# ENERGY PERFORMANCE ANALYSIS ON WATER SYSTEM AT SYARIKAT AIR MELAKA BERHAD IN LOJI AIR BERTAM, MELAKA

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**A report submitted in partial fulfilment of the requirement for the degree of Electrical Engineering (Industrial Power)**



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**MAY 2018**

" I hereby declare that I have read through this report entitle "Energy Performance Analysis on Water System at Syarikat Air Melaka Berhad in Loji Air Bertam, Melaka" and found that it has complied the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

| | |
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| Date | : 18th May 2018 |

I declare that this report "Energy Performance Analysis on Water System at Syarikat Air Melaka Berhad in Loji Air Bertam, Melaka" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

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Date : 18th May 2018

# DEDICATION

بسم الله الرحمن الرحيم

To my beloved parents, Abdullah bin Mat Husin and Manirah Ainun binti Mokhtar Ahmad for nursing me with affection and love and their dedicated partnership for success in my life.

To my respected supervisor, Prof Madya Ir. Dr. Md Nazri Bin Othman for his complete and endless guidance.

To my helpful friends for their endless support and help.

To my future soul mate.

# ACKNOWLEDGEMENT

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## ABSTRACT

Increasing energy cost and concern about global climate change highlight the need to realize energy self-sufficient in water distribution and treatment plant. A study on energy performance was conducted at Syarikat Air Melaka Berhad (SAMB) specification at Loji Air Bertam at Melaka to identify the most energy consumption system and proposed a method to reduce the energy consumption and to increase the system efficiency. Energy self-sufficient water system plant have been studied to reduce operation costs, energy consumption and system efficiency. By analysing the existing system in SAMB, the most energy contribution system is identified. After analysing the transformer`s load distribution and energy consumption, the inefficient performance of transformer is because of the low amount of load running by each transformer. The role of transformer is to step down the voltage and provide isolation between primary and secondary. High distribution voltage levels is then passed through distribution transformer before going down to end-use levels. The programming language used in this study is Matlab. By doing analysis on effect load on transformer, combination of load is a great way to achieve energy savings as the efficiency is increase. Future recommendation is proposed in this project.

# ABSTRAK

Kadar kenaikan kos tenaga dan kprihatinan terhadap perubahan iklim seantera telah memperjelaskan lagi keperluan untuk menyedari tenaga yang memadai di dalam penyaluran air and rawatan air Satu kejian terhadap terhadap prestasi tenaga telah dijalankan di Syarikat Air Melaka Berhad (SAMB) spesifikasi di Loji Air Bertam di Melaka untuk menilai system yang menggunakan tenaga yang paling banyak dan mencadangkan satu cara bagi mengurangkan penggunaan tenaga dan meningkatkan efisiensi. Tenaga yang memadai di dalam system air telah dikaji untuk mengurangkan kos operasi, tenaga penggunaan dan system efisiensi. Dengan menganalisa system yang sedia wujud di SAMB, system yang menggunakan tenaga yang paling banyak telah dikenal pasti. Setelah menanalisa pengagihan beban transformer dan penggunaan tenaga, prestasi transformer tidak cekap adalah kerana jumlah beban yang rendah yang dikendalikan oleh setiap transformer. Peranan transformer adalah untuk menurunkan voltan yang tinggi and membekalkan pengasingan antara bahagian pertama dan kedua. Voltan yang tinggi kemudiannya disalurkan melalui transformer pengedaran sebelum diagihkan ke pengguna terakhir. Bahasa program yang digunakan di dalam kajian ini adalah menggunakan perisian *MATLAB*. Melalui analisis yang dilakukan terhadap kesan beban terhadap transformer, penggabungan transformer adalah cara yang berkesan untuk mencapai penjimatan tenaga dengan meningkatnya effisiensi. Cadangan masa hadapan diteruskan dan dibincangkan di dalam projek ini.

# TABLE OF CONTENT

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| NO | SHORT FORM | STAND FOR |
|---|---|---|
| 1 | SAMB | Syarikat Air Melaka Berhad |
| 2 | EPA | Environmental Protection Agency |
| 3 | LAB | Loji Air Bertam |
| 4 | LAD | Loji Air Daf |
| 5 | FYP | Final Year Project |
| 6 | C-BT | Colorado-Big Thompson Project |
| 7 | UV | Ultra Violet |
| 8 | DAF | Dissolve Air Floatation |
| 9 | UFM | Ultra Filtration Membrane |
| 10 | PRV | Pressure Reducing Valve |
| 11 | SCADA | Supervisory Control and Data Acquisition |
| 12 | U.S | United State |
| 13 | GHG | Green House Gases |
| 14 | MG | Million Gallons |
| 15 | O&M | Operating and Maintenance |
| 16 | PV | Photovoltaic systems |
| 17 | kW | Kilo Watt |
| 18 | EAM | Engineering Asset Management |
| 19 | DAG | Dissolved Gas Analysis |
| 20 | IEEE | Institute of Electrical and Electronics Engineers |
| 21 | IEC | International Electrotechnical Commission |
| 22 | kA | Kilo Ampere |
| 23 | TNB | Tenaga Nasional Berhad |
| 24 | LV | Low Voltage |
| 25 | TX | Transformer |

# LIST OF SYMBOLS

| | |
|---|---|
| $I_S$ | Full load current |
| $S_{rated}$ | Power rated |
| $V_S$ | Secondary voltage |
| $Z_k$ | Impedance on short circuit |
| $Z(\%)$ | Percent impedance |
| $I_{sc}$ | Short circuit current |
| $\theta_{sc}$ | Short circuit power factor degree |
| $P_{SC}$ | Short circuit power |
| $V_{SC}$ | Short circuit voltage |
| $Z_{SE}$ | Series impedance |
| $R_{eq}$ | Equivalent resistance |
| $X_{eq}$ | Equivalent reactance |
| $P_{core}$ | No load (Core Losses) |
| $V_P$ | Primary Voltage |
| $a$ | Ratio of Primary voltage with Secondary voltage |
| $R_c$ | Resistance $R_c$ |
| $P_{cu}$ | Load (Copper Losses) |
| $P_{out}$ | Power output |
| $\theta$ | Degree of power factor |
| VR | Voltage regulation |
| η | Efficiency |
| PF | Power factor |

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.0 Overview

This chapter will focus more on research background, problem statement about what is going on with this project, what is really motivating to do this project, the overall scope on this project and most vital is the objective of this project.



## 1.1 Research Background

Syarikat Air Melaka Berhad (SAMB) is a company pledged in the management of water supply for Malacca state which are pledged for the treatment and responsible for portable water delivery in Malacca. Government have trusted and give a part to SAMB without negotiate the activity of Perbadanan Air Melaka. Government has a greater responsibility to manage and deliver an efficient water supply to the people in this country. There are three dams which are Durian Tunggal, Jus and Asahan which are built in order to fulfil the need of people in Malacca that can sustain maximum capacity of 75 billion cubic litres of water. In the other hand, Malacca has total of three main reservoirs which are Kesang Satu, Kesang Dua and Tasik Ayer Keroh and other smaller reservoirs and water facilities. For knowledge, the state are receiving 300 million litres of raw water from Sungai Malacca, and daily, it receives around 100 million litres from Sungai Gerisik in Muar and 54 million litres from Sungai Kesang.

Water can be allocate to have a portion of amount about 1360 million $km^3$ on the surface of earth and most of it sources are from seas and ocean up to 97%. About 37 million $km^3$ of total is fresh water [1]. All the water mostly are placed in inaccessible ground water around 8 million $km^3$ and lakes, streams and reservoir about 0.126 million $km^3$ [2].

The idea of the water system is to ship water from water treatment facility to consumers for use in domestic environment. Water system has two basic function which is primarily it needs to transfer enough amounts of water for consumer consumption requirements and secondly water system needs to be reliable which is the amount of water needed to be available 24 hours a day, 365 days a year. Every municipal water system need to have water supply source that is both adequate and reliable for the city to be served. The primary water source of water for area Ayer Keroh in Melaka is the dam located at Durian Tunggal.

People around the nations involve in many social activity and by receiving clean and safe water, they can having a secure life style and that is the reason why sustainable water management is vital. With the growing population, there will also be an increases in demands for drinking supply as water is essential in life and for other social needs too.



Reservoirs are refilled by many sources including stream flow, groundwater, snow, and/or rainfall. Various activity involve in daily life in social lifestyle including hydropower, irrigation, potable supplies, fishing and recreation that is the primary purposed of water storage and also to reduce the risk of flood and droughts [3]. The two reservoirs fund the water to a treatment plant which is impurities removal and chemical adding process take place to bring the water into compliances with the Environmental Protection Agency (EPA) regulations on clean water for domestic use. Then, the purified water is pumped to several different storage basins around the city for release into the delivery system piping network on demand for consumers use. To maintain adequate pressure in the water system during varying periods of consumers use, additional pumping stations are provided. Water are then flows to the primary, secondary and distributor main to supply services lines to individual water consumer.

Other than that, several steps are used to produce a supply of portable water. It need to be bear that each water supply has its own precise specification for organising portability. Step one is screening which is the water is passed through a series of screens built to get rid of debris and other foreign matter. Usually screens is used to prevent clogging and essentially removed for cleaning and backwashed from high pressure pumps. Step two is pre sedimentation which is while the water moves along each reservoir, the sediment such as sand and salt settles to the bottom. Step three is coagulation which is a coagulant (aluminium sulphate), is added to the water while it flows to the sedimentation basins.

## 1.2 Problem Statement

Human needs water. As do all the living life. Water for human consumption comes from some basic sources. Some of water comes from well to supply and individual residence, small public sector properties and small commercial enterprises and some of it also comes from municipal water systems that provide portable water to a wide array of commercial property and domestic use buildings. This project uses the Loji Air Bertam, Durian Tunggal as an example in order to introduce concepts associated with a fundamental understanding of water delivery systems detailed in water treatment plant and the energy performance of the system.

As the water reticulate daily for consumers demand, efficient transformer system for water treatment design had progressively been (growing) in importance as the usage of water resources increase as the population and industrial development rises. In the connection, the energy cost are growing rapidly. Based on energy consumption in transformer system with low operating load, step need to be taken as to reduce the energy cost. Analysis based on the existing system is taken and the suggestion for better transformer system operation is suggested. There are several problems in water pumping system which can brings effect to energy efficiency of water pump including unreasonable amount of load being transferred by each transformer in SAMB contribute to high amount of electric consumption generated in return brings effect to energy efficiency of water transfer system. In accordance, unsuitable amount of load in each transformer which in accordance creates a lot of losses in it makes cost maintenance higher, hence SAMB will increase the rate of bill to the consumer. To reduce the electricity consumption for energy intensive operation, the energy efficiency strategies are required and many method have been proposed from expert.

Many electrical facilities in the power distribution systems that are extremely sensitive and above all is distribution transformer which plays a specific and vital role in joining electric lines and client appliances. Inconsiderable number of distribution transformer contribute from sloppy mainframe of distribution transformer surge to problems in the economic operation of power systems [51].

## 1.3 Objective



The objectives of this project are:



1. To study the overall energy calculation usage on water system.
2. To study the behaviour of most energy contribution in clear water system and transformer performance.
3. To recommend the potential improvement for transformer`s efficiency and operating cost.

## 1.4 Scope

The project to be done at Syarikat Air Melaka Berhad, Loji Bertam Melaka. The data for the overall system performance are obtained from the Syarikat Air Melaka Berhad (SAMB) Malaysia. The premise referred as SAMB LAB.

The scope of work is to study closely the existing system operation occur in the premise and make observation about the energy wastages. The project will describe the overall system of the premise. Based on the overall description, the transformer performance system will be focused on and analyse in detail. The system of transformer is following the standard provided by SAMB. The efficiency affect the system performance and eventually low efficiency will give the high energy demand and contribute to an increase in overall cost.

Eventually, the purpose of this research is to estimate the load at a specific transformer capacity in the future, calculate the efficient load for optimizing the performance of transformer, calculate the cost consumption on existing transformer load and saving that can be achieved and operate the transformers in balanced and conscientious manner without failure.



## 1.5 Project Outline

The remainder of this project is organised as follows:

Chapter 2: Literature Review

The theoretical part about this project will be covered and discussed with detail about the water supply system performance. An intensive review on behaviour of system performance has been made along with the explanation.

Chapter 3: Methodology

In this part, it will covered with all project flow during to complete this Final Year Project (FYP) report. Overall of this chapter will be a milestone before start any of the experiment.

Chapter 4: Result and Discussion

All the report that has been recorded along the experiment are stated in this chapter.

Chapter 5: Conclusion

The conclusion on the project is made based on the objective.

# CHAPTER 2

# LITERATURE REVIEW

## 2.0 Introduction

Literature review has been done from the beginning of the project. The primary purposed of this process is to accumulate and search more knowledge and information needed to ensure that the project run smoothly and successfully. Since information and knowledge are needed throughout the development of this project, this process was very helpful continuously until this project reached its ending. Furthermore, there are still some important parts need to be researched clearly to ensure the functionality of the system. Overall, every important part in this researched are based on thesis from past researches, journal, theories, and articles.



## 2.1 History of Water Supply and Distribution

Nowadays, water stream into the residence in most of the world is intact to drink. The source of water is guarded against pollution and stream from various sources such as river flow and groundwater. In years before 90s, the world have been influenced with commonly dangerous disease which is known as deadly waterborne disease and during that time, intact drinking water have not exist yet. Table 2.1 below shows the history of the construction of water supply and its distribution since 1990.

Table 2.1: Timeline of water supply and its distribution [4].

| Year | Development |
|---|---|
| 1900 | **Chicago opens Sanitary and Ship Canal**<br>The main route of the sanitary and ship canal opens, it tend to reverse the flow of the Chicago river. Between Chicago and the town of Lockport, the 28-mile, 24-foot-wide drainage canal has been built by Illinois. Illinois is a person charged for the design to transfer water from Lake Michigan to sewage dumped from various sources. The project is directed by Rudolph Hering, chief engineer of the Commission on Drainage and Water Supply. |
| 1913 | **River Aqueduct in Los Angeles**<br>Once the construction Los Angeles-Owens River Aqueduct is finished it managed to bring up water to Los Angeles basin in distance of 238 miles from Owens Valley of the Sierra Nevada Mountains. William Mulholland, and immigrant from Ireland devised a system to bring the water by gravity flow. |
| 1914 | **Sewerage Practice, Volume I: Design of Sewers**<br>Leonard Metcalf and Harrison P. Eddy both were Boston engineers has published the American Sewerage Practice, Volume I: Design of Sewers, which explain in detail about the key professional obligation of engineers. |
| 1915 | **New Catskill Aqueduct is completed**<br>The new Catskill Aqueduct is expected to finish in December. This aqueduct able to transfer mountain water from west of the Hudson River to the water distribution system of Manhattan when this 92-mile long aqueduct joins the Old Croton Aqueduct system. With the speed of flow 4 feet per second, it manage to transfer out 500 million gallons of water daily. |
| 1919 | **Chlorination of urban water formula**<br>A formula for the chlorination of urban water supplies is proposed by civil engineer of the Maryland Department of Health in Baltimore. In 1908, sodium hypochlorite is used for chlorination, but there was no |

| | |
|---|---|
| | regulation of standards and correct amount to be used. To overcome this, analysis on the bacteria, acidity and factors related to taste and purity is studied. By the 1930s waterborne disease are manage to be eliminate by chlorination and filtration. The formula is still used today in all around the world. |
| 1930 | **Hardy Cross Method**<br>Hardy Cross, civil and structural engineer, has proposed a method for the analysis and design of water flow in simple pipe distribution systems while maintaining the water pressure. This technique enables engineers to produce tons of mathematical calculations correspond to distribute loads and moments in building complex structures without the benefit of computers. |
| 1935 | **Hoover Dam**<br>After five years in construction, the dam construction is completed and able to provide water for irrigation and municipal water supplies for Nevada, Arizona and California, and generates electricity for Las Vegas and most of Southern California. |
| 1938-1957 | **Colorado-Big Thompson Project (C-BT)**<br>The 13 mile Alva B. Adams Tunnel, brings the water under the Continental Divide, from a series of reservoirs on the Western Slope of the Rocky Mountains to the East Slope. It delivering 230k acre-feet of water annually to help flow more than 600k acres of farmland in North Eastern Colorado and to provide municipal water supplies and generates electricity for Colorado`s Front Range. |
| 1955 | **Ductile cast-iron pipe as an industry standard.**<br>Ductile cast-iron pipe is applied in water distribution systems. Due to its incredible characteristic, it has become the industry standard for the metal. |
| 1970 | **Aswan High Dam**<br>The Aswan High Dam which about 5 kilometre upstream from the original Aswan Dam (1902) is finished its construction. Lake Nasser, the world`s third biggest reservoir is formed with water impounds from this dam with capacity of 5.97 trillion cubic feet. The new dam |

| | |
|---|---|
| | provides Egypt with more than 10 billion kilowatt-hour of electric power every year. |
| 1980 | **Bardenpho process**<br>Known as the Bardenpho process is a process that transform nitrates in activated sludge into nitrogen gas then is pass out into the air. Generally, it dissolved a high percentage of suspended solids and organic material. This technique is develop by a South African engineer, James Barnard. |
| 1996 | **UV Waterworks**<br>And effective and reasonable device for water purification has been develop by a scientist at Lawrence Berkeley National Laboratory in California. UV Waterworks function as to render viruses and bacteria harmless which use ultraviolet light. Approximately a single unit can disinfect 4 gallons of water a minute which is satisfied to provide intact drinking water for up to 1500 people, at a minimal cost. |

## 2.2 Water Supply System in Malaysia

Malaysia has provide water supply to consumer around the world for many occasion in few years back. Table 2.2 below shows a flow of the history of water supply system in Malaysia.

