

# AUTOMATIC ROOM TEMPERATURE CONTROL

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## ABSTRACT

This project proposes an automatic room temperature controller, which uses the difference between the outside and inside room temperature. The difference is assumed to affect the compressor speed in order to achieve the desired set point. The frequency of the speed compressor is also taken into account. The project involves finding the mathematical model of an air conditioning system, designing a controller and performing a simulation to analyse the performance of the designed controller using Matlab/Simulink. The controller is based on adaptive fuzzy to control the temperature room. The result shows that the controller is able to follow the input reference and the output response of adaptive fuzzy control has better tracking performance. The developed system is hoped to address the issue of high cost electricity.



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## ABSTRAK

Projek ini adalah berkaitan kawalan suhu bilik secara automatik dengan melibatkan perbezaan suhu di dalam bilik dan di luar bilik. Perbezaan suhu dijangka akan memberi kesan kepada kelajuan pemampat untuk mencapai nilai suhu yang ditetapkan. Frekuensi kelajuan pemampat juga diambil kira. Projek ini melibatkan pengiraan model matematik di dalam sistem penyaman udara, merekacipta kawalan dengan menggunakan simulasi dan menganalisis kecekapan kawalan yang direkacipta dengan menggunakan program matlab. Jenis kawalan yang direka adalah “*adaptive fuzzy*” yang digunakan untuk mengawal suhu bilik. Keputusan yang dihasilkan menunjukkan bahawa kawalan yang direka mampu untuk mengikut rujukan data masukan dan tindakbalas keluaran “*adaptive fuzzy*” merupakan kawalan yang lebih cekap. Diharapkan agar projek yang dihasilkan ini dapat mengurangkan kos elektrik yang tinggi.

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## LIST OF SYMBOLS AND ABBREVIATIONS

$Q$	-	mass flow rate
$\lambda$	-	coefficient of discharge
$V_{comp}$	-	compressor cylinder volume
$\omega$	-	compressor rotary frequency (Hz)
$V_{suc}$	-	specific volume of the refrigerant at the inlet of compressor
$C$	-	mass flow rate coefficient
$P_{in}$	-	pressure inlet
$P_{out}$	-	pressure outlet
$V_{in}$	-	specific volume of the refrigerant at the inlet
$T_{out}$	-	discharge temperature
$T_{in}$	-	suction temperature
$n$	-	ratio of specific heats (1.4 for air)
$T_{room}$	-	actual temperature room
$T_{outdoor}$	-	outdoor temperature room
$T_{indoor}$	-	discharge temperature from air conditioning system
$T_r(s)$	-	indoor temperature ( °C)
$f(s)$	-	revolution frequency (Hz)
$K_{s,}$	-	magnification factor ( °C /Hz)
$T_s$	-	time constant (min) $\lambda$
$\tau$	-	delay time (min)

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Project Background

Nowadays, the air conditioning is widely used especially in warm countries including Malaysia. Usually the conventional air conditioning is always cooling the room depending on the fixed temperature setting and is not automatically adjusted for the comfort of the users. In the central air conditioning control field, excellent real-time, high reliability, and good intelligence are proposed by many researchers. The traditional PID algorithm is, in fact, still playing a main role in the control process. The air conditioning system has becoming a field to be researched to improve the user convenience by applying intelligent system such as Adaptive Fuzzy controller.

While the enhanced air conditioning system is being designed, the consideration of the type of control system must be included in a modeling design. In particular the controller must be able to avoid the inefficiency of having the air conditioning operate all the time. Several control options were considered at presence sensing circuit, which would turn the air conditioning off when people are not in the room with the air conditioning and a temperature sensor input, which would change the air conditioning operation depending on room temperature [1]. Based on the observation of the using the present conventional air conditioning application, it always working all the time without a systematic control. Therefore, the control of the air conditioning is adjusted through a feedback control system to monitor and maintain a constant temperature based on the data input from the sensor.

This project presents an air conditioning temperature control by using the current temperature in the room as well as outside temperature. The difference between the two temperature sensors will affect to compressor speed to achieve the desired point. Only when the

difference between indoor and outdoor temperatures is small or zero, and the indoor temperature exceeds a predefined threshold does the controller run the air conditioner. This research focuses only on main component, which is the compressor system, in air conditioning that significantly affects the temperature change.

## **1.2 Problem Statement**

The problem happens when the air conditioning is still functioning although in the event of cold weather. The function is uncontrolled and must be manually turned on and off. Sometimes it can lead to high usage of electricity which in turn raises the electricity bill when the user forgot to switch it off. The system also does not have the capacity to adjust the room temperature regardless of the ambient temperature. To address the problem, the automatic room temperature control that can control the temperature automatically is proposed. The advantages of such a system are less energy usage, and provides more convenient to the consumers.

## **1.3 Objectives**

The objectives of this project are:

1. To find the mathematical model of an air conditioning system.
2. To design a controller using Matlab/Simulink based on adaptive fuzzy.
3. To analyses the performance of the controller.

## **1.4 Scope of The Project**

Below are the scopes of the project:

1. The controller used is Adaptive Fuzzy
2. Matlab simulation program is used to simulate the performance of the controller.
3. Inside and outside room temperature are used in the controller design.
4. The analysis controller performance in terms of automatic temperature control based on the speed of compressor of air conditioning system.

## 1.5 Thesis Structure

The report begins with the project background which includes an introduction to air conditioning system. The section states the objective of the project. The scope of the design, which consists of four aspects that related with the design of the controller, is also stated.

Chapter 2 is presents the literature reviews, highlighting related research on this project taken from books and the journals. This chapter begins with the study about the principal of the air conditioning system and the function of compressor that affects the temperature room. The types of structure controller are also discussed in this chapter and the summary from the design controller that others researcher are summarised.

Chapter 3 discusses about the methodology of this project. It shows the flow chart that illustrates the whole research process. The method to design the mathematical model for the plant, design the fuzzy membership function and the adaptive fuzzy are discussed in this chapter.

Chapter 4 presents the result and analysis that have been done by simulation using Matlab/Simulink. This chapter also discusses about the controller output and the performance of the controller.

The last chapter summarises and concludes this project with recommendations for future works.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Principles of Air Conditioning System

Air conditioning involves more than lowering the air temperature. It includes dehumidifying, cleaning (filtering), and circulating the air [2]. Good air conditioning systems perform all of these functions, although most people focus on the cool concept. In the broadest sense of the term, air conditioning also means heating, humidification, and ventilation [3]. The air conditioning system has many dynamical variables and a typical nonlinear time variable multivariate system with disturbances and uncertainties. It very difficult to find the mathematical model to describe the process over wide operating range [5].

The goal with air conditioning is to capture heat in the house and throw it outside. The difference between the air conditioning and cooling system are the air conditioning system for an application for the cooling system as a control system for the movement of air, moisture and temperature changes in a sanitary particular space and the cooling system. The basic vapor compression designed to cool down the environment through exposure to a boiling liquid. System is required to produce the temperature of a space.

