UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVEMENT OF CHILLER SYSTEM AND ENERGY SAVING TOWARDS HEALTHY BUILDINGS

NUR FATINI BINTI ABDUL RAZAK

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (REFRIGERATION AND AIR-CONDITIONING SYSTEM) WITH HONOURS

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A thesis submitted
in fulfillment of the requirements for the degree of
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PROFESOR MADYA Ts. DR. UMAR AL-AMANI BIN HAJI AZLAN
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DEDICATION

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ABSTRACT

This research explores and suggests innovative ways to optimise chiller systems in order to achieve significant energy savings while promoting healthier building environments. It is becoming more and more critical to lessen the impact on the environment and improve occupant well-being as building energy consumption increases. An essential part of heating, ventilation, and air conditioning (HVAC) systems, chiller systems are crucial for maintaining the thermal comfort of the inside of buildings. Nonetheless, a large amount of the energy used by a building is often attributed to their operation. The study begins with analysing the state of chiller systems as it is currently, identifying inefficiencies, and determining how they affect total energy usage. Following this, the research focuses at cutting-edge methods and technology for improving chiller systems, with a focus on increasing energy efficiency. These improvements help the global effort to minimise carbon footprints and fight climate change in addition to reducing operating costs. The study explores the direct relationship between indoor air quality (IAQ) and the efficiency of chiller systems. The study investigates how improved chiller systems can improve indoor air quality (IAQ) and make environments healthier. A key aspect of occupant well-being, indoor air quality affects comfort, productivity, and general health. Through simultaneously decreasing energy use and enhancing indoor air quality, this study aims to provide a comprehensive strategy for building performance. A case study is provided to validate the solutions that were suggested. It shows how chiller system upgrades were successfully implemented in a real-world building situation. The outcomes show major decreases in environmental impact, significant energy savings, and improvements in indicators of indoor air quality. It contributes to the continuing conversation about environmentally friendly building practices by highlighting how important chiller systems are to achieving energy efficiency and fostering hygienic indoor environments. The results provide insightful information to building owners, and facility managers, helping them to make decisions that will improve the environment and the well-being of their individuals.

ABSTRAK

Penyelidikan ini meneroka dan mencadangkan cara inovatif untuk mengoptimumkan sistem penyejuk bagi mencapai penjimatan tenaga yang ketara sambil mempromosikan persekitaran bangunan yang lebih sihat. Ia menjadi semakin kritikal untuk mengurangkan kesan terhadap alam sekitar dan meningkatkan kesejahteraan penghuni apabila penggunaan tenaga bangunan meningkat. Bahagian penting sistem pemanasan, pengudaraan dan penyaman udara (HVAC), sistem penyejuk adalah penting untuk mengekalkan keselesaan haba bahagian dalam bangunan. Walau bagaimanapun, sejumlah besar tenaga yang digunakan oleh bangunan sering dikaitkan dengan operasinya. Kajian bermula dengan menganalisis keadaan sistem penyejuk seperti sekarang, mengenal pasti ketidakcekapan, dan menentukan cara ia mempengaruhi jumlah penggunaan tenaga. Berikutan ini, penyelidikan memfokuskan pada kaedah dan teknologi canggih untuk menambah baik sistem penyejuk, dengan tumpuan untuk meningkatkan kecekapan tenaga. Penambahbaikan ini membantu usaha global untuk meminimumkan jejak karbon dan melawan perubahan iklim selain mengurangkan kos operasi. Kajian itu meneroka hubungan langsung antara kualiti udara dalaman (IAQ) dan kecekapan sistem penyejuk. Kajian itu menyiasat bagaimana sistem penyejuk yang dipertingkatkan boleh meningkatkan kualiti udara dalaman (IAQ) dan menjadikan persekitaran lebih sihat. Aspek utama kesejahteraan penghuni, kualiti udara dalaman mempengaruhi keselesaan, produktiviti dan kesihatan umum. Melalui pengurangan penggunaan tenaga secara serentak dan peningkatan kualiti udara dalaman, kajian ini bertujuan untuk menyediakan strategi komprehensif untuk prestasi bangunan. Kajian kes disediakan untuk mengesahkan penyelesaian yang dicadangkan. Ia menunjukkan bagaimana peningkatan sistem penyejuk berjaya dilaksanakan dalam situasi bangunan dunia sebenar. Hasilnya menunjukkan penurunan besar dalam kesan alam sekitar, penjimatan tenaga yang ketara, dan penambahbaikan dalam penunjuk kualiti udara dalaman. Ia menyumbang kepada perbualan berterusan tentang amalan bangunan mesra alam dengan menonjolkan betapa pentingnya sistem penyejuk untuk mencapai kecekapan tenaga dan memupuk persekitaran dalaman yang bersih. Hasilnya memberikan maklumat bernas kepada pemilik bangunan, dan pengurus kemudahan, membantu mereka membuat keputusan yang akan meningkatkan persekitaran dan kesejahteraan individu mereka.

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HVAC - Heating, Ventilating, Air-Conditioning
ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAS - Building Automation System
VSD - Variables Speed Drive
CHWP - Chilled Water Pump
CDWP - Condenser Water Pump
CT - Cooling Tower
EPG - Energy Performance Gap
kW - Kilowatt
RT - Refrigerant tonnes

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CHAPTER 1

INTRODUCTION

1.1 Background

Improving chiller systems has become an essential part of energy saving and sustainability in the effort for eco-friendly and sustainable building practices. Chiller systems are essential for controlling indoor temperature, providing comfort for occupants, and preserving optimal conditions for a range of industrial operations. The need to review and improve the efficiency of these systems continues to increase as the world community deals with challenges brought on by climate change and the depletion of natural resources. The heating, ventilation, and air conditioning (HVAC) system load really accounts for around 40–50% of the building energy consumption among all of the load-side energy needs (Zhao et al., 2023).

Cooling and dehumidification of indoor areas are the functions of chiller systems, which are essential parts of modern HVAC (Heating, Ventilation, and Air Conditioning) systems. These systems have historically been related to high energy usage and a major increase in the carbon footprint of a building. A paradigm change in the design and operation of chiller systems has been driven by need to move towards greener and more environmentally friendly approaches. The continuous improvement of energy efficiency is a vital part of responsible building management as well as a concern for the environment. The main objective as we embark on this path to improve chiller systems is to achieve an acceptable balance between energy savings and the development of environments that improve occupant well-being.

Energy efficiency in chiller systems requires an extensive review of the operational and technical approaches. A new age in chiller design has been made possible by advances in technology including the use of variable speed drives, advanced heat exchangers, and smart controls. For example, variable speed drives minimize energy waste at low load by enabling the system to modify its speed in accordance with the real cooling requirement. Meanwhile, advanced control systems make use of real-time data analytics to optimize the chiller's efficiency, guaranteeing that it performs at its best under a variety of circumstances. These developments contribute to the sustainability of building operations by lowering energy usage and increasing equipment longevity.

With the advancement of industrialization and urbanisation, the majority of individuals now spend about 90% of their time indoors, whether it be in their homes or workplaces. The building environment's quality imposes a substantial influence on the well-being and efficiency of its residents. Since the initial documentation of sick building syndrome resulting from ventilation in the 1980s, there has been a substantial increase in study about the impact of buildings on human well-being. Recently, there has been a significant rise in focus on interior ventilation and air quality standards, mainly due to the worldwide epidemic caused by the coronavirus (Wang et al., 2024). Improved indoor air quality and energy efficiency go together hand in hand, and this is one of the most important components of the chiller improvements. A well planned and maintained chiller system may greatly improve indoor air quality in addition to lowering the consumption of energy. Conventional systems frequently neglect the significance of humidity control, creating conditions that encourage the growth of mold and allergies. These risks are actively reduced by upgraded chiller systems with innovative dehumidification capabilities, resulting in healthier indoor environments. This connection between energy efficiency and health highlights the need for sustainable building strategies, which integrate environmental responsibility with occupant well-being.

Improvements to chiller systems have significant economic effects that cannot be overstated. Even while switching to modern technology may appear expensive at first, there are several reasons to upgrade current systems over time, including lower operating expenses and energy bills. Energy-efficient chillers are eligible for several green building certifications and benefits in addition to consuming less power. Energy-efficient chiller systems are becoming a strategic and ethical choice as governments and corporations place a higher priority on sustainability. This will help buildings and businesses establish themselves as leaders in the responsible use of resources. Improving chiller systems is a way of balancing energy efficiency, occupant well-being, and environmental responsibility. A comprehensive strategy that goes beyond energy conservation and involves keeping the inside healthier is required in the transition to sustainable building practices. Integrating technology improvements with a larger commitment to sustainability is crucial as they continue to transform the landscape of chiller systems. A future where buildings actively contribute to the health of its occupants and the environment, instead of just by consuming less energy, is becoming closer due to the combination of energy-efficient technology, improved indoor air quality, economic viability, and renewable energy integration.

The development of chiller systems is a major step in the direction of energy-efficient, healthy buildings. By integrating eco-friendly refrigerants, variable speed motors, and advanced control systems, chiller systems have become models of sustainable technology. In addition to conserving energy, these systems actively improve indoor air quality, creating surroundings where individuals' health and welfare are given first priority. The ongoing development of chiller systems is an excellent instance of how technological innovation can work in equilibrium with the environment in order to create environments that are not only energy-efficient but also improve the general well-being and productivity of those who occupies them, especially as the building industry continues to prioritize sustainability and occupant comfort.

1.2 Problem Statement

Uncomfortable indoor temperatures are caused by inefficient HVAC chiller systems, which use excessive amounts of energy and are unable to deliver enough cooling in many commercial buildings. This inefficiency has a negative impact on the productivity and health of the occupants in addition to increasing energy expenses. Finding and implementing into action solutions that optimize chiller system performance and lower energy usage while preserving a hygienic both interior environment is a challenge.

The health and well-being of building occupants depend significantly on indoor air quality (IAQ), however many HVAC chiller systems fell lacking in this aspect. Ineffective ventilation or filtering of indoor air by these systems may result in poor air quality along with potential health problems. Creating healthier building environments requires developing solutions, such enhanced filtration and ventilation technologies, that integrate IAQ improvements with chiller system functioning.

Building chiller systems that are still in use today often lack energy-efficient features and are slightly outdated. These old systems cost more to operate because they use too much energy and need maintenance more frequently. Finding affordable solutions to upgrade or replace these old chillers with more cutting-edge energy-efficient models that not only use less energy but also enhance temperature control and dependability to create a healthier within atmosphere is a problem.

1.3 Research Objective

A comprehensive approach is required to improve HVAC (Heating, Ventilation, and Air Conditioning) chiller systems with a particular focus on energy savings and the encouragement of healthy buildings. The following are the endeavor’s primary objectives:-

i) To increase the energy efficiency of the chiller system in a way which encourages a healthier indoor environment. This involves reducing energy consumption while preserving or increasing indoor air quality. It also involves upgrading to more energy-efficient equipment, optimizing chiller operations, and placing modern control systems in action.

ii) To improve the indoor air quality by regulating the chiller system’s operation. This include reducing air pollutants, controlling humidity, and making sure that the inside air is properly filtered and ventilated. A healthy indoor environment lowers the risk of respiratory illnesses and improves occupant well-being.

1.4 Scope of Research

The scope of this research are as follows:

i) Investigating the energy consumption of chiller system and the importance of energy efficient systems for sustainable and healthy buildings. Essential data needed for the energy optimization of chiller and production parameters will be given through this analysis.

ii) Assessment of current energy consumption in old chiller and new chiller are required to investigate the energy savings for both chillers. The results indicated that the new chiller are improved in terms of energy saving compare to the old chiller. Additionally, the data measurement for both chillers are obtains at Furama, Bukit Bintang. The old chiller are made by York with the capacity 150RT and the new chiller are made by Carrier with the capacity 423R and for new chiller there are 2 nos. of Carrier water-cooled inverter screw chillers, 2 nos. of new chilled water pump, 2 nos. of new condenser water pump and 2 sets of new cooling tower. All pumps and cooling tower motors are equipped with variable speed drive (VSD).

iii) New Building Automation System (BAS) is equipped to provide fully optimization of new chiller plant. Other than that, this study involves the exploration of building automation systems for holistic energy management and analysis of the impact of chiller upgrades on energy consumption and indoor environmental quality. Furama Bukit Bintang Hotel consists of 27 floors which being served by the centralized air-conditioning system. There are 433 rooms, lounge, restaurant, meeting rooms, function rooms and etc. The chiller plant is located on roof top at Level 28.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to review and assess the research of HVAC chiller and its system improvement and energy saving that has been conducted. An overview of the evolution of HVAC chillers throughout history will be discussed before the review gets started. The context comprehending the development and progress of research on this topic will be provided by this section. This research follows with explore the main theoretical frameworks and theories that have contributed to the way research currently comprehend HVAC chillers system improvement and energy savings towards a healthy building. This chapter also will additionally discuss history and materials of the HVAC chillers and examples of methods used in earlier studies, as well as their advantages and disadvantages. The review will also go through any differences of results that may have been discovered throughout the literature.