Table 2.2: History of Malaysia water supply system [5]

| Year | Development |
|---|---|
| 1804 | In order to bring a clear stream water from hill to town, an aqueduct is constructed and it was made of bricks. For this purposed, water pipes were laid under the streets and then tin pipes is used to transport water to homes. |
| 1877 | The aqueduct was eventually change with a cast iron main because of the aqueduct`s bricks were often dislodged. First water main in Malaysia is in the Penang water supply network and the traces of it still exist. |
| 1906 | In Kuala Lumpur, a sand filter of Ampang intake was built for treatment process. |
| 1915 | A technology for treatment process which using hypochlorite are created and soon the gaseous chlorine are proposed. |
| 1950 | Malaya had around 1.15 million population and it needs to supply 195 million litres of water. In order to achieve this, Malaya had 100 treatment plant. |
| 1990 | Interstate water transfers from Sungai Muar, Johor to Durian Tunggal dam, Melaka. |
| 1999 | In total, there are 69 dams operate functionally in Malaysia. For water supply purposed there are 35 dams, for multi purposed, there are 16 dams and the rest are for irrigation and hydro-power generation. |

| | |
|---|---|
| 2001-2005 | The 8th Malaysia Plan is constructed in order to increase the water demand by 5.4% from 2001 to 2005 and for this project, RM 4 billion is allocated for this project. |
| 2006-2010 | The 9th Malaysia Plan is proposed to study the on water supply related project of total RM 8.1 billion specification of RM2.7 billion for new water project purposed. |

## 2.3 Type of Water Distribution System

### 2.3.1 Grid Iron system

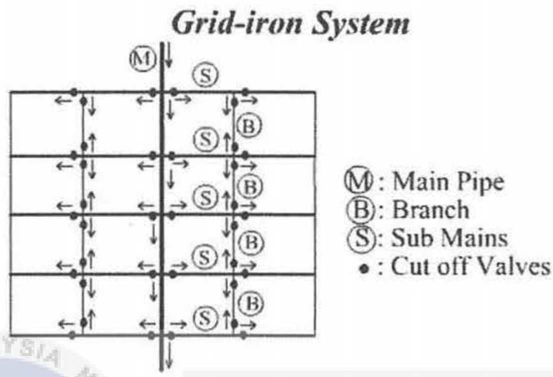



Figure 2.1: The Grid Iron system.



Figure 2.1 above shows the grid iron system. By having this type of connection, water are able at any point from more than one direction because all the pipe are interconnected with no dead ends. Stagnation are always occurred in many type of branching but not for this type. In case of breakdown in the pipe, as for this system which in interconnected, the system will keep on receiving water which will flow from the other side.

The whole process is mainly focused form the perpendicular path of the main supply pipes through the rectangular area to the sub mains take off [21]. In case of fire, the system will supply lot of water. Water reached all point with minimum head loss. As for the cost, pipe cost is quite high as it need more connection which requires more length of pipe and same with valve. Other than called grid iron system, the system also called as interlaced system [22].

### 2.3.2 Ring system

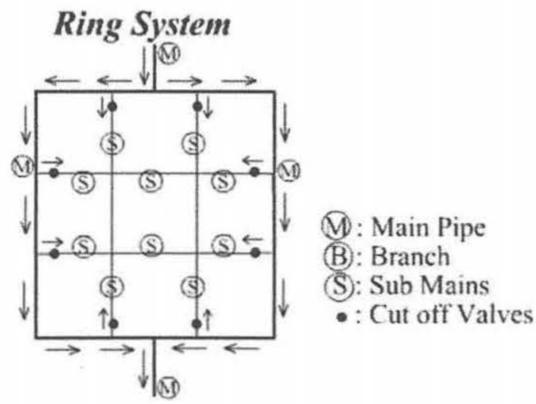



Figure 2.2: The Ring system.

Figure 2.2 above shows the ring system. If looked closely in the network system the connection is in circular form which the main supply form a ring around the distribution region. As can be seen in the figure, the main supply is on along the peripheral roads and from there, the branches are connected out through. The pipe determination is quite easy. The role of water in case of fire is the same with grid iron system which will lot of water are available. For the applications of this system, most of it is reliable for town or area having well planned streets and roads [22].

### 2.3.3 Radial system

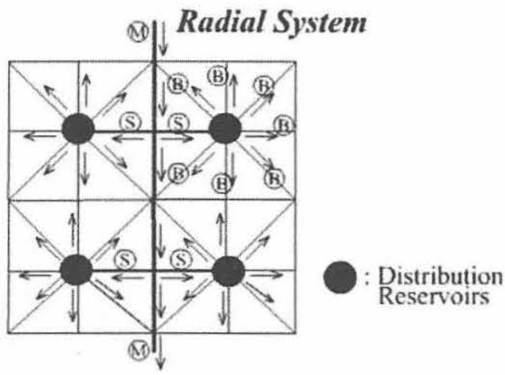



Figure 2.3: The Radial system.

Figure 2.3 above shows the radial system. All area in this system is divided into a number of districts and main distribution and sub-main is connected by only single path. For this type of system connection, the distribution reservoir is located at the centre of each district where pipe run radially and the water is then pumped into the reservoir. The system provides quick service and without huge loss of head. The calculation of pipe size is easy for this system. In terms of advantages, the system cost is reasonable and simple in planning, design and operation. The system also have disadvantage which is when a fault occur, all connected consumer will get affected. The system much gives fast services and without occurring lot of head loss [22].

### 2.3.4 Dead End system

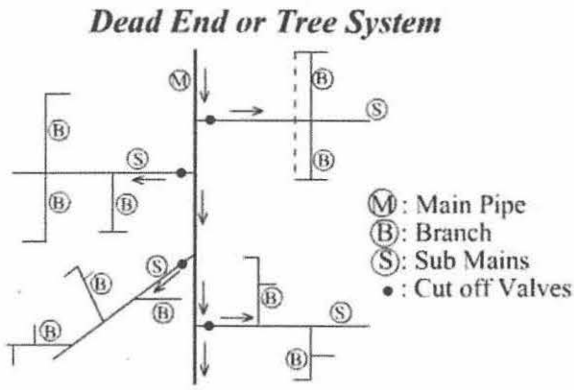



Figure 2.4: The Dead End or Tree system.

Figure 2.4 above shows the dead end or tree system. It is also called tree system as it identical to the branching of a tree. It consists of main line which is the source of water supply that runs through the populated region, sub-mains connected along the main roads and branches connected to sub-mains and are located along the streets [22]. In terms of pipe, the service pipe which connects the house with the main pipe have diameter of 100 to 200 mm [23]. The operational cost is minimum and number of cur-valves need also less. If construction happen to be in this type of connection, the receiving end from pipe will be without water until the work is finished. As for application, the system is not recommended as it less fortune in maintaining pressure. To overcome the head loss which is greater, large diameter pipe is needed.

## 2.4 Sustainable Water Management

### 2.4.1 Water Treatment System

Water treatment system are in various form and not necessary each will have the same pattern [6]. Some of the plant is commercial and clandestinely owned and maintained. In terms of design, they have goal in providing intact and trusted drinking water to consumer. The volume and type of treatment enforced by a public water system alter with the source type and quality. The major public health of the 20$^{th}$ century is disinfection in drinking water which is serious [6]. Lot process of treatment is used including filtration, flocculation and sedimentation in removing contaminants from drinking water.

In SAMB, water treatment process consist of several common process including coagulation, sedimentation, filtration and disinfection. In supplying clean and intact water supply for the use of consumers, the process are crucial. One of the new technology used by SAMB for greater water quality is called Dissolve Air Floatation (DAF). Flocculated particle and suspended solid is common impurity exist in water and micro air bubbles which is the main technique use in DAF process tend to attach to this impurity and float it up. Malaysia have two water treatment plants with intelligence water treatment technology. One is Air Bertam water treatment plant in Malacca with DAF technology and Sungai Rumput water treatment plant in Selangor with Ultra Filtration Membrane (UFM).

According to water treatment manager, chlorination process in SAMB has been improved by using electro-chlorination for their disinfection process instead of using conventional chlorination method. In term of productivity and water quality, electro-chlorination is more intact, reasonable and more adequate. In addition, the process can prohibit iron particles from dissolve into water for further filtration process. The water treatment process in SAMB can be seen in Figure 2.5.

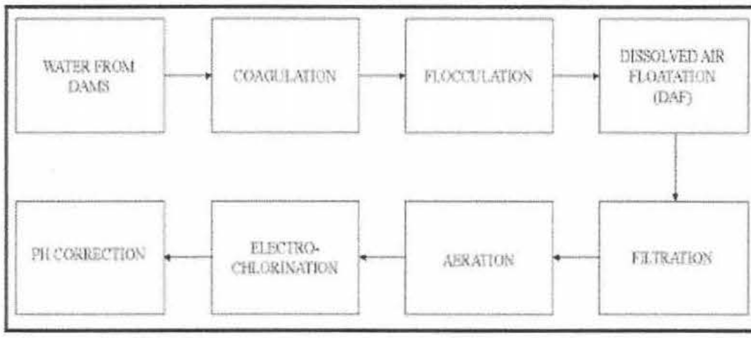



Figure 2.5: The water treatment system process in Syarikat Air Melaka Berhad (SAMB).

### 2.4.2 Water Distribution Management

In all distribution system, water loss is happen to occur in any kind of ways and the just the volume alter [7]. To overcome this problem, water companies are enforced to governing it. The problem might happen because of unsatisfied performance of pipe network. Water are sent to the consumer from water source facility where this process is handle by water distribution systems daily suitable with the water demand. During the hours that water being used for personal hygiene and house chores is when the water consumption is at highest whereas the water use is lowest during the night.

According to the engineer at SAMB, the pressure control is the cinch and a prompt method of saving water and reducing leakage. By governing the pressure at the peak time, large amount of water can be produced. The usage of water vary during day and night.

In process of water flowing from water distribution tanks to consumers, pressure maintaining is important. A logger is use in distribution network in determining the accurate required pressure. Data loggers enable SAMB to accumulate important information on their network achievement, from the stress of the pressure exert in the network, measure leakage and also certify the performance of Pressure Reducing Valve (PRV). The performance of Pressure Reducing Valve (PRV), leakage and pressure exert can be accumulate by data loggers. PRV is the main component in governing the pressure in the distribution network which is use in maintaining system pressure intactly below the desired limit in part of a hydraulic network system.

In terms of effective cost and leakage monitoring, it is mostly contribute by leakage auditing [7]. Distribution system consist of zones and leakage activity occurred in this particular zone is auditing by leakage auditing. Zone and district stream are should also be included in a flow measuring system in water distribution system. By this, engineer are able to run the system in small area and take control of the system. From previous research, leakage can be detected through various way and one of it is by complaint done by consumers. Through this method the leakage are being able to be detected in fastest way and the repairing process can be made quickly to avoid more losses.

SAMB has been using a system called Supervisory Control and Data Acquisition (SCADA in monitoring the water supply system. In this system, the auditing process is controlled by this system in terms of data delivery for many kind of parameters. By involved the system networking with SCADA, all operation in and out can be done precisely and adequate including easily detection on any problem occurred.

## 2.5 Energy on Maintenance of System

### 2.5.1 Energy Contribution

According to previous research, three to four percent of energy use comes from drinking water and waste water systems [8]. 56 billion kWh annually and generation of 45 million tons of greenhouse gases (GHG) is produced by this kind of energy portion. 25 to 40 percent of total energy is accounted from drinking and wastewater systems [9]. 80 percent are coming from cost of electricity [8]. Energy usage can vary on water source which include volume produced and service area.

Figure 2.6 below shows energy consumption for a usual drinking water system total of 1500 kWh/million gallons (MG) which are 100 kWh/MG for transmitance, 250 kWh/MG for treatment and 1150 kWh/MG for storage and distribution [10]. In supplying purpose, usually water system contribute to high energy consumption basically on its pumping system which is about 1800 kWh/MG chiefly [8]. As we aware that pumping system consuming a large amount energy and is it approximately accounts for 90-99% of overall energy used in water system [11].



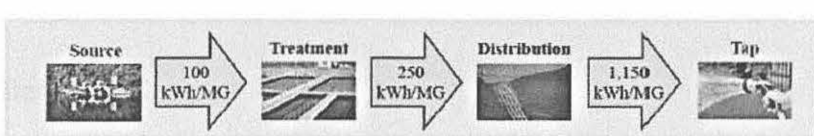



Figure 2.6: Average Energy Consumption in a Drinking water system

### 2.5.2 Energy Efficiency

In this globalisation era, entry to consolidate various kind of water systems is express a standard commodity. Water systems confront many defiance including increasing threats to watersheds and aquifers, changing consent and public-health standards, shifts in population (growth and loss) and greater customer prediction. In maintaining the quality of water supply and growing water demand, water industry has become one of the world largest industry for treating material [14 As it grows further and bigger, lot of energy is being used and many kind of studies have been proved that high energy efficiency can contribute to low energy used [12][13][14]. A lot of method have been proposed for energy efficiency implementation as it will increase water system sustainability in industry.

In water system industry energy efficiency can be achieve with the contribution of the staff, operating maintenance (O&M), improved the existing technology treatment and community outreach. Some system available with photovoltaic systems (PV) technology which is one of method to attain energy efficiency which is its applicable inside the plant by adequate of installation [15]. Various way are available for energy saving in order to save money by taking advantages of energy adequate opportunities including energy audits, water accounting and many more.