The schematic of air conditioning system is illustrated in Figure 2.1, which shows that the air conditioning is a complex system. Based on the schematic of system air conditioning, the main material that effect the cooling system is Freon gas. On the inside of a coil a substance such as Freon 12 or Freon 22 which is brand names for a refrigerant are used. This refrigerant is a colorless gas at atmospheric temperature and pressure [3]. The coils inside manipulate the Freon to make it a liquid or a gas. The Freon runs in a loop, passing through the indoor coil, through a

copper pipe to the outdoors, through the outdoor coil, and back inside through another pipe to the indoor coil.

The main components are evaporator coil, blower fan, compressor and condensing coil. In this project are only focus based on the application compressor in air conditioning system that is effect the temperature room. The compressor is the main component for the cooling system.

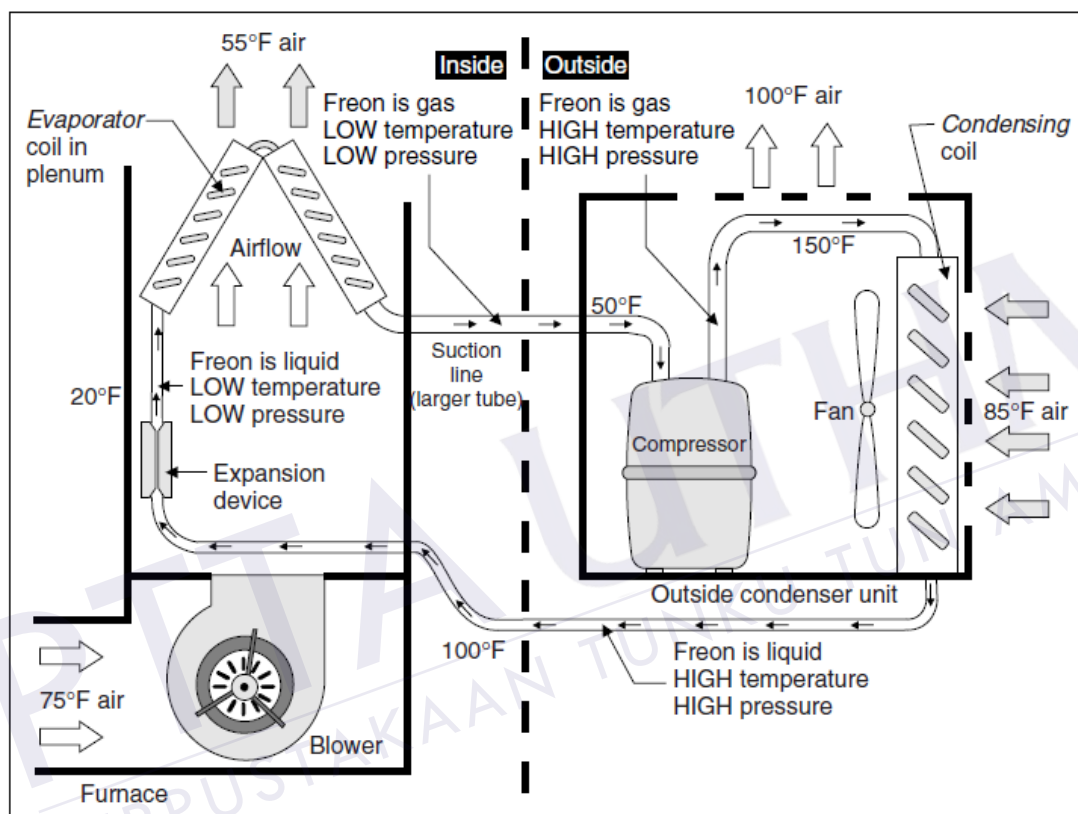


Figure 2.1: Schematic of Air Conditioning System [3]

Air conditioning system is process the transfer heat. Two coils are installed at inside and outside house. The transfer head occur from the inside and the outside house through the piping. The warm air from inside house is through indoor coil and the warm air discharge outside house through the outdoor coil. The function of fans is blowing air across the evaporator and condenser coil when the air conditioning system is running. The evaporator coil and condenser coil in an air conditioner are heat exchangers. The function of refrigerant that collect heat from the house, moves it outside and releases it into the outdoor air. The compressor is squeezing a cool low pressure gas into hot high pressure gas. The expansion device at near the evaporator

coil is converting a hot high pressure liquid to cool low pressure liquid. The Freon gas convert to Freon liquid after final process cooled air for surrounding room.[3]

## 2.2 Function of Compressor that Effect the Temperature

The function of compressors are similar to pumps both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible while some can be compressed, the main action of a pump is to pressurize and transport liquids. The compressor will inhaling refrigerant from the evaporator coil and then compressing it into the condenser coil. The compressor is usually driven by electric motors that require high electrical power to drive the compressor. The compressor is usually controlled by a thermostat that measures the room air temperature. If the room temperature was quite cold, the thermostat will turn off the compressor. Adjusting the motor speed can control the refrigerant mass flow rate. The refrigerant mass flow rate, in turn is the main factor governing heat exchange in the condenser and evaporator, which exchange determines temperature. In summary then, adjustments of compressor motor speed can control the temperature of an air-conditioned room [44].

The basic of the vapor compression are designed to cool down the environment through the boiling liquid. This system is required to produce the temperature that need for ambient space. Figure 2.2 illustrates the flow of cooling system in which the compressor is the main component. The operation of compressor when is turned on, it will be interesting to inhale refrigerant from the evaporator coil and compressed it to condenser coil. The temperature of evaporator coil will become cold and condenser coil will get hot. The fan at evaporator coil draws air outside to coil and the cold air will occur. The fan at condenser oil draws air outside to reduce the refrigerant temperature in the coil. The high pressure refrigerant that comes from the outside condenser coil will change to the low pressure refrigerant. When the temperature room was quite cool, the thermostat will turn off the compressor. When the room temperature rises above of the desired level of cold, the thermostat will turn on the compressor. The suitable control algorithm, the compressor can function at the power level that required maintaining the desired ambient temperature.