2.2 Heating Ventilating Air-Conditioning (HVAC)

An entire engineering system called a Heating, Ventilating, and Air Conditioning (HVAC) system is made to control and regulate the outside temperature within a building or small area. It consists of three main purposes, which are:-

i) Heating

During cold weather, the HVAC system offers a way to increase the temperature within buildings. Electric heaters, boilers, and furnaces are examples of heating components that are commonly used to do this.

Figure 2.1: Industrial Furnaces

ii) Ventilating

To maintain air quality and eliminate pollutants, ventilation entails the circulation of air between indoor and outdoor areas. Fans, ducts, and vents are some of the parts of the HVAC system that help move fresh air around and remove unwanted air.

Figure 2.2: Air Duct Ventilation System

iii) Air-Conditioning

In warm or hot weather, air conditioning requires cooling and dehumidifying indoor air. Refrigeration cycles and components including compressors, evaporators, and condensers are commonly used to achieve cooling.

Figure 2.3: Air-conditioning for home

2.2.1 Basic Components Air-Conditioning

Basically, there are four basic component of air-conditioning which are compressor, condenser, expansion valve and evaporator. The basic parts of air conditioning systems work to regulate and maintain the temperature and quality of the air within buildings. The compressor, which is in control of pressurizing and moving refrigerant throughout the system, is the primary part of the system. In the evaporator and condenser coils, the refrigerant changes phases, going from a gas to a liquid. Heat from the inside air is taken in by the evaporator coil, which is located inside the indoor unit, and released outside by the condenser coil, which is located inside the outdoor unit. These coils are connected by copper tubing to create a closed loop that helps the refrigerant exchange heat more easily.

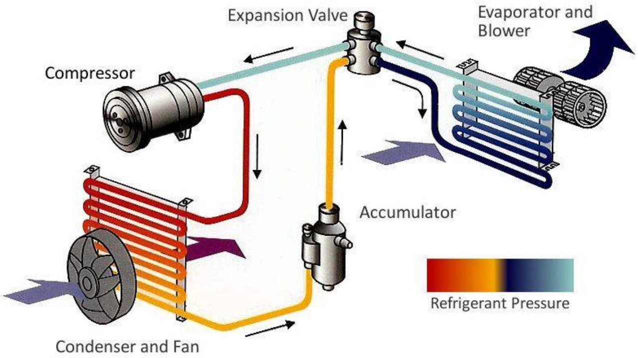


Figure 2.4: Working principles of basic part air-conditioning

2.2.2 Chiller Definition’s

A mechanical device called a chiller is used to convert heat from a liquid usually water to a refrigerant gas. It uses a cycle of compression, condensation, expansion, and evaporation to help with the absorption or rejection of heat. It works on the principles of thermodynamics and refrigeration. In order to maintain ideal environmental conditions, chillers are frequently used in HVAC (Heating, Ventilation, and Air Conditioning) systems and industrial operations. By controlling thermal conditions, they are essential for sustaining product integrity, keeping the inside temperature comfortable and increasing the effectiveness for multiple industrial applications.

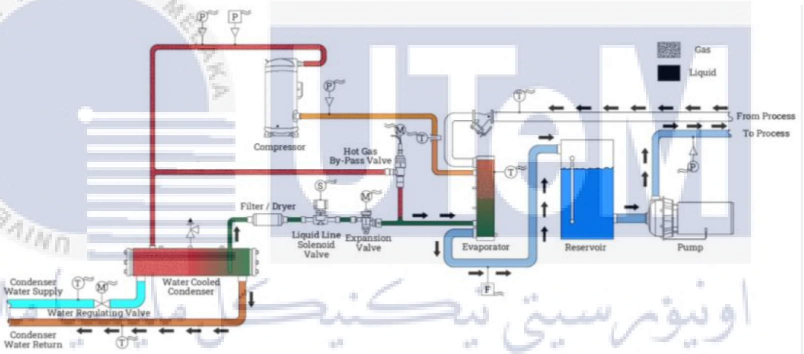


Figure 2.5: Chiller Circulating Process

2.2.2.1 Water-Cooled Chiller

One type of chiller that removes heat out of the water to cool it for use in projects, commercial buildings, or residential structures is the water-cooled chiller, which recycles the water back into the operating cycle. In reality, chillers move heat to another area that requires temperature control from a place that does.

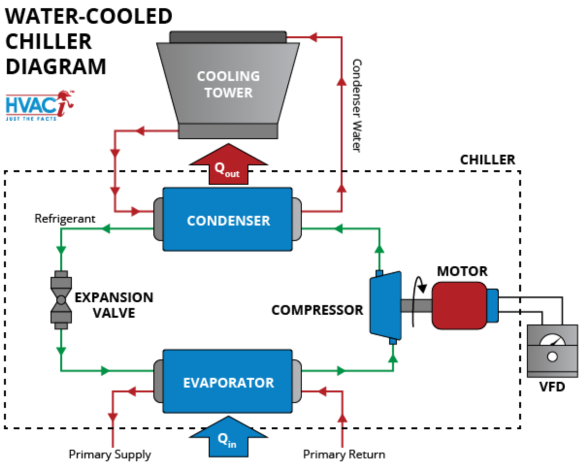


Figure 2.6: Process of water-cooled chiller

In order to effectively regulate temperatures in a wide range of applications, a water-cooled chiller works by circulating water through a closed-loop refrigeration system. The compressor in the chiller starts the process by compressing a refrigerant, increasing its temperature and pressure. After passing through a condenser, the high-energy refrigerant transfers heat to the water that is moving throughout the system. The water is pushed out to an outdoors cooling tower or another heat rejection device when it has heated up, releasing the heat it had absorbed into the atmosphere. In the meantime, the refrigerant changes into a low-pressure, low-temperature liquid as a result of losing heat. After going through an expansion valve, the liquid refrigerant quickly swells and evaporates in the evaporator. The refrigerant absorbs heat from the process or area that has to be cooled during this phase change. The cycle is repeated when the cooled water keeps circulating and the refrigerant flows back to the compressor, maintaining the ideal temperatures.

2.2.2.2 Air-Cooled Chiller

Air-cooled chillers are refrigeration units that use outside air to remove heat in order to cool and control temperature. The compressor, condenser, expansion valve, and evaporator compose these chillers. Air-cooled chillers, in contrast to water-cooled systems, release heat into the surrounding air through fans and finned coils. The compressor increases the refrigerant’s temperature and pressure to start the refrigeration cycle. After passing through the condenser, the heated refrigerant releases heat into the surrounding air. This procedure eliminates the need for water cooling systems by enabling air-cooled chillers to effectively remove heat from industrial processes or areas.

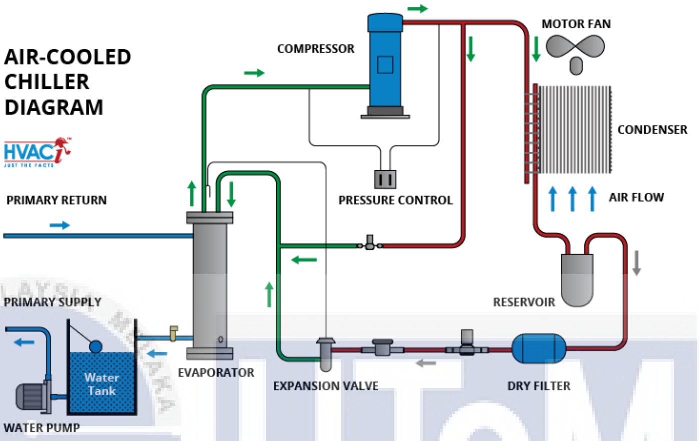


Figure 2.7: Process of air-cooled chiller

A refrigeration system utilized to cool water or another fluid for air conditioning needs is called an air-cooled chiller. Refrigerant is circulated through a closed loop consisting of an expansion valve, compressor, condenser, and evaporator in order for it to function. The water in the evaporator starts to evaporate into a low-pressure vapor as the refrigerant absorbs heat from it. The vapor is then heated and pressured by the compressor, condensing in an air-cooled condenser to release heat into the surrounding air. After going through an expansion valve and experiencing a rapid expansion, the high-pressure liquid refrigerant exits the evaporator and starts the cycle again. Air-cooled chillers are great for a variety of applications since they don’t require a separate cooling water system because they disperse heat through fans and finned coils.

2.2.2.3 Centrifugal Chiller

The vapor compression cycle is used by a centrifugal chiller to cool water. It disperses the heat from the compressor and the chilled water collection into a water loop. A cooling tower is used to chill the water loop. The fact that centrifugal chillers have comparatively few moving components makes them desirable. They last a long time and easy to maintain. Compact and very capable of chilling, centrifugal chillers offer a large capacity.

Figure 2.8: Centrifugal Chiller

2.2.2.4 Reciprocating Chiller

Screw, scroll, and reciprocating compressors are examples of positive displacement compressors. Reciprocating compressors utilize cylinders with pistons functioning as pumps to increase refrigerant pressure. They can be either water- or air-cooled. Reciprocating chillers, which have a capacity range of 10 – 1,800 Kw (3 – 510 refrigeration tons), are more compact than centrifugal chillers. Direct volume reduction between revolving screws compresses the gas in screw compressors, which are sometimes referred as rotary compressors.

Similar to a vehicle engine, the reciprocating chiller compresses the gas inside through the use of pistons. Several pistons are used to compress and heat the gas. The heated gas inside the system is not discharged by a tailpipe, which is the difference. The adjustable intake and exhaust valves, which may be opened to let the piston just idle, accomplish the criteria for this kind of chiller. Capacity may be managed by leaving the piston in place when cold water is needed. This chiller system is capable of handling its particular load demands on the system because of its extreme adaptability. Using a hot gas bypass, it may also be possible to regulate capacity to match demand. It is believed that this method is not the most efficient one available. Certain chiller systems empty pistons by using both capacity control methods. In order to fulfil demand, the same chiller systems can also make use of the hot gas bypass.

Figure 2.9: Reciprocating Chiller

2.2.2.5 Scroll Chiller

A scroll chiller is a kind of refrigeration system that removes heat from a designated area by compressing refrigerant using a scroll compressor. A compressor, a condenser, an evaporator, and a refrigerant generally component of a system.

The refrigerant is compressed and moved through the system by use of two spiral-shaped scrolls, one fixed and one revolving, in a scroll compressor, a kind of positive displacement compressor. The efficiency of a scroll chiller is one of its primary advantages. Compared to other compressor types, scroll compressors are known for having a high coefficient of performance (COP), which allows them to deliver more cooling output per unit of energy input. Over time, this can result in considerable energy savings, particularly in big commercial or industrial environments with heavy cooling requirements.

Figure 2.10: Scroll Chiller

2.2.2.6 Screw Chiller

Screw Chillers are vapor compressor chillers that move the coolant through the system using a screw compressor. Compact installation, silent operation, reduced maintenance costs, and excellent energy efficiency are a few of the primary advantages. Additionally, they are perfect for tall buildings.

Figure 2.11: Components in Screw Chiller

The two types of compressors that are referred to as screw chillers are single and twin screw. Screw chillers are often more expensive than other types of chillers, such as centrifugal and reciprocating, because of their dependability and efficiency. Single screw chillers are less costly and require less maintenance than the other selection.

The term of single screw compressor refers to the one primary rotor that turns in order to turn on the gate star wheels. Compression takes place in the top and lower parts of the compressor housing and is caused by the main rotor’s rotation. The refrigerant is pulled in by the main rotor’s revolution. One of the star wheels releases the compressed refrigerant once it has been shut.

Compact and smaller in size, single screw compressors are very effective in small applications. In addition to being more suitable for smaller applications, single screw compressors frequently experience issues with star wheel wear.

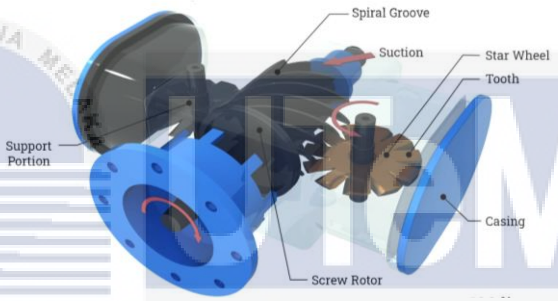


Figure 2.12: Single Screw Compressor

Two shafts are connected to two helical rotors in twin screw compressors. It is said that one of the rotors is the male and the other is the female. There are usually more flutes on the female rotor than the male. The male lobe functions as a continuous piston during rotor movement, rolling down into the female flutes, which operate as a cylinder by trapping refrigerant and continuously decreasing space to increase the refrigerant’s pressure. The volume of the refrigerant is compressed and decreased as it enters the grooves of the female rotor. The pressurized refrigerant gas is released through the outlet valve when the male rotor lobe reached the end of the groove.