### 2.5.3 Benefit of Energy Efficiency

Above all the benefits that the system can get that most precious is money saving. Energy consumption in running water system can be huge and exemplify certain portion in system`s operating budget and eventually consume high cost. The water sector consume huge amount of energy for an ample of reasons along with system enlargement correspond with many purposed. New treatment plant and intensive energy treatment are the result of that kind of purpose which are including population expansion and new or revised regulations. By improving energy efficiency, same level of service and water quality will be achieve requiring less energy used.

The activity of existing infrastructure can be extends with energy efficiency. System sustainability is devotes by assimilate practice of energy efficiency into daily routine process and overall system planning. Water systems are more attuned to the overall state of their infrastructure by auditing equipment for energy efficiency and can proactively take steps to make sure equipment is function adequately. In turn, this steps lessen equipment strain and minors operation and maintenance demand.

Next, energy efficiency reduce greenhouse gas (GHG) emissions. Direct impact can be seen on GHG emission cut as reducing the energy consumption. A number of municipalities and states over the world have entrenched action to reduce carbon footprints and GHG emissions. Drinking water and wastewater systems plays a vital part in meeting this goals.

Customer expect a good result in water they paying for and by having high energy efficiency in water system in industry, the water system eventually will operate more efficient and this will enhance the customer relationship in a good feedback.

Study in America has been made that shows 95% of water rate are mostly vital than compared to other service [16].



## 2.6 Type of Water Pump

There are various type of pump and motor used in water supply and distribution system such as low-lift pumps, high-lift pumps and booster pumps. Low-lift pumps function as to lift the surconfront water at large volume and bring it to nearby treatment plant at relatively low discharge pressure. High-lift pumps function as discharge treated water into arterial mains while booster pumps raise water into an elevated storage tank and increase the pressure within the distribution system. In addition, most pump used in water distribution system are of the centrifugal type and positive-displacement type. Both type of pumps follow the same purpose of life, which is to move water from one centre to another continuously. Both pumps have a wide range of variety of options that useful for project specific needed. Study in solar pumping system plays an extensive aspect in efficiency of water system and by this case, they applied the modular centrifugal pump with variable speed. The depth height in 100 m and they applied 30 $m^2$ PV systems and 46 stage commercial submersible pumps with payback period around 0.5 to 2.5 years.

So many type of pump can choose from and most of them are widely used around the world. Mainly water pumps used for dewatering purpose and bring water from one point to another continuously. Pumps are frequently used to bring water from a bore or water stream (creek, river) to a water storage at a greater elevation, or to pressurise the water system to deliver it through a pipeline around the feedlot [17]. Pumps used in water distribution system and mostly in water treatment system which is focused in this project should be evaluated based on performance, low downtime, durability and price. To be cleared on the type of pumps that are suitable to use in water treatment system, better understanding will be important to increase the durability of pump, reduce operational cost and eventually increase systems overall performance.

Variant type of applications acquire variant types of pumps. Pumps are chosen based on system requirements, discharge pressure, flow capacity, and availability of space [18]. The design considerations in a pressurised system include pump type (centrifugal, turbine and positive displacement), pump capacity (single, multi-pump, distance and volume of water to be transferred) and pump control (automatic pressure, timed, manual) [17]. The types of pumps usually found in water distribution systems are centrifugal pumps, vertical turbine pumps and submersible pumps.

Centrifugal pump type is commonly used in water distribution industry in which it has rotating impeller which function as adding the energy to the water flow and raise pressure inside the pump casing. Some industry use diesel fuel to power the motor in pumping system which in return will rotates the shaft. Water flows in centrifugal pump by opening centre called suction and form this part, rotating impeller will take over which convey a high velocity to the fluid and circulated and pitch outward. The flow rate depends on the pressure against which it runs. The greater the pressure, the minor the flow or discharge. Vertical turbine pumps are frequently used at raw water intakes and at booster stations in the distribution system. The water stream vertically through a route or uniform cross-sectional area. In this pumps, water stream flows through a cross-sectional route area. The impeller is placed in the centre along the axis and impeller`s blade are carved so that the water stream in a radial direction. As for positive-displacement pump, it deliver a fixed quantity of water and water is pushed or displaced form pump casing. The pressure exerted in the system not affected the flow capacity when the water runs.

Usually deep mines water system used centrifugal pump with capacities range between 2 and 10 MW [19]. With the application of centrifugal type of pump in this system, it contribute to 42% of overall electricity usage [20].

## 2.7 Transformer

Transformer in SAMB LAB step down the high voltage to low voltage. As in specification, transformer with capacity 1250kVA in SAMB LAB step down voltage of 11kV to 6.6kV as the motor that running the pump complies with the low current produce. Size of coil use in stator of the motor will be small as to produce power to the pump with low current. Transformer 1500Kva step down the current from 11kV to 0.433kV as the load is using the standard voltage for residential. Cable use in load transmission from the transformer is using the size that adequate with the amount of current flowing from the stepping down process of voltage. Power system complies of power transmission network which one of the cynical assets are power transformer. Power transformer subsist a complex system. Transformer complies of a winding sometimes two or more windings, with or without magnetic core which for inducing mutual coupling between circuits [38]. Transformers plays an important role in the operation in electricity transmission and grid system which the while operation affect the operation of linked components. They complies with miscellany of inner manufacture item basically metals and plastics. Materials plugged within oil-immersed transformer consist of insulating fluids complies with dielectric and thermal characteristics whereas in dry-cast transformer the inner components are sheathe with polymeric resin [39]. Transformers condition when it related to high temperature, emergency overloading and continuous operation in outdoor environment if not controlled can create huge failure [48]. Transformer`s efficiency is calculated like any other equipment by the ratio of output power and input power. It has high efficiency as it has no rotating part where stays above 95%. Even a small changes in efficiency will give compelling energy savings.

Losses in transformer can be divided into two different parts which are no load losses can be said as core losses and on-load losses known as winding losses [50]. No load losses always stays constant and contributed from energy consumed from magnetizing part and eddy currents flows in transformer`s iron plates. On-load losses vary by the transformer`s loading and comes from the winding of transformer from both primary and secondary windings in form of heat losses. When on-load losses and no-load losses are equal, efficiency of a transformer is at maximum stage. With the important role of the power transformer, if it happen to have a deterioration may create plunge downfall and fatal knockout in the power grid. A lot of problems can occur due to transformer`s failure such as disturbance in operating systems. This problems creates huge maintenance cost and long term recovery for the bruise components [49]. The essentiality of rising authenticity of power transformer can be analysed deeply from a financial point of view [52]. Facts have stated that between year 1997 and 2001, there were overall losses caused by power transformer downfall in the US with an amount of 286 million [24]. The waning population of power transformer has a development increment since 1975 [25].



As aware, transformer is the most vital equipment of the electricity distribution network and if any failure causes by it will interrupt the power supply and lower the performance of power supply [36, 37]. Power transformer`s engineering asset management has been developed and applied for decades all around the world. Parkes has proposed on the concept of engineering asset management (EAM) in earliest [33]. EAM has purposed of developing optimization strategy regarding the performance, risk and expense modelled over the life cycle of asset management [34]. Transformer`s physical condition can be monitored through on-line system for maintenance decisions as during the operating conditions, frequently chemicals are generated inside the transformer. As for diagnosis the fault of transformer, Kelly has used dissolved gas analysis (DGA) along it [32].

In electrical power system, power transformer happen to be the most extravagant and the key components by interconnecting the power transmission and distribution system [46, 47]. Generation, transmission, distribution and performance of electrical energy in power system has linked with transformers. Series of test are performed on behalf of transformer to adequate the performance of that particular transformer in accordance with IEEE or IEC standards before it enter the market [40-43]. Commonly applied test that been perform on transformers are no-load and open-circuit test which eventually will produce series of data points at different excitation voltage levels, with rms current and active power. No-load losses although small, it is contributing on transformers energy losses as long as the transformer is empowered [44, 45].

## 2.8 Problem Affecting the Energy Performance

As transformers is an important equipment to power system, a failure occur in this system can creates a lot of upcoming effect and preventive maintenance has to be addressed to extend the lifetime of this equipment. Various research has develop the many kind of maintenance models to address the problem of power transformer maintenance [52]. A problem has been addressed on the power transformer as an effect of the unscheduled outages which the result is on losses occur also inconveniences for residential consumers [31]. In meantime, a method has been develop to increase the life span of power transformer also the annual cost by Aldhubaib and Salama where a reliability centred maintenance and stand-in access has been popularized for care escalation and replacement [26]. In Markov, Dhople et al. has comes out with an idea of capturing the uncertainty on the reliability with a set-theoretic model and a reward model for magnify the accessibility of power transformers [27]. A system has been develop from a techno-economic perspective to determine the life expectancy of transformers [28]. Lima et al. has designed a framework for power transformers considering the loss for life which influenced by overload conditions [29]. A model also have been develop to optimize the serviceability of power transformer by Abiri-Jahmori et al. [30].

Performance, reliability and life spans of transformer can be enhance and an idea of condition based maintenance has been introduced by Arshad, Islam and Khaliq [35]. For a specific transformer capacity, kVA can be determined using specific equation that are depends on the basic transformer parameters which are phase, voltage and current of the load. Transformer circuit can be hardly conduct if the installer is lack of understandings of transformer fundamentals as the units consist of dry-type. For the protection of a transformer, a device of an overcurrent can be put on the primary side which is not more than 1.25 times the primary full-load current [53]. Overcurrent is a serious issue and to protect the transformer from it, an adequate supply of electrical wires is necessary. This measure takes the ampere rating to be considered when sizing the overcurrent protection devices for transformer.

Transformer has no internal moving parts and one of the highly efficient electrical devices. Transformer being used for it capability of the voltage changing measures and it use electromagnetic induction as a medium for energy transportation from one point to another [54]. The usual optimum full load efficiency of transformer is between 95% to 98.5%. The key for efficient transformer is when the output and input are nearly having the same value.

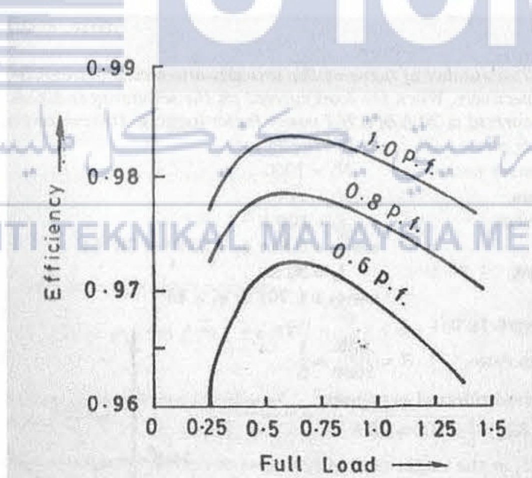



Figure 2.7: Variations of efficiency with power factor at different loadings.

Transformer are design to be in its maximum efficiency at 50% of loading and through the overall region of load as in Figure 2.7 window of 50% to 60% if at the optimum operation [55]. Moreover, other measure of failure can be classified as electrically, thermal and mechanically [54]. Studying the performance and status of transformer during their process has an important role to prevent any possible defect.

# CHAPTER 3

# METHODOLOGY

## 3.0 Research Design

To accomplish the objective of this study, a few stages of procedure will be conduct accordingly to the enlisted methodology. This series stage of methodology is done to assure that the research will be successfully meeting the objectives. The first stage is data collection based on the existing system that need to analyse. Once all the data have been collected, next is data sample preparation which is the data is tabulated and characterizes to study the performance on the existing active system according to specification provided by SAMB. By having all the data sample preparation, the transformer energy performance is then further analyse using software which is Matlab. After that, several improvement suggestion is made based on calculation. The Research Methodology Chart of the study is shown in Figure 3.1

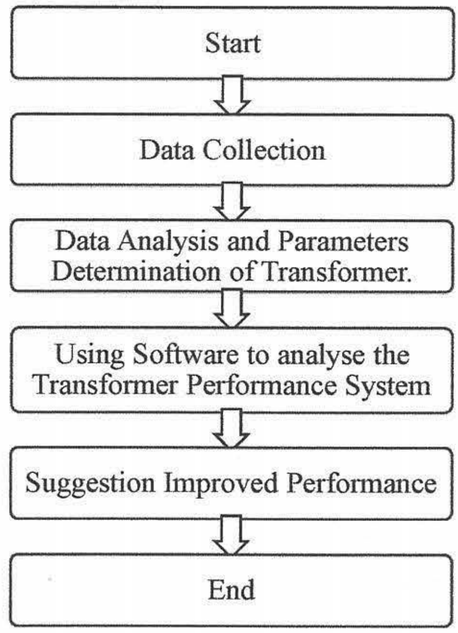
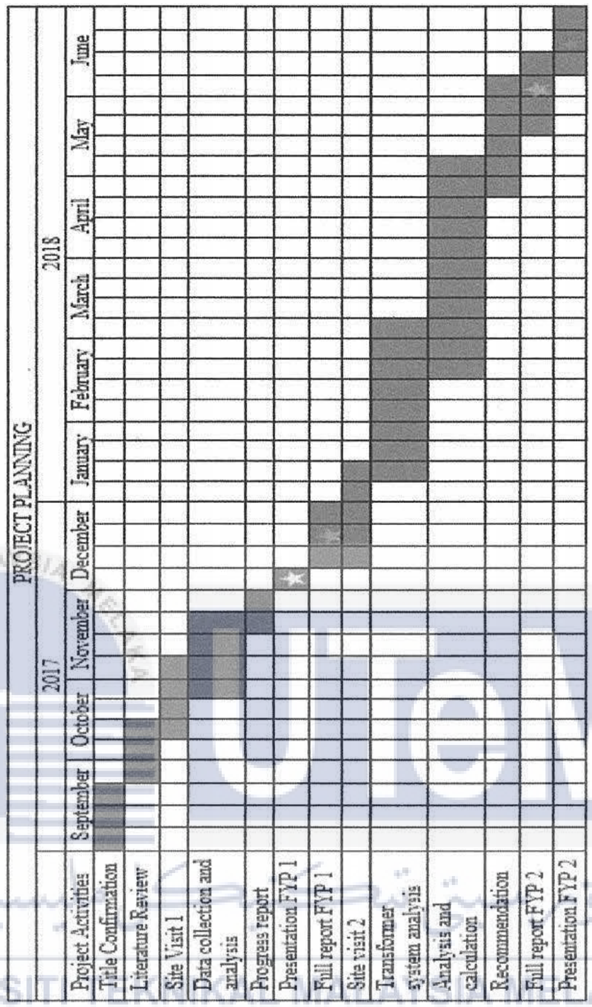



Figure 3.1: Research Methodology Chart

## 3.1 Gantt Chart






Milestone:

★ Presentation FYP 1 = 27th November 2017

★ Full Report FYP 1 = 22nd December 2017

★ Full Report FYP 2 = 18th May 2018

★ Presentation FYP 2 = 21st May 2018

Figure 3.2: Gantt chart for the Project Planning FYP 1

In figure 3.2, the Gantt chart is a timeline that is used as a project management tool to illustrate how the project will run. It is also used to organize project flow to finish each task correspond to the time frame given. Failure to finish the work in time will drag time and reduce successful of the project.