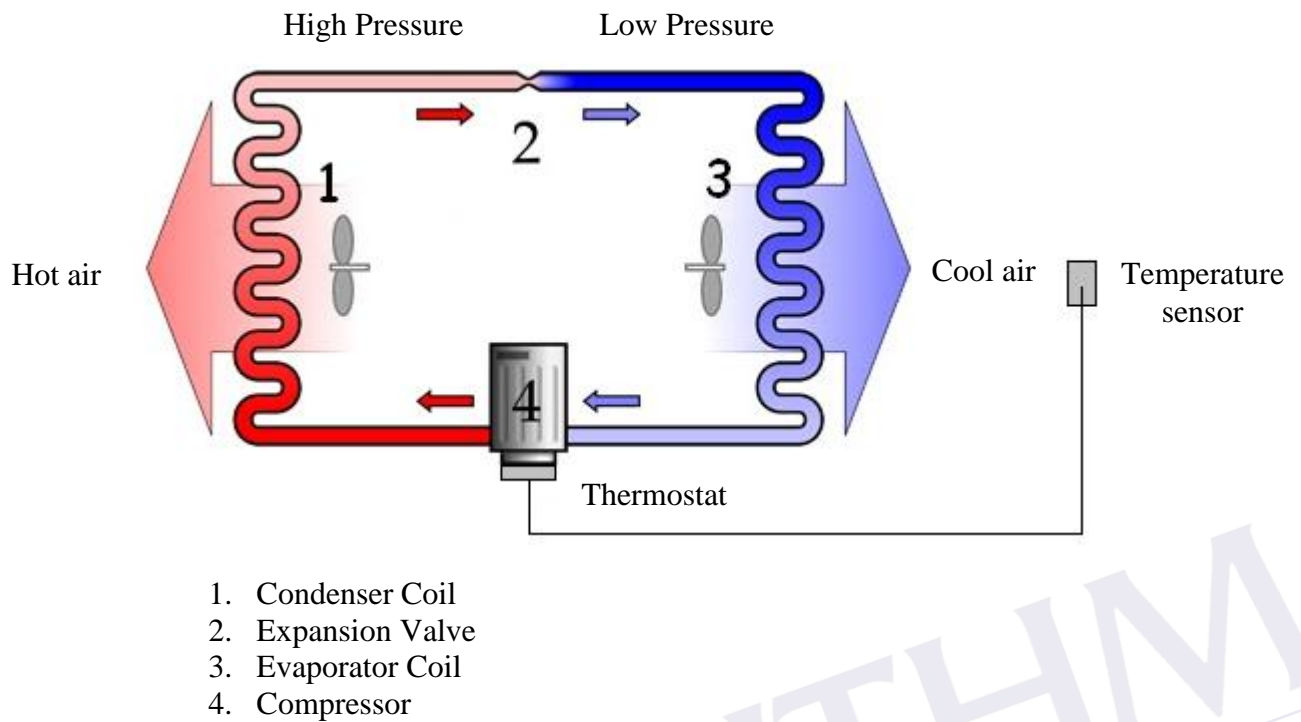


Figure 2.2: The process of cooling system [27]

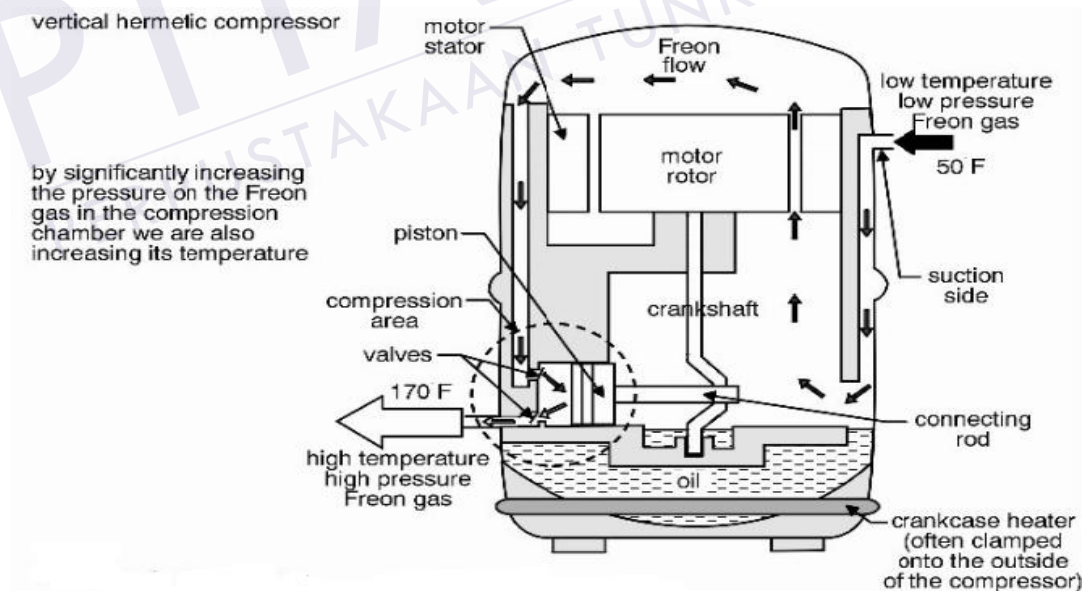


Figure 2.3: The flow of the Freon in compressor [3]

Figure 2.3 shows the flow of the Freon gas and the changing of temperature and pressure in compressor. When the compressor is compressing, the pressure and temperature are high. At early entry compressor, the pressure and temperature are

low and then it flows to the compression area. Motor are moving and the piston will move up and down in compression chamber and it will be increasing the temperature and pressure.

### **2.3 Factors Affecting Cooling Load**

The cooling capacity of air conditioners is usually measured in tons. One ton equals 12,000 BTU (British Thermal Units) per hour. The term one ton comes from the amount of heat required to melt a block of ice that weighs one ton. The amount of cooling required depends on a large number of factors. These include the outdoor temperature, the outdoor humidity, the level of insulation in the house, the amount of air leakage in the house, the amount of southern, eastern, and western facing glass in the house whether this glass is single, double, or triple glazed, whether the glass is a low emissivity glass; and whether window treatments (curtains or blinds) are kept closed or open. Other factors include the amount of shading from trees, roof overhang, awnings, or buildings and how much heat is generated in the house by the people and equipment inside [28]. All this factors are effecting the cooling load and to calculated the value of BTU in the room, we must consider for all this factors.

### **2.4 Fuzzy Logic Control (FLC)**

Fuzzy Logic Controller (FLC) which was formerly introduced by Lotfi A.Zadeh in 1965 is the one of the most powerful controller which can control non-linear system because of it non-linearity characteristic behaviour. Fuzzy Logic Control (FLC) is one of the intelligent control systems that are a successful solution to many control problems. The fuzzy models can represent the highly nonlinear processes and can smoothly integrate a priori knowledge with information obtained from process data.[4] Many control solution need the mathematical model of the system to be controlled, but the FLC only need the measurement of input and output signals of the system to be controlled.[5]

This controller consists of fuzzy membership function, fuzzy rules and defuzzification. Fuzzy membership rules are used to set the input and output range in several level such as low, medium and high. The fuzzy rules are used to relate and

combine the input and output of FLC. Commonly, the relation of input and output are using “OR” and “AND” logic. Defuzzification is used to convert the rules output to appropriate value which is to be used by plant. This controller is widely used in air conditioner.[24]

Fuzzy Logic Controller has three successive blocks through which the control signal is generated in Figure 2.4. The first block fuzzification the input, this fuzzification input is sent through an inference block where decisions are made by firing certain rules. The fuzzy control system is based on the theory of fuzzy sets and fuzzy logic. Previously a large number of fuzzy inference systems and defuzzification techniques were reported. The output of the inference engine is a set of fuzzification knowledge which is converted to a crisp control signal through a technique of defuzzification. This crisp output is applied to the plant to be controlled.[18]