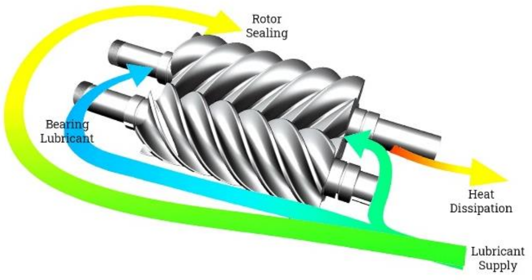


Figure 2.13: Twin Screw Compressor

2.2.2.7 Absorption Chiller

An absorption chiller is a closed loop cycle that produces refrigeration or cooling using waste heat. Three basic concepts indicate this cycle of absorption cooling. The first is that a gas condenses as it cools down and a liquid boils, or vaporizes. Second, a liquid’s boiling point decreases when pressure is lowered above it, and third, heat moves from warmer to colder surfaces.

A thermochemical "compressor" is crucial for the absorption cooling process. There are two types of fluids used: an absorbent and a refrigerant. The fluids dissolve easily in one another due to their great “affinity” for one another. Lithium bromide (Li Br) serves as the absorbent and water as the refrigerant in a water-lithium bromide vapor absorption refrigeration system. Water and lithium bromide are combined to form a solution in the absorber when the lithium bromide absorbs the water refrigerant.

The refrigerant, which can often be water, flows throughout the system and is easily capable to change phases from liquid to vapor. The process is driven by heat from the combustion of natural gas or waste heat. The refrigerant moves heat from one place to another by boiling at a lower temperature and pressure than it normally would due to its strong affinity for the absorbent, which is often lithium bromide or ammonia.

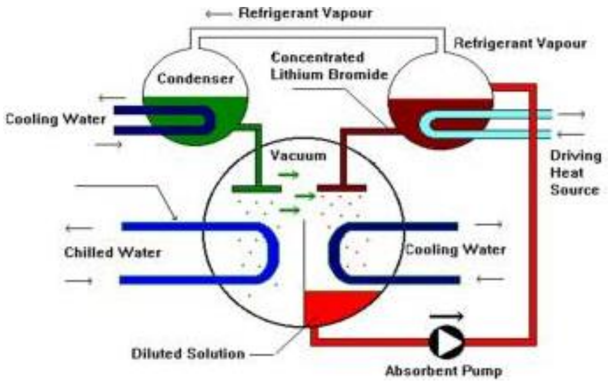


Figure 2.14: Working Principle of Absorption Chiller

2.2.2.8 Variable Refrigerant Flow (VRF)

A system that uses refrigerant for both heating and air conditioning is appropriately referred as one offering variable refrigerant flow, or VRF. VRF is essentially a large-scale, ductless HVAC system that runs effectively. Compared to conventional split air conditioning systems, VRF allows many indoor units—each designed for a particular use—to be integrated into a single system. These systems, which enable simultaneous heating and cooling operations, fall into one of two categories: heat pump or heat recovery.

By using inverter compressors, VRF (Variable Refrigerant Flow) systems are able to operate more efficiently. Unlike non-inverter systems that continuously run at maximum capacity, these inverters allow the compressor to regulate its speed in accordance with the particular requirements of each location. When operating at lower speeds and capacities, inverter systems may provide significant efficiency benefits compared to non-inverter systems that operate in a binary on/off mode. Due to their efficiency improvements and versatility, VRF solutions have particular appeal to facility managers and commercial areas. Their adaptability allows customization to meet the demands of multiple projects.

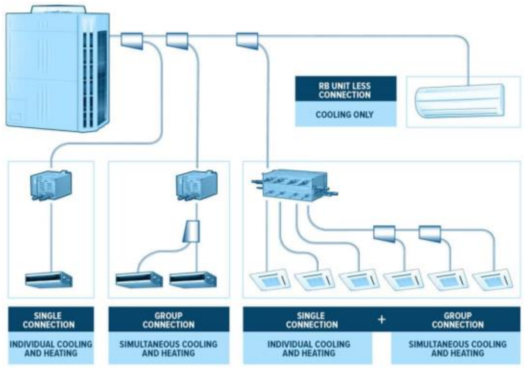


Figure 2.15: Refrigerant branch lines for cooling and single, group connections for individual and simultaneous cooling heating

2.2.3 Cooling Tower

To remove extra heat from a building or industrial operation, cooling towers are common heat rejection devices used in HVAC and industrial systems. Hot water from processes or air conditioning systems is cycled through the tower, which works on the basis of evaporative cooling, where some of it evaporates, eliminating heat. After cooling, the water is brought back for recirculation. By releasing heat into the environment and using the latent heat of vaporization, cooling towers improve energy efficiency. These towers are essential for preserving the ideal temperatures for systems and equipment. They are available in a variety of configurations, including cross flow and counter flow.

The industry standard for cooling towers is the closed-circuit cooling tower, which consists of a tower, water distributor, water collection, fan, pump, heat exchange coil, and circulating pool. In order to facilitate the transfer of heat, certain closed-circuit cooling towers additionally pack in the coil section. The system's operation revolves around using the heat exchanger coil to separate the cooled industrial medium from the cooling water passing through the tower and using the evaporation of the water film and convective heat exchange between the water film and the air outside the tube to remove heat for waste heat rejection and industrial cooling water recycling (Zhou et al., 2024).

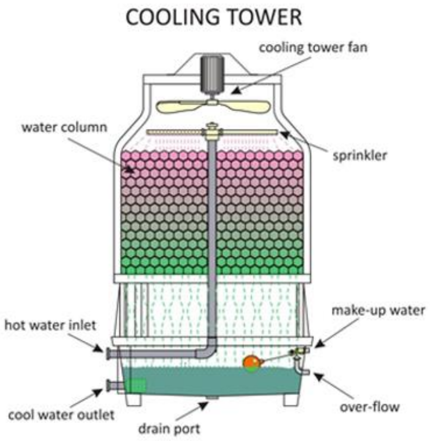


Figure 2.16: Cooling Tower Diagram

2.2.4 Chilled Water Pump

A chilled water pump, particularly in chiller plants, is an essential part of HVAC systems. It facilitates heat absorption by moving chilled water from the chiller to the building's cooling coils and back. The pump, which is powered by an electric motor, maintains up a steady flow to ensure that chilled water is transferred through the system effectively. Energy usage may be optimized by varying the pump's speed in accordance with the cooling demand. Its sensors allow it to detect pressure differences and adjust performance as necessary. All things considered, the chilled water pump is essential to preserving reliable and cost-effective cooling in commercial and industrial buildings. The most common way to reduce energy consumption in a chilled water system is to use variable flow operation, and most central air conditioning systems are designed with several chilled water pumps running in parallel. The control strategy determines the energy consumption of a set of parallel pumps operating with the same pipe network flow. (Xuefeng et al., 2015)

Figure 2.17: Chilled Water Pump

2.2.5 Condenser Water Pump

Through the circulation of water between the chiller's condenser and cooling tower, the condenser water pump is an essential component of the chiller system equipment. The heat gained by the building's air conditioning system is made easier to reject using this pump. The chiller's condenser absorbs heat from the heated refrigerant gas as it flows through it, and the pump transfers that heat to the cooling tower where it is dissipated. A building's total energy efficiency in the cooling system is supported by the condenser water pump's efficient operation, which also guarantees excellent chiller performance and efficient heat exchange.

The small steam turbine feeding water pump cannot have its exhaust steam connected directly to the main condenser because of the inherent weaknesses of the air-cooled device. The reason for this is because the backpressure of an air-cooled steam turbine is far greater than that of a water-cooled one, and it fluctuates a lot due to variations in the surrounding temperature. The air-cooled type machine is required for the little turbine of the feeding water pump because the exhaust steam is linked to the main condenser of the unit (Wei et al., 2012).

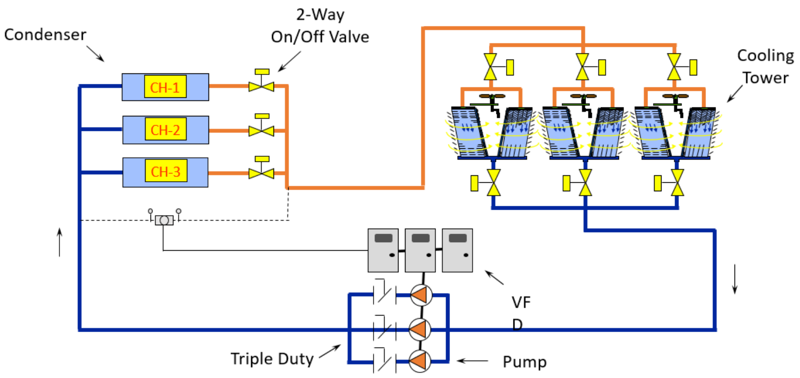


Figure 2.18: Parallel pumping in condenser water pump

2.2.6 Variable Speed Drive (VSD)

Electric devices and power networks may exchange energy using variable speed drives, or VSDs. Rectifiers, storage capacitors, and inverters are the usual components of AC-DC-AC power converters (Hokayem et al., 2017).

An electric motor can operate at various speeds instead of a fixed rate due to an electrical component called a variable speed drive (VSD), which controls the motor's torque and speed. VSDs accurately match the electrical supply to the motor by adjusting its voltage and frequency to match the required load. This feature reduces power input during times of low demand, which optimizes energy usage. VSDs improve efficiency in applications such as chiller systems by enabling different speeds for compressors and fans. This allows the system to adapt dynamically to changing cooling requirements and ultimately save energy while prolonging the equipment's lifetime.

Installing devices that can adjust the motor speed to match the building's actual demand which is typically lower than the design peaks used to size the HVAC system is a fundamental step towards achieving energy savings in HVAC systems. During most of the year, inefficient functioning might be caused by part load. This is why modern electric motors and, by consequently, motor-driven machinery (such as fans, pumps, and so on) come with variable speed drives (VSDs) that allow the user to control the speed at which the motor rotates. Attached to a variable speed motor are components like fans, pumps, and compressors, which exhibit diverse behavior when the speed is changed. Consequently, VSDs may be used by chillers, air handlers, heat pumps, pumping systems, and terminal devices such as fan coils in an effort to achieve more efficient system central plants. Due to VSD technology, these parts may work in combination or separately from the building management system (Schibuola et al., 2018).

Figure 2.19: Variable Speed Drives

2.2.7 Building Automation System (BAS)

A cyber-physics system, consisting of a physical-engineered system, cyber control core, and communication networks, is what makes HVAC based on Building Automation Systems (BASs) different from traditional HVAC. It fulfils the HVAC needs for low energy consumption, optimal comfort, productivity, and safety by intelligently controlling and scheduling the physical devices (physical-engineered system) via a cyber-control core (Zhao et al., 2023).

A building automation system (BAS) integrates the many features provided by a building's control system into a data collecting and control system. Examples of such features include the ability to monitor and regulate environmental factors like temperature and air quality as well as HVAC systems, lighting, energy, access, security, fire, and the transmission of fault signals. Energy optimization is achieved by BASs through the use of sensors that gather data on control parameter status, actuators that carry out physical operations, and communication and interoperability.

A Building Automation System (BAS) is a centralized control system that oversees and supervises the mechanical, electrical, and HVAC systems of a building. It combines several sensors, controls, and actuators to enhance the performance of heating, ventilation, air conditioning, lighting, and security systems. Building Automation Systems (BAS) provide the immediate gathering of data, its analysis, and the automated regulation of processes, therefore improving energy efficiency, occupant satisfaction, and operational efficiency. Facility managers may remotely monitor and change settings, use energy-saving techniques, and get notifications for system failures using a user-friendly interface. Building Automation Systems (BAS) are crucial in the operation of intelligent buildings, as they significantly contribute to the promotion of sustainability, cost reduction, and efficient facility management. The field layer, which comprises interactions with sensors and actuators, the automation layer, which comprises devices and processes, and the management layer, which is located at the plant level, are the three functional levels that make up BAS. The ability of BAS to minimize EPG while maintaining passenger comfort has contributed to its rising popularity (Qiang et al., 2023).

2.3 Energy Savings

In developed countries, the energy use of major buildings, including hotels, museums, hospitals, and commercial buildings, contributes to almost 20% of total energy consumption worldwide. The growing popularity of heating, ventilation and air conditioning (HVAC) systems, the addition of new building services, rising comfort levels, and people spending more time inside buildings are some of the factors contributing to this high consumption (Alonso et al., 2019).

In order to improve energy efficiency in a plant with several chillers, it is recommended to initially analyze the performance of each chiller independently and then the plant as a whole. A significant amount of real data is collected and stored by building management systems (BMS), and this data may be examined and used to discover implicit knowledge (Alonso et al., 2019).

