# AIR HEATER TEMPERATURE TEMPERATURE CONTROL USING LYAPUNOV BASED ADAPTIVE FUZZY CONTROLLER USING MATLAB

***A Thesis Submitted***
**In Partial Fulfillment of the Requirements**
**For the Degree of**

## BACHELOR OF TECHNOLOGY

**By**


**SOURAV SAHU (12/IC/52)**
**Md RAMIUR RAHAMAN (12/IC/25)**
**KUSHAL MANDAL (12/IC/24)**
**SAUVIK GHOSH (12/IC/47)**
**RUPTANU DE (12/IC/41)**
**KIRAN SETHI (12/IC/18)**

Under the guidance of

**Mr. Manas Sarkar**
**Associate Professor**
*To the*

**Department of Instrumentation & Control Engineering**
Haldia Institute of Technology

June-2016

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**Approved by**

**(Mr. Manas Sarkar)**
**Project Supervisor**

**(Prof. D.Dey)**
**Head of the Department**

*to the*


**Department of Instrumentation & Control Engineering**

Haldia Institute of Technology


June-2016

# DECLARATION

We hereby certify that the the project entitled **"AIR HEATER TEMPERATURE CONTROL USING LYAPUNOV BASED ADAPTIVE FUZZY CONTROLLER USING MATLAB**" by Sourav Sahu, University Roll No. 10304012052 in partial fulfillment of requirements for the award of degree of B.Tech submitted in the Department of **Instrumentation and Control Engineering** at **HALDIA INSTITUTE OF TECHNOLOGY** under **WEST BENGAL UNIVERSITY OF TECHNOLOGY**, KOLKATA is an authentic record of our own work carried out under the supervision of Mr. Manas Sarkar. The matter presented has not been submitted by me in any other University / Institute for the award of B.Tech Degree.

| 1.Md Ramiur Rahanman | 2.Kushal Mandal | 3.Sauvik Ghosh | 4.Ruptanu De | 5.Kiran Shety |
|---|---|---|---|---|
| (10304012025) | (10304012024) | (10304012047) | (10304012041) | (10304012018) |

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Name of the Supervisor:

**Mr. Manas Sarkar**

Designation:

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(Signature)

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**Dr. Dilip Dey**

Head of the Department

Instrumentation and Control Engineering

# ACKNOWLEDGEMENT

We would like to express sincere gratitude towards our Project Guide Mr. Manas Sarkar and to our honourable Head of the Department Dr. Dilip Dey for their immense help and support for the accomplishment of our B.Tech final year project entitled: **"Air heater temperature temperature control using lyapunov based adaptive fuzzy controller using MATLAB".** And in the last but not the least our heartfelt thanks to all our classmates for their support and help. The experience of this project as an Instrumentation & Control Engineering student is an excellent experience. We are thankful to respected departmental teachers of our department without the guidance of who's our visit and understanding of each part would have not been possible.

We would also like to express our sincere thanks to all the faculty members of Instrumentation and Control Engineering Department for their kind co-operation. We would like to acknowledge the assistance of all our friends in the process of completing this work.

Finally, we express our sincere gratitude to our parents for their constant encouragement and support.

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# LIST OF ABBREVIATIONS

# LIST OF FIGURES

# SYNOPSIS

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**Degree for which submitted: Bachelor in Technology**

**Department: Instrumentation and Control Engineering**

**Thesis Title: "Air heater temperature temperature control using lyapunov based adaptive fuzzy controller using MATLAB"**

**Name of thesis Supervisor: Mr. Manas Sarkar**

**Month and year of thesis submission: June, 2016**

# ABSTRACT

This project proposes an air heater 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 heater temperature system, designing a controller and performing a simulation to analyse the performance of the designed controller using MATLAB. 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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# INTRODUCTION

- **Project Background :-**

Nowadays, the air heater temperature is widely used especially in warm countries including Malaysia. Usually the conventional air heater temperature 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 heater temperature 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 heater temperature 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 heater temperature system is being designed, the consideration of the type of control system must be included in a modelling design. In particular the controller must be able to avoid the inefficiency of having the air heater temperature operate all the time. Several control options were considered at presence sensing circuit, which would turn the air heater temperature off when people are not in the room with the air heater temperature and a temperature sensor input, which would change the air heater temperature operation depending on room temperature. Based on the observation of the using the present conventional air heater temperature application, it always working all the time without a systematic control. Therefore, the control of the air heater temperature 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 heater 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 2 difference between indoor and outdoor temperatures is small or zero and the indoor temperature exceed a predefined threshold does the controller run the air conditioner. This research focuses only on main component, which is the compressor system, in air heater temperature that significantly affects the temperature change.

- **Problem Statement :-**

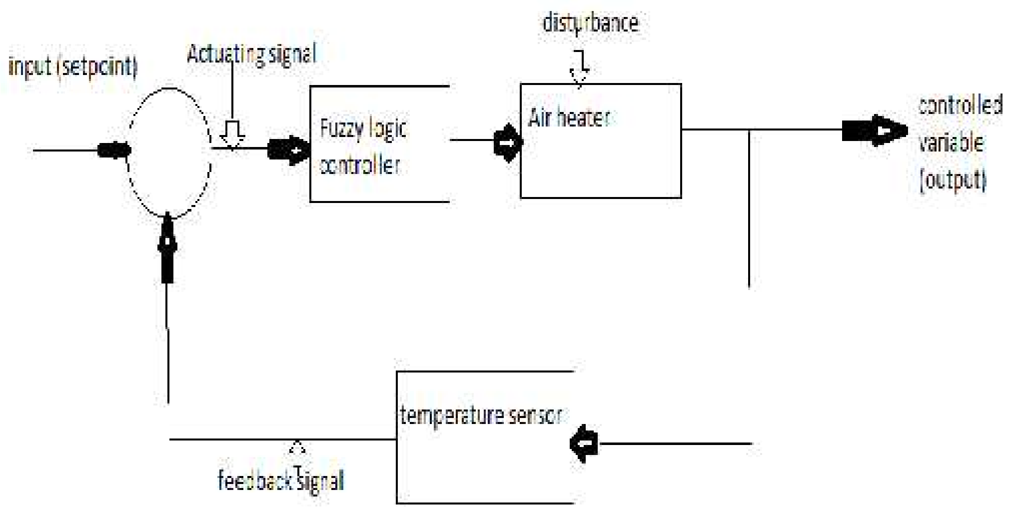
The problem happens when the air heater temperature is still functioning although in the event of cold weather. The function is uncontrolled and must be manually turned on and off. Sometimes it can lead to high usage of electricity which in turn raises the electricity bill when the user forgot to switch 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.

- **FUZZY CONTROL:**

A. It is a fuzzy logic controller (FLC) designed to control the temperature of an air heater temperature.

B. They can be in software or hardware and can be used anything from small circuit to large mainframes.

- **<u>Block Diagram:</u>**




Block diagram of an air heater temperature control using fuzzy logic controller

Fig: 1

- 
- **<u>Description</u>:**

The process comprises of a fuzzy logic controller (FLC), air heater temperature and temperature sensor. In this figure the temperature control system of an air heater temperature works on the basic principle of the fuzzy logic. Non linear mapping of an input data set to a scalar output data is known as fuzzy logic system. This system consists of four main parts:

a. Fuzzifier

b. Rules

c. Interference engine

d. Defuzzifier

In order to exemplify the usage of fuzzy logic system, we consider a temperature control system controlled by a fuzzy logic controller. The temperature of the air heater temperature can be adjusted by the current temperature of the air heater temperature and the target value by define system. The comparison between current and target temperature can be compared by fuzzy engine at certain period of time and produces a command of heating or cooling.

The Matlab code for this system is yet not derived, but it will be continued to be derived in future.

- **<u>Lyapunov's Law</u>:**

A control-Lyapunov function is a function V: D tends to R that is continuously differentiable, positive definite (that is V(x) is positive except at x=0 where it is zero), and such that

$$\forall x \neq 0 \text{ , } \exists u \qquad V(x , u) = \Delta V(x) . f(x , u) < 0$$

The last condition is the key condition; in words it says that for each state *x*

We can find a control *u* that will reduce the "energy" V. Intuitively, if in state we can always find a way to reduce the energy to zero that is to bring the system to a stop.

# OBJECTIVE AND SCOPE OF THE PROJECT

## Objectives:

The objectives of this project are:

1. To find the mathematical model of an air heater temperature system.
2. To design a controller using MATLAB based on adaptive fuzzy.
3. To analyses the performance of the controller.

## 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 heater temperature system.

# REVIEW OF LITERATURE

Almost every household in the world has a heater temperature or air conditioner of some description. The aim of our project was to design a fuzzy system whereby a heater temperature like this could be operated with the most effectiveness given several climatic variables. As a secondary aim, we also wished to create a system which wasted the minimum amount of energy while still providing an effective heating/cooling system. Our model focuses on a heater temperature/air conditioner designed for domestic use which is mostly automated but does require a user input also. The flaw identified with normal heater temperatures for example, was one of the following; either the room would be heated to a desired temperature at which point the heater temperature would automatically switch of and the room temperature immediately begin to fall again, perhaps re-activating the system or; The system would simply have to be turned on and off manually by the user continually. Our claim is that both systems aren’t as effective as they could be once fuzzy logic is applied correctly.