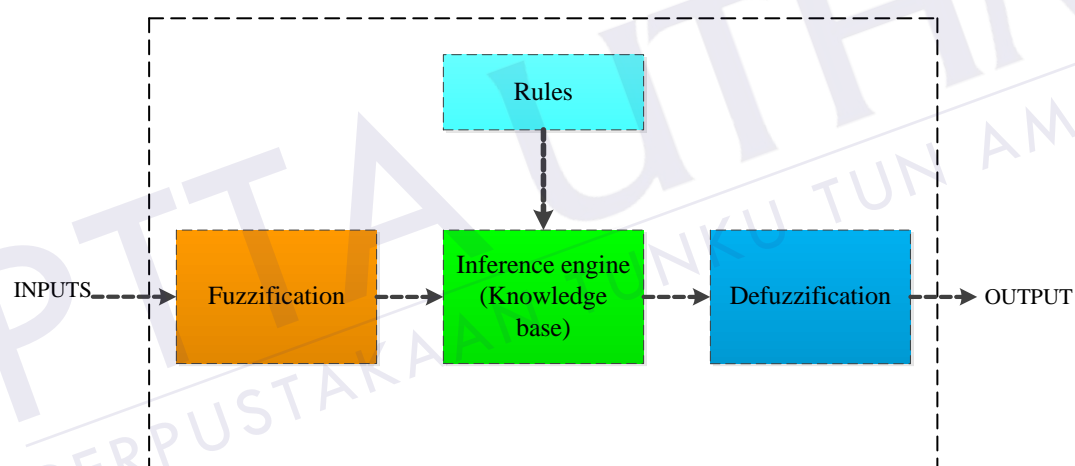


Figure 2.4: Block Fuzzy Logic Controller

The fuzzy control can overcome some shortcomings of traditional PID. The fuzzy controller is a language controller. The algorithm of fuzzy control can be obtained from experience and optimized from the operation, which has advantages such as powerful anti-interference, faster response and strong robust. But the fuzzy is a nonlinear control and the controlled object's output has the static error. The union of fuzzy control and traditional PID control can enhance various aspects of the control process in the air condition system.[17,11]

## 2.5 PID Controller

The most important and popular controller in industrial process is Proportional Integral Derivative (PID) because it easy to understand and easy to be used as a controller. But there are major problems that occur when using the PID controller which cause disturbance and environmental condition on the structural of the system. However when it compared to other controller, the PID are better and simple structure [7]. To the controlled object in air condition system, the traditional PID control can be applied, but it has some disadvantages such as inconvenient tuning parameters, faint anti-interference and large overshoot [17]. The traditional PID control method has the characteristics of simple construction, good stability, and mature theories. But the PID method excessively depends on the model parameters, and the robustness is poor [6].

From a mathematical viewpoint, the PID control works to push the error  $e(t)$  to zero, where

$$e(t) = T(t) - T_0 \quad (2.1)$$

with  $T(t)$  being the measured temperature input and  $T_0$  being the set point temperature. The control voltage  $u_c(t)$  takes the form:

$$u_c(t) = k_p e(t) + k_i \int e(t)dt + k_d \frac{\partial e(t)}{\partial t} \quad (2.2)$$

where  $k_p$ ,  $k_i$  and  $k_d$  are scale factors for the proportional, integral and differential terms respectively.

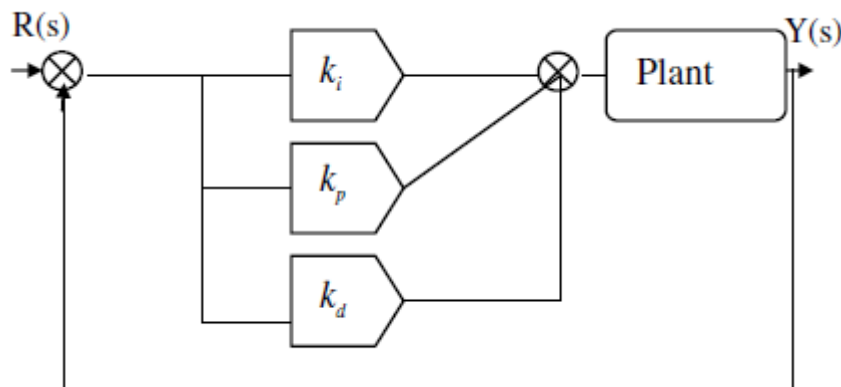


Figure 2.5: Feedback control system

## 2.6 Fuzzy PID Controller

Each controller, either PID or Fuzzy has advantages and disadvantages. To improve the performance of this controller, the two controllers may be combined to gain advantages of both. PID works perfect in linear system while Fuzzy functions well for non linear system. The purpose of combining FLC and PID controller is to have a best result from the two relatively simple controllers, which might be similar to a complex controller. In realizing this idea, FLC is used to tune the PID gain. Self tuning can also improve the performance of PID controller. Therefore, a PID type Fuzzy controller is preferred in the non-linear process due to its simplicity, robustness and variable structure. The hybrid of fuzzy and PID controllers takes advances of the non-linear characteristics of the fuzzy controller and the accuracy near a set point which is guaranteed by classical PID controller. [8-17]

There are several combinations of hybrid fuzzy logic and PID existed. In the study of fuzzy-PID controller structure, there are five types of combination of fuzzy logic and PID that already have been used. They are Fuzzy PD+I, Fuzzy PI+D, Fuzzy PI+Fuzzy PD, Fuzzy P+ID and Fuzzy P+Fuzzy I +Fuzzy D. Each of them have their own advantages and disadvantages and also how to tune and setting.

### 2.6.1 Fuzzy PD control with parallel integral action (Fuzzy PD + I)

According to [45], the structure of this approach can be achieved by placing a fuzzy PD controller in parallel with the conventional integral controller as shown in Figure 2.6.

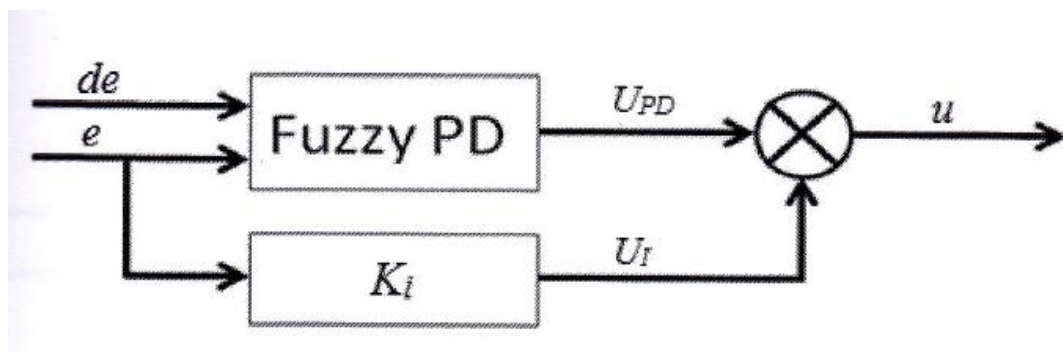


Figure 2.6: Fuzzy PD control with integral controller

From Figure 2.6, the control action is obtained with the sum of output from the fuzzy PD controller and the output from the conventional integral controller.  $de$  and  $e$  are derivative error and error input respectively.  $U_I$  is the output of integral gain while  $U_{PD}$  is the output from hybrid fuzzy PD.  $u$  is the fuzzy PD+I combination output. The structure can be represented in a mathematical equation as:

$$u(k) = U_{PD}(k) + K_i e(k) \quad (2.3)$$

where  $K_i$  is integral gain that has to be determined.