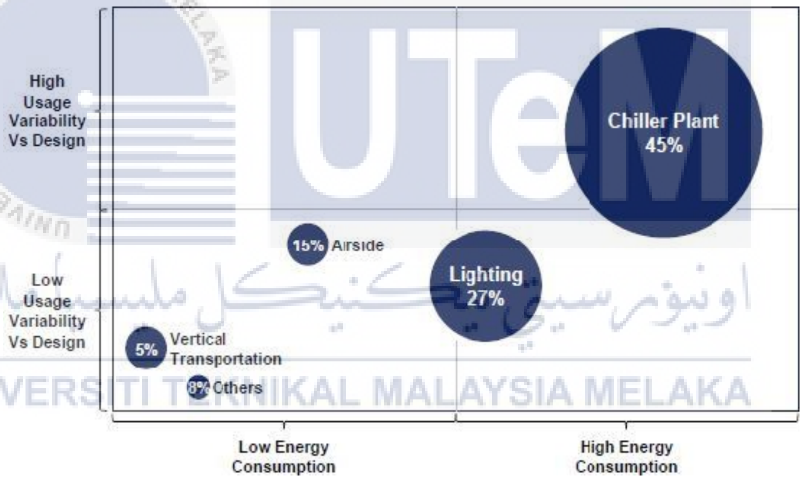
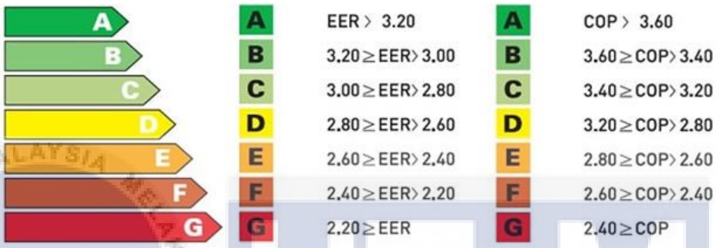


Figure 2.20: Percentage of building energy consumption

The chiller plant, which accounts for 45% of building energy consumption overall, is an important factor in all of the factors. This percentage emphasises how crucial it is to maximise the chiller system's efficiency because it has a direct influence on the building's overall energy performance. Since lighting uses 27% of energy, it is imperative to adopt energy-efficient lighting practices and solutions. 15% of the energy used is accounted for by the airside systems, which are in charge of ventilation and air conditioning. This indicates the possibility of achieving energy savings by using modern HVAC controls and technology.

Five percent of energy use is attributed to vertical mobility, which includes escalators and lifts. This suggests that there are opportunities for energy-efficient designs and operating solutions in this area. The remaining 8% that is ascribed to "others" represents a variety of additional sources, highlighting the significance of a thorough approach to energy management in order to recognise and handle a range of energy-consuming components in buildings. Attaining total energy efficiency and sustainability in building operations requires thorough evaluation and optimisation of these components.



A	EER › 3.20	A	COP › 3.60
B	3.20 ≥ EER › 3.00	B	3.60 ≥ COP › 3.40
C	3.00 ≥ EER › 2.80	C	3.40 ≥ COP › 3.20
D	2.80 ≥ EER › 2.60	D	3.20 ≥ COP › 2.80
E	2.60 ≥ EER › 2.40	E	2.80 ≥ COP › 2.60
F	2.40 ≥ EER › 2.20	F	2.60 ≥ COP › 2.40
G	2.20 ≥ EER	G	2.40 ≥ COP

Figure 2.21: Energy Ratings

Associations like the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) in the United States or the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) often develop EER testing procedures and standards. Each of these organizations strive to create and maintain standards that producers may use to evaluate and test the effectiveness of their chillers and other cooling equipment. The EER ratings supplied by manufacturers are ensured to be consistent and comparable across multiple products by use of standardized testing techniques.

2.3.1 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

To further the fields of HVAC, refrigeration, and air conditioning, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) is an established professional organization. Established in 1894, ASHRAE is a world-renowned organization that facilitates networking among HVAC&R (Heating, Ventilation, Air Conditioning, and Refrigeration) experts, as well as the development of standards for the efficient and environmentally friendly operation of building systems. As a nonprofit organization, ASHRAE's aim is to promote engineering excellence through the publication of standards and recommendations, the conduct of research, and the organization of conferences. When it comes to influencing their operations, promoting for environmental responsibility, and ensuring people in built environments feel comfortable and safe, the society is essential.

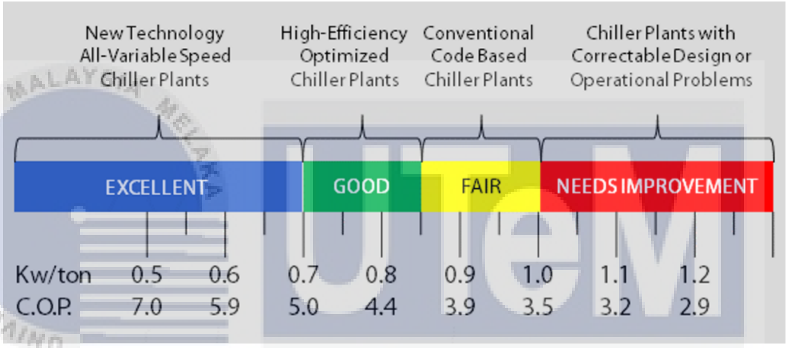


Figure 2.22: ASHRAE- Chiller Plant Efficiency

2.4 Healthy Buildings

Indoor air quality (IAQ) is a key component of healthy buildings, which are constructed and maintained to maximize occupant productivity and well-being. The mix of pollutants, humidity, and ventilation that exist within a building is all included in the term “indoor air quality.” The overall health and comfort of its residents are enhanced by a healthy building’s dedication to maintaining natural, uncontaminated air.

Efficient ventilation systems that remove indoor contaminants and bring in fresh outside air are vital elements of healthy buildings. This reduces the development of allergens, particle debris, and volatile organic compounds (VOCs), among other airborne pollutants.

Furthermore, maintaining a pleasant atmosphere and preventing the spread of mold need effective humidity regulation. The number of hazardous substances released into the air is further reduced by using low-emission furniture, paints, and materials.

A healthy interior atmosphere may be created via routine maintenance, air quality monitoring, and the addition of natural components or outdoor spaces. By giving priority to these elements, healthy buildings seek to lower the chance of allergies, breathing issues, and other health problems brought on by poor indoor air quality, eventually creating an environment that improves the well-being of its residents.

2.4.1 Indoor Air Quality (IAQ)

The term “indoor air quality,” or “IAQ,” describes the state of the air in enclosed areas like homes, workplaces, or buildings, with an emphasis on how it affects the comfort and health of those who live there. In addition to elements like humidity and temperature, the presence of contaminants like dust, mold, allergies, and chemicals affects indoor air quality (IAQ). In addition to creating a comfortable and healthy living or working environment and lowering the risk of respiratory ailments and other health-related difficulties, good indoor air quality guarantees that the air is clean, well-ventilated, and free of dangerous pollutants.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This methodology explores the particulars of improving chiller systems, with a focus on energy usage optimization to produce buildings that are both sustainable and considerate of occupant well-being.

The initial step involves an extensive assessment of the current chiller systems, analyzing their performance parameters and identifying inefficiencies. Then, specific improvements are put into practice, making use of modern technology and innovative technical solutions that enhance the overall efficiency of the system. In order to obtain the most efficient energy savings, this strategy takes a comprehensive approach that includes equipment selection, system design, and operational methods.

In addition, the study of integrating predictive maintenance algorithms with smart building technologies is being conducted in order to ensure proactive and continuous surveillance of chiller systems. By keeping constant thermal comfort, this not only maximizes energy efficiency but also helps to create healthier indoor environments. Through the implementation of this methodology, buildings may transform into sustainable entities that emphasize the well-being of humans while lowering their carbon footprint. This kind of strategy can ultimately lead to the harmonic integration of environmental responsibility and human health.

3.2 Process of Measurement

This thesis involves process of measuring chiller efficiency by evaluating the effectiveness of the chiller system in transforming electrical energy into cooling output. Metrics like the Energy Efficiency and Coefficient of Performance are often used for measuring efficiency. Important variables like flow rates, chilled water temperatures, and input power are recorded throughout this operation. Next, divide the cooling capacity by the electrical power usage to get the efficiency ratio. Better efficiency is shown by a greater COP or EER, which translates to the chiller's capacity to provide efficient cooling with less energy input, supporting energy conservation and sustainable operation. The overall project process are shown in Figure 3.1 while the measurement process are shown in Figure 3.2.

3.2.1 Project Flow Chart

As shown in Figure 3.1, the first step in creating a project flow chart for energy-saving improvements to a building's chiller system is to determine its scope. Understanding the current configuration, its individual components, and the energy usage involved are required for success. After that, initial measurements are established by identifying important performance indicators such as energy consumption and operating efficiency. The next stage is to put measuring, instrumentation, and monitoring systems into place to collect data on the chiller system's functioning in real time. After gathering data, a thorough analysis is carried out to find areas that may need improvement. This study might look at the effectiveness of the system's present parts, potential problems, and performance as a whole. To establish performance targets, energy efficiency is then benchmarked against industry standards. To improve energy efficiency, control techniques are put into place and equipment is improved in light of the findings. This might entail changing out old parts, adding better insulation, or integrating modern technologies.

Finally, recommendations and reporting round out this project. A thorough report is produced, outlining the modifications that were made, the advantages that were noticed and suggestions for future upgrades or maintenance. With the effective implementation of energy-saving measures, the project officially comes to a conclusion and contributes to a more sustainable and healthy building environment.

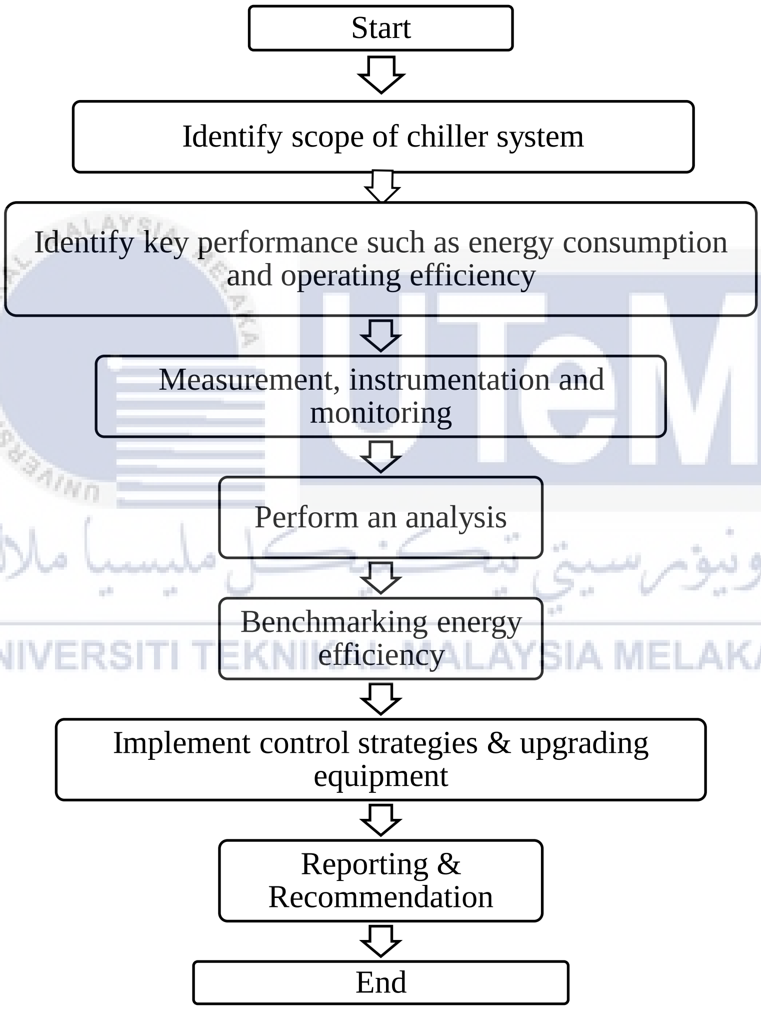


Figure 3.1: Flow Chart of Overall Project

3.2.2 Measurement Flow Chart

The measurement flow chart is a systematic approach to increasing efficiency and lowering energy consumption with the purpose of improving a chiller system and energy savings towards a healthy building. As shown in Figure 3.2, the process starts with a focus on safety, making sure that all required safeguards are put in place and that individuals are outfitted with the right personal protective equipment (PPE). Thermocouples are then placed to measure variations in temperature, and the power metre is then linked to the chiller system's electrical supply to monitor its energy use. The chilled water system also has flow metres to measure flow rates, which offer essential details about the system's operation.

Following the installation of the instrumentation, a data logger is turned on to continually record measurements for a certain period of time, capturing changes in energy usage under various operating circumstances. A thorough evaluation of the effectiveness of the chiller system is made possible by the methodical analysis of the data that has been obtained in order to spot patterns and trends. The collected data is used to calculate the energy efficiency and energy consumption (in kW/h), which provide measurable indicators of the system's performance. The final step involves gathering the results into an energy usage report that includes graphical representations for easy comprehension. This all-encompassing strategy ensures an in-depth understanding of the energy dynamics of the chiller system, enabling well-informed decisions for enhancement and aiding in the development of healthy and energy-efficient buildings.