## 3.2 Overall Flowchart

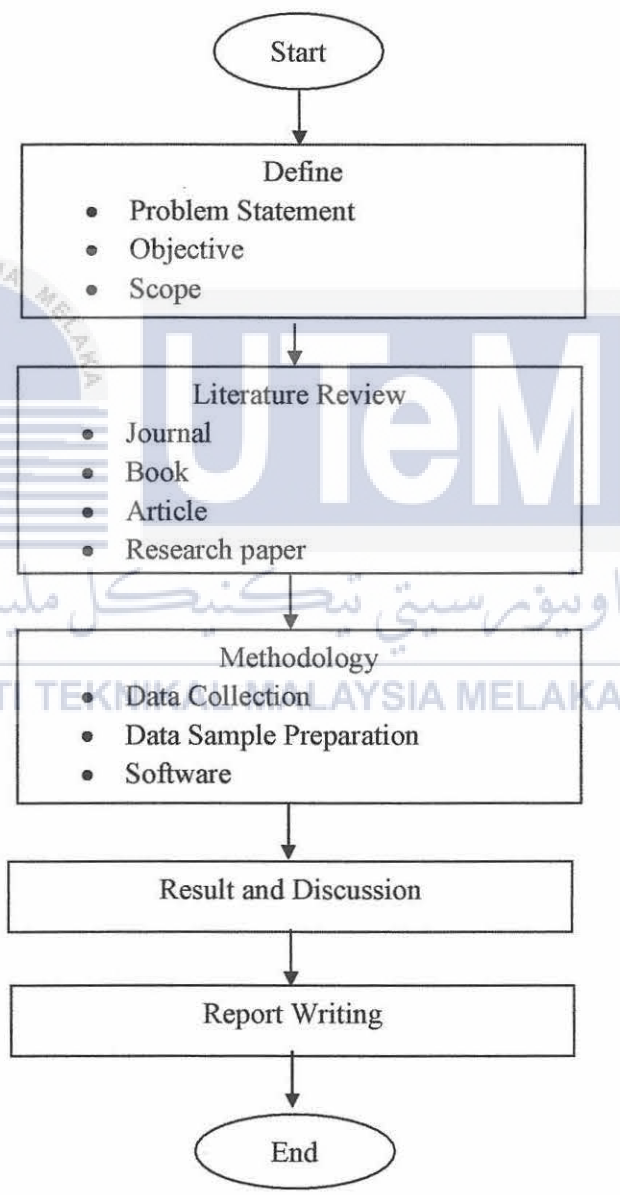



Figure 3.3: Flowchart of the project methodology.

## 3.3 Technical Research

Basically, the research throughout this project included the correlation between mechanical, electrical and control mechanism. The calculation and theory are related towards each other. The information accumulated in this project are came from journal, book, article and research paper. This project is branched into 2 league which are:

1. Data collection
2. Simulation

Data is tabulated in words and the graph of efficiency and voltage regulation is based on the table.

### 3.3.1 Data Collection

After collecting the prescribed data, the calculation of the system parameters in done by using the following formula. To perform the efficiency and voltage regulation curve, the primary parameter needed is power load and power no-load losses. The value however can get from the manufacturer description and by getting the prescribe value, all the calculation to get the remaining parameter value can be performed. The calculation in this project involve three transformer ratings which are 750kVA (11/0.433kV), 1250kVA (11/6.6kV) and 1500kVA (11.0.433kV).

$$I_{full\ load} = \frac{S_{rated}}{V_{S,rated} \times \sqrt{3}} \tag{3.1}$$

$I_{full\ load}$ = Rated current at full load, (A)

$S_{rated}$ = Power rated, (kVA)

$V_{S,rated}$ = Secondary voltage, (V)

$$Z_k = \frac{Z(\%)\ X\ V_{S,rated}{}^2}{S_{rated}} \tag{3.2}$$

$Z_k$ = Impedance on short circuit, $(\Omega)$

$Z(\%)$ = Percent impedance, (%)

$$I_{sc} = \frac{V_{S,rated}}{Z_k \text{x} \sqrt{3}} \tag{3.3}$$

$I_{sc}$ = Short circuit current, (A)

$$P_{load} = I_{\emptyset}{}^2 R_{eq} \tag{3.4}$$

$P_{load}$ = Load power, (W)

$I_{\emptyset}$ = Phase Current, (A).

$R_{eq}$ = Equivalent resistance, $(\Omega)$



Calculation in per phase:

$$S_{\emptyset} = \frac{S_{rated}}{3} \tag{3.5}$$

$S_{\emptyset}$ = Apparent power in per phase, (kVA).



$$P_{load}\ losses = \frac{P_{load(3\emptyset)}}{3} \tag{3.6}$$

Calculation of transformer in delta-connection:

$$V_{L-L} = V_{\emptyset} \tag{3.7}$$

$$I_{L-L} = I_{\emptyset}\sqrt{3} \tag{3.8}$$

$V_{L-L}$ = Line to line voltage, (V).

$I_{L-L}$= Line to line current, (A).

Calculation of transformer in wye-connection:

$$V_{L-L} = V_{\emptyset}\sqrt{3} \tag{3.9}$$

$$I_{L-L} = I_{\emptyset} \tag{3.10}$$

$$\text{Impedance (\%)} = \frac{V_{drop}}{V_{\emptyset}} \tag{3.11}$$

$V_{drop}$ = Voltage drop, (V)

$V_{\emptyset}$ = Phase Voltage, (V).

$$Z_{eq} = \frac{V_{drop}}{I_{\emptyset}} \tag{3.12}$$

$Z_{eq}$ = Series impedance, $(\Omega)$



$${Z_{eq}}^2 = {R_{eq}}^2 + {X_{eq}}^2 \tag{3.13}$$



$X_{eq}$ = Equivalent reactance, $(\Omega)$

$$\frac{V_P}{a} = V_S + R_{eq} I_S + jX_{eq} I_S \tag{3.14}$$

$V_P$ = Primary Voltage, (V)

$a$ = Ratio of Primary voltage with Secondary voltage

At different load:

$$I_{s,rated} = \frac{S_{rated}}{V_{S,rated} \times \sqrt{3}} \quad \text{x} \quad \text{(Load)} \tag{3.15}$$

$$P_{cu} = \left(I_{s,rated}\right)^2 R_{eq} \tag{3.16}$$

$$P_{core} = \frac{(V_P/a)^2}{R_C} \tag{3.17}$$

$P_{core}$ = No load (Core Losses) ,(W)

$R_c$ = Resistance $R_c$, (Ω)

$$P_{cu} = \left(I_{S,rated}\right)^2 R_{eq} \tag{3.18}$$

$P_{cu}$ = Load (Copper Losses), (W)

$$P_{out} = V_S \, I_S \cos\theta \tag{3.19}$$

$P_{out}$ = Power output, (W)

$\theta$ = Degree of power factor, (°)



$$\text{Power losses} = P_{cu} + P_{core} \tag{3.20}$$

$$P_{in} = P_{cu} + P_{core} + P_{out} \tag{3.21}$$

$$\text{Percentage losses} = \frac{P_{cu} + P_{core}}{P_{in}} \text{ x } 100\% \tag{3.22}$$

$$VR = \frac{V_P/a - V_{S,fl}}{V_{S,fl}} \text{ x } 100\% \quad (3.23)$$

VR = Voltage regulation, (%)

$$\eta = \frac{V_S I_S \cos\theta}{P_{cu} + P_{core} + V_S I_S \cos\theta} \text{ x } 100\% \quad (3.24)$$

η = Efficiency, (%)

Energy consumption, (kW) = (Percent Load x $S_{rated}$ x PF) / Efficiency (3.25)

PF = Power factor

Cost consumption, (RM) = Energy consumption (kW) x Number of hours per day x Number of running times per year x Electricity cost per kWh

(3.26)



Total cable cost = Price per meter (RM) x Distance from low load to high load transformer (m)

(3.27)

Total initial investment, (RM) = Cable cost + Labor cost (3.28)

Savings,(RM/year) = Cost consumption of combine transformer with different load – Cost consumption of one transformer with new load

(3.29)

$$\text{Cash inflow per period, (RM/month)} = \frac{\text{Savings (RM/year)}}{12 \text{ months}} \tag{3.30}$$

$$\text{Payback period (month)} = \frac{\text{Initial investment (RM)}}{\text{Cash inflow per period (RM)}} \tag{3.31}$$

### 3.3.2 Simulation

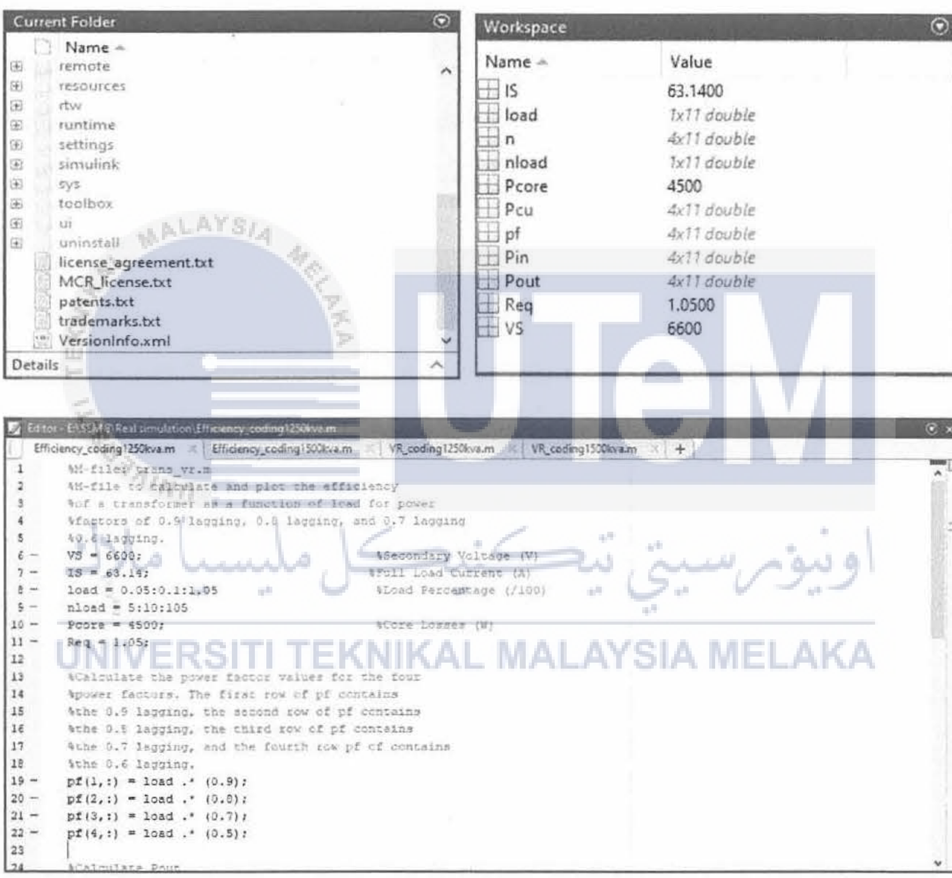





Figure 3.4: Data of transformer system recorded in Matlab Software

Figure 3.4 shows how data is recorded in Matlab Software. This software function as to record and calculate the variety of data of transformer system including all the parameter of the transformer. Firstly, load losses and no load losses are need to be consider above of other parameters in performing system curve. Load losses is depends based on the transformer`s loading which also contain the heat losses and eddy currents. Heat losses plays the largest amount of the load losses. No load losses comes from magnetizing current which to energize the core of the transformer. After all the parameter is calculated, the system curve can be tabulated. By inserting all the parameters in the specific coding, the value for the data needed will comes out in form of graph. Detailed observations on the graph is done in getting the specific value.

The system in running for several power factor which is from 0.6 PF, 0.7 PF, 0.8 PF and 0.9 PF. Through the graph simulated, the maximum efficiency of the system can be obtained and being compared with the existing load efficiency. Thus, the most efficient varying load can be take into account. The primary purpose of load varying efficiency is to bring the small amount of load from one transformer into another transformer which will reduce the amount of transformer running. If a transformer running at a maximum efficient load, high efficiency system will run and thus reduce amount of cost generated. Usually the transformer efficiency curve is provided by the manufacture but due to some circumstances, the system curve is define manually.

# CHAPTER 4

# RESULT AND DISCUSSION

## 4.0 Introduction

This chapter shows the data, tabulated and analyse that have been collected during this project. The data recorded are based on SAMB technician, engineer, water treatment manager and document recorded by SAMB.



## 4.1 Data Collection

### 4.1.1 Data of the Electrical Distribution

The premise receive its High Tension (HT) 11kV electricity supply from Tenaga Nasional Berhad (TNB) through single metering point and step-down to Low Voltage (LV) through step-down transformer. Electricity supply is distributed via the Main Switch Board for SAMB LABLAD and Main Switch Board for DAF. Table 4.1 and table 4.2 below show the detail of the distribution end-loads for SAMB LABLAD premise [56]. This data is obtained from the LABLAD report audit by SAMB [56]. Table 4.1 specifies the location of the transformer`s load for Loji Air Bertam (LAB) and table 4.2 specifies the location of the transformer`s load for Loji Air Daf (LAD).

Table 4.1: Summary of SAMB LAB electrical distribution [56].

| | **TX1** | **TX2** | **TX3** | **TX4** | **TX5** | **TX6** |
|---|---|---|---|---|---|---|
| **No** | **LAB** | | | | | |
| 1 | KUBOTA PUMP | WEIR 12 MGD PUMP | WEIR 5 MGD PUMP 1 | PCM | OFFICE | WEIR 8 MGD PUMP |
| 2 | | | WEIR 5 MGD PUMP 2 | | | |

Table 4.2: Summary of SAMB LAD Electrical Distribution [56].

| | **TX1** | **TX2** | **TX3** | **TX4** | **TX 1500KVA** | **TX COMPACT** | **TX 1500KVA** |
|---|---|---|---|---|---|---|---|
| **No** | **DAF 1** | | | | **DAF 2** | | |
| 1 | PUMP 900 & 700 | PUMP 900 & 700 | | | PUMP 200kW | | PUMP 200kW |

### 4.1.2 Data of the Compressed Air System

The premise air compressor demand is being supplied by separate compressed air systems for every building. Compressed air is used in back wash operation in SAMB LAB. Table 4.3 below shows detail air compressor system specification in SAMB LAB [56]. There are total of 5 air compressor operate in SAMB LAB with the same model, type and rating. The quantity of air compressor for each location are different as the load operating power is different for each location. Compressor consume about 435kWh of energy in the overall system. By this amount, in percentage it is about just 3% which is minor. The usage is not really affect the cost consumption

Table 4.3: Air Compressor System used in Bertam Lama Water Plant [56].

| **No** | **Location** | **Model** | **Type** | **Rating , (kW)** | **Quantity** |
|---|---|---|---|---|---|
| 1 | Kubota Pump House | Hitachi | Piston | 7.5 | 2 |
| 2 | Clear water tank | Hitachi | Piston | 7.5 | 1 |
| 3 | Gallery | Hitachi | Piston | 7.5 | 3 |
| 4 | Weir Pump House | Hitachi | Piston | 7.5 | 2 |
| 5 | Filter | Hitachi | Piston | 7.5 | 3 |
| Total Installed | | | | | 11 |

### 4.1.3 Data of the Air Conditioning System

The air conditioning at the SAMB LABLAD premise is mainly being used in the offices or control rooms in the pump house. The Air-conditioning system is mainly of Air- Cooled Split Unit. Table 4.4 below shows the type of model of the air conditioning being used in Bertam Lama Water Treatment Plant together with the rating and quantity used [56]. There are total of 6 air conditioning operate in SAMB LAB with different model, horse power, type and rating. The quantity of air conditioning for each location are different as the load operating power is different for each location. Air conditioning consume about 751.65kWh of energy in the overall system. By this amount, in percentage it is about just 4% which is not really huge. The usage is does affect the cost consumption but when compared to others, it is not the huge system that affect the cost consumption of the overall system.