The advantage of this approach is that the integral action can remove the system steady state error. However, this approach has poor transient response because of the integral gain,  $K_i$ . To achieve a faster response, the integral gain should be large. But, if the gain is too high it will cause damping oscillation which will decrease the transient response. The value of integral gain must be determined properly.

### 2.6.2 Fuzzy PI control with parallel derivative action (Fuzzy PI+D)

According to [45], the structure of this approach can be achieved by placing a fuzzy PI controller in parallel with the conventional derivative controller as shown in Figure 2.7.

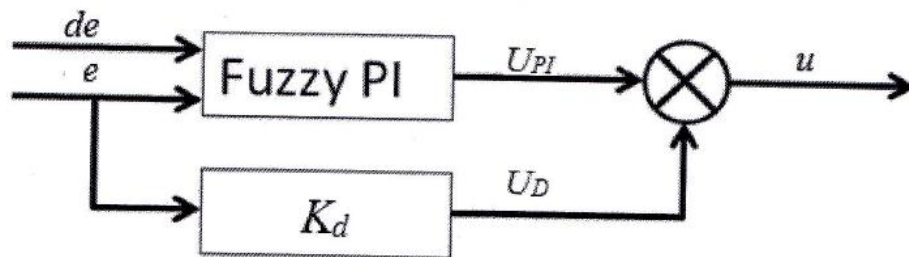


Figure 2.7: Fuzzy PI control with derivative controller



From Figure 2.7, the control action is obtained with the sum of output from the fuzzy PI controller and the output from the conventional derivative controller.  $de$  and  $e$  are derivative error and error input respectively.  $U_D$  is the output of derivative gain while  $U_{PI}$  is the output from hybrid fuzzy PI.  $u$  is the fuzzy PI+D combination output. The structure can be represent in mathematical equation as:

$$u(k) = U_{PI}(k) + K_d de(k) \quad (2.4)$$

where  $K_d$  is derivative gain that has to be determined.

The advantage of this approach is that the derivative action can avoid the derivative kick and reduce the high frequency noise which can occur while using fuzzy PD+I controller. This approach can increase the transient response which can be in improvement for fuzzy PD+I controller. But if the derivative gain is too high, it can slow the steady state response which can decrease the performance of the whole controller. The value of derivative gain must be determined properly for better result.

For tuning the fuzzy PI+D controller, it is recommended to tune the fuzzy PI control first without using derivative gain,  $K_d$ . Then keep input gains unchanged after adding derivative gain,  $K_d$ .

### 2.6.3 Fuzzy PI control with parallel fuzzy PD control (Fuzzy PI + Fuzzy PD)

According to [45], the general type of this structure of fuzzy PID controller is shown in Figure 2.8. The control action is obtained with the sum of output from the fuzzy PI controller and the output from the fuzzy PD controller.

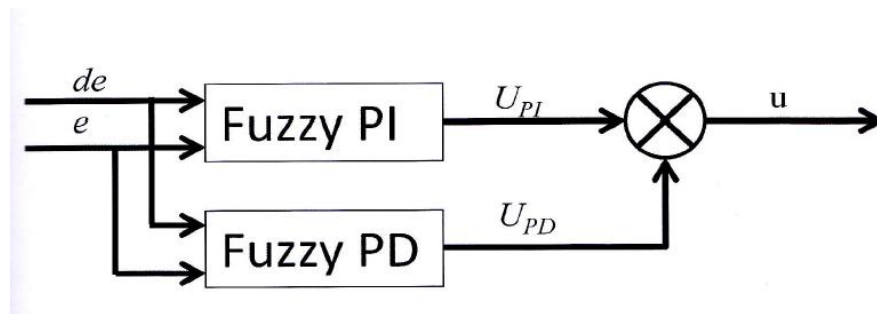


Figure 2.8: Fuzzy PI controller with fuzzy PD controller

From Figure 2.8, the control action is obtained with the sum of output from the fuzzy PI controller and the fuzzy PD controller.  $de$  and  $e$  are derivative error and error input respectively.  $U_{PI}$  is the output from hybrid fuzzy PI while  $U_{PD}$  is the output from hybrid fuzzy PD.  $u$  is the fuzzy PI+ fuzzy PD combination output.

This type of structure can avoid the complexity of the rule-base and membership function design. The both fuzzy PI and fuzzy PD controllers can use the same membership function and the same rule base. Only the gain for the input and output signals have to be tuned properly. The final control action can be expressed as a sum of both control action as below:

$$u(k) = U_{PI}(k) + U_{PD}(k) \quad (2.5)$$

For tuning the fuzzy PI + fuzzy PD controller, it is recommended to tune the fuzzy PI controller first without using the fuzzy PD controller. Then keep the gains for input signals unchanged after adding fuzzy PD control and adjust the gains for output signals to obtain an appropriate result. The simulation result using fuzzy PD + I, fuzzy PI+D and fuzzy PI + fuzzy PD controller compared to PID controller is shown in Figure 2.9.

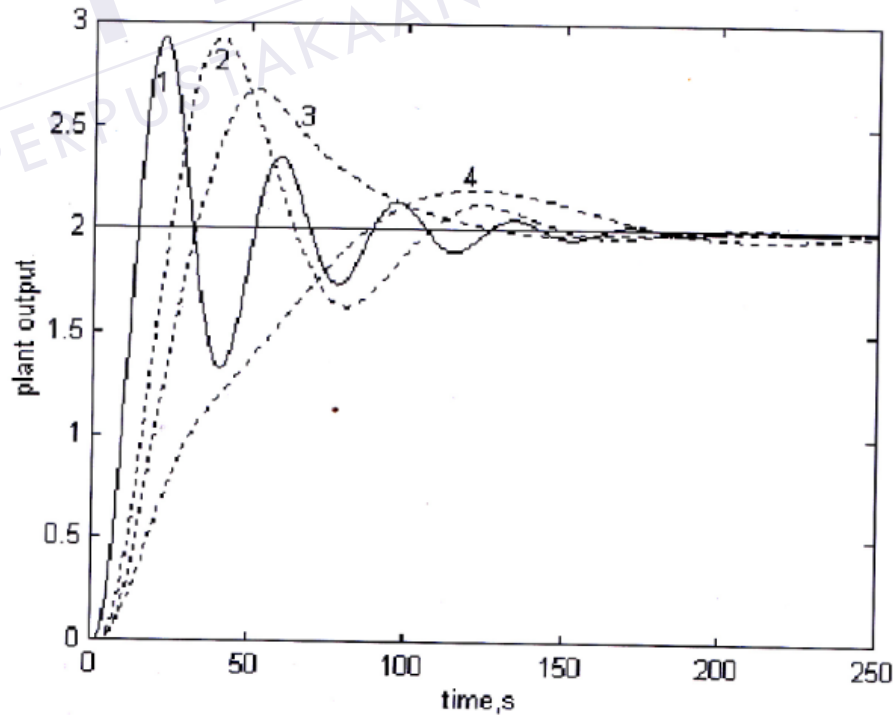


Figure 2.9: Simulation result of fuzzy PID compared to classical PID controller



where

1. Classical PID controller
2. Fuzzy PI + fuzzy PD controller
3. Fuzzy PI + D controller
4. Fuzzy PD + I controller

#### 2.6.4 Fuzzy P control with parallel integral and derivative action (Fuzzy P+ID)

The general structure of this approach can be achieved by placing a fuzzy P controller in parallel with the conventional integral and derivative controllers as shown in Figure 2.10.