## ❖ **Principles of Air Conditioning System:-**

Air conditioning involves more than lowering the air temperature. It includes dehumidifying, cleaning (filtering), and circulating the air. 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. 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.

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 vapour 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, 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 colourless gas at atmospheric temperature and pressure. 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.

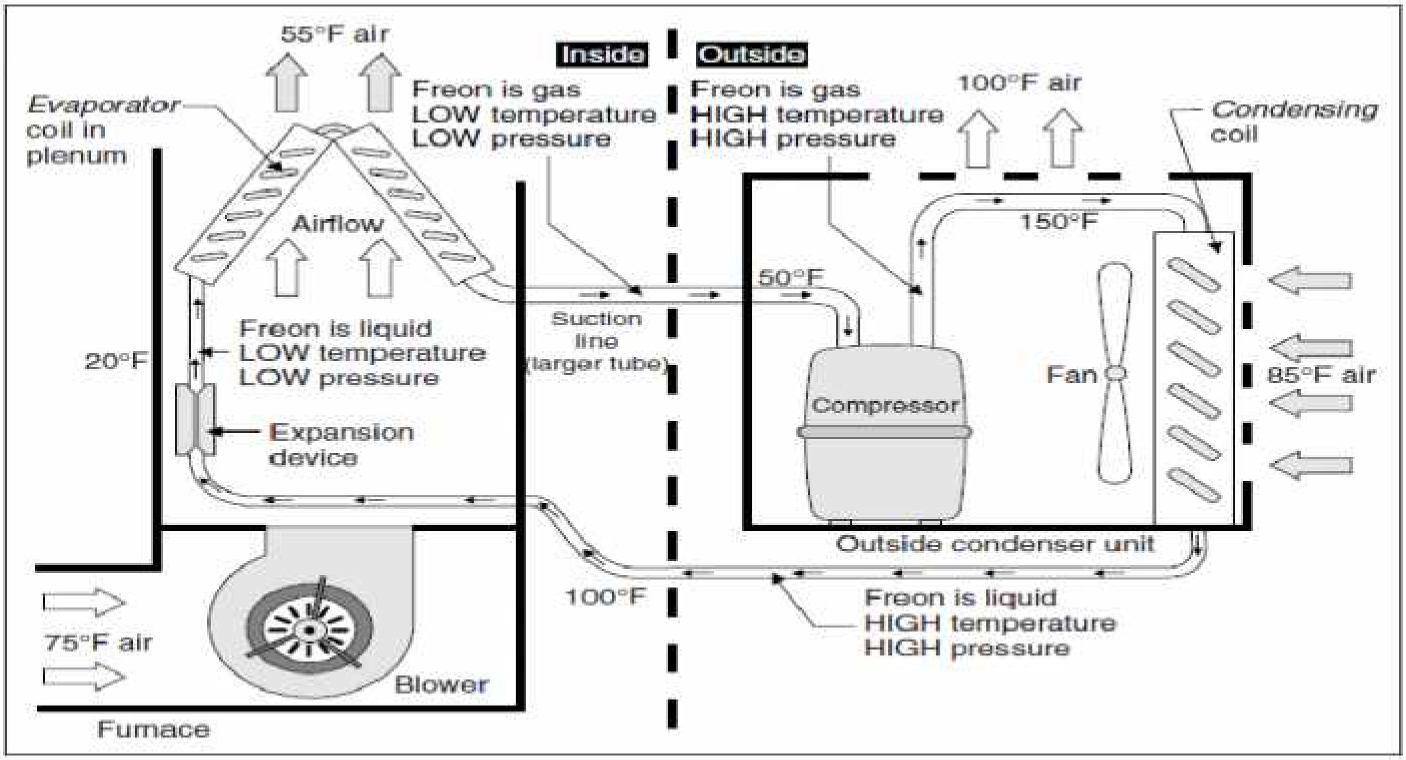



Fig.2:- Schematic of Air Heater Temperature System

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.

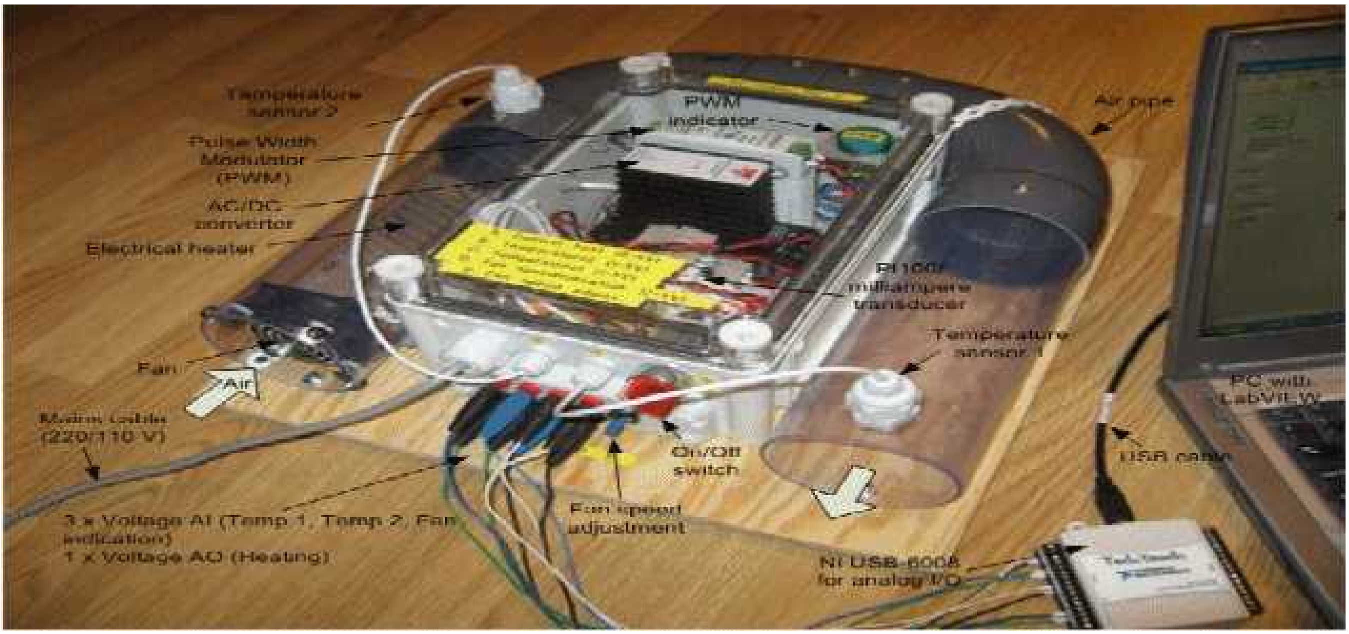



Fig.3:- A mathematical model of an Air Heater system

- **<u>Function of Compressor that Effect the Temperature</u>:**

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.

The basic of the vapour 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:4 illustrate 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.

