UPVC line 1	UPVC line 2	UPVC line 3	UPVC line 4	HDPE line 5	HDPE line6	HDPE line 7	HDPE LINE 8	Geo membrane 9	Green sheet 10	Flat hose 11	Accessories 12	Total
Compensated	249.55	142.9	88.55	82.9	72.77	83.22	232.55	228.15	288.55	1127.05	66.4	799.55	3462.14
Non compensated	*279.91*	*259.48*	*198.482*	*120.16*	*126.88*	*217.16*	*168.03*	*192.82*	*446.32*	*38.25*	*35.835*	*651.55*	2734. 9
total	529.46	402.38	287.032	203.06	199.65	300.38	400.58	420.97	734.87	1165.3	102.23	1451.1	6197.0

Table C 1 Equivalent flat rate tariff of EEU **Invalid source specified. [63]**

Annexure: - 3.1 (Ref. Clause 3.7 & 6.1(a))-Existing Consumer Categories and Billing Cycle

No.	Tariff Category & Block Identification	Monthly Consumption(kWh)	Billing Cycle
1	**Domestic**		Monthly
	Equivalent Flat Rate		
	1st Block	0-50	Monthly
	2nd Block	51-100	Monthly
	3rd Block	101-200	Monthly
	4th Block	201-300	Monthly
	5th Block	301-400	Monthly
	6th Block	401-500	Monthly
	7th Block	Above 500	Monthly
2	**General**		Monthly
	Equivalent Flat Rate		Monthly
	1st Block	0 - 50	Monthly
	2nd Block	Above 50	Monthly
3	**Low Voltage Time of Day Industry**		Monthly
	Equivalent Flat Rate		
	Peak		
	Off - Peak		
4	**High Voltage Time of Day Industry @ 15KV**		Monthly
	Equivalent Flat Rate		
	Peak		Monthly
	Off – Peak		Monthly
5	**High Voltage Industry @ 132KV**		Monthly
	Equivalent Flat Rate		
	Peak		Monthly
	Off – Peak		Monthly
6	**Street Lighting Tariff**		Monthly
	Equivalent Flat Rate		Monthly