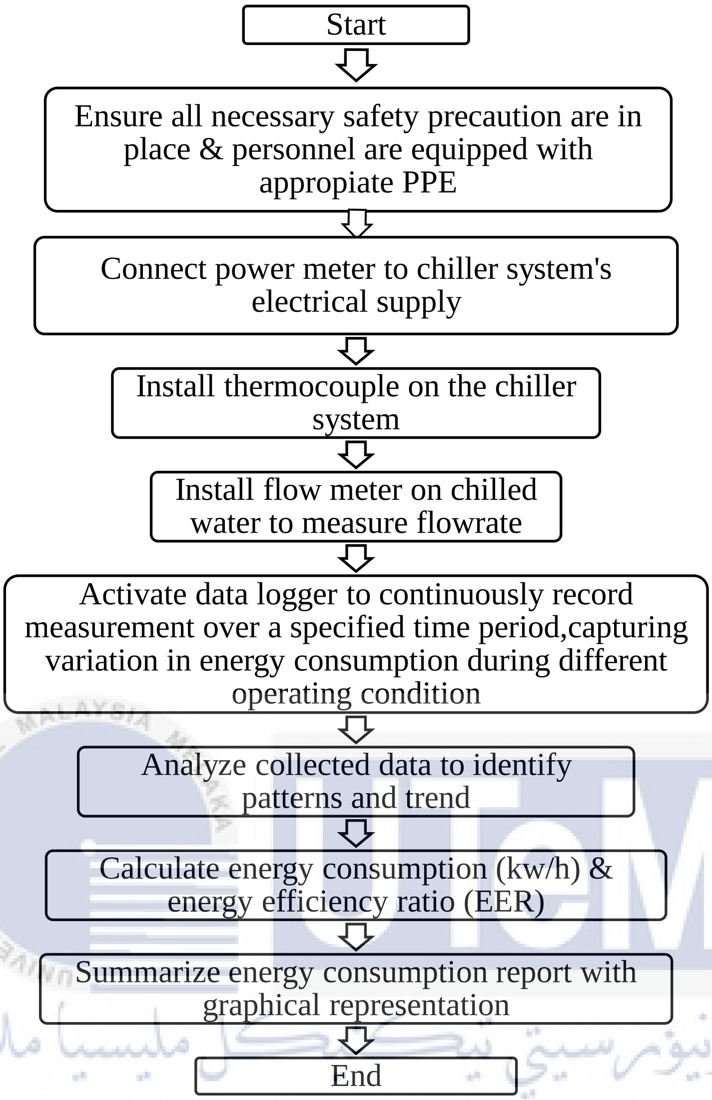


Figure 3.2: Flow Chart of Measurement

3.2.3 Chiller Selection

To maximize a chiller system's energy efficiency, chiller selection is crucial. Load variations, part-load performance, and compatibility with energy-saving devices are issues that should be considered while making the best options. The system may be optimized for different situations by using chillers with high-efficiency compressors and variable speed drives (VSDs). This allows for exact capacity modulation. Improved chiller performance is achieved by the use of advanced control algorithms and smart sensors. Reduced energy consumption and increased overall sustainability are major benefits of a more responsive and adaptable system that results from matching chiller selection with energy-saving targets.

3.2.3.1 Old Chiller

Table 3.1: Specifications of Old Chiller System

Type	Brand	Model	Capacity
Air-Cooled Chiller	YORK	YSCA 150SE S1 HG	150 RT

As shown in Table 3.1, the old cooling system is a 150 refrigeration tons (RT) air-cooled chiller from YORK with the model number YSCA 150SE S1 HG. Because of its air-cooling development, this model is ideal for regions where water is limited or not readily available. The YSCA 150SE S1 HG model in particular is indicative of a standard sound rating (S1), high-glycol capacity (HG), and standard efficiency level (SE). The 150 RT capacity of this chiller makes it an important part of it cooling systems.

3.2.3.2 New Chiller

Table 3.2: Specifications of New Chiller System

Type	Brand	Model	Capacity
Water -Cooled Chiller	CARRIER	30XW-V408	420 RT

From Table 3.2, the Carrier 30XW-V408, a water-cooled chiller, is a perfect option because of its impressive capacity of 420 RT and its use of VSD technology. By enabling the chiller to rapidly change its speed in response to changing cooling needs, VSD improves operational efficiency by optimizing energy use and minimizing waste. Recognized for its advanced design, the 30XW-V model from Carrier guarantees dependable and accurate temperature management in many different scenarios.

A cooling tower is part of the system that works with the water-cooled chiller to remove the extra heat that is produced after the refrigeration process is complete. In keeping with sustainable standards in HVAC systems, this integrated system with a cooling tower and 30XW-V chiller highlights a comprehensive strategy for energy savings. Optimal cooling performance, energy savings, and environmental responsibility may all be achieved with the help of the Carrier 30XW-V, owing to its large capacity and modern features.

3.3 Parameters of Study

A comprehensive evaluation of the energy-saving potential of chiller systems should take into consideration an array of important factors in order to evaluate and optimize system performance. Firstly, is by analyze the chiller’s efficiency ratings, such as the Energy Consumption (kW) and Energy Efficiency (kW/RT) , to determine the performance of the chillers.

3.4 List of Equipment

Power measurements (Yokogawa CW240), water flow measurements (GE PT878), temperature measurements (Yokogawa Datum-Y XL100) and Building Automation System (BAS) were used to obtain the energy consumption of Air-Cooled Chiller (Old) and Water-Cooled Chiller (New)

The equipment used are as follows:-

iii) Yokogawa CW240

Figure 3.3: Yokogawa CW240

The CW240 power meter is a comprehensive device for evaluating equipment lifecycles, improving energy efficiency, and identifying potential areas of improvement. Beyond only monitoring power consumption, the meter offers detailed information about how an item of equipment, part of a plant, or a whole operation is operated.

Users may more accurately determine the maintenance, repair, and replacement schedules for equipment like transformers and motors by using the included clamp-on components and probes. Details are given on demand and load factors, as well as fluctuations in voltage and current during motor startup.

iv) GE PT878

Figure 3.4: GE PT878

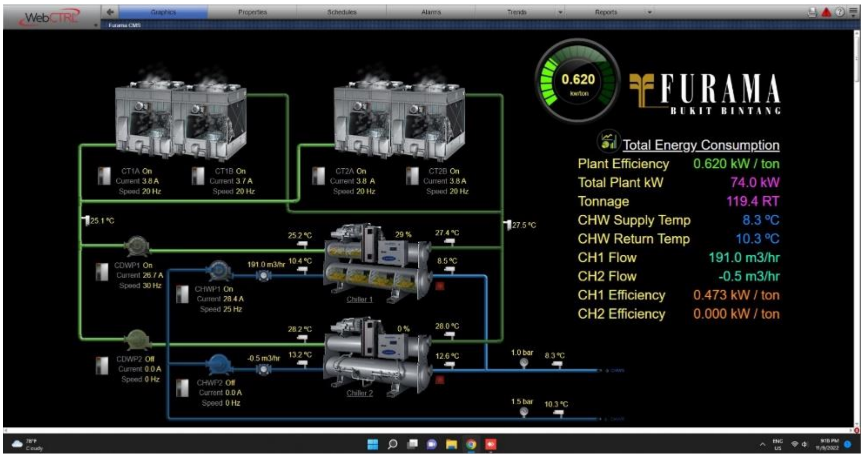
For any type of flow survey project, the TransPort PT878 flow meter is ideal. The TransPort PT878 flowmeter observes flow rate through metal, plastic, or even concrete-lined pipes without breaking the wall of the pipe by using clamp-on transducers.

v) Yokogawa Datum-XL100

Figure 3.5: Yokogawa Datum-XL100

A compact, lightweight, portable data recorder and data station is the Yokogawa XL100. Temperature (thermocouple, resistance temperature detector) and voltage may be adjusted for each channel on these portable data stations.

vi) Building Automation System (BAS)



Total Energy Consumption	
Plant Efficiency	0.620 kW / ton
Total Plant kW	74.0 kW
Tonnage	119.4 RT
CHW Supply Temp	8.3 °C
CHW Return Temp	10.3 °C
CH1 Flow	191.0 m3/hr
CH2 Flow	-0.5 m3/hr
CH1 Efficiency	0.473 kW / ton
CH2 Efficiency	0.000 kW / ton

Figure 3.6: Snipshot of new chiller plant system through BAS in PC

A Building Automation System (BAS), which offers real-time monitoring, control, and data analytics features, is essential for assessing the energy usage of new chiller plants. In order to gather information on critical parameters such chilled water flow rates, temperatures, electrical consumption, and operational condition, the BAS interfaces with sensors and meters within the chiller plant. The BAS enables constant communication between the components of the chiller system through a centralized control interface.

BAS is a data collection and control system which incorporates many features offered by a building's control system. These features include, but are not limited to, monitoring temperature and air quality, controlling lighting and HVAC systems, power management, controlling access, controlling security and fire safety, notifying users of defects, and more. BAS are computer-based automated systems that depend on actuators to carry out physical operations, sensors to collect data relating to the condition or status of control parameters, and communication and interoperability to maximize total energy optimization using BAS (Habib et al., 2023).

3.5 Measurement of Power, Water Flow and Temperature

It is essential to use a precise measuring technique to improve the chiller system's performance and help achieve energy-saving goals for healthier buildings. In order to determine the electrical demand of the chiller, accurate instruments measure power usage. The system's heat exchange efficiency is optimised by the use of flow rate gauges for water. To further optimise energy consumption and management, temperature sensors are strategically positioned to record changes in the chilled water supply and return. With this comprehensive monitoring approach, performance can be analysed in real-time, allowing for fine-tuning and modifications to achieve a health-conscious and energy-efficient targets in building environments.

3.5.1 Power

Chiller power measurement was carried out using the Yokogawa CW240 power analyzer. The previous air-cooled chillers were measured by clamping the outgoing power cables. The voltage was taken by connecting the leads to the corresponding phase. The power analyzer automatically calculates the power consumption from the current, voltage and power factor measurements.

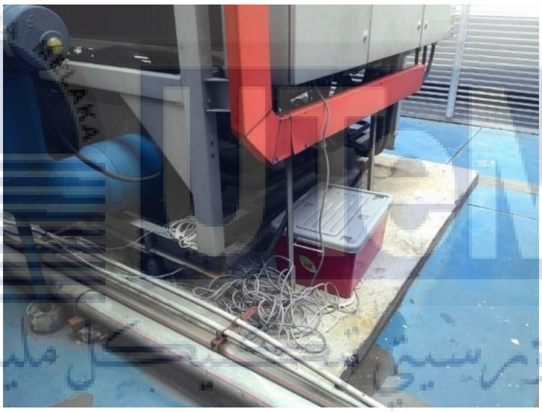


Figure 3.7: Logging meters kept in the box near to the chiller

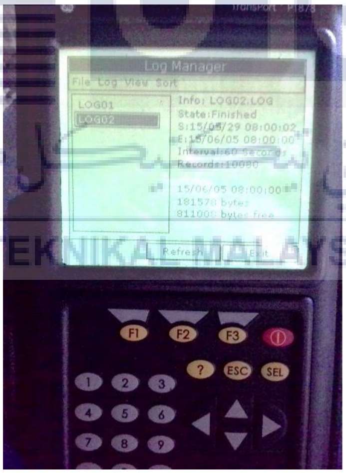
```
LIST          INTEG.  LOAD1 INST.        2015/06/04
                                          15:31:57
                                         WIRING
U1    410.7  V    I1    0.246 kA          3P3W3I
U2    412.7  V    I2    0.246 kA         LOAD
U3    412.2  V    I3    0.244 kA              1
Uave  411.9  V    Iave  0.245 kA         U  600V
                                          x  1.00
                                         A 1500A
                                          x  1.00
P     0.154 MW    PA    28.0  °
Q     0.082 Mvar  f     50.02 Hz
S     0.175 MVA                          PLL
PF    0.883                               U1  50Hz
                                         INTER.
                                            1min
```

Figure 3.8: Electrical power data being logged

3.5.2 Flow Rate

Chilled water flow rate was measured at the supply main header using GE PT878 ultrasonic flow meter. The ultrasonic transducers were clamped to the pipes at the required distance and the flow rate reading was logged for at least 1 week.

Figure 3.9: Flow meter clamp on chilled water pipe header



Info: LOG02.LOG
State:Finished
S:15/05/29 08:00:02
E:15/06/05 08:00:00
Interval:60 Seconds
Records:10080

15/06/05 08:00:00
181578 bytes
811008 bytes free

Figure 3.10: Log manager of flow meter

3.5.3 Temperature

Chilled water temperatures in and out were measured by inserting the Pt100 temperature sensors into the existing thermowell of supply and return temperatures on each of running chiller. The sensors were connected to the Yokogawa XL100 data logger and the data were logged for at least 24 hours.