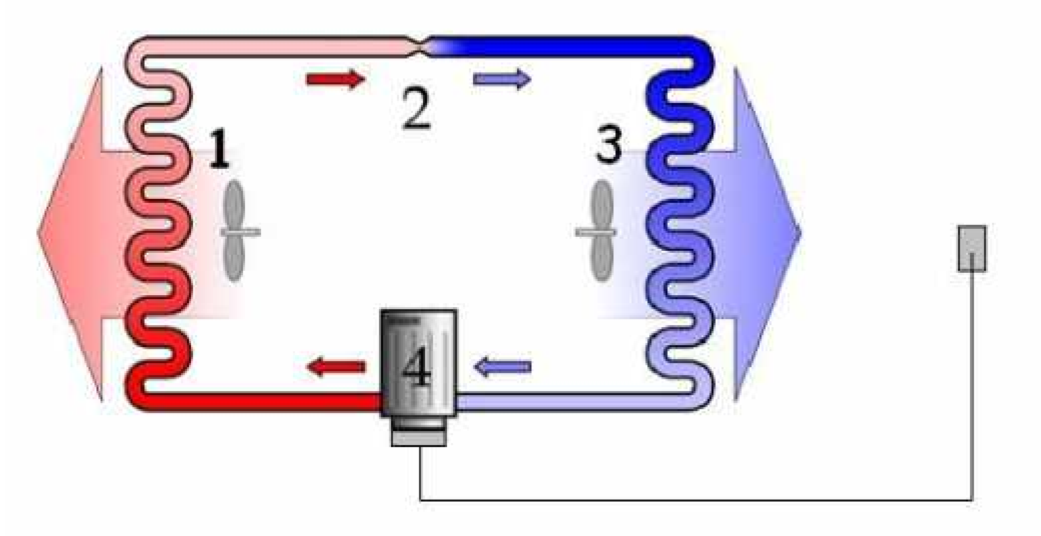



Fig.4:- The process of cooling system

1. Condenser Coil; 2. Expansion Valve; 3. Evaporator Coil; 4.Compressor

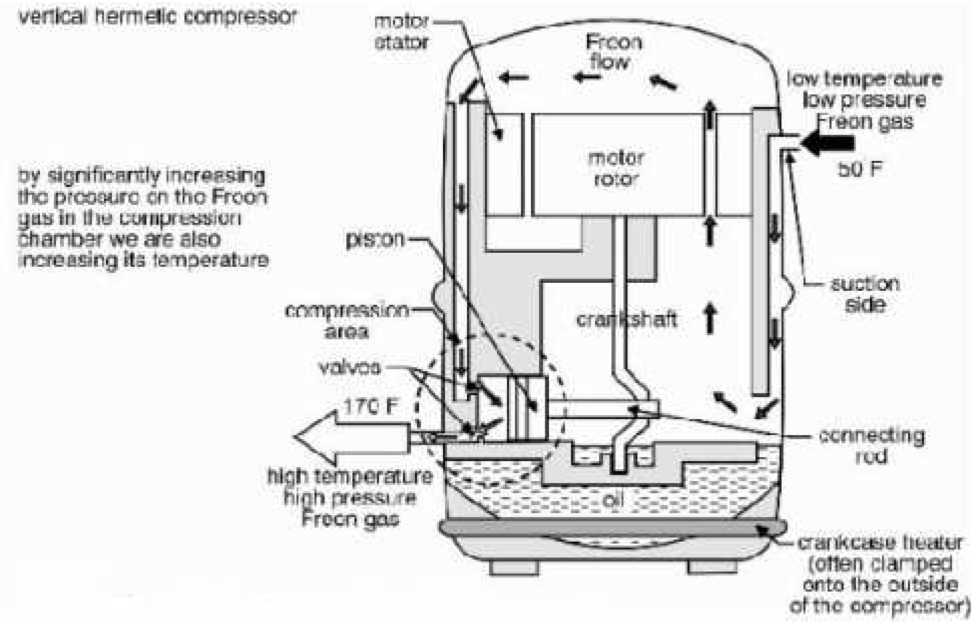



Fig.5:- The flow of the Freon in compressor

Figure. 5 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.

- **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.


Fig.6:-Air Heater Process

- **<u>Where FLC is used?</u>**

➢ The description of the technological process is available only in word form, not in analytical form.

➢ It is not possible to identify the parameters of the process with precision.

➢ The description of the process is too complex and it is more reasonable to express its description in plain language words.

➢ The controlled technological process has a “fuzzy” character, i.e. its behavior is not fully unequivocal under precisely defined conditions.

➢ Or it is not possible to precisely define these conditions.

- **<u>Advantages of using fuzzy technique</u>:**

➢ Simplicity of control and Smooth operation

➢ High degree of tolerance

- Low cost
- Reduce the effect of Non-linearity
- Inherent approximation capability
- Possibility to design without knowing the exact mathematical model of the process.

## ❖ <u>FUZZY THEORY</u>

### • The beginning of fuzzy set:

Fuzzy theory was initiated by Lotfi A. Zadeh in 1965 as an extension of the classical control theory. According to him classical control theory put too much emphasis on precision and therefore could not the complex systems. Later he formalized the ideas into the paper "Fuzzy set." Fuzzy sets are sets whose elements have degrees of membership.

### • If-Then rules of fuzzy systems:

Fuzzy systems are knowledge based or rule based systems. The heart of a fuzzy system is a knowledge base consisting of the so- called If-Then rules. A fuzzy If-Then statement in which some words are characterized by continuous membership functions. After defining the fuzzy sets and assigning their membership functions, rules must be written to describe the action to be taken for each combination of control variables. These rules will relate the input variables to the output variable using If-Then statements which allow decisions to be made. The If (condition) is an antecedent to the Then (conclusion) of each rule. Each rule in general can be represented in the following manner:

If (antecedent) Then (consequence).

For example:

If the speed of the car is high, then apply less force to the accelerator.

If pressure is high, then volume is small.

### • Difference between classical set and fuzzy set:

Let U be the universe of discourse, or universal set which contains all the possible elements of concern in each particular context or application.

## ➢ Classical set:-

A classical (crisp) set A in the universe of discourse U can be defined by listing all of its members (the list method) or by specifying the properties that must be satisfied by the members of the set(the rule method).

The list method can be used only for finite sets and is therefore limited use. The rule method is more general. In the rule method, a set A is represented as,

$$A=\{x \in U | \text{ x meets some conditions}\}$$

Another method to define a classical set A-the membership method, which introduces a zero-one membership function (also called characteristic function) for A, denoted by μA(x),such that

$$\mu A(x) = \{1 \text{ if } x \in A$$
$$0 \text{ if } x \text{ not } \in A\}$$

Crisp sets are binary in nature.

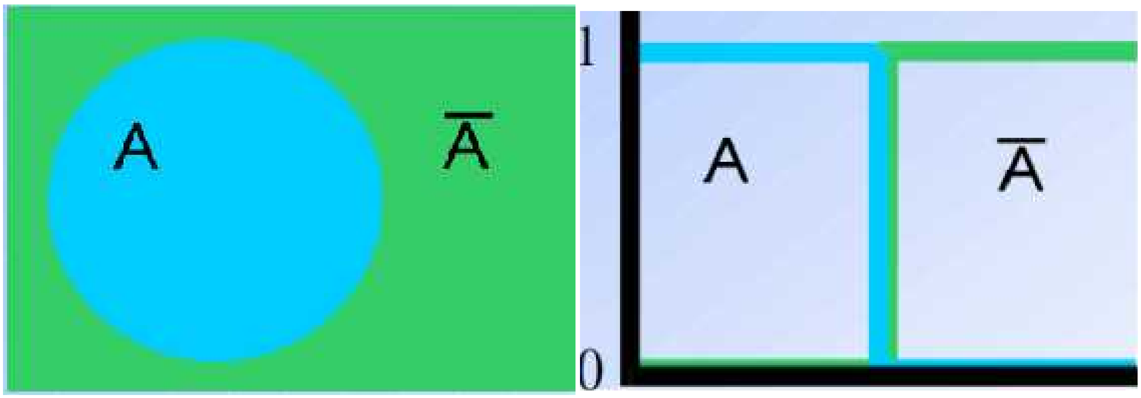



Fig.7: Venn diagram and grade of belonging of crisp set A

## ➢ Fuzzy set:

A fuzzy set in a universe of discourse U is characterized by a membership function μA(x) that takes values in the interval [0, 1].

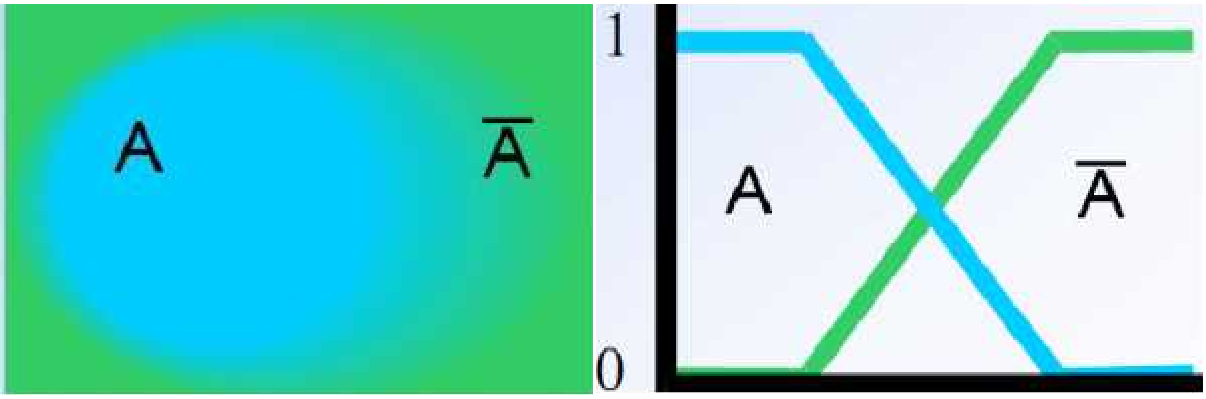



Fig.8:- Venn diagram and grade of belonging of fuzzy set A

A fuzzy set A in U may be represented as a set of ordered pairs of a generic element x and its membership values, that is

$$A=\{(x,\underbrace{\mu_A(x)}_{\text{Membership function (MF)}}) \mid x\in U\}$$

Fuzzy set

Universe or universe of discourse

- **<u>Fuzzy sets with a continuous universe</u>:**

Let A be a fuzzy set named “numbers closed to zero.” Then a possible membership function for A is ,

$$\mu_A(x) = e^{-x^2}$$

Where x ϵ According to this membership function, the number 0 and 2 belong to the fuzzy set to