Table 4.4: Air Conditioning system used in Bertam Lama Water Plant [56].

| No | Model | Rating, (kW) | Quantity |
|---|---|---|---|
| 1 | Wall mounted 1.5 HP | 0.75 | 1 |
| 2 | Wall mounted 1.5 HP | 1.12 | 8 |
| 3 | Wall mounted 2.0 HP | 1.49 | 5 |
| 4 | Wall mounted 2.5 HP | 1.86 | 2 |
| 5 | Ceiling Cassette 2.0 HP | 1.49 | 3 |
| 6 | Ceiling Cassette 3.0 HP | 2.24 | 2 |
| Total | | | 21 |

### 4.1.4 Data of the Lighting system

Most of the SAMB LABLAD lighting type is Fluorescent (FL) T8 36W with 70%, Spot light Incandescent Lamp (I) 220W with 4%, CFL down light 18W with 9%, High mast Incandescent Flood light Incandescent Lamp (I) 1000W with 6%, and street light Incandescent Lamp (I) 150W with 11% from total installed lighting of 324 tubes. SAMB LABLAD also has a list of the lighting installed for each block (Appendix B). Table 4.5 below shows summary of quantity and type of lighting installed at Bertam Lama Water Plant [56]. There are total of 5 type of lighting use in SAMB LAB with different model and rating. The quantity of lighting used for each location are different for various type of location where the lighting system are placed. The more quantity of lighting indicates the flux intensity of the location. Lightning consume about 283kWh of energy in the overall system. By this amount, in percentage it is about just 2% which is less. The usage is not really affect the cost consumption.

Table 4.5: Summary of type of installed lighting at Bertam Lama Water Plant [56].

| No | Type of Lighting | Quantity |
|---|---|---|
| 1 | Fluorescent Lamp (FL) T8 36W | 227 |
| 2 | CFL Downlight 18W | 30 |
| 3 | High mast Incandescent Light 1000W | 20 |
| 4 | Street light Incandescent 150W | 35 |
| 5 | Spot light 220W | 12 |
| Total Installed | | 324 |

### 4.1.5 Data of the Motor Pump

The data collection of motor pump in this project will focused on only at Weir Pump House. In general, all the pumps are more than 20 years old and have poor pumping efficiency and performance. Currently, there are two weir pumps being used as another two pump had damaged and one of the head is not meet the requirement of the system. . Pumping system consume about 15,222kWh of energy in the overall system. By this amount, in percentage it is about 91% which is major. The usage is does affect the cost consumption of the overall system. Table 4.6 and table 4.7 below show the type of brand, model, rating and specification of pump and motor used at Bertam Lama Water Plant [56].

Table 4.6: Pump used by Weir Pump House at Bertam Lama Water Plant [56].

| No | Brand | Model | RPM (r/min) | Design Cap ($m^3/h$) | Head (m) |
|---|---|---|---|---|---|
| 1 | Toroshima | TBA | 980 | 2273 | TBA |
| 2 | Weir | 62840-008 | 1480 | 947 | 40.25 |
| 3 | Weir | 62840-008 | 1480 | 947 | 40.25 |
| 4 | Worthington | 500-LNN-600 | 1480 | 1515 | 46.25 |

Table 4.7: Motor used by Weir Pump House at Bertam Lama Water Plant [56].

| No | Brand | Type | Model | RPM (r/min) | Power (kW) |
|---|---|---|---|---|---|
| 1 | Siemens | TBA | IL87562 | 980 | 400 |
| 2 | Kirloskar | Slip Ring Motor | KCW 35527 | 1480 | 280 |
| 3 | Kirloskar | Slip Ring Motor | KCW 35527 | 1480 | 280 |
| 4 | Teco | Induction Motor | AEJS – PA001 | 1485 | 500 |

### 4.1.6 Energy Usage for Bertam Lama Water Plant

Table 4.8 below shows that higher energy consumption is on pump with 15,222 kWh/year and the lowest energy consumption is on lighting equipment with 283.00 kWh/year due to less usage and mostly use in SAMB LAB office [56].

Table 4.8: List of Energy Usage of Bertam Lama Water Plant [56].

| Equipment | kWh/year |
|---|---|
| Light | 283.00 |
| Pump | 15,222 |
| Air Cond | 751.65 |
| Compressor | 435.00 |
| **Total** | **92,248** |



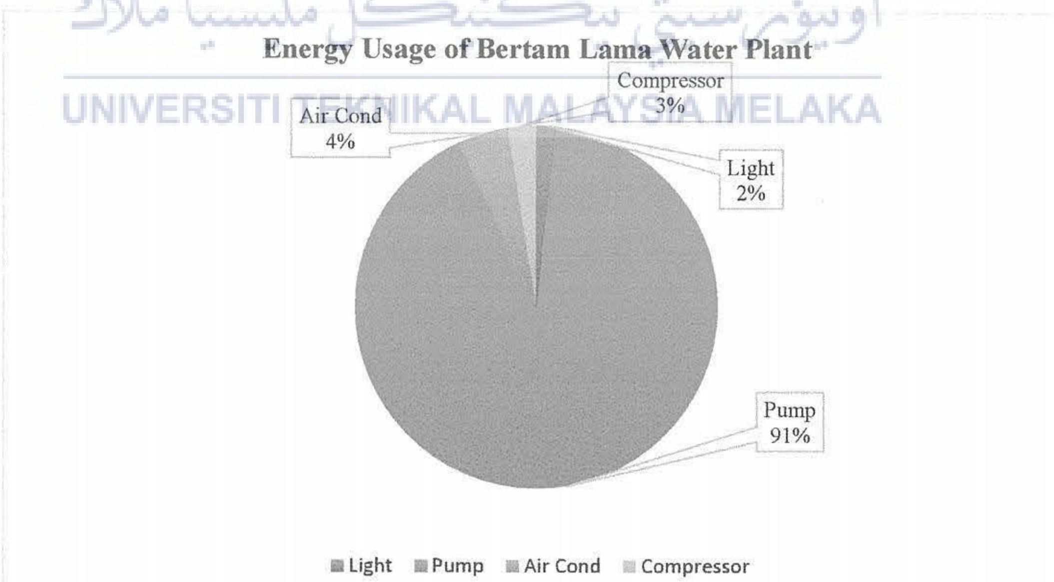



Figure 4.1: Pie Chart Energy Usage of Bertam Lama Water Plant [56].

### 4.1.7 Data of Transformer Distribution Load at SAMB LAB

There are 6 transformers at SAMB LAB but only 5 transformer are actively utilised for water treatment process. The value of energy usage for each transformers in table 4.9 below for SAMB LAB are obtained from the SAMB LAB report audit in year 2017 [56]. According to Table 4.9 below, Transformer 2 takes the highest portion of energy usage because the 12 MGD pump located at this transformer while transformer 4 take less energy consumption.

Table 4.9: Transformer energy usage for SAMB LAB [56].

| Source | kWh/year |
|---|---|
| 11/6.6 kV 1250kVA Transformer 1 which provides power to Kubota Pump | 5,062 |
| 11/6.6 kV 1250kVA Transformer 2 which provides power to 12 Million Gallon per Day (MGD) Weir Pump. | 9,811 |
| 11/0.433 kV 1500kVA Transformer 3 which provides power to 5 MGD Weir Pump. | 5,918 |
| 11/0.433 kV 1500kVA Transformer 4 which provides power to PMC | 638.17 |
| 11/0.433 kV 1500kVA Transformer 5 which provides power to the offices | 1,564 |

### 4.1.8 Data on Main Intake Load Profile

Throughout this research, the scope for research is only for Loji Air Bertam (LAB). 5 separate energy profiling were conducted on LAB main supply. The value of max peak load and load percentage for each transformers in table 4.10 for SAMB LAB are obtained from the SAMB LAB report audit in year 2017 [56]. The load for all the transformers are at minimum and inefficient. The efficient load for transformer is at 50%. Small amount of load operate at low frequency thus contribute to high cost consumption.

Table 4.10: Data for each Transformer in SAMB LAB Load Profile [56].

| Transformer | Capacity, (kVA) | Max Peak Load, (kW) | Percentage Load, (%) | Power Factor, (Pf) | Efficiency |
|---|---|---|---|---|---|
| 1 | 1250 | 229 | 20 | 0.9 | 0.9770 |
| 2 | 1250 | 433 | 38 | 0.9 | 0.9850 |
| 3 | 1500 | 266 | 20 | 0.9 | 0.9780 |
| 4 | 1500 | 133 | 10 | 0.9 | 0.9510 |
| 5 | 1500 | 94 | 7 | 0.9 | 0.9380 |

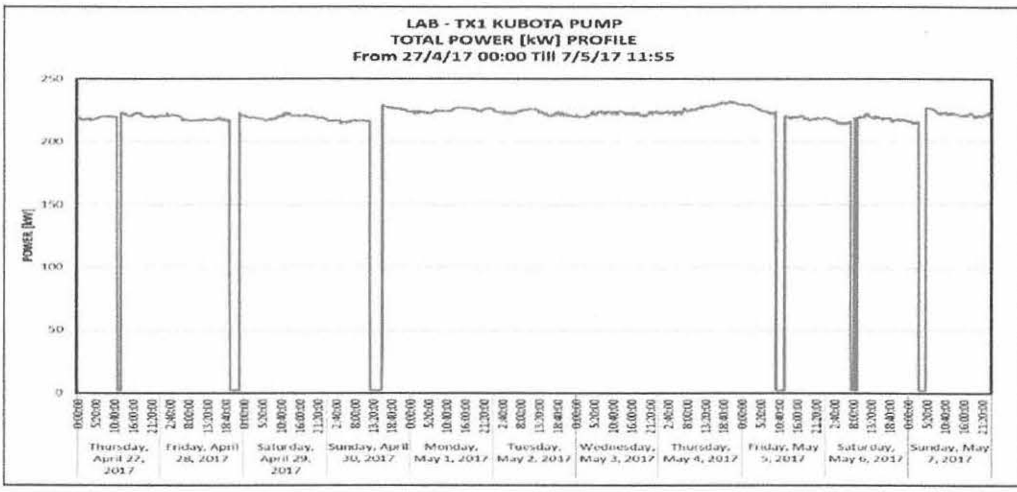



Figure 4.2: Daily load profile of electrical demand for LAB 11/6.6kV 1250kVA Transformer 1, Kubota Pump [56].

Figure 4.2 above shows the load profile for Transformer 1 which provides power to Kubota Pump where the data is collected in a week from 27 April 2017 to 7 May 2017 [56]. Based on the load profile, load of Transformer 1 is about 20% of the power capacity of the 1250kVA.



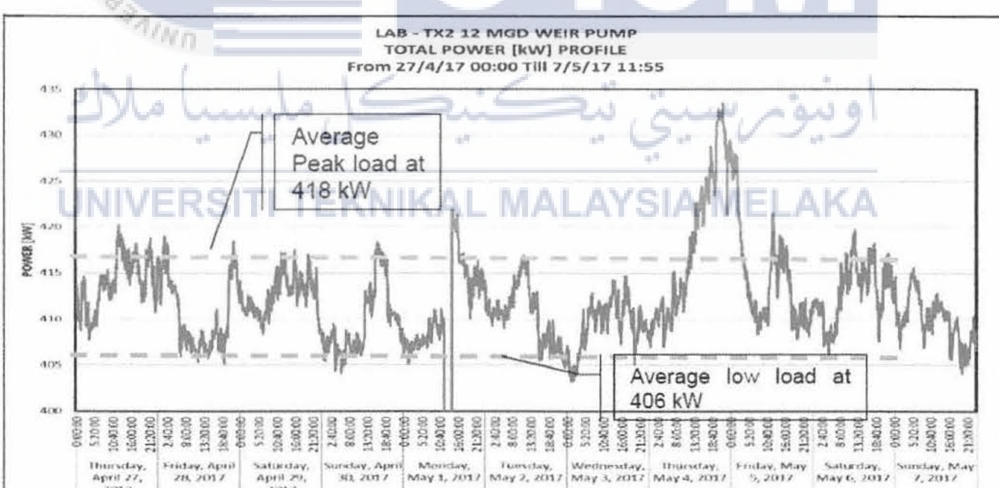



Figure 4.3: Daily load profile of electrical demand for LAB 11/6.6kV 1250kVA Transformer 2, 12 MGD Weir Pump [56].

Figure 4.3 above shows the load profile for Transformer 2 which provides power to 12 MGD Weir Pump where the data is collected in a week from 27 April 2017 to 7 May 2017 [56]. Based on the load profile, load of Transformer 2 is about 38% of the power capacity of the 1250kVA.

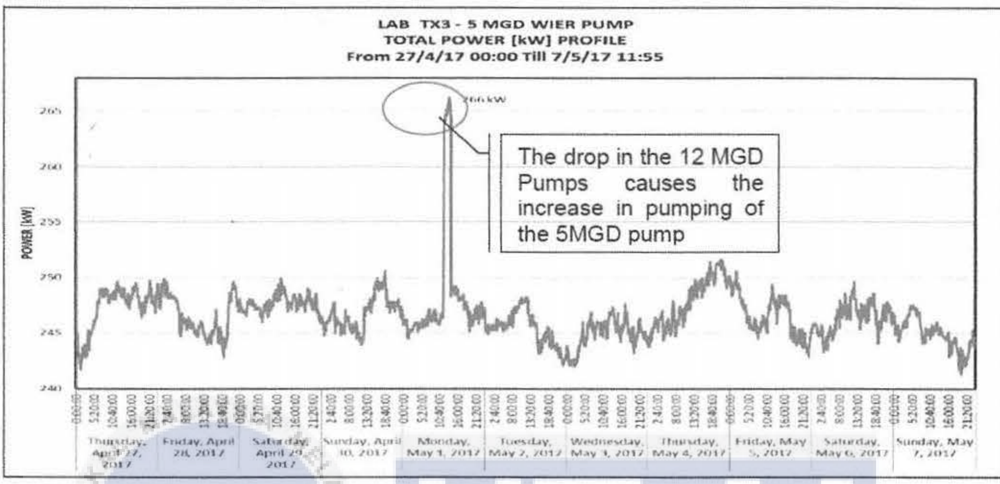



Figure 4.4: Daily load profile of electrical demand for LAB 11/0.433kV 1500kVA Transformer 3, 5 MGD Weir Pump [56].

Figure 4.4 above shows the load profile for Transformer 3 which provides power to 5 MGD Weir Pump where the data is collected in a week from 27 April 2017 to 7 May 2017 [56]. Based on the load profile, load of Transformer 3 is about 20% of the power capacity of the 1500kVA.

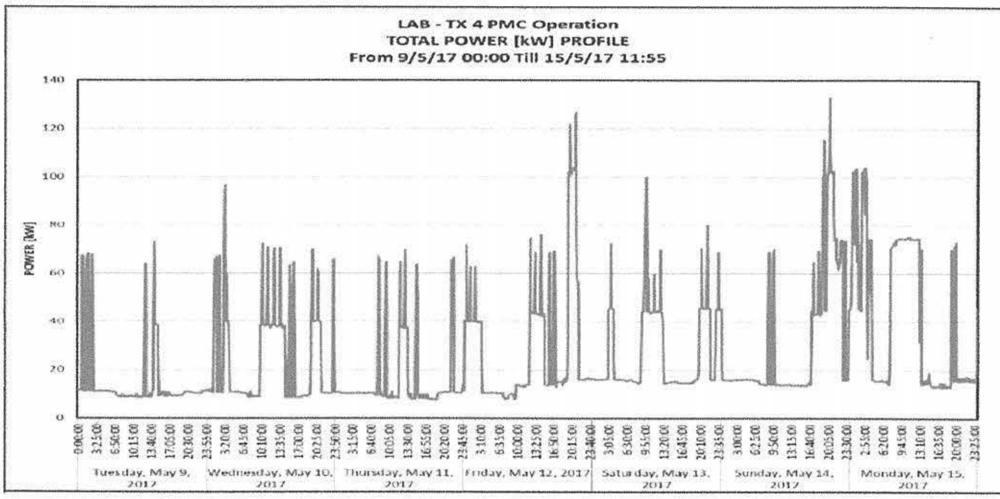



Figure 4.5: Daily load profile of electrical demand for LAB 11/0.433kV 1500kVA Transformer 4, PMC operation [56].