Figure 3.11 : Temperature sensors were inserted in both chilled water supply & return thermowell

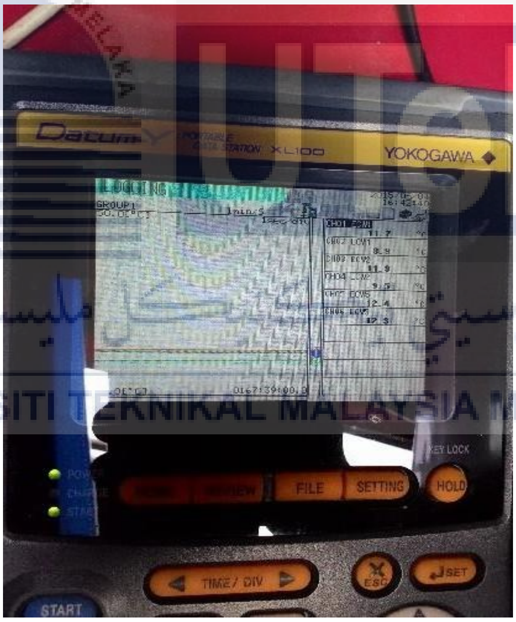


Figure 3.12: Data logger showing Air-Cooled Chiller of chilled water supply and return temperature

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter of this thesis presents the findings and discussion part, which analyses the modifications that were made and how they affected the efficiency of the chiller system and the amount of energy used. This research intends to make an important improvement to HVAC by providing understanding of the relationship of cutting-edge technology, energy efficiency, and indoor environmental quality. Not only the sustainability improvements' actual effects made exposed in this section, but their relevance to environmentally friendly building practices as a whole is also thoughtfully assessed. By analysing the results, drawing conclusions, and comparing them to previous research and industry standards, this discussion aims to give an in-depth overview of how better chiller systems alongside energy savings may contribute to healthier and more environmentally friendly buildings.

4.2 Results and Analysis of Energy Consumption

First, the analysis evaluates the current chiller system's baseline energy usage, taking into account many elements like load profiles, operational characteristics, and environmental conditions. This thesis finds inefficiencies and possible opportunities for improvement by systematically collecting and analysing data.

Next, an analysis is conducted on the application of energy-efficient solutions such improved insulation, variable speed drives, and control systems. The financial viability of these improvements is assessed using a cost-benefit analysis. The impacts of these enhancements on general occupant health, thermal comfort, and indoor air quality are all being thoroughly investigated at the same time.

After the suggested improvements were put into practice, the findings show a significant reduction in energy consumption. This study additionally highlights the benefits of these advancements in terms of improving humidity levels, air quality, and temperature control in order to create a healthier indoor environment.

4.2.1 Old Chiller Plant System Energy Consumption

Table 4.1: Energy consumption of old chiller plant system

Old Chiller Plant System (Air-Cooled Chiller)	
Equipment	Efficiency (kW/RT)
Chiller	1.437
CHWP - 1	0.074
CHWP - 2	0.077
TOTAL	1.588

The energy consumption of an old chiller plant system, in particular when using an Air-Cooled Chiller, depends on by numerous factors and corresponding efficiency. The Chiller Efficiency is a crucial data, defined as 1.437 kW/RT (kilowatts per refrigeration tonne). The value shown indicates the energy consumption required to generate one tonne of refrigeration.

Furthermore, the efficiency of the Chilled Water Pump (CHWP) is of major significance. The efficiency of CHWP 1 is 0.074 kW/RT, whereas the efficiency of CHWP 2 is 0.077 kW/RT. The above data represent the amount of energy used by the chilled water pumps for each refrigeration tonne.

The overall efficiency of the chiller plant system is determined by combining the efficiencies of the chiller and the chilled water pump (CHWP). The overall efficiency in this particular case is calculated as 1.588 kilowatts per refrigeration tonne (kW/RT). The result considers the total energy consumption of the chiller and the chilled water pumps, offering an in-depth evaluation of the system's overall efficiency.

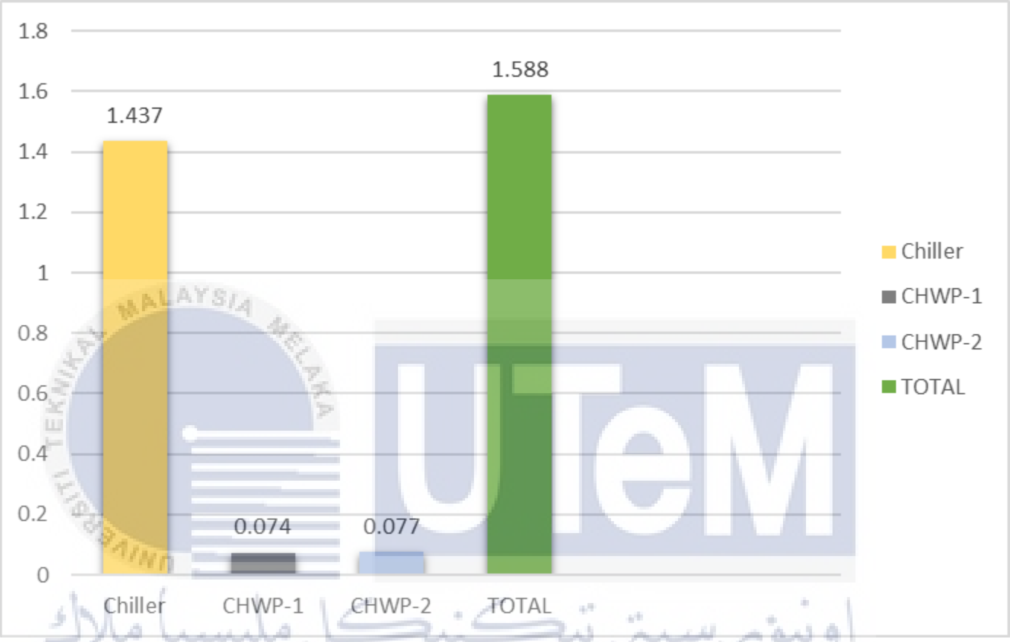


Figure 4.1: Bar chart of efficiency of each equipment for old chiller plant

Nothing that a higher kW/tonnes of the chiller plant system, a less energy efficient of the system. Meaning that more electricity is required to produce the desired cooling effect. This results indicated that the old chiller system are lack of technological advancements.

4.2.2 New Chiller Plant System Energy Consumption

Table 4.2: Energy consumption of new chiller plant system

New Chiller Plant System (Water-Cooled Chiller)	
Equipment	Efficiency (kW/RT)
Chiller	0.506
CHWP-1	0.060
CDWP-1	0.071
CT-1	0.008
CT-2	0.008
TOTAL	0.652

The assessment of overall efficiency of a new chiller plant system, particularly one incorporating a Water-Cooled Chiller, depends heavily on the energy usage. The chiller's efficiency is an important component, and it is clearly stated as 0.506 kW/RT (kilowatts per refrigeration tonne). This data point represents the energy efficiency of the chiller by measuring the amount of energy used to generate one tonne of refrigeration, which is a standard unit for measuring cooling capacity.

In addition, the Chilled Water Pump (CHWP) and Condenser Water Pump (CDWP) contribute to the total energy usage. The CHWP 1 has an energy consumption value of 0.060 kW/RT, whereas the CDWP 1 has an energy consumption value of 0.071 kW/RT. These pumps are essential for circulating chilled water throughout the system and ensuring optimal working conditions.

Cooling towers, which are crucial for removing heat from the chiller system, also contribute to energy usage. Cooling Tower 1 and Cooling Tower 2 each have an energy consumption rate of 0.008 kilowatts per refrigeration tonne (kW/RT). These statistics indicate the amount of energy required to operate the fans and other components that are attached to the cooling towers.

The overall efficiency of the newly implemented chiller plant system is reported as 0.652 kilowatts per refrigeration tonne (kW/RT). This comprehensive data takes into account the collective energy usage of the chiller, pumps, and cooling towers, offering a holistic assessment of the system's effectiveness in supplying cooling capacity.

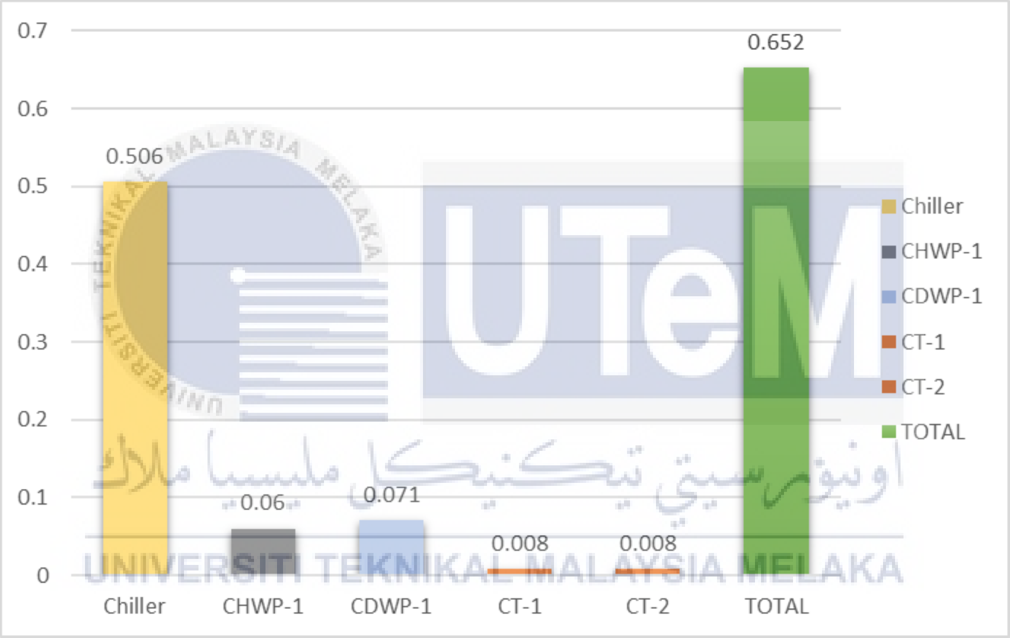


Figure 4.2: Bar chart of efficiency of each equipment for new chiller plant

Nothing that a the lower kW/tonnes of the chiller plant system, the more energy efficient of the system. Meaning that less electricity is required to produce the desired cooling effect. This results indicated that the new chiller system is advanced technology and have proper insulation on pipes and equipment.

4.3 Efficiency between old chiller and new chiller

Table 4.3: Average Energy Efficiency Old Chiller & New Chiller

Equipment	Average Energy Efficiency (kW/RT)
Old Chiller (Air-Cooled Chiller)	1.59 kW/RT
New Chiller (Water-Cooled Chiller)	0.65 kW/RT
Improved Chiller Efficiency	0.936 kW/RT (59%)

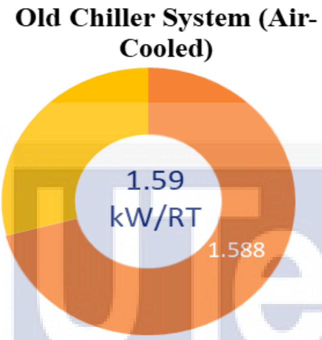


Figure 4.3: Old Chiller Average Efficiency

In order to clarify the results of chiller efficiency measurements, this discussion will compare the average energy efficiency of two different chillers, a metric that illustrates the relationship between cooling output and electrical power input of an old chiller and a new one. The calculated 1.59 kW/RT old chiller's efficiency which are shown in Figure 4.1, raises questions regarding how much energy it uses and how much it costs to run. Referring to Figure 2.21, this chiller's comparatively poor efficiency raises the possibility that it is using antiquated technology, lacking of the innovations and improved engineering found in current models. Thus, the old chiller need improvement based on ASHRAE guidelines. Excessive power usage may necessitate replacement or retrofitting due to its potential to increase electricity bills and negatively harm the environment.

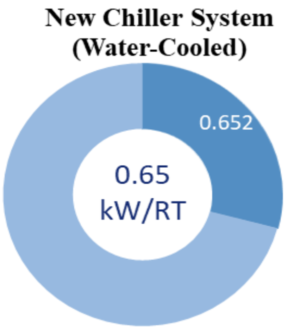


Figure 4.4: New Chiller Average Efficiency

With an average efficiency of 0.65 kW/RT in Figure 4.2, the new chiller is a major advancement over the old chiller. Improved design, optimised components such as VSD, and technological developments such as BAS are probably accountable for this increased efficiency. In terms of cost and environmental effect and also referring to ASHRAE in Figure 2.21, a lower efficiency number means that the new chiller can provide greater cooling output for the same amount of electrical power input.