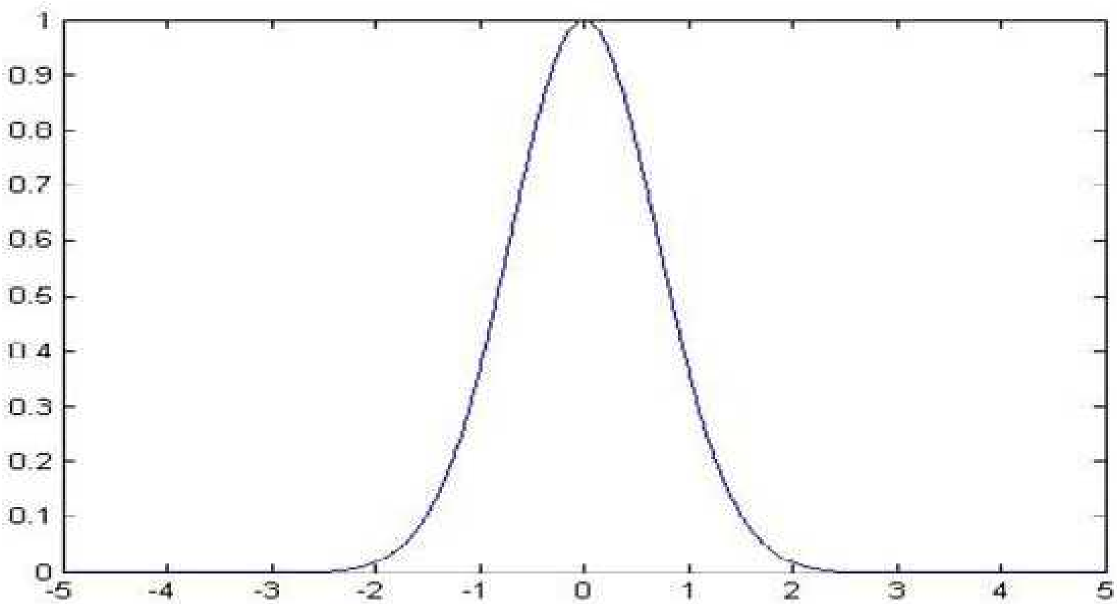





Fig: 9 - A possible membership function to characterize “number close to degrees of $e_0$=1 and $e_{-4}$ ,respectively

So the construction of fuzzy set depends on two things:-

(1) The identification of suitable universe of discourse.

(2) The specification of an approximate MF‟s. As MF‟s are subjective, which means MF‟s are specified for the same concept.

## ➢ What is fuzzy logic?

Fuzzy logic is the superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth -- truth values between "completely true" and "completely false". It is made possible through the concept of degree of membership.

## ➢ How does FL work?

FL requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. For example, a simple temperature control system could use a single temperature feedback sensor whose data is subtracted from the command signal to compute "error" and then time-differentiated to yield the error slope or rate-of-change-of-error, hereafter called "error-dot". Error might have units of degs F and a small error considered to be 2F while a large error is 5F. The "error-dot" might then have units of degs/min with a small error-dot being 5F/min and a large one being 15F/min. These values don't have to be symmetrical and can be "tweaked" once the system is operating in order to optimize performance.

## ➢ Why fuzzy systems?

Fuzzy logic has rapidly become one of the most successful of today's technologies for developing sophisticated control systems. The reason for which is very simple. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches (e.g. linear control design), and purely logic-based approaches (e.g. expert systems) in system design. Other approaches require accurate equations to model real-world behaviours; fuzzy logic can accommodate the ambiguities of real-world human language and logic. It provides both an intuitive method for describing systems in human terms and automates the conversion of those system specifications into effective models.

## ➢ **Application area of fuzzy logic**:

**1: Controller application:** An application delivery controller (ADC) is a computer network device in a data enter, often part of an application delivery network (ADN), that helps perform common tasks such as those done by web sites to remove load from the web servers themselves.

**2: Communication engineering:** Telecommunications engineering, or telecoms engineering, is an engineering discipline that brings together all electrical engineering disciplines including computer engineering with systems engineering to enhance telecommunication systems. The work ranges from basic circuit design to strategic mass developments.

**3: Image processing:** In imaging science, image processing is processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image.

**4: Production engineering:** Production Engineering is a combination of manufacturing technology with management science. A production engineer typically has a wide knowledge of engineering practices and is aware of the management challenges related to production.

**5: System identification:** System identification is the art and science of building mathematical models of dynamic systems from observed input-output data. It can be seen as the interface between the real world of applications and the mathematical world of control theory and model abstractions.

**6: Consumer electronics:** Consumer electronics refers to any device containing an electronic circuit board that is intended for everyday use by individuals.

## ❖ FUZZY CONTROLLER:

### • Fuzzy logic controller (FLC):

Fuzzy logic control is a control algorithm based on a linguistic control strategy, which is derived from expert knowledge into an automatic control strategy. The operation of a FLC is based on qualitative knowledge about the system being controlled .It doesn't need any difficult mathematical calculation like the others control system. While the others control system use difficult mathematical calculation to provide a model of the controlled plant, it only uses simple mathematical calculation to simulate the expert knowledge

The requirement for the application of a FLC arises mainly in situations where:

- ✓ The description of the technological process is available only in word form, not in analytical form.
- ✓ It is not possible to identify the parameters of the process with precision.
- ✓ The description of the process is too complex and it is more reasonable to express its description in plain language words.
- ✓ The controlled technological process has a “fuzzy” character.
- ✓ It is not possible to precisely define these conditions.

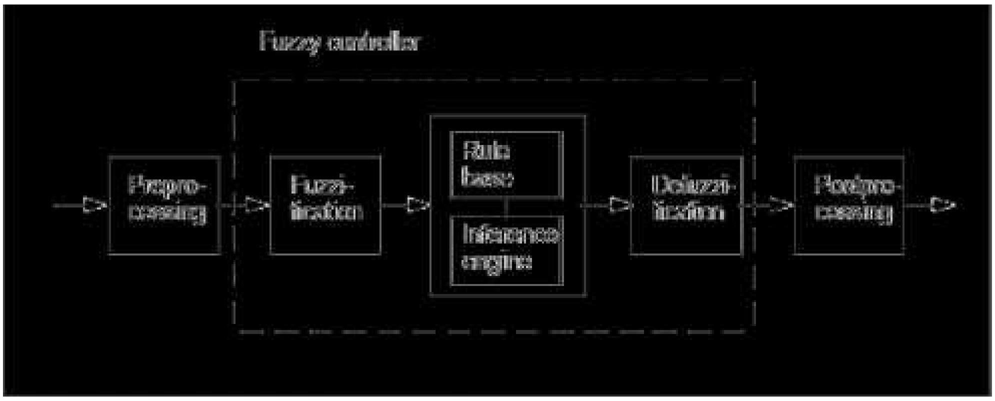



Fig.10:- Structure of fuzzy logic controller

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 andcombine 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.

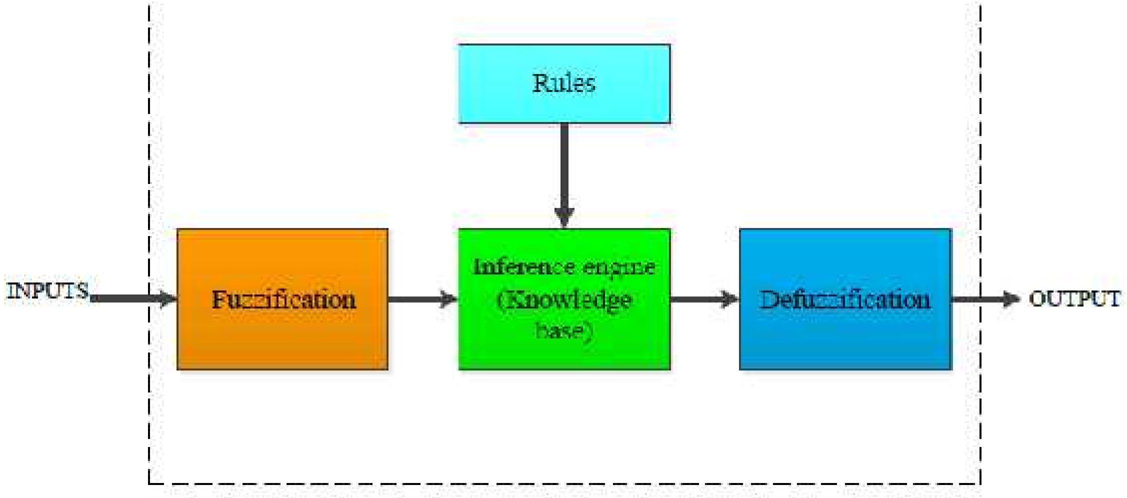



Fig.11:-Block Fuzzy Logic Controller

Fuzzy Logic Controller has three successive blocks through which the control signal is generated in Figure 11.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.