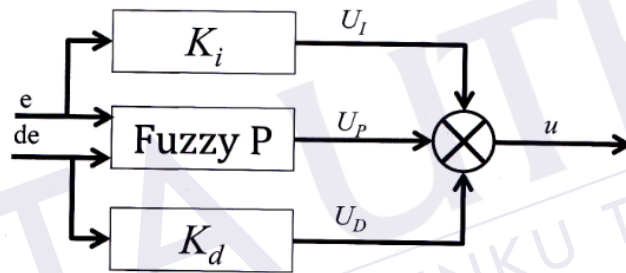


Figure 2.10: Fuzzy P controller with integral and derivative controller

From Figure 2.10, the control action is obtained with the sum of output from the fuzzy P controller and the output from the conventional integral controller and the output from the conventional derivative controller.  $de$  and  $e$  are derivative error and error input respectively.  $U_I$  is the output of integral gain,  $U_P$  is the output from hybrid fuzzy P and  $U_D$  is the output of derivative gain while  $u$  is the fuzzy P + ID combination output. The structure can be represented in mathematical equation as below:

$$u(k) = U_P(k) + K_i e(k) + K_d de(k) \quad (2.6)$$

where  $K_i$  is integral gain and  $K_d$  is derivative gain that have to be determined.

According to [46], this approach has the following features:

1. It is easy to design because it has only one parameter to be adjusted based on original PID controller.
2. The fuzzy P+ID controller keeps the simple structure of the PID controller.
3. The sufficient stability condition shows that the same stability remains unchanged if the original PID controller structure is replaced by the fuzzy P + ID controller structure.

The idea of combining the fuzzy logic with PID controller using this type of structure is to use the integral and derivative controller as stabilizer while fuzzy P controller used to improve the control performance. The fuzzy P term improve overshoot and rise time response while integral term reduces steady state error and derivative term reduce overshoot and improve the combined controller process stability. For tuning the fuzzy P+ID controller, proportional , integral and derivative gain must be tune properly from the original PID structure. Then the proportional controller is replaced by fuzzy P.

#### 2.6.5 Fuzzy P control with parallel Fuzzy I and Fuzzy D(FuzzyP + Fuzzy I+Fuzzy D)

The general structure of this approach can be achieved by placing a fuzzy P controller in parallel fuzzy I controller and fuzzy D controller as shown in Figure 2.11.

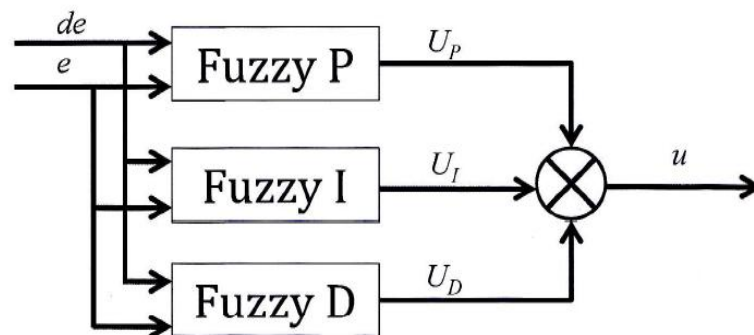


Figure 2.11: Fuzzy P controller with fuzzy I and fuzzy D controller

From Figure 2.11, the control action is obtained with the sum of output from the fuzzy P controller, the output from the fuzzy I controller and the output from the fuzzy D controller.  $u_p$  is the output of the fuzzy P controller,  $u_i$  is the output of the fuzzy I controller and  $u_d$  is the output of the fuzzy D controller while  $u$  is the fuzzy P + fuzzy I + fuzzy D controller combination output. The structure can be represented in mathematical equation as below:

$$u(k) = u_p(k) + u_i(k) + u_d(k) \quad (2.7)$$

According to [47], the advantages of using this structure type are:

1. The structure is similar to original conventional PID controller which is placed parallel to each other.
2. The fuzzy P + fuzzy I + fuzzy D controller structure will increase the degree of freedom of the controller where user has more flexibility to achieve the desired response.
3. The fuzzy P + fuzzy I + fuzzy D controller can reduce overshoot and settling time.
4. This type of structure can avoid the complexity of the rule-base and membership function design where all fuzzy P, fuzzy I and fuzzy D controllers can use the same membership functions and the same rule base.

Each of the fuzzy parameter is tuned manually in suitable range value. Then the fuzzy logic controller will tune the PID controller gain automatically to get the best result. This operation is called self tuning PID controller gain by using fuzzy logic.

## 2.7 Intelligent Adaptive Controller

A plant may vary with time; therefore the real process model may differ from the model used for designing controller. The variation of the process may be caused by a change in the operating conditions or the environment. For such circumstances, an adaptive control strategy can be considered. An adaptive control system is one in

which the controller parameters are adjusted automatically to compensate for the changing process conditions or environment.

In many cases, it is necessary or useful to have a model of the system available online while the system is in operation. The model should then be based on observations up to the current time. The need for such an on-line model construction typically arises since a model is required in order to take some decision about system [47]. Adaptive control is an approach to controlling systems that adjusts over time in response to changing conditions and knowledge acquired by the controller. Rather than remaining static or attempting to cope with minor deviations, adaptive control actively responds to changes in the system to improve the control.

This approach is needed with dynamic systems in unstable environments, ranging from aircraft to medical robots. With adaptive control, the controller collects data about the environment of the system is operating in and uses this information to make adjustments to how the system is controlled. Examples of adaptive control can be seen in some vehicles with the ability to adjust automatic braking systems for wet and icy conditions. In these cases, the system responds to the conditions to improve accuracy, effectiveness, and efficiency to make driving safer and easier in a wide variety of settings. In recent years, Fuzzy Logic Control (FLC) [45] and Artificial Neural Network (ANN) [33], the branches of Artificial Intelligence (AI), have traced considerable attention as candidates for novel computational systems because of the variety of advantages that they offer over the conventional computational systems. [47] have proposed a model reference adaptive neurocontroller based on feed-forward neural network with momentum back-propagation learning algorithm. This approach is only utilized for nonlinear system. However, it needs a small number of tuning parameters requiring a few trials and error to be properly selected.