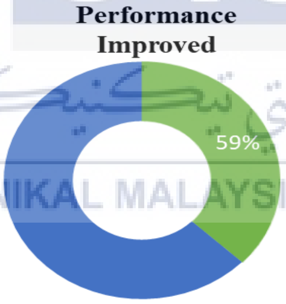


Figure 4.5: Improved Efficiency

Chiller efficiency comparisons illustrate how cooling industry technology has advanced. A chiller improvement from an older model with an energy efficiency of 1.59 kW/RT to a newer model with an energy efficiency of 0.65 kW/RT might result in significant savings on operating costs, improved energy efficiency, and less environmental impact. The improved chiller efficieny percentage are shown in Figure 4.3, which is 59% chiller efficiency are improved from the old chiller.

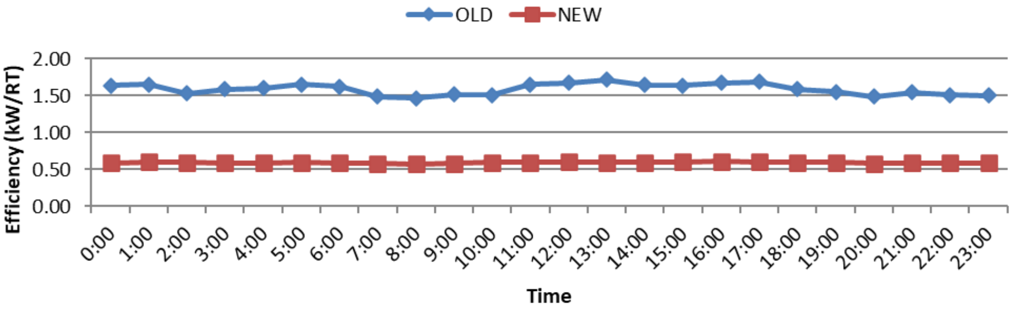


Figure 4.6: Efficiency between old and new chiller plant system

The efficiency comparison graph illustrates the performance enhancements gained by technology developments and system upgrades in the chiller plant system, comparing the old and new systems. The x-axis generally represents the time frame, while the y-axis indicates the efficiency of the chiller plant equipment.

The efficiency of the ageing chiller plant system may exhibit a consistent or decreasing trend over time. The decrease in performance may be due to the ageing of equipment, becoming outdated of technologies, and the effects of wear and tear, resulting in a reduction in the entire system's efficiency. With a rise in the cooling load, the weaknesses of the outdated system may become more noticeable, leading to increased energy consumption and operating expenses.

On the other hand, the efficiency curve for the new chiller plant system is going to indicate a more advantageous trend. At lower cooling loads, the combination of advanced technology and optimised components results in a high level of efficiency. As the cooling load increases, the efficiency stays consistently steady, showing the system's capacity to adapt and sustain optimal performance. The graph depicting the new system may have a more higher and flatter plateau, suggesting consistent efficiency even when confronted with changing operating circumstances.

The clear visual contrast between the two curves highlights the superior performance of the new chiller plant system, demonstrating its greater efficiency, decreased energy usage, and enhanced overall sustainability in comparison to the older version. This visual depiction acts as an argumentative representation of the advantages obtained by upgrading to a modern and effective chiller plant technology.

4.4 Return on Investment (ROI)

Table 4.4: Table of Return On Investment (ROI)

Description	Energy Saving/ Reduction
Estimated Total TNB Bill Savings Per Year	RM 625,087
Total Project Amount	RM 2500000
Payback Period	4 Years
Return On Investment	25%

The 25% Return on Investment (ROI) signifies the profitability of the project, which focuses on strengthening the chiller system to improve energy efficiency and promote healthier buildings. This indicator estimates the percentage growth of the initial investment within a particular period of time, demonstrating the financial feasibility of the project.

The planned modifications have proven to be highly successful, as seen by the expected annual TNB (Tenaga Nasional Berhad) bill savings of RM 625,087. The significant yearly savings not only help reduce costs but also support sustainable practices by optimizing energy usage.

The project's overall cost of RM 2,500,000 represents the initial investment needed to execute the improvements to the chiller system. The Payback Period, which spans over a duration of 4 years, represents the timeframe required for the project to provide returns that are equivalent to the initial expense. Here, a payback period of 4 years indicates an extremely quick return, highlighting the project's efficiency and attractiveness.

This project is a strategic investment that offers substantial advantages to both stakeholders and the community, owing to its mix of economic benefits and preservation of the environment. To summarize, the project's excellent return on investment (ROI), significant yearly cost reductions, and relatively quick payback period provide evidence of its economic viability. This emphasizes the significance of allocating resources towards energy-efficient technology to improve buildings and the environment.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, it is essential to improve chiller systems and look for ways to save energy if we desire to create buildings that are healthy and sustainable. Particularly, these enhancements resulted in an excellent improved chiller efficiency percentage of 59% and an new chiller efficiency of 0.65 kW/RT. Not only does this lead to significant reductions in energy use, but it also helps with environmental conservation efforts by decreasing the amount of carbon dioxide emissions from the building.

Because of their critical function in sustaining pleasant indoor conditions, chillers' energy efficiency is of the greatest importance. The effectiveness of these changes is in line with worldwide efforts to take part in climate change and improves the financial viability of building operations. The effectiveness of the implemented measures, which can include incorporating renewable energy sources, optimizing operating procedures, and enhancing technology, is shown by the 59% increase in chiller efficiency.

Considering healthy buildings is of the highest priority in modern design and operation, even beyond the quantitative measures. Energy savings are only one benefit of better chiller systems, which also help make buildings healthier places to live. Indoor air quality and general comfort are strongly related to the correct regulation of humidity and temperature, which are essential components of efficient chiller systems. With more and more people realizing that indoor environmental quality affects occupant health and productivity, this is more important than ever.

In addition, the general trend towards more environmentally friendly lifestyle decisions is coherent with the developments in chiller technology. Increasingly, people, companies, and governments are seeing an awareness about the need of conserving energy and managing resources responsibly. An huge improvement in chiller energy efficiency has been made in this case, demonstrating a dedication to environmentally friendly and socially concerned building practices.

Organizations like ASHRAE, which is committed to improving HVAC technology, play an important role in the search for healthy buildings. Innovations that enhance building environments generally and increase energy efficiency in particular can only be driven by collaboration between industry experts, academics, and regulatory agencies.

In conclusion, the chiller system upgrades, with an improved chiller energy efficiency of 0.936 kW/RT and an impressive 59% increase in chiller efficiency percentages, are a great step forward in creating healthy and sustainable buildings. Beyond only cutting energy use, these upgrades show that the HVAC industries is serious about protecting the environment, making buildings healthier for their residents, and improving current practices. In due to the ongoing difficulties caused by climate change and limited resources, these advancements highlight the need of constantly improving and innovating in order to create responsible and resilient built environments.

5.2 Recommendations

For future improvements, accuracy of the energy efficiency estimation results could be enhanced as follows:

i) Consider a top priority to examine the current chiller system thoroughly, taking into account things like efficiency, operating conditions, and load requires. In order to improve energy efficiency and the system's overall effectiveness, it is important to thoroughly analyse its capacity modulation and part-load efficiency.

ii) Consider renewable and alternative energy sources like solar or geothermal in addition to the chiller system as part of the energy-saving strategies. In order to find and fix places where energy is being wasted, it's need do a thorough energy audit. Improve insulation, install energy-efficient appliances, and inquire for heat recovery systems. To increase the total energy-saving potential, it is also important to assess the possibility of combining energy storage technologies and demand-side control strategies.

iii) Determine how the chiller improvements will affect the comfort and IAQ of the building's occupants. A healthy both indoor environment may be achieved through the use of ventilation methods, humidity management, and improved air filtering technology. Ensure that the planned modifications help save energy while also meeting established health and comfort criteria by working with experts in the area of indoor environmental quality. Maintaining ideal indoor air quality should be a top priority, thus it's important to prioritise the installation of smart building technology that can adapt to changing occupancy and climatic circumstances.

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APPENDICES

APPENDIX A Calculation for energy efficiency & ROI

Coefficient of Performance (COP) = $\frac{Cooling\ Output\ (kW)}{Electrical\ Input\ (kW)}$

System Efficiency (kW/RT) = $\frac{Power\ Input\ to\ Chiller\ (kW)}{Refrigeration\ Capacity\ of\ Chiller\ (RT)}$

Improved Chiller Efficiency (kW/RT) = $Old\ Chiller\ Efficiency\ - New\ Chiller\ Efficiency$

Percentage of improved chiller efficiency (%) = $\frac{Improved\ Chiller\ Efficiency}{Old\ Chiller\ Efficiency} \times 100\%$

Return On Investment (%) =
$$\frac{Total\ Estimated\ Electrical\ Consumption\ Savings\ Per\ Year\ (\frac{kWh}{year})}{Total\ Project\ Amount\ (RM)} \times 100\%$$

APPENDIX B Energy consumption of old chiller plant system for 24 hours

Equipment	Chiller			CHWP-1		CHWP-2		Overall System	
Time	**RT**	**kW**	**kW/RT**	**kW**	**kW/RT**	**kW**	**kW/RT**	**kW**	**kW/RT**
0000	266	394	1.48	20.41	0.08	21.26	0.08	435.67	1.64
0100	273	409	1.50	20.41	0.07	21.26	0.08	450.50	1.65
0200	281	388	1.38	20.41	0.07	21.26	0.08	429.17	1.53
0300	276	395	1.43	20.41	0.07	21.26	0.08	436.83	1.59
0400	277	401	1.45	20.41	0.07	21.26	0.08	443.00	1.60
0500	268	401	1.50	20.41	0.08	21.26	0.08	442.83	1.65
0600	272	399	1.47	20.41	0.08	21.26	0.08	441.00	1.62
0700	311	422	1.35	20.41	0.07	21.26	0.07	463.17	1.49
0800	290	383	1.32	20.41	0.07	21.26	0.07	424.83	1.47
0900	285	391	1.37	20.41	0.07	21.26	0.07	432.67	1.52
1000	280	382	1.36	20.41	0.07	21.26	0.08	423.17	1.51
1100	274	412	1.50	20.41	0.07	21.26	0.08	454.00	1.65
1200	255	385	1.51	20.41	0.08	21.26	0.08	426.17	1.67
1300	256	397	1.55	20.41	0.08	21.26	0.08	439.00	1.71
1400	265	394	1.49	20.41	0.08	21.26	0.08	435.33	1.64
1500	279	414	1.48	20.41	0.07	21.26	0.08	455.33	1.63
1600	265	401	1.51	20.41	0.08	21.26	0.08	442.67	1.67
1700	268	410	1.53	20.41	0.08	21.26	0.08	451.83	1.68
1800	287	413	1.44	20.41	0.07	21.26	0.07	454.83	1.59
1900	288	406	1.41	20.41	0.07	21.26	0.07	447.83	1.55
2000	279	374	1.34	20.41	0.07	21.26	0.08	415.17	1.49
2100	287	401	1.40	20.41	0.07	21.26	0.07	443.00	1.54
2200	274	372	1.36	20.41	0.07	21.26	0.08	413.50	1.51
2300	302	411	1.36	20.41	0.07	21.26	0.07	452.67	1.50

APPENDIX C Energy consumption of new chiller plant system for 24 hours

Equipment	**Chiller**				**CHWP**		**CDWP**		**CT-1**		**CT-2**		**Overall System**	
Time	**%**	**RT**	**kW**	**kW/RT**	**kW**	**kW/RT**	**kW**	**kW/RT**	**kW**	**kW/RT**	**kW**	**kW/RT**	**kW**	**kW/RT**
0000	43%	171	86	0.503	10.50	0.061	12.33	0.072	1.33	0.008	1.33	0.008	111.52	0.653
0100	42%	166	85	0.510	10.50	0.063	12.33	0.074	1.33	0.008	1.33	0.008	110.16	0.664
0200	42%	168	85	0.505	10.50	0.063	12.33	0.073	1.33	0.008	1.33	0.008	110.22	0.656
0300	42%	168	84	0.498	10.50	0.062	12.33	0.073	1.33	0.008	1.33	0.008	109.20	0.649
0400	42%	167	82	0.494	10.50	0.063	12.33	0.074	1.33	0.008	1.33	0.008	107.96	0.647
0500	41%	162	81	0.500	10.50	0.065	12.33	0.076	1.33	0.008	1.33	0.008	106.72	0.657
0600	43%	173	86	0.498	10.50	0.061	12.33	0.071	1.33	0.008	1.33	0.008	111.65	0.645
0700	42%	169	84	0.494	10.50	0.062	12.33	0.073	1.33	0.008	1.33	0.008	109.01	0.645
0800	42%	169	82	0.487	10.50	0.062	12.33	0.073	1.33	0.008	1.33	0.008	107.98	0.638
0900	43%	172	85	0.496	10.50	0.061	12.33	0.072	1.33	0.008	1.33	0.008	110.88	0.644
1000	43%	172	88	0.508	10.50	0.061	12.33	0.072	1.33	0.008	1.33	0.008	113.14	0.656
1100	44%	175	89	0.509	10.50	0.060	12.33	0.070	1.33	0.008	1.33	0.008	114.64	0.654
1200	44%	176	91	0.516	10.50	0.060	12.33	0.070	1.33	0.008	1.33	0.008	116.45	0.660
1300	44%	175	89	0.510	10.50	0.060	12.33	0.071	1.33	0.008	1.33	0.008	114.56	0.656
1400	44%	175	89	0.511	10.50	0.060	12.33	0.071	1.33	0.008	1.33	0.008	114.91	0.657
1500	46%	182	95	0.521	10.50	0.058	12.33	0.068	1.33	0.007	1.33	0.007	120.51	0.661
1600	47%	189	99	0.527	10.50	0.056	12.33	0.065	1.33	0.007	1.33	0.007	124.88	0.662
1700	48%	190	100	0.523	10.50	0.055	12.33	0.065	1.33	0.007	1.33	0.007	125.09	0.658
1800	46%	185	96	0.517	10.50	0.057	12.33	0.067	1.33	0.007	1.33	0.007	121.28	0.655
1900	45%	179	91	0.510	10.50	0.059	12.33	0.069	1.33	0.007	1.33	0.007	116.79	0.652
2000	44%	178	89	0.499	10.50	0.059	12.33	0.069	1.33	0.007	1.33	0.007	114.25	0.642
2100	44%	176	89	0.504	10.50	0.060	12.33	0.070	1.33	0.008	1.33	0.008	114.01	0.649
2200	45%	180	91	0.504	10.50	0.058	12.33	0.069	1.33	0.007	1.33	0.007	116.08	0.646
2300	45%	178	89	0.501	10.50	0.059	12.33	0.069	1.33	0.007	1.33	0.007	114.85	0.644