## ➢ <u>Fuzzification</u>:

The first step in designing a fuzzy controller is to decide which state variables represent the system dynamic performance must be taken as the input signal to the controller. Fuzzy logic uses linguistic variables instead of numerical variables. The process of converting a numerical variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called fuzzification. This is achieved with the different types of fuzzifiers. There are generally three types of fuzzifiers, which are used for the fuzzification process; they are

1. Singleton fuzzifier
2. Gaussian fuzzifier
3. Trapezoidal or triangular fuzzifier

## ➢ Rule base:

A decision making logic which is, simulating a human decision process, inters fuzzy control action from the knowledge of the control rules and linguistic variable definitions. The rules are in “If Then” format and formally the If side is called the conditions and the Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured inputs error (e) and change in error (de). In a rule based controller the control strategy is stored in a more or less natural language. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

## ➢ Inference engine:

Inference engine is defined as the Software code which processes the rules, cases, objects or other type of knowledge and expertise based on the facts of a given situation. When there is a problem to be solved that involves logic rather than fencing skills, we take a series of inference steps that may include deduction, association, recognition, and decision making. An inference engine is an information processing system (such as a computer program) that systematically employs inference steps similar to that of a human brain.

# METHODOLOGY

## ➢ Introduction:

In this section, 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.

## ➢ 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.12 illustrates the flow of the 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.

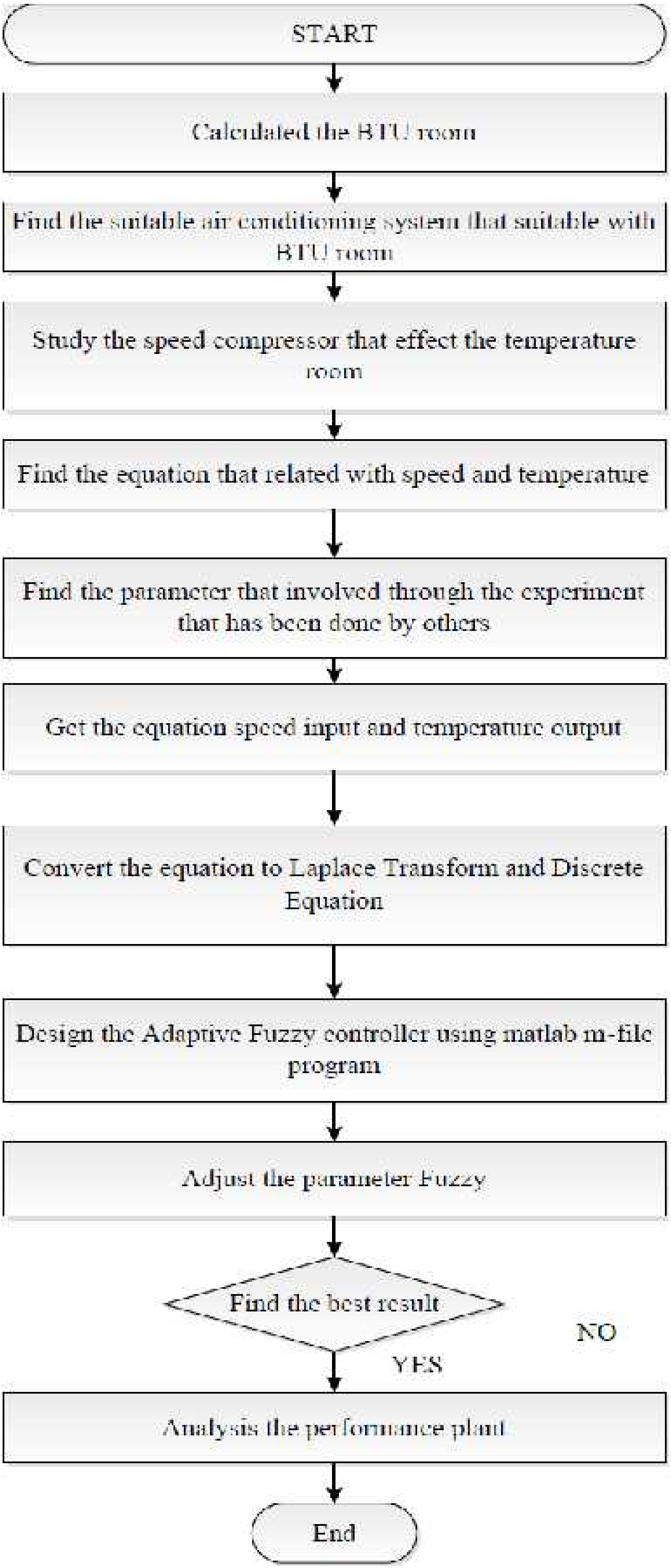



Fig.12:- Flowchart Design Process

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.

The controller is based on the adaptive fuzzy controller and is realized using MATLAB programming. 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.

- ## Control System Block Diagram

The block diagram system is illustrated in Figure 13. 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.

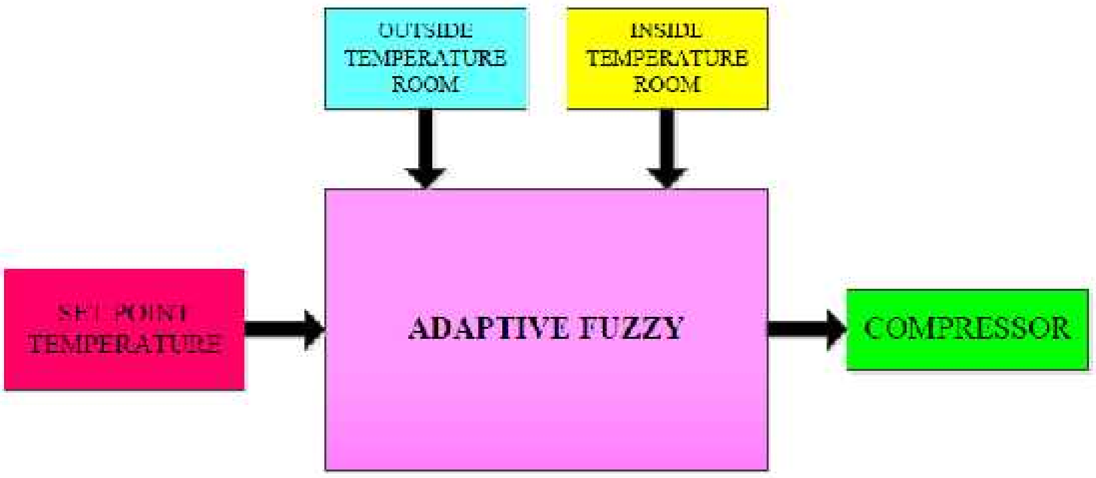



Fig.13:- Block Diagram System

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.

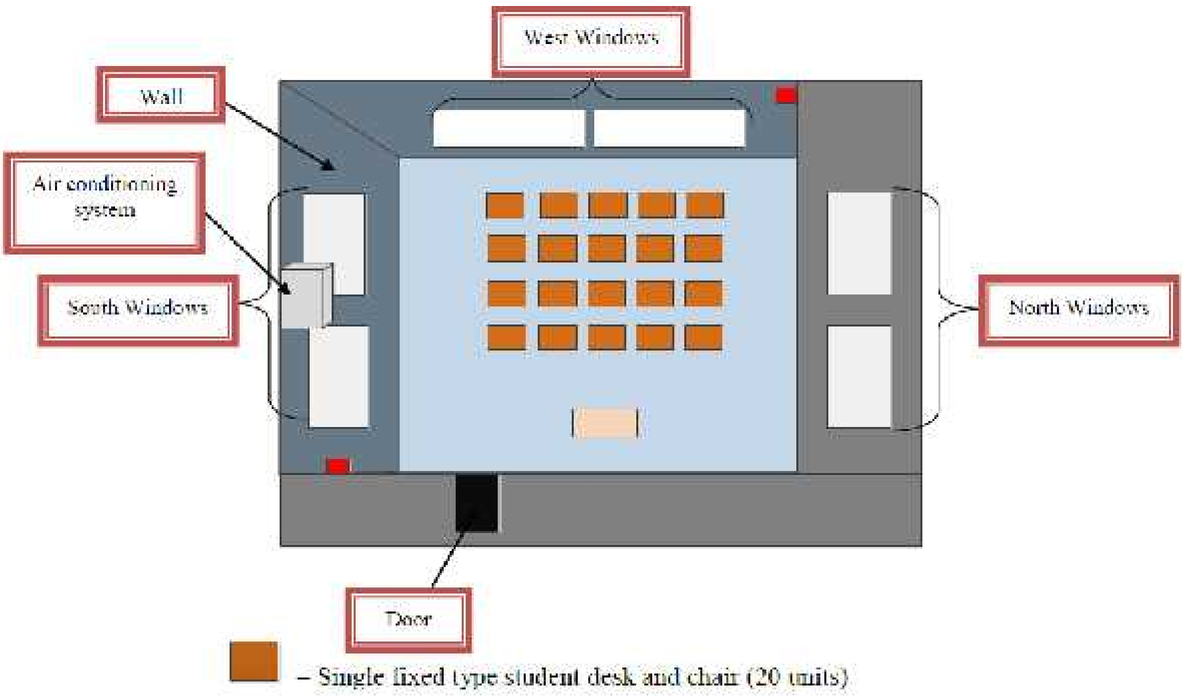



Fig.14:-Calculation Classroom BTU

## ➢ **System:**

The meteorological elements we took into account were the 'room temperature' and the dew point of the room; 'humidity'. We started by modelling with the more commonly used relative humidity but soon realised that the calculations of this figure are already based on the temperature thanks to. So we refer to humidity as the amount of water vapour currently in the air of the room. We hypothesised that the ideal humidity was around 10 degrees Celsius, with a comfortable range between 8-12 based on.