In addition, it not suitable for system with time delay, which is due to the fact that the output of the plant is not directly influenced by the controller's parameter. An adaptive fuzzy control algorithm has been proposed by [47] for a class of uncertain nonlinear non-affine SISO systems. The authors conclude that the proposed algorithm guarantees all the signals in the closed-loop system are bounded and the tracking error converges to a bounded compact sets. [39] have proposed an indirect adaptive fuzzy controller based on model reference control scheme for a class of SISO nonlinear systems to provide asymptotic tracking of reference signal. They used Takagi-Sugeno (T-S) type fuzzy system to represent the plant model structure. They

found that the system is remains steady in spite of the application of brusque parameters variations of the system.

[48] have designed ANFIS PID controller which is based on the Adaptive Neuro-Fuzzy Inference System to control the Steam Generators (SG) water level on the computer. They used the neural network which has ability of self-studying to calculate the fuzzy rule and membership function with back-propagation algorithm to overcome the awkward task of choosing membership function of fuzzy controller. They conclude that the ANFIS PID control effect is better than fuzzy controller or general cascade PI controller and they found that ANFIS needs empirical data to establish fuzzy rule and adjust membership function. So more empirical data needs to be obtained to achieve the better control effect.

From the types of controller that are discuss, it can be conclude that all types of hybrid fuzzy logic and PID controller structure will give better result compared to PID controller alone. The improvements that can be achieved using fuzzy PID controller are increment of rise time and settling time and reduction of overshoot and transient response.



PTTA  
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## CHAPTER 3

### METHODOLOGY

#### 3.1 Introduction

In this chapter, the methodology to develop the controller from including, doing the literature review, deriving the mathematical model of the plant and designing the controller is described. The plant mathematical model is used to represent the real application which was simulated using a program code in Matlab. The controller is based on Adaptive Fuzzy.

#### 3.2 The process flow

The flow of the process starts with studying the journal and documentation that related with this research and understand the flow to design. The first step is to derive the mathematical model of the system. This is very important because all the parameter must be accurate to get the best result. But for this research, the air conditioning system is very complicated equation if the all aspect are taken into account. Hence, this study only focuses on the compressor speed and the temperature room. The Figure 3.1 illustrates the flow of the process.

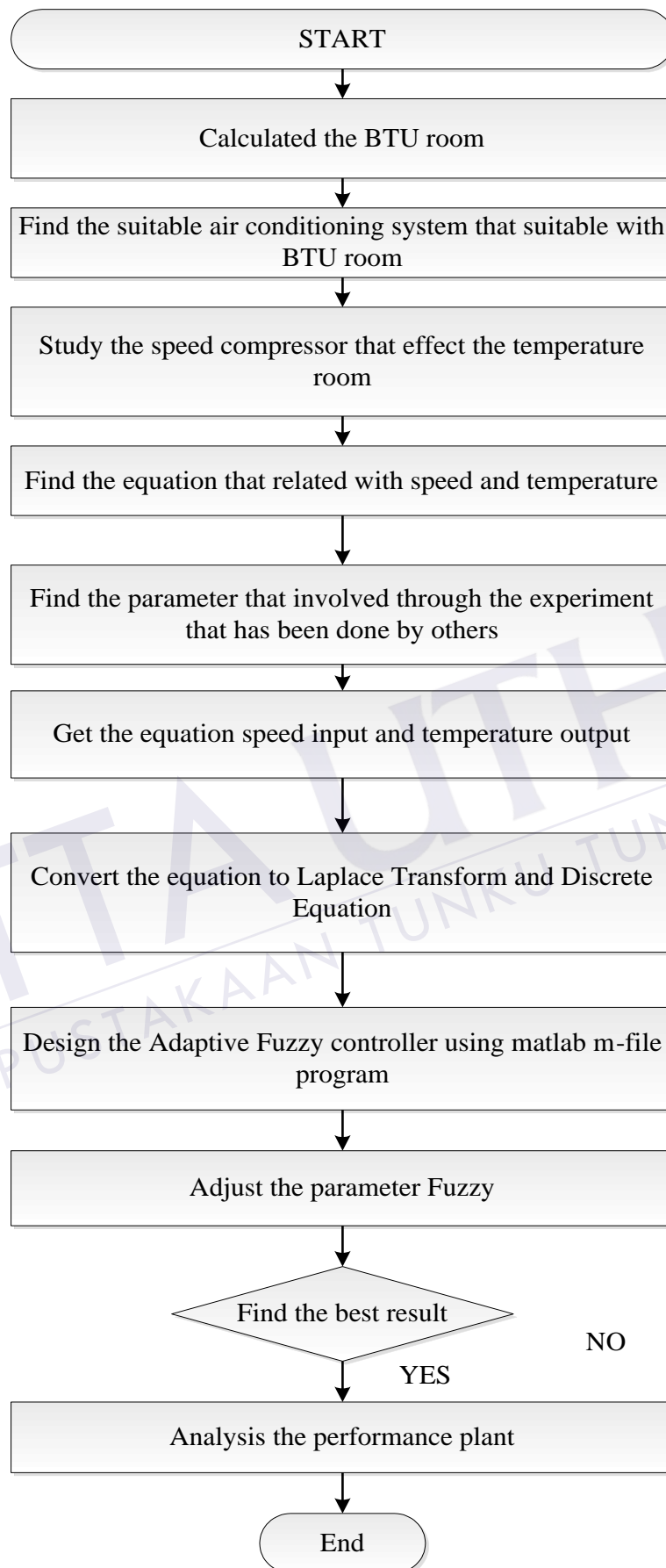


Figure 3.1: Flowchart Design Process

In order to find the mathematical model of the plan, firstly the calculation of room BTU is taken into account. The heat from the room will affect the actual room temperature. To find the value of the BTU, the all aspect heat load must be considered. The heat load depends on a number of factors, by taking into account those that apply in your circumstances and adding them together a reasonably accurate measure of the total heat can be calculated. Factors include the floor area of the room, the size and position of windows, and whether they have blinds or shades, the number of room occupants, the heat generated by equipment and the heat generated by lighting.

Based on the BTU room value, the air conditioning system is selected. From the air conditioning system, the type of compressor will be known. The compressor that affects the temperature room equations is very complicated. The process of heat transfer starts from the compressor speed to evaporator coil and the condenser coil. The condenser coil then changes the output temperature. To find the relationship between speed compressor and output temperature, the evaporator and condenser are ignored. The parameters that are involved are obtained through the experiments that have been done by the others researches [44].

The controller is based on the adaptive fuzzy controller and is realized using Matlab programming and Simulink. The fuzzy block parameters are designed using the fuzzy.fis that is available in Matlab. The plant is controlled with adaptive fuzzy controller. To get the best performance, the parameters of adaptive fuzzy controller are adjusted. It is quite a challenging task to tune the parameters.