APPENDIX D Table of Old and New Chiller Plant Performance Comparison

Time	Old Chiller System			New Chiller System		
	RT	kW	kW/RT	RT	kW	kW/RT
0:00	266	435.7	1.64	171	111.5	0.65
1:00	273	450.5	1.65	166	110.2	0.66
2:00	281	429.2	1.53	168	110.2	0.66
3:00	276	436.8	1.59	168	109.2	0.65
4:00	277	443.0	1.60	167	108.0	0.65
5:00	268	442.8	1.65	162	106.7	0.66
6:00	272	441.0	1.62	173	111.7	0.65
7:00	311	463.2	1.49	169	109.0	0.64
8:00	290	424.8	1.47	169	108.0	0.64
9:00	285	432.7	1.52	172	110.9	0.64
10:00	280	423.2	1.51	172	113.1	0.66
11:00	274	454.0	1.65	175	114.6	0.65
12:00	255	426.2	1.67	176	116.5	0.66
13:00	256	439.0	1.71	175	114.6	0.66
14:00	265	435.3	1.64	175	114.9	0.66
15:00	279	455.3	1.63	182	120.5	0.66
16:00	265	442.7	1.67	189	124.9	0.66
17:00	268	451.8	1.68	190	125.1	0.66
18:00	287	454.8	1.59	185	121.3	0.65
19:00	288	447.8	1.55	179	116.8	0.65
20:00	279	415.2	1.49	178	114.2	0.64
21:00	287	443.0	1.54	176	114.0	0.65
22:00	274	413.5	1.51	180	116.1	0.65
23:00	302	452.7	1.50	178	114.9	0.64
Off Peak	279.9	440.83	1.58	170.2	110.74	0.65
Peak	275.6	438.99	1.60	178.2	116.38	0.65
Average	358.6	439.76	1.59	144.4	114.03	0.65
Max	463.2	463.17	1.71	190.3	125.09	0.66
Min	254.6	413.50	1.47	106.7	106.72	0.64

APPENDIX E Table of payback and ROI estimation calculation

No	Description	Remarks	Unit	Energy Savings/Reduction
1	Chiller Plant System Efficiency (Old Air-Cooled System)	Off Peak	kW/RT	1.577
		Peak	kW/RT	1.595
		Average	kW/RT	1.588
2	Chiller Plant System Efficiency (New Water-Cooled System)	Off Peak	kW/RT	0.651
		Peak	kW/RT	0.653
		Average	kW/RT	0.652
3	Average Chiller Plant System Savings		kW/RT	0.936
			%	59%
4	Average Building Load	Off Peak	RT	170
		Peak	RT	178
		Average	RT	175
5	Chiller Plant System Max Power	Existing	kW	463.2
		New	kW	125.1
6	Chiller Plant Energy Savings	Off Peak	kWh	157.8
		Peak	kWh	167.9
		MD	kW	338.1
6a	Chiller Plant Energy (Per Year)	Off Peak	kWh	1,578.0
		Peak	kWh	2,350.2
		MD	kW	4,056.9
7	Annual Operating Hours	Off Peak	Hours	3,650.000
		Peak	Hours	5,110.000
8	Tariff Rate C2	Off Peak	RM / kWh	0.224
		Peak	RM / kWh	0.365
		MD	RM / kW	45.100
9	Estimated TNB Bill Savings Per Year	Off Peak	RM	129,017
		Peak	RM	313,104
		MD	RM	182,966
		Total	RM	625,087
10	Estimated Electrical Consumption Savings Per Year	Off Peak	kWh/Year	575,968
		Peak	kWh/Year	857,819
		MD	kWh/Year	4,057
		Total	kWh/Year	1,433,788
11	Total Project Amount		RM	2,500,000.000

No	Description	Remarks	Unit	Energy Savings/Reduction
12	Payback Period		Years	4.0
13	Return On Investment (ROI)		%	25%

APPENDIX F Gantt Chart for PSM 1

PROJEK SARJANA MUDA 1 GANTT CHART

PROJECT: PROJEK SARJANA MUDA 1
STUDENT: NUR FATINI BINTI ABDUL RAZAK

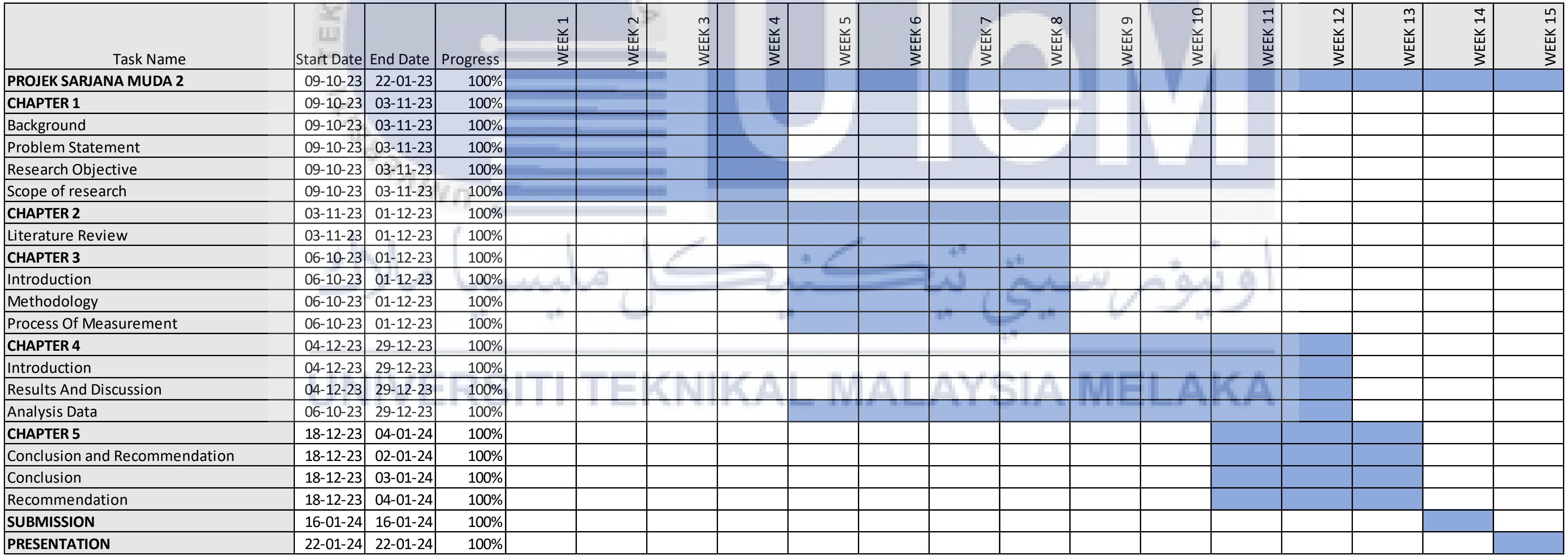
Task Name	Start Date	End Date	Progress	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15
PROJEK SARJANA MUDA 1	13-03-23	10-07-23	100%	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
CHAPTER 1	13-03-23	03-04-23	100%	■	■	■	■											
Background	13-03-23	03-04-23	100%	■	■	■	■											
Problem Statement	13-03-23	03-04-23	100%	■	■	■	■											
Research Objective	13-03-23	03-04-23	100%	■	■	■	■											
Scope of research	13-03-23	03-04-23	100%	■	■	■	■											
Significant of study	13-03-23	03-04-23	100%	■	■	■	■											
CHAPTER 2	03-04-23	01-05-23	100%				■	■	■	■	■							
Literature Review	03-04-23	01-05-23	100%				■	■	■	■	■							
CHAPTER 3	01-05-23	29-05-23	100%								■	■	■	■	■			
Introduction	01-05-23	29-05-23	100%								■	■	■	■	■			
Methodology	01-05-23	05-06-23	100%								■	■	■	■	■			
Expected Result	05-06-23	16-06-23	100%													■		
SUBMISSION	21-06-23	21-06-23	100%														■	
PRESENTATION	26-06-23	27-06-23	100%															■

APPENDIX G Gantt Chart for PSM 2

PROJEK SARJANA MUDA 2 GANTT CHART

PROJECT: PROJEK SARJANA MUDA 2

STUDENT: NUR FATINI BINTI ABDUL RAZAK



Task Name	Start Date	End Date	Progress	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15
PROJEK SARJANA MUDA 2	09-10-23	22-01-23	100%	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
CHAPTER 1	09-10-23	03-11-23	100%	■	■	■	■											
Background	09-10-23	03-11-23	100%	■	■	■	■											
Problem Statement	09-10-23	03-11-23	100%	■	■	■	■											
Research Objective	09-10-23	03-11-23	100%	■	■	■	■											
Scope of research	09-10-23	03-11-23	100%	■	■	■	■											
CHAPTER 2	03-11-23	01-12-23	100%				■	■	■	■	■							
Literature Review	03-11-23	01-12-23	100%				■	■	■	■	■							
CHAPTER 3	06-10-23	01-12-23	100%					■	■	■	■							
Introduction	06-10-23	01-12-23	100%					■	■	■	■							
Methodology	06-10-23	01-12-23	100%					■	■	■	■							
Process Of Measurement	06-10-23	01-12-23	100%					■	■	■	■							
CHAPTER 4	04-12-23	29-12-23	100%									■	■	■	■			
Introduction	04-12-23	29-12-23	100%									■	■	■	■			
Results And Discussion	04-12-23	29-12-23	100%									■	■	■	■			
Analysis Data	06-10-23	29-12-23	100%					■	■	■	■	■	■	■	■			
CHAPTER 5	18-12-23	04-01-24	100%											■	■	■		
Conclusion and Recommendation	18-12-23	02-01-24	100%											■	■	■		
Conclusion	18-12-23	03-01-24	100%											■	■	■		
Recommendation	18-12-23	04-01-24	100%											■	■	■		
SUBMISSION	16-01-24	16-01-24	100%														■	
PRESENTATION	22-01-24	22-01-24	100%															■

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya,
76100 Durian Tunggal,
Melaka, Malaysia.

☎ +606 270 1000
+606 270 1022
www.utem.edu.my

FAKULTI TEKNOLOGI KEJURUTERAAN MEKANIKAL

Tel : +606 270 1184 | Faks : +606 270 1064

Rujukan Kami (Our Ref):
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Tuan

PENGKELASAN TESIS SEBAGAI TERHAD BAGI TESIS PROJEK SARJANA MUDA

Dengan segala hormatnya merujuk kepada perkara di atas.

2. Dengan ini, dimaklumkan permohonan pengkelasan tesis yang dilampirkan sebagai TERHAD untuk tempoh **LIMA** tahun dari tarikh surat ini. Butiran lanjut laporan PSM tersebut adalah seperti berikut:

Nama pelajar: NUR FATINI BINTI ABDUL RAZAK (B092010107)
Tajuk Tesis: IMPROVEMENT OF CHILLER SYSTEM AND ENERGY SAVING TOWARDS HEALTHY BUILDINGS

3. Hal ini adalah kerana IANYA MERUPAKAN PROJEK YANG DITAJA OLEH SYARIKAT LUAR DAN HASIL KAJIANNYA ADALAH SULIT.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"
"KOMPETENSI TERAS KEGEMILANGAN"

Saya yang menjalankan amanah,

Professor Madya Ts. Dr. Umar Al-Amani Bin Haji Azlan
Penyelia Utama
Fakulti Teknologi Kejuruteraan Mekanikal
Universiti Teknikal Malaysia Melaka