The room temperature is usually higher than air temperature so we modelled five categories of room temperature to reflect this accurately. These membership functions take values between 0 and 30 degrees Celsius but values below 0 and above 30 can simply be treated as equal to 0 and 30 respectively.

User input is required for our other two variables; ‘user input’ and ‘energy saving’. The first variable is set as the desired temperature of the room and is a choice between low, medium and high chosen on a knob between 0 and 30 degrees Celsius which is marked with the aforementioned choice of settings. The energy saving setting is chosen as how much the user wants the system to concentrate on saving energy on a scale from 0 to 1 with 0 being the least energy conscious setting and 1 being the highest.

The output ranges from -15 to 15 where -15 is the highest heat output and 15 is the highest cooling output. The system reflects the fact that high humidity means the room will feel warmer and that the desired energy saving setting should mean that the output is less severe for those who wish to save more energy.

The fuzzy sets used were as follows:

1. Room Temperature (Very Warm, Warm, Mild, Cold, Very Cold)

2. Humidity (Dry, Optimum, Humid)

3. User Input (Low, Medium, High)

4. Energy Saving (On, Off)

## ➢ **Process:**

Firstly, crisp values for room temperature are delivered to the system by the thermometer and humidity by the hygrometer, both of which could easily be built-in components. The user sets a value on the desire temperature knob, which is interpreted as the ‘user input’, as well as the energy saving level on another knob, which takes a value anywhere between 0 and 1 as described above. The energy saving level in particular is mapped to its linguistic variables (on, off) in such a way that allows the user to set any desired degree of energy conservation. This fuzzification of energy consciousness is something we thought vital to our model as most people aren’t either extremely energy saving, or extremely energy wasting, but lie somewhere in between.

The extremes of temperature (Very cold, Very warm) have a large effect on the output values of the system because we thought these two conditions to be the ones when the system is most required to operate, almost (but not entirely!) regardless of the other variables. Thus these two situations carry the most weight in our system. The energy saving value also greatly affects the output at its extremes (like temperature does) but there isn't as much variability in intermediate values like between 0.3-0.7 for example.

The fuzzy values are converted to an output setting for the air heater which takes values between -15 and 15.

## ➢ **Simulation:**

The effect described above of the energy saving setting is depicted in the following where we chose average values for all other variables, but switch the energy saving from 0 (no saving) to 1(most energy saving). The values were as follows:

| Room Temperature | Humidity | User Input | Energy Saving | Output |
|---|---|---|---|---|
| 20 | 10 | 15 | 0 | 12.7 |
| 20 | 10 | 15 | 1 | 5.24 |

So the output was much lower under the energy conscious setting, meaning the air conditioner was still cooling the room, but not as quickly thus using less energy.

The MATLAB picture below is particularly useful for explaining how the energy saving feature works compared to room temperature. We can see that when the energy setting is low and the room temperature is average (from about 13-17 degrees Celsius) then the output values isn't often zero for varying room temp. However, if we look at the far side of the graph when the energy setting is high, there are many output values near 0 for average room temperatures. This means the system is using less energy at average room temperatures, when energy saving is high, and is less worried about using energy when this setting is low.

Initially, we had graphed the energy saving wrongly in that, we hadn't actually included an 'off' membership function which made the variable a non-fuzzy one. Thankfully we fixed that.

- **PROGRAMME CODE:**

```
 h=0.2;
t=linspace(0,60,6000);
  for k=1:1:6000
      r(k)=20;
  end
 for k=1:1:6000

   if k==1
       e(k)=1;
       e_dot(k)=0;
       u(k)=0;
       X1(k)=0;
       X2(k)=0;
      % X3(k)=0;
      % X4(k)=0;
   else
       GE=3;
       GE_DOT=5;
       GU=8;
        e(k)=r(k)-X1(k-1);
        e_dot(k)=(e(k)-e(k-1));
        E(k)=e(k)*GE;
        E_DOT(k)=e_dot(k)*GE_DOT;
        u(k)=evalfis([E(k) E_DOT(k)],sys);
        U(k)=u(k)*GU;
        f1=h*f(X1(k-1),X2(k-1));
```

```
 g1=h*g(U(k),X1(k-1),X2(k-1));

% z1=h*z(X3(k-1),X4(k-1));

% r1=h*r(u(k),X3(k-1),X4(k-1));


 f2=h*f((X1(k-1)+f1/2),(X2(k-1)+g1/2));

 g2=h*g(U(k),(X1(k-1)+f1/2),(X2(k-1)+g1/2));

 %z2=h*z((X3(k-1)+z1/2),(X4(k-1)+r1/2));

 %r2=h*r(u(k),(X3(k-1)+z1/2),(X4(k-1)+r1/2));



f3=h*f((X1(k-1)+f2/2),(X2(k-1)+g2/2));

g3=h*g(U(k),(X1(k-1)+f2/2),(X2(k-1)+g2/2));

% z3=h*z((X3(k-1)+z2/2),(X4(k-1)+r2/2));

% r3=h*r(u(k),(X3(k-1)+z2/2),(X4(k-1)+r2/2));


 f4=h*f((X1(k-1)+f3),(X2(k-1)+g3));

 g4=h*g(U(k),(X1(k-1)+f3),(X2(k-1)+g3));

%z4=h*z((X3(k-1)+z3),(X4(k-1)+r3));

 %r4=h*r(u(k),(X3(k-1)+z3),(X4(k-1)+r3));


 X1(k)=(X1(k-1))+((f1+f4)+2*(f2+f3))/6;


 X2(k)=(X2(k-1))+((g1+g4)+2*(g2+g3))/6;

 %X3(k)=(X1(k-1))+((z1+z4)+2*(z2+z3))/6;


 %X4(k)=(X2(k-1))+((r1+r4)+2*(r2+r3))/6;
```

```
   end




end

      plot(t,X1)
```

PROGRAMME CODE:

```
a = newfis('Air_Heater');
a.input(1).name = 'room_temp';
a.input(1).range = [0 30];
a.input(1).mf(1).name = 'very_cold';
a.input(1).mf(1).type = 'trimf';
a.input(1).mf(1).params = [0 0 7.5];
a.input(1).mf(2).name = 'cold';
a.input(1).mf(2).type = 'trimf';
a.input(1).mf(2).params = [0 7.5 15];
a.input(1).mf(3).name = 'warm';
a.input(1).mf(3).type = 'trimf';
a.input(1).mf(3).params = [15 22.5 30];
a.input(1).mf(4).name = 'very_warm';
a.input(1).mf(4).type = 'trimf';
a.input(1).mf(4).params = [22.5 30 30];
a.input(1).mf(5).name = 'mild';
a.input(1).mf(5).type = 'trimf';
a.input(1).mf(5).params = [7.5 15 22.5];
a.input(2).name = 'humidity';
a.input(2).range = [0 30];
a.input(2).mf(1).name = 'dry';
a.input(2).mf(1).type = 'trapmf';
a.input(2).mf(1).params = [0 0 6 10];
a.input(2).mf(2).name = 'optimal';
a.input(2).mf(2).type = 'trimf';
a.input(2).mf(2).params = [8 12 16];
a.input(2).mf(3).name = 'humid';
a.input(2).mf(3).type = 'trapmf';
a.input(2).mf(3).params = [14 18 30 30];
a.input(3).name = 'user_input';
a.input(3).range = [0 30];
a.input(3).mf(1).name = 'low';
a.input(3).mf(1).type = 'trapmf';
a.input(3).mf(1).params = [0 0 16 20];
a.input(3).mf(2).name = 'medium';
a.input(3).mf(2).type = 'trimf';
a.input(3).mf(2).params = [16 20 24];
a.input(3).mf(3).name = 'high';
a.input(3).mf(3).type = 'trapmf';
a.input(3).mf(3).params = [20 24 30 30];
a.input(4).name = 'energy_saving';
a.input(4).range = [0 1];
a.input(4).mf(1).name = 'on';
a.input(4).mf(1).type = 'trimf';
a.input(4).mf(1).params = [0 1 1];
```

```
a.input(4).mf(2).name = 'off';
a.input(4).mf(2).type = 'trimf';
a.input(4).mf(2).params = [0 0 1];
a.output(1).name = 'heat_setting';
a.output(1).range = [-15 15];
a.output(1).mf(1).name = 'heat'
a.output(1).mf(1).type = 'trimf';
a.output(1).mf(1).params = [-27.32 -15 -9];
a.output(1).mf(2).name = 'off';
a.output(1).mf(2).type = 'trimf';
a.output(1).mf(2).params = [-6 0 6];
a.output(1).mf(3).name = 'cool';
a.output(1).mf(3).type = 'trimf';
a.output(1).mf(3).params = [9 13 27];
a.output(1).mf(4).name = 'heat_slightly';
a.output(1).mf(4).type = 'trimf';
a.output(1).mf(4).params = [-15 -9 0];
a.output(1).mf(5).name = 'cool_slightly';
a.output(1).mf(5).type = 'trimf';
a.output(1).mf(5).params = [0 9 15];
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a.rule(1).consequent = [1];
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a.rule(1).connection = 4;
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a.rule(7).consequent = [1];
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a.rule(7).connection = 4;
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a.rule(11).weight = 1;
a.rule(11).connection = 4;
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a.rule(14).consequent = [2];
a.rule(14).weight = 1;
a.rule(14).connection = 4;
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a.rule(15).consequent = [3];
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a.rule(18).consequent = [3];
a.rule(18).weight = 1;
a.rule(18).connection = 4;
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```

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a.rule(35).connection = 3;
a.rule(36).antecedent = [4 3];
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```