Figure 4.5 above shows the load profile for Transformer 4 which provides power to PMC where the data is collected in a week from 9 May 2017 to 15 May 2017 [56]. Based on the load profile, load of Transformer 4 is about 10% of the power capacity of the 1500kVA.



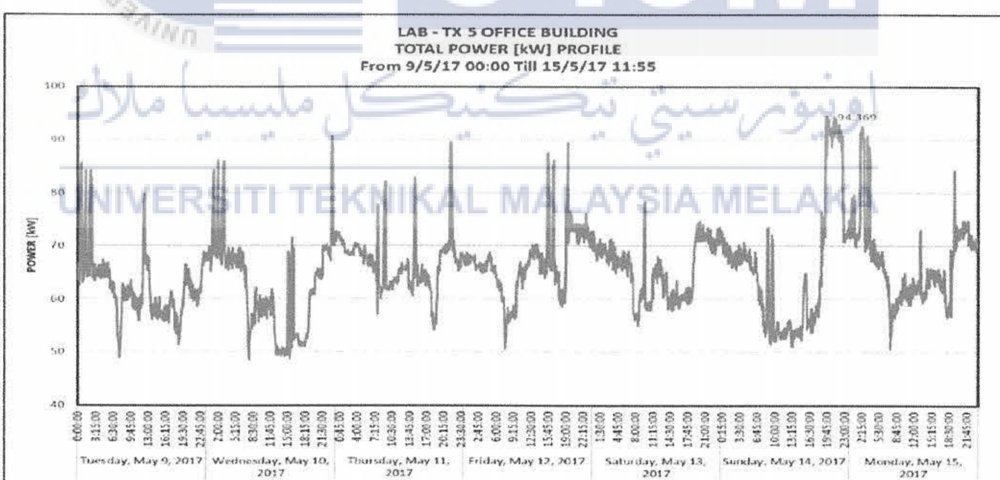



Figure 4.6: Daily load profile of electrical demand for LAB 11/0.433kV 1500kVA Transformer 5, Office building [56].

Figure 4.6 above shows the load profile for Transformer 5 which provides power to PMC where the data is collected in a week from 9 May 2017 to 15 May 2017 [56]. Based on the load profile, load of Transformer 5 is about 7% of the power capacity of the 1500kVA.

### 4.1.9 Data of the transformer system

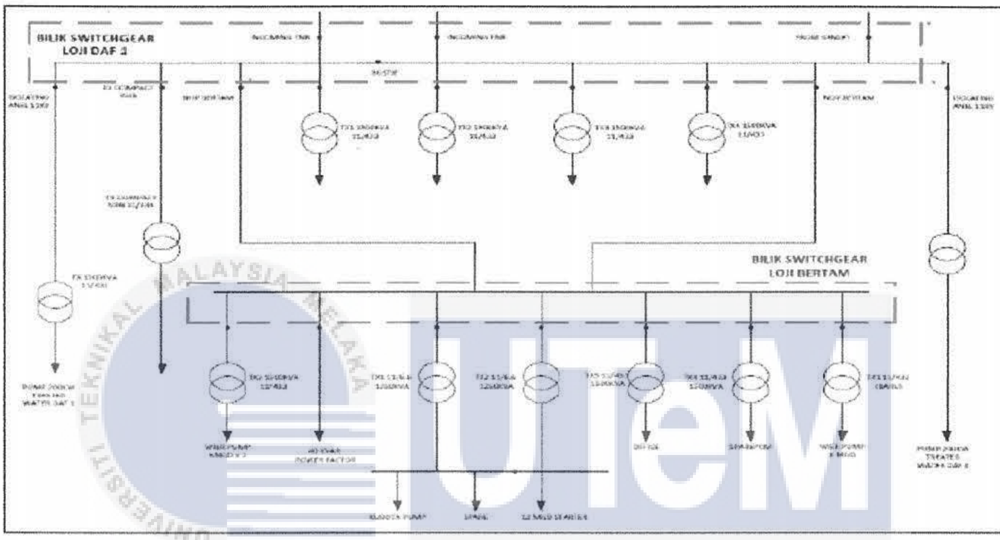



Figure 4.7: Electrical layout at SAMB LABLAD [56].

Figure 4.7 shows the distribution layout of SAMB LABLAD which cover whole SAMB including the Loji Air Bertam (LAB) and Loji Air Daf (LAD) [56]. The premise received its High Tension (HT) 11kV electricity supply from Tenaga Nasional Berhad (TNB) through single metering point and step-down to Low Voltage (LV) through step-down transformers. Electricity supply is distributed via the Main Switch Board (TX1, TX2, TX3, TX4, TX5 and TX6) for SAMB LABLAD and Main Switch Board (TX1, TX2, TX3, TX4, TX 1500kVA, TX Compact) for DAF. The analysis will focus on transformers in Loji Air Bertam (LAB).

Table 4.11: Equivalent transformer specification based on Transformer EFG3L with similar capacity as Transformer MEIDEN of 11/6.6kV 1250kVA.

| Parameters | | Value |
|---|---|---|
| Losses ,(W) | | |
| o | Load (Copper losses, $P_{cu}$), (W) | 12500 |
| o | No-Load (Core losses, $P_{core}$), (W) | 4500 |
| Impedance , Z%, (%) | | 5 |

Table 4.12: Equivalent transformer specification based on Transformer EFG3L with similar capacity as Transformer MEIDEN of 11/0.433kV 1500kVA.

| Parameters | | Value |
|---|---|---|
| Losses ,(W) | | |
| o | Load (Copper losses, $P_{cu}$), (W) | 17000 |
| o | No-Load (Core losses, $P_{core}$), (W) | 5100 |
| Impedance , Z%, (%) | | 6 |

Table 4.11 and 4.12 above show the specification on transformers with capacity of 1250kVA at 11/6.6kV and 1500kVA at 11/0.433kV. However, the specifications are based on similar specification of Transformer EFG3L with same capacity as the transformer at SAMB LAB. The detail of Transformer EFG3L is shown in Appedix

#### 4.1.9.1 Calculation of the data of the transformer

Table 4.13: Parameters specifications for Transformer 11/6.6kV 1250kVA and Transformer 11/0.433kV 1500kVA.

| Parameters | Transformer Capacity, (kVA) | |
|---|---|---|
| | 1250 | 1500 |
| $V_{s,rated}$, (V) | 6600 | 433 |
| $I_{full\ load}$, (A) | 109.35 | 2000 |
| $Z_k$, (Ω) | 1.7424 | 0.0075 |
| $I_{sc}$,(kA) | 2.187 | 33.33 |
| $I_\emptyset$, for delta-connection(A) | 63.13 | |
| $V_\emptyset$, for wye-connection (V) | | 250 |
| $S_\emptyset$, in phase,(kVA) | 416.67 | 500 |
| $P_{load}$ $losses$,in phase, (W) | 4166.67 | 5666.67 |
| $R_{eq}$, (Ω) | 1.05 | 0.00142 |
| $Z_{eq}$, (Ω) | 5.23 | 0.06 |
| $X_{eq}$, (Ω) | j5.12 | j0.06 |
| $V_{drop}$, (V) | 330 | 15 |



In table 4.13 above, the parameters of the both transformer type 11/6.6kV 1250kVA and type 11/0.433kV 1500kVA are identify from calculation. From formula in (3.1), the full load current can be determined. The value of the rated power and rated secondary voltage is already determined from the specifications and will carry to the next calculation of impedance on short circuit in formula (3.2). The value of short circuit current is calculated from formula (3.3). The value of phase current and phase voltage is calculated from formula (3.8) and (3.9). Using the formula (3.6) and (3.13), the value of load power losses in per phase and equivalent resistance can be obtained. The value of rated power in per phase is calculated from formula (3.5). The value of voltage drop, series impedance, equivalent reactance is obtained from formula (3.11), (3.12) and (3.13).

### 4.1.10 Efficiency data of transformer

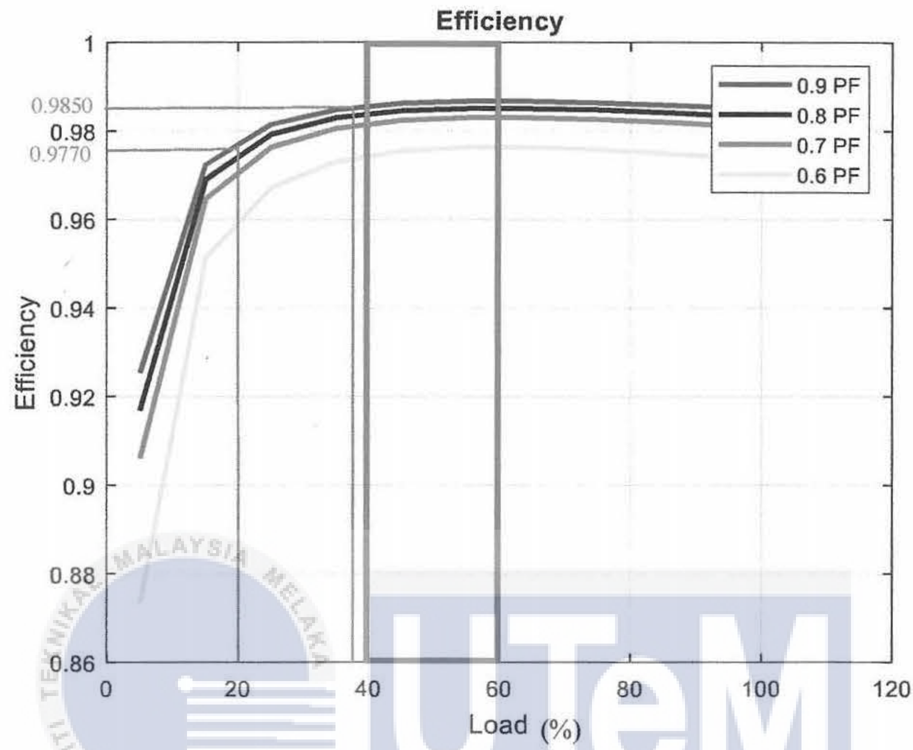



Figure 4.8: Efficiency curve for 11/6.6kV 1250kVA transformer with different power factor.

Figure 4.8 above shows the efficiency curve for 11/6.6kV 1250kVA transformer. The load percentage for transformer 1250kVA is at 20% and 38% which the efficiency are at 0.9770 and 0.9850. The most efficient efficiency is at 1.0. The efficient load`s efficiency in this curve is in the range of 40% to 60% plotted with red region where the efficiency is higher than 0.98 and approaching 1.0.

Table 4.14: Efficiency data for 11/6.6kV 1250kVA transformer.

| Load (%) | Power factor, (PF) | Efficiency |
|---|---|---|
| 20 | 0.9 | 0.9770 |
| 38 | 0.9 | 0.9850 |
| 40 | 0.9 | 0.9860 |
| 58 | 0.9 | 0.9870 |
| 60 | 0.9 | 0.9870 |
| 80 | 0.9 | 0.9860 |
| 100 | 0.9 | 0.9850 |

The value of efficiency is calculated using formula (3.24) where it is substitute into the coding. The most efficient efficiency is at 1.0. According to the table 4.14 above, the efficiency of the most efficient is in the range between 40% to 60% load. Transformer 1 running at 20% load which the efficiency is at 0.9770 is less efficient compare to load between the range of 40% to 60%.

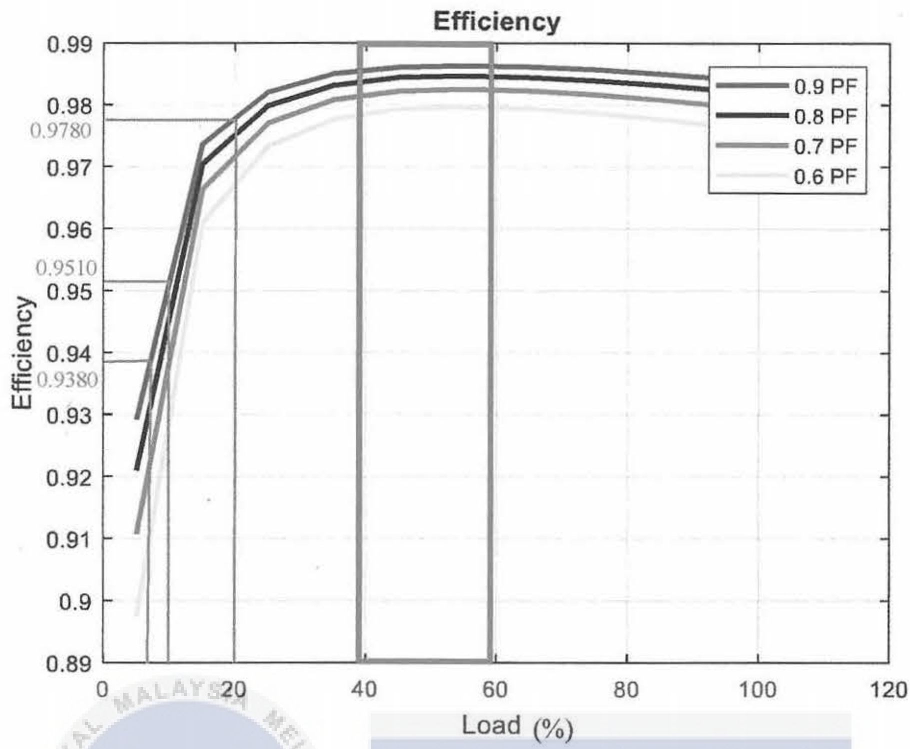



Figure 4.9: Efficiency curve for 11/0.433kV 1500kVA transformer with different power factor.

In figure 4.9 above, the most efficient load is between 40% to 60%. The load percentage for transformer 1250kVA is at 7%, 10% and 20% which the efficiency are is below 0.98. The most efficient efficiency is at 1.0. The efficient load`s efficiency is plotted with red region where the efficiency is higher than 0.98 and approaching 1.0.

Table 4.15: Efficiency data for 11/0.433kV 1500kVA transformer.

| **Load (%)** | **Power factor, (PF)** | **Efficiency** |
|---|---|---|
| 7 | 0.9 | 0.9380 |
| 10 | 0.9 | 0.9510 |
| 20 | 0.9 | 0.9780 |
| 37 | 0.9 | 0.9850 |
| 40 | 0.9 | 0.9860 |
| 60 | 0.9 | 0.9870 |
| 80 | 0.9 | 0.9970 |
| 100 | 0.9 | 0.9850 |

The value of efficiency is calculated using formula (3.24) where it is substitute into the coding. The most efficient efficiency is at 1.0. According to the table 4.15 above, the efficiency of the most efficient is in the range between 40% to 60% load. Transformer 5 and Transformer 4 running at 7% and 10% load which the efficiency is at 0.9380 and 0.9510 is less efficient compare to load between range of 40% to 60% which are above 0.98.