### **3.3 Control System Block Diagram**

The block diagram system is illustrated in Figure 3.2. The two input variable from the actual room temperature and the outside room temperature. The difference between the two temperatures allows the controller to control the speed of the compressor to the desired set point temperature.



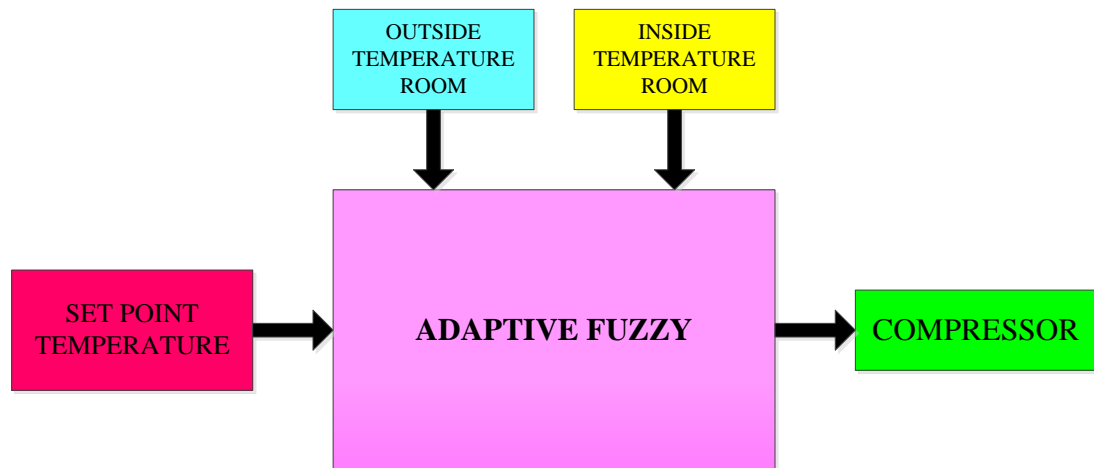


Figure 3.2: Block Diagram System

As the speed of an induction motor is proportional to the frequency of the AC, the compressors runs at different speeds. A controller can then sample the current ambient air temperature and adjust the speed of the compressor appropriately.

The output of fuzzy controller is the compressor speed that has 4 different modes that are off, low, medium and fast. The difference of the two temperatures readings by temperature sensors will be compared to the set point value in order to get the comfortable temperature for consumers. The set point temperature for this project is set to 20° C. The heat from the room is taken into account to measure the actual room temperature. The calculation of BTU room will be discussed in next section.

### 3.4 Calculation classroom BTU

The arrangement of the class room is shown in Figure 3.3. The heat from the class room must be considered as it affects the actual room temperature. The BTU of the room has to be calculated to determine the total load heat.

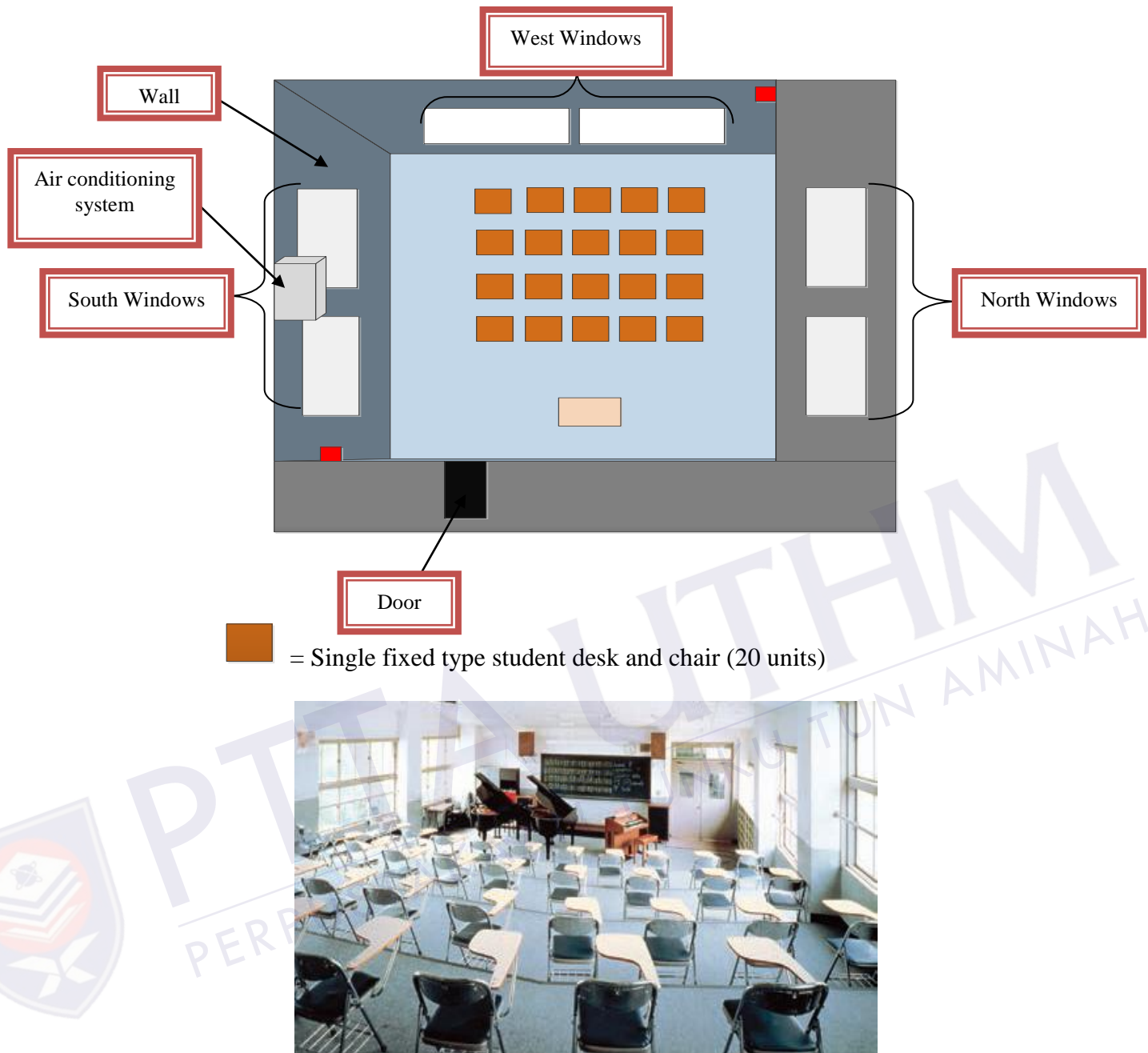


Figure 3.3: Classroom arrangement

### 3.4.1 Floor Area of Room

The amount of cooling required depends on the area of the room. To calculate the area in square meters:

$$\text{Room Area BTU} = \text{Length (m)} \times \text{Width (m)} \times 337 \quad (3.1)$$

$$4\text{m} \times 5\text{m} \times 337 = 6740\text{m}^2$$

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