```
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a.rule(45).connection = 4;
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a.rule(57).connection = 1;
a.rule(58).antecedent = [2 2];
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a.rule(58).weight = 2;
a.rule(58).connection = 2;
a.rule(59).antecedent = [2 2];
a.rule(59).consequent = [2];
a.rule(59).weight = 2;
a.rule(59).connection = 4;
```

```
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a.rule(61).connection = 2;
a.rule(62).antecedent = [2 3];
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a.rule(62).connection = 4;
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a.rule(71).antecedent = [3 3];
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a.rule(72).antecedent = [3 3];
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a.rule(75).antecedent = [4 1];
a.rule(75).consequent = [3];
a.rule(75).weight = 2;
a.rule(75).connection = 2;
```

```
a.rule(76).antecedent = [4 2];
a.rule(76).consequent = [1];
a.rule(76).weight = 2;
a.rule(76).connection = 3;
a.rule(77).antecedent = [4 2];
a.rule(77).consequent = [2];
a.rule(77).weight = 2;
a.rule(77).connection = 3;
a.rule(78).antecedent = [4 2];
a.rule(78).consequent = [3];
a.rule(78).weight = 2;
a.rule(78).connection = 2;
a.rule(79).antecedent = [4 3];
a.rule(79).consequent = [1];
a.rule(79).weight = 2;
a.rule(79).connection = 3;
a.rule(80).antecedent = [4 3];
a.rule(80).consequent = [2];
a.rule(80).weight = 2;
a.rule(80).connection = 3;
a.rule(81).antecedent = [4 3];
a.rule(81).consequent = [3];
a.rule(81).weight = 2;
a.rule(81).connection = 5;
a.rule(82).antecedent = [5 1];
a.rule(82).consequent = [1];
a.rule(82).weight = 2;
a.rule(82).connection = 2;
a.rule(83).antecedent = [5 1];
a.rule(83).consequent = [2];
a.rule(83).weight = 2;
a.rule(83).connection = 2;
a.rule(84).antecedent = [5 1];
a.rule(84).consequent = [3];
a.rule(84).weight = 2;
a.rule(84).connection = 4;
a.rule(85).antecedent = [5 2];
a.rule(85).consequent = [1];
a.rule(85).weight = 2;
a.rule(85).connection = 2;
a.rule(86).antecedent = [5 2];
a.rule(86).consequent = [2];
a.rule(86).weight = 2;
a.rule(86).connection = 2;
a.rule(87).antecedent = [5 2];
a.rule(87).consequent = [3];
a.rule(87).weight = 2;
a.rule(87).connection = 4;
a.rule(88).antecedent = [5 3];
a.rule(88).consequent = [1];
a.rule(88).weight = 2;
a.rule(88).connection = 5;
a.rule(89).antecedent = [5 3];
a.rule(89).consequent = [2];
a.rule(89).weight = 2;
a.rule(89).connection = 2;
a.rule(90).antecedent = [5 3];
a.rule(90).consequent = [3];
a.rule(90).weight = 2;
a.rule(90).connection = 4;
```

# RESULT AND DISCUSSION

After doing the programme in MATLAB script file we can get all about the air heater system. We also can get the FIS structure of input and output of the air heater system and the MF of each input and output. We can also generate the surface of the system and also get the plot of the input and output. All this thing can be done by particular some rule that have to give in the programming code.

We have given those plots and surface of the system in the following below:

After getting run of the programming code we should get:

```
name: 'Air_Heater'
type: 'mamdani'
andMethod: 'min'
orMethod: 'max'
defuzzMethod: 'centroid'
impMethod: 'min'
aggMethod: 'max'
input: [1x4 struct]
output: [1x1 struct]
rule: [90]
```

When we type the following code in the command window we get the following answer:

i) **a.type**

ans =

mamdani

**ii) getfis(a)**

Name = Matlab

Type = mamdani

NumInputs = 4

InLabels =

room_temp

humidity

user_input

energy_saving

NumOutputs = 1

OutLabels =

heat_setting

NumRules = 90

AndMethod = min

OrMethod = max

ImpMethod = min

AggMethod = max

DefuzzMethod = centroid

ans =

Matlab

**iii) getfis(a,'Inlabels')**

ans =

room_temp

humidity

user_input

energy_saving

**iv) getfis(a,'input',1)**

Name = room_temp

NumMFs = 5

MFLabels =

very_cold

cold

warm

very_warm

mild

Range = [0 30]

ans =

Name: 'room_temp'

NumMFs: 5

mf1: 'very_cold'

mf2: 'cold'

mf3: 'warm'

mf4: 'very_warm'

mf5: 'mild'

range: [0 30]

**v) getfis(a,'output',1)**

Name = heat_setting

NumMFs = 5

MFLabels =

heat

off

cool

heat_slightly

cool_slightly

Range = [-15 15]

ans =

Name: 'heat_setting'

NumMFs: 5

mf1: 'heat'

mf2: 'off'

mf3: 'cool'

mf4: 'heat_slightly'

mf5: 'cool_slightly'

range: [-15 15]

vi) **getfis(a,'input',1,'mf',1)**

Name = very_cold

Type = trimf

Params = [0 0 7.5]

ans =

Name: 'very_cold'

Type: 'trimf'

params: [0 0 7.5000]

**vii) a.input**

ans =

1x4 struct array with fields:

name

range

mf

**viii) a=setfis(a,'name','gravity')**

a =

name: 'gravity'

type: 'mamdani'

andMethod: 'min'

orMethod: 'max'

defuzzMethod: 'centroid'

impMethod: 'min'

aggMethod: 'max'

input: [1x4 struct]

output: [1x1 struct]

rule: [1x90 struct]

**ix) showfis(a)**

1. Name gravity
2. Type mamdani
3. Inputs/Outputs [4 1]
4. NumInputMFs [5 3 3 2]
5. NumOutputMFs 5
6. NumRules 90
7. AndMethod min
8. OrMethod max
9. ImpMethod min
10. AggMethod max
11. DefuzzMethod centroid
12. InLabels room_temp
13. humidity
14. user_input
15. energy_saving
16. OutLabels heat_setting
17. InRange [0 30]
18. [0 30]
19. [0 30]

20. [0 1]

21. OutRange [-15 15]

22. InMFLabels very_cold

23. cold

24. warm

25. very_warm

26. mild

27. dry

28. optimal

29. humid

30. low

31. medium

32. high

33. on

34. off

35. OutMFLabels heat

36. off

37. cool

38. heat_slightly

39. cool_slightly

40. InMFTypes trimf

41. trimf

42. trimf

43. trimf

44. trimf

45. trapmf

46. trimf

47. trapmf

48. trapmf

49. trimf

50. trapmf

51. trimf

52. trimf

53. OutMFTypes trimf

54. trimf

55. trimf

56. trimf

57. trimf

58. InMFParams [0 0 7.5 0]

59. [0 7.5 15 0]

60. [15 22.5 30 0]

61. [22.5 30 30 0]

62. [7.5 15 22.5 0]

63. [0 0 6 10]

64. [8 12 16 0]

65. [14 18 30 30]

66. [0 0 16 20]

67. [16 20 24 0]

68. [20 24 30 30]

69. [0 1 1 0]

70. [0 0 1 0]

71. OutMFParams [-27.32 -15 -9 0]

72. [-6 0 6 0]

73. [9 13 27 0]

74. [-15 -9 0 0]

75. [0 9 15 0]

**x) plotmf(a,'input',1)**

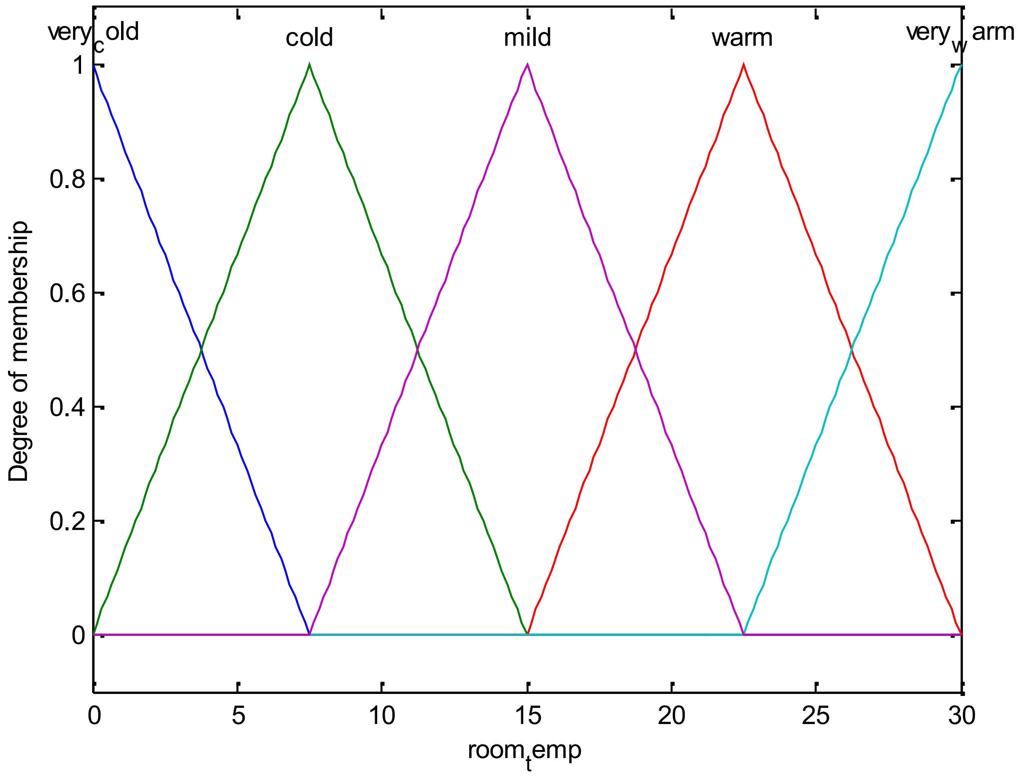


Fig.14: Membership Function of the Inputs

**xi) plotmf(a,’input’,1)**

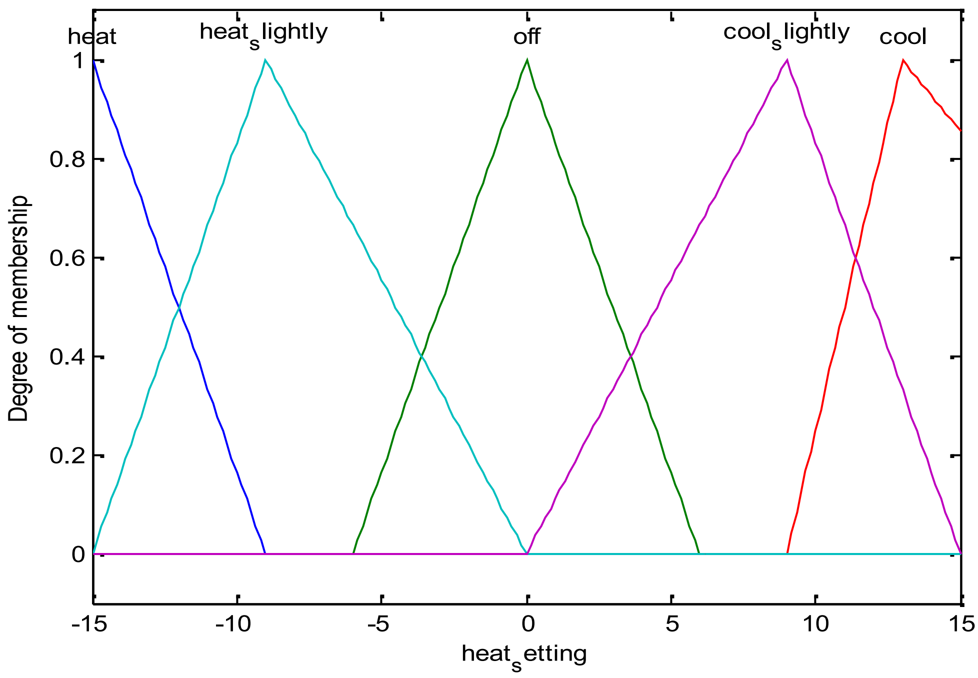


Fig.15:-Membership Function of Outputs

**xii) gensurf(a)**

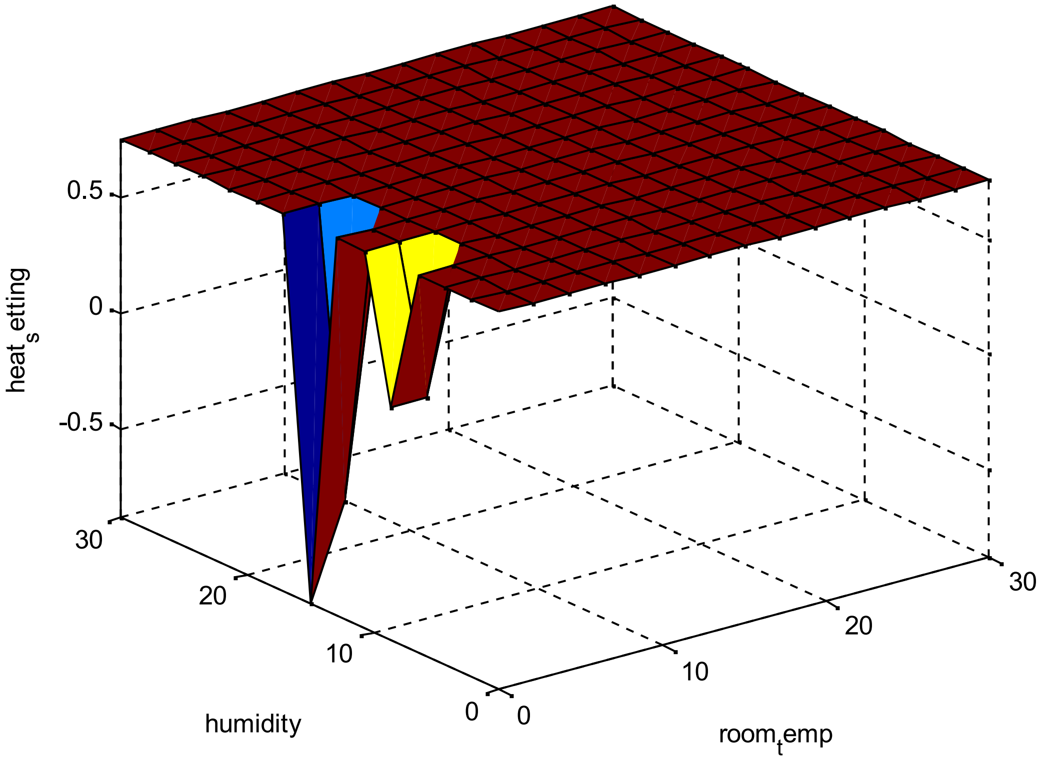


Fig.16: surface of the Air Heater System

# CONCLUSION

In this project we have studied about different method for temperature control of Air heater controller. The steady state operation and its various characteristics of Air heater controller are studied. We have also studied basic definition and terminology of fuzzy logic and fuzzy set. This project introduces a design method of two inputs and three outputs self-tuning fuzzy PID controller and make use of MATLAB fuzzy toolbox to design fuzzy controller. The fuzzy controller adjusted the proportional, integral and derivate (KP, KI, KD) gains of the PID controller according to speed error and change in error .From the simulation results it is concluded that ,compared with the conventional PID controller, self-tuning PID controller has a better performance in both transient and steady state response. The self tuning FLC has better dynamic response curve, shorter response time, small overshoot, small steady state error (SSE),high steady precision compared to the conventional PID controller. It has also some future scope. MATLAB simulation for speed control of separately excited DC motor has been done which can be implemented in hardware to observe actual feasibility of the approach applied in this thesis. This technique can be extended to other types of motors. The parameters of PID controller can also be tuned by using genetic algorithm (GA).

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