### 4.1.11 Voltage Regulation data for transformer

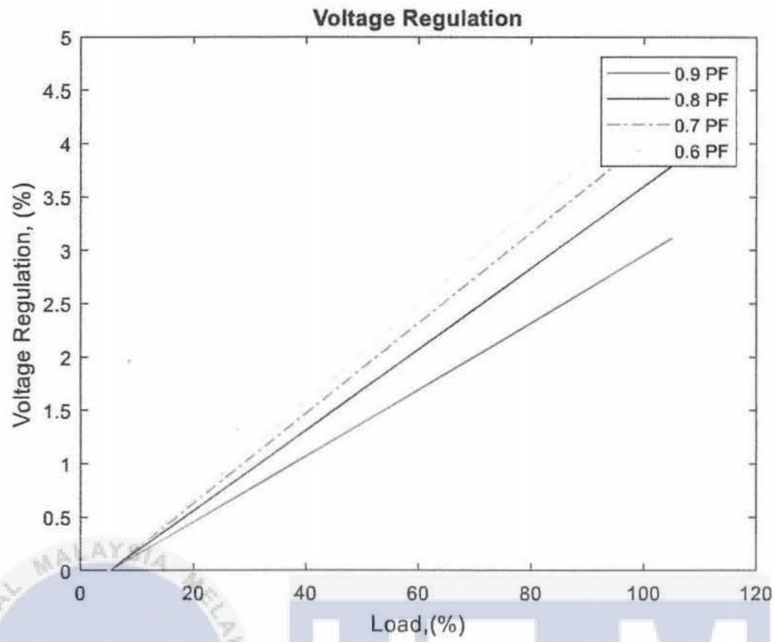



Figure 4.10: Voltage regulation versus load for 11/6.6kV 1250kVA transformer with different power factor.

The figure 4.10 shows the voltage regulation of 1250kVA transformer where the data is tabulated in table 4.16 below. To get the best performance of the transformer, the voltage regulation should be lowest as possible. It can be seen that the percentage is increasing as the amount of load increases. The value for the best voltage regulation is at load 20%.

Table 4.16: Voltage regulation data for 11/6.6kV 1250kVA transformer.

| Load (%) | Power factor, (PF) | Voltage regulation, (%) |
|---|---|---|
| 20 | 0.9 | 0.62 |
| 38 | 0.9 | 1.17 |
| 40 | 0.9 | 1.23 |
| 58 | 0.9 | 1.64 |
| 60 | 0.9 | 1.85 |
| 80 | 0.9 | 2.48 |
| 100 | 0.9 | 3.12 |

The value of voltage regulation is inserted in coding using formula (3.23). According to the table 4.16 above, the minimum voltage regulation is at 0.62 with load of 20% of Transformer 1. Transformer 2 running at 38% load which its value of voltage regulation is 1.17% is good enough.

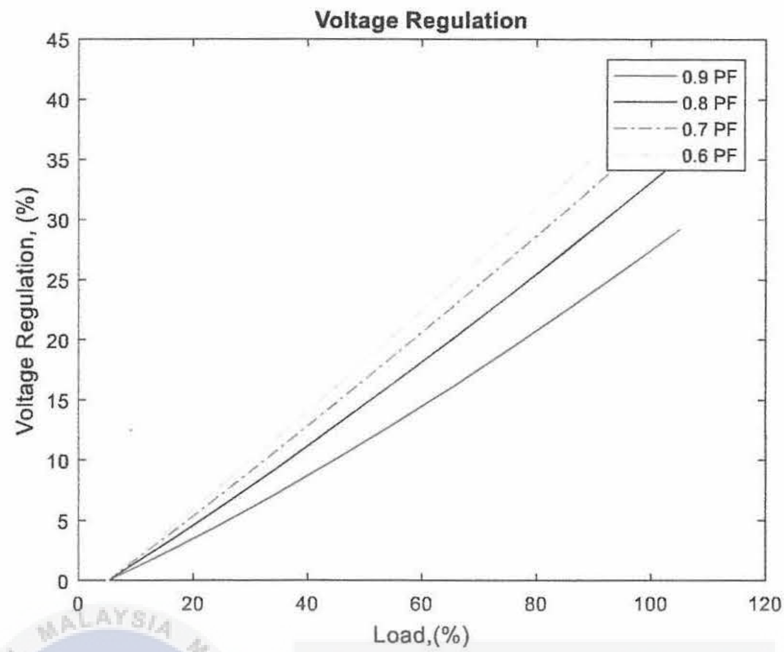



Figure 4.11: Voltage regulation versus load for 11/0.433kV 1500kVA transformer with different power factor.

The figure 4.11 shows the voltage regulation of 1500kVA transformer where the data is tabulated in table 4.17 below. To get the best performance of the transformer, the voltage regulation should be lowest as possible. It can be seen that the percentage is increasing as the amount of load increases. The value for the best voltage regulation is from load 7%.

Table 4.17: Voltage regulation data for 11/0.433kV 1500kVA transformer.

| Load (%) | Power factor, (PF) | Voltage regulation, (%) |
|---|---|---|
| 7 | 0.9 | 1.60 |
| 10 | 0.9 | 2.29 |
| 20 | 0.9 | 4.74 |
| 37 | 0.9 | 7.91 |
| 40 | 0.9 | 10.10 |
| 60 | 0.9 | 16.10 |
| 80 | 0.9 | 22.40 |
| 100 | 0.9 | 29.30 |

The value of voltage regulation is inserted in coding using formula (3.23). According to the table 4.17 above, the minimum voltage regulation is at 1.60 with load of 7% of Transformer 5. Transformer 4 and Transformer 3 running at 10% and 20% load which their value of voltage regulation is 2.29% and 4.74%.

### 4.1.12 Losses data on each transformer

Table 4.18: Data on the losses for each load of Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA.

| **Transformer capacity, (kVA)** | **Load, (%)** | **Parameters** | | | | |
|---|---|---|---|---|---|---|
| | | $I_{s,rated}$,(A) | $P_{out}$,(kW) | $P_{in}$, (kW) | **Power losses, (W)** | **Percentage losses, (%)** |
| **1250** | **10** | 6.31 | 110.67 | 115.30 | 4625.42 | 4.01 |
| | **20** | 12.63 | 225.06 | 230.06 | 5002.47 | 2.17 |
| | **30** | 18.94 | 337.50 | 343.13 | 5629.98 | 1.64 |
| | **40** | 25.26 | 450.12 | 456.63 | 6509.91 | 1.43 |
| | **50** | 31.57 | 562.59 | 570.23 | 7639.50 | 1.34 |
| | **60** | 37.88 | 675.03 | 684.05 | 9019.92 | 1.32 |
| | **70** | 44.20 | 787.65 | 798.30 | 10653.97 | 1.33 |
| | **80** | 50.51 | 900.09 | 912.62 | 12536.47 | 1.37 |
| | **90** | 56.83 | 1012.71 | 1027.38 | 14673.39 | 1.43 |
| | **100** | 63.14 | 1125.15 | 1142.21 | 17057.97 | 1.49 |
| **1500** | **10** | 200 | 135 | 140.27 | 5270.40 | 3.76 |
| | **20** | 400 | 270 | 275.78 | 5781.60 | 2.10 |
| | **30** | 600 | 405 | 411.63 | 6633.60 | 1.61 |
| | **40** | 800 | 540 | 547.83 | 7826.40 | 1.43 |
| | **50** | 1000 | 675 | 684.36 | 9360 | 1.37 |
| | **60** | 1200 | 810 | 821.23 | 11234.40 | 1.37 |
| | **70** | 1400 | 945 | 958.45 | 13449.60 | 1.40 |
| | **80** | 1600 | 1080 | 1096.01 | 16005.60 | 1.46 |
| | **90** | 1800 | 1215 | 1233.90 | 18902.40 | 1.53 |
| | **100** | 2000 | 1350 | 1372.14 | 22140 | 1.61 |

In table 4.18, before getting percentage losses for both capacity of transformer, the rated load current based on every load is calculated using formula (3.15) and the power losses is calculated using formula (3.20). The value of output power and input power is calculated using formula (3.19) and (3.21). After getting all the value needed, percentage losses is being calculated using formula (3.22).

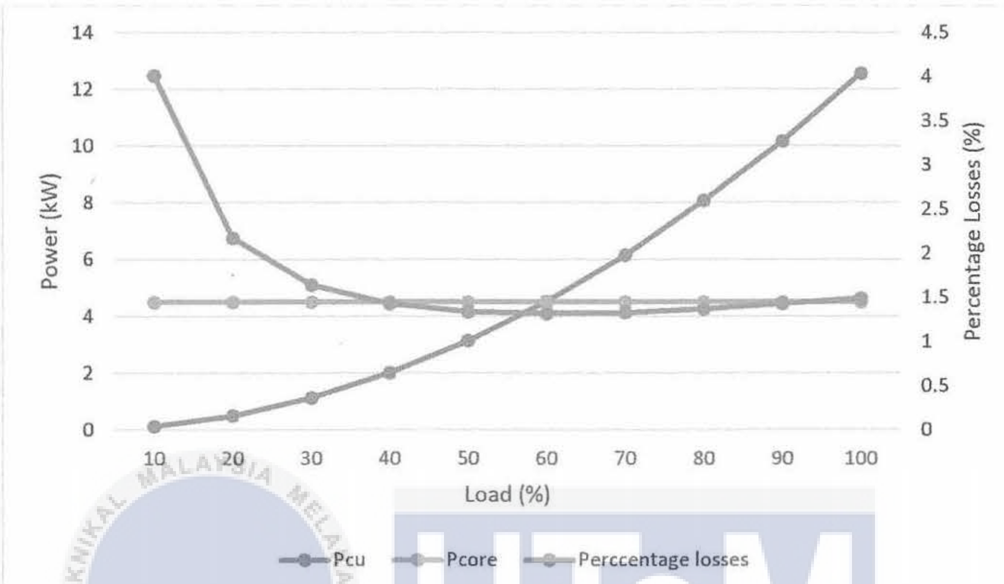



Figure 4.12: Graph of Pcu, Pcore and Percentage losses of 11/6.6kV 1250kVA transformer.

The plot in figure 4.12 is prepared of core and copper losses with percentage losses in a 1250kVA transformer with 4.5kW as fixed losses. It is can be seen obviously that minimum percentage losses occur when the value of copper losses and core losses are equal which at 60% load. In transformer design system, it has been designed to be efficient at 50% to 60% of loading.

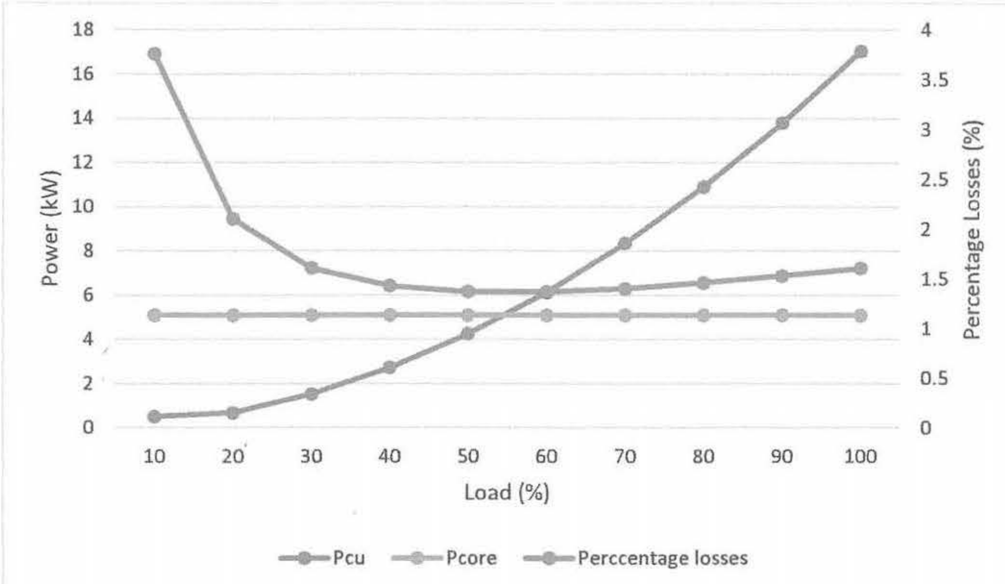



Figure 4.13: Graph of Pcu, Pcore and Percentage losses of 11/0.433kV 1500kVA transformer.

The plot in figure 4.13 is prepared of core and copper losses with percentage losses in a 1250kVA transformer with 5.1kW as fixed losses. It is can be seen obviously that minimum percentage losses occur when the value of copper losses and core losses are equal at approximate 55% load. In transformer design system, it has been designed to be efficient at 50% to 60% of loading.

### 4.1.13 Cost consumption data for transformer

**Norm of calculation:**

Electricity cost per kWh = 33.60 RM/kW.

Number of running times per year = 365 days

Number of hours running per day for Transformer 1250kVA = 24 hours

Number of hours running per day for Transformer 1500kVA = 8 hours.

Before getting the value of energy consumption, efficiency is obtained from table 4.14 and 4.15 for each load of transformers. Table 1.49 below shows the cost consumption for load at Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA for existing set up. In the table 4.19 below, the value of energy consumption and cost consumption are calculated using formula (3.25) and (3.26). Cost of consumption for transformers 1250kVA and transformers 1500kVA with new load are also determined to see the saving that can be achieve.



Table 4.19: Cost consumption for load at Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA for existing set up.

| Transformer capacity, (kVA) | Load, (%) | Parameters | | |
|---|---|---|---|---|
| | | Efficiency | Energy consumption, (kW) | Cost consumption, (RM/year) |
| 1250 | 20 | 0.9770 | 230.30 | 665,751.24 |
| | 38 | 0.9850 | 434.01 | 1,254,636.11 |
| | 58 | 0.9870 | 661.09 | 1,911,091.19 |
| 1500 | 7 | 0.9380 | 100.75 | 97,082.70 |
| | 10 | 0.9510 | 141.96 | 136,792.66 |
| | 20 | 0.9780 | 276.07 | 266,021.05 |
| | 37 | 0.9850 | 507.11 | 488,651.20 |

Table 4.20 below shows the data of the initial investment of Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA for proposed redistribution. In table 4.20 below, the value of voltage is obtained from the rating of transformer and the current is calculated through formula (3.15). The size of cable and price per meter is obtained from the datasheet of cable. The distance from the low load transformer to the high load transformer is obtained from the estimation process in site survey for each load location in the SAMB LAB. After calculate the value of cable cost using formula (3.27), the value of initial investment is calculated using formula (3.28).

Table 4.20: Data of the initial investment of Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA for proposed redistribution.

| **Transformer capacity, (KVA)** | **Load (%)** | **Voltage (V)** | **Current (A)** | **Size of cable ($mm^2$)** | **Price per meter (RM)** | **Distance from low load to high load transformer (m)** | **Total price (RM)** |
|---|---|---|---|---|---|---|---|
| **1250** | 20 | 6600 | 21.87 | 16 | 50 | 50 | 2,500 |
| | Total cable cost | | | | | | = 2,500 |
| | Total initial investment = cable cost + labor cost | | | | | | = 5,000 |
| **1500** | 7 | 415 | 146.08 | 50 | 120 | 50 | 6,000 |
| | 10 | 415 | 208.68 | 120 | 120 | 50 | 12,500 |
| | Total cable cost | | | | | | = 18,500 |
| | Total initial investment = cable cost + labor cost | | | | | | = 37,000 |

Table 4.21 below shows the saving that can be achieved by combining the load of transformer with only one transformer running for the specific transformer capacity based on the existing set up and proposed redistribution. The total cost consumption for two transformers of 1250kVA and cost consumption of three transformers of 1500kVA is calculated by adding the cost consumption of the loads. The savings for each transformer capacity is calculated using formula (3.29).

Table 4.21: Saving for Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA based on the existing set up and proposed redistribution.

| **Transformer capacity, (KVA)** | **Description parameters** | **Price, (RM)** |
|---|---|---|
| **1250** | Total cost consumption for two transformers operating at load of 20% and 38%. | = RM 1,920,585.35/year |
| | Total cost consumption for one transformer operating at load of 58%. | = RM 1,911,091.19/year |
| | **Savings** | **= RM 9494.16/year** |
| **1500** | Total cost consumption for three transformers operating at load of 7%, 10% and 20%. | = RM 499,896.41/year |
| | Total cost consumption for one transformer operating at load of 37%. | = RM 488,651.20/year |
| | **Savings** | **= RM 11,245.21/year** |

Cash inflow per period in table 4.22 above is calculated from savings in table using formula (3.30). The payback period is calculated through formula (3.31). Shows that 6 months payback period is needed for Transformer 1250kVA and 39.48 months payback period for Transformer 1500kVA.

Table 4.22: Payback period of Transformers 11/6.6kV 1250kVA and Transformers 11/0.433kV 1500kVA.

| Parameters | Transformer capacity, (kVA) | |
|---|---|---|
| | 1250 | 1500 |
| Cash inflow per period, (RM/month) | 791.18 | 937.10 |
| Payback period, (Months) | 6 | 39.48 |

### 4.1.14 Improvement suggestion on transformer



It has been decided that improvement to be done at 11/6.6kV 1250kVA Transformer 1, 11/6.6kV 1250kVA Transformer 2, 11/0.433kV 1500kVA Transformer 3, 11/0.433kV 1500kVA Transformer 4 and 11/0.433kV 1500kVA Transformer 5. The suggestion is to combine the low load of transformer 1 with load at transformer 2 as they have the same capacity and load at transformer 5 and load at transformer 4 with load at transformer 3 where they have the same capacity. The combination of load will save some amount of money in perhaps will reduce the cost of consumption. Although through the combination of load will save some amount, by operating the combination load transformer to the max efficient load will save some more money. Hence, by operating the transformer of 1250kVA at load of 58% will save cost around RM 9,494.16/year with payback period of 6 months in table 4.21 and 4.22. Moreover, operate the transformer of 1500kVA at load of 37% will save cost around RM 11,245.21/year with payback period of 39.48 months which equals to 3.3 years in table 4.21 and 4.22.

## 4.2 Result Discussion

The data collection from the premise is tabulated in table according to each system. Hence, above the overall system, the further analysis is conducted on transformer system. A detailed observation and discussion in done by the previous student for the pump and motor part. As for this project, the transformer performance system is analyse based on its load. And by this, the further method to overcome this high energy consumption is done throughout this project. However, the project will focused on transformer in Loji Air Bertam (LAB) which have consist of 5 transformer (11/6.6kV 1250kVA TX1, 11/6.6kV 1250kVA TX2, 11/0.433kV 1500kVA TX3, 11/0.433kV 1500kVA TX4, 11/0.433kV 1500kVA TX5). The operation of all transformer with small size of load is not economical since it produce practically same amount of losses in the overall transformer capacity and performance of the operation.

However, the small amount of load can be combined with other transformer that running a small load too. By having this combination, the number of transformer running will be reduce thus producing same amount of losses other than having a lot amount of transformer but still producing very same amount of losses. From 5 transformer running it will be reduce to 2 transformer only running. The new combination load transformer will running at more efficient load which will optimise the transformer system performance thus reduce the operating cost.

# CHAPTER 5

# CONCLUSION

## 5.0 Introduction

This chapter will compress every one of the previous chapters.



## 5.1 Conclusion

Overall active system in Loji Air Bertam (LAB) has been analysed and further analysis is done on transformer system. Type of transformers use in SAMB LAB are step down transformer brand model of MEIDEN with O.N.A.N cooling system type. The first objective which is to study the overall energy calculation usage on water system is achieved by getting the data from the site. There are total of 5 transformer in action in LAB. Each of the transformer operate at a low amount load as tabulated in chapter 4. With this low amount of load which at the same time consequently has produced almost the same amount of losses for each transformer. In the meantime, SAMB has intention to minimize the amount of transformer use and by considering the request, the further analysis on transformer has been done. Based on the finding data on each transformer, the efficiency curve has been plotted also the losses curve. The curve is plotted in programming language which is MATLAB by running the specific coding (Appendix D). The second objective is to study the behaviour of the transformer loading and its performance in clear water system in achieved. Referring to the curve, amount of efficient load to be operated on each transformer can be found. The transformers specification are obtain from the similar capacity of Transformer EFG3N. The other parameters of transformer are calculated using the list of formula thus the amount of cost consumption and saving can be identified. The suggestion improvement is proposed which are combining the transformer`s load. Transformers with very low amount of load with the same capacity are combine together which means only one transformer representing the load of the combine transformer. The new transformer will run at more efficient load thus contribute to a significant saving. The third objective is also achieved by recommended the potential improvement for transformer`s efficiency and operating cost.

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# APPENDIX A

| No | LOCATION | TYPE OF LAMPS | | | | | TOTAL |
|---|---|---|---|---|---|---|---|
| | | FL T8 36W | DL CFL 18W | HM I 1000W | SL I 150W | SP CFL 220W | |
| 1 | Lobby | 16 | | | | | 16 |
| 2 | Stair | 11 | | | | | 11 |
| 3 | Pantry | | 4 | | | | 4 |
| 4 | Laboratory | 27 | | | | | 27 |
| 5 | Sains Office | 6 | | | | | 6 |
| 6 | Operation room | 24 | | | | | 24 |
| 7 | Meeting room | 18 | | | | | 18 |
| 8 | Toilet Grn Floor | 4 | | | | | 4 |
| 9 | female surau | 2 | | | | | 2 |
| 10 | water testing room | 14 | | | | | 14 |
| 11 | Foyer | 6 | | | | | 6 |
| 12 | Female Toilet | 2 | | | | | 2 |
| 13 | Corridor | 8 | | | | | 8 |
| 14 | Office | 32 | | | | | 32 |
| 15 | H.O.D Facility | 8 | | | | | 8 |
| 16 | Officer room | 2 | | | | | 2 |
| 17 | Stair | 5 | | | | | 5 |
| 18 | Surau | 11 | | | | | 11 |
| 19 | Meeting room | 12 | | | | | 12 |
| 20 | Working area | | 22 | | | | 22 |
| 19 | Technician room | | 4 | | | | 4 |
| 20 | Quality manager | 4 | | | | | 4 |
| 21 | SCADA room | 12 | | | | | 12 |
| 22 | Toilet | 3 | | | | | 3 |
| 23 | Outside | | | | | 12 | 12 |
| 24 | Compound lighting | | | | 35 | | 35 |
| 25 | High mast | | | 20 | | | 20 |
| | Total Installed | 227 | 30 | 20 | 35 | 12 | 324 |

Table D-1: Summary of lighting system at each block at Bertam Lama Water Plant

**APPENDIX B**

| TARIFF E2- MEDIUM VOLTAGE PEAK OFF-PEAK INDUSTRIAL TARIFF | |
|---|---|
| **For each kilowatt of maximum demand per month during the peak period** | 32.90 RM/kW |
| **For all kWh during the peak period** | 33.60 RM/kW |
| **For all kWh during the off-peak period** | 19.10 sen/kWh |
| **The minimum monthly charge is RM600.00** | |

E25- Electrical Tariff

# APPENDIX C

```
>> %M-file: trans_vr.m
%M-file to calculate and plot the efficiency
%of a transformer as a function of load for power
%factors of 0.9 lagging, 0.8 lagging, and 0.7 lagging
%0.6 lagging.
VS = 6600;                              %Secondary Voltage (V)
IS = 63.14;                             %Full Load Current (A)
load = 0.05:0.1:1.05                    %Load Percentage (/100)
nload = 5:10:105
Pcore = 4500;                           %Core Losses (W)
Req = 1.05;

%Calculate the power factor values for the four
%power factors. The first row of pf contains
%the 0.9 lagging, the second row of pf contains
%the 0.8 lagging, the third row of pf contains
%the 0.7 lagging, and the fourth row pf of contains
%the 0.6 lagging.
pf(1,:) = load .* (0.9);
pf(2,:) = load .* (0.8);
pf(3,:) = load .* (0.7);
pf(4,:) = load .* (0.5);

%Calculate Pout.
Pout =3.*VS.*IS.*pf;

%Calculate Pcu
Pcu(1,:) =3.*((load .* IS).^ 2).* (Req);
Pcu(2,:) =3.*((load .* IS).^ 2).* (Req);
Pcu(3,:) =3.*((load .* IS).^ 2).* (Req);
Pcu(4,:) =3.*((load .* IS).^ 2).* (Req);

%calculate Pin.
Pin = Pcu + Pcore + Pout;

%Calculate efficiency
n = (Pout./Pin);
```

```
%Plot the efficiency
plot (nload,n(1,:),'b-','Linewidth',2)
hold on;
plot (nload,n(2,:),'k-','Linewidth',2);
hold on;
plot (nload,n(3,:),'r-','Linewidth',2);
hold on;
plot (nload,n(4,:),'y-','Linewidth',2);
hold on;
title ('Efficiency');
xlabel ('Load');
ylabel ('Efficiency');
legend ('0.9 PF','0.8 PF','0.7 PF','0.6 PF');
hold off;
grid on;
save all;
```

**Coding for efficiency of transformer.**

```
>> %M-file: trans_vr.m
%M-file to calculate and plot the voltage regulation
%of a transformer as a function of load for power
%factors of 0.8 lagging, 1.0, and 0.8 leading.
VS = 6600;                                %Secondary Voltage (V)
IS = 63.14;                              %Full load current (A)
load = 0:0.1:1.0                          %Load percentage (decimal)
nload = 5:10:105
Req = 1.05;                               %Equivalent R (ohms)
Xeq = 5.12;                              %Equivalent X (ohms)

%Calculate the current values for the three
%power factors. The first row of I contains
%the lagging currents, the second row of I contains
%the unity currents, and the third row of I contains
%the leading currents.
I(1,:) = load .* IS .* (0.9 - j*0.4359);
I(2,:) = load .* IS .* (0.8 - j*0.6);
I(3,:) = load .* IS .* (0.7 - j*0.7141);
I(4,:) = load .* IS .* (0.6 - j*0.8);

%Calculate VP/a.
VPa = VS + Req.*I + j.*Xeq.*I;

%Calculate voltage regulation
VR = (abs(VPa) - VS) ./ VS .* 100;

%Plot the voltage regulation
plot (nload,VR(1,:),'b-');
hold on;
plot (nload,VR(2,:),'k-');
hold on;
plot (nload,VR(3,:),'r-.');
plot (nload,VR(4,:),'y-..');
title ('Voltage Regulation');
xlabel ('Load,(%)');
ylabel ('Voltage Regulation, (%)');
legend ('0.9 PF','0.8 PF','0.7 PF','0.6 PF');
hold off;
```

**Coding for voltage regulation of transformer**

# APPENDIX D

## 11/0.433kV EFG3L (STANDARD LOSS TYPE)

### Technical Data

| Rated power (kVA) | (DN8042) | (DN8228) | (DN9066) | (DN9429) | (DN8451) |
|---|---|---|---|---|---|
| | **1250** | **1500** | **1600** | **2000** | **2500** |
| Ratio | 11000/433V (75kV BIL) Dyn11 50Hz | | | | |
| No load loss (W) | 1500 | 1700 | 1800 | 2100 | 2300 |
| Load loss at 75deg (W) | 12500 | 17000 | 19100 | 20000 | 26500 |
| Impedance (%) | 5 | 6 | 5 | 6 | 6 |
| Efficiency (%) at 100% load | 98.69 | 98.68 | 98.70 | 98.86 | 98.87 |

Table D-2: The specifications for Transformer EFG3L (Standard Loss Type)

**APPENDIX F**

**Calculation for parameters value of Transformer 1250Kva (11/6.6kV).**

- The full load current on the secondary side of the transformer is

$$I_{full\ load} = \frac{S_{rated}}{V_{S,rated} \times \sqrt{3}} = \frac{1250000}{6600\ x\ \sqrt{3}} = 109.35\text{A}$$

- To get the short circuit current, the calculation below have been made:

$$Z_k = \frac{Z(\%)\ X\ V_{S,rated}{}^2}{S_{rated}} = \frac{(0.05)\ X\ (6600^2)}{1250000} = 1.7424\Omega$$

$$I_{sc} = \frac{V_{S,rated}}{Z_k \times \sqrt{3}} = \frac{6600}{1.7424\Omega\ x\ \sqrt{3}} = 2.187\text{kA}$$

- To get value of $R_{eq}$ and $X_{eq}$, use the calculation below in per phase:

$$S_\emptyset = \frac{S_{rated}}{3}$$

$$= \frac{1250kVA}{3}$$

$$= 416.67\text{kVA}$$

- Since the connection is in delta-connection:

$$V_{L-L} = V_\emptyset$$

$$I_{L-L} = I_\emptyset \sqrt{3}$$

$$I_\emptyset = \frac{109.35}{\sqrt{3}}$$

$$= 63.13\ \text{A}$$

- Full load losses in per phase:

$$P_{load} = \frac{12500}{3}$$

$$= 4166.67 \text{ W}$$

$$P_{load} = I_{\emptyset}{}^{2} R_{eq}$$

$$4166.67 = 63.13^{2} R_{eq}$$

$$R_{eq} = 1.05\ \Omega$$

- Impedance (%) = $\frac{V_{drop}}{V_{\emptyset}}$

$$0.05 = \frac{V_{drop}}{6.6kV}$$

$$V_{drop} = 0.33\text{kv}$$

$$Z_{eq} = \frac{V_{drop}}{I_{\emptyset}}$$

$$= \frac{0.33kV}{63.14}$$

$$= 5.23\ \Omega$$

$$Z_{eq}{}^{2} = R_{eq}{}^{2} + X_{eq}{}^{2}$$

$$X_{eq} = 5.12\ \Omega$$

$$R_{eq} = 1.05\Omega\ , \quad X_{eq} = j5.12\Omega$$

**Calculation for parameters value Transformer 1500Kva (11/0.433kV)**

- The full load current on the secondary side of the transformer is

$$I_{full\ load} = \frac{S_{rated}}{V_{S,rated} \times \sqrt{3}} = \frac{1500000}{433\ x\ \sqrt{3}} = 2000\ \text{A}$$

- To get the short circuit current, the calculation below have been made:

$$Z_k = \frac{Z(\%)\ X\ V_{S,rated}{}^2}{S_{rated}} = \frac{(0.06)\ X\ (433\ ^2)}{1500000} = 0.0075\Omega$$

$$I_{sc} = \frac{V_{S,rated}}{Z_k \text{x} \sqrt{3}} = \frac{433}{0.0075\Omega\ x\ \sqrt{3}} = 33.33\text{kA}$$

- To get value of $R_{eq}$ and $X_{eq}$, use the calculation below in per phase:

$$S_{\emptyset} = \frac{S_{rated}}{3}$$

$$= \frac{1500kVA}{3}$$

$$= 500\ \text{kVA}$$



- Since the connection is in wye-connection:

$$I_{L-L} = I_{\emptyset}$$

$$V_{L-L} = V_{\emptyset}\sqrt{3}$$

$$V_{\emptyset} = \frac{433}{\sqrt{3}}$$

$$= 250\ \text{A}$$

- Full load losses in per phase:

$$P_{load} = \frac{17000}{3}$$

$$= 5666.67 \text{ W}$$

$$P_{load} = I_{\emptyset}{}^2 R_{eq}$$

$$5666.67 = 2000^2 R_{eq}$$

$$R_{eq} = 0.00142\ \Omega$$

- Impedance (%) = $\frac{V_{drop}}{V_{\emptyset}}$

$$0.06 = \frac{V_{drop}}{250V}$$

$$V_{drop} = 15 \text{ V}$$

$$Z_{eq} = \frac{V_{drop}}{I_{\emptyset}}$$

$$= \frac{15V}{250}$$

$$= 0.06\ \Omega$$

$$Z_{eq}{}^2 = R_{eq}{}^2 + X_{eq}{}^2$$

$$X_{eq} = 0.06\ \Omega$$

$$R_{eq} = 0.00142\Omega\ , \quad X_{eq} = j0.06\Omega$$