Improving Performance of the Greenhouse by Using Fuzzy Logic Controller (In case Ethiopian greenhouse System)

Betelhem Alemu Wachamo

A Thesis Submitted to

Department of Electrical Power and Control

Engineering School of Electrical Engineering and Computing

Presented in Partial Fulfillment of the Requirement for the Master of Science Degree in Electrical Power and Control Engineering (Control Engineering)

Office of Graduate Studies

Adama Science and Technology University

October, 2023

Adama, Ethiopia

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DECLARATION

I hereby declare that this thesis masters entitled "**Improving performance of the greenhouse by using fuzzy logic Controller (In case Ethiopian greenhouse system)**" is my own work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Betelhem Alemu ____________________ ____________________

Name of student Signature Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled "**Improving performance of the greenhouse by using fuzzy logic Controller (In case of Ethiopian greenhouse system)**" prepared under my guidance by **Betelhem Alemu** submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Electrical Power and Control Engineering, postgraduate in Control Engineering.

Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Assistant Professor Endalew Ayenew (Ph.D.)	________________	__________
Advisor	Signature	Date

APPROVAL PAGE

I the advisors of the thesis entitled **"Improving performance of the greenhouse by using fuzzy logic Controller (In case of Ethiopian greenhouse system)"** and developed by Betelhem Alemu, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Assistant Professor Endalew Ayenew (Ph.D.)	____________________	__________
Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Betelhem Alemu have read and evaluated the thesis entitled "**Improving performance of the greenhouse by using fuzzy logic (in Ethiopian greenhouse system)**" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in control engineering.

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Dr Beteley Teka		October 22, 2023
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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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Office of Postgraduate Studies, Dean	Signature	Date

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ABSTRACT

Greenhouse are populare in agriculture for several reasons: extended growing seosons, protecting from exterm weather, pest and disease control, improved crop quality, water conservation and higher crop yields, Overall, greenhouse choice for a around the world. In a specilized plant factory operating in challenging environments the key parameters that require control are temperature and humidity. Controlers like adaptive and proportional integral derivative (PID) have been developed and tested in real-world settings. Eventhough they did not consider constraints and parameter interactions, they showed outcomes of effectiveness of the control system. However, it is currently impractical to apply the same approach for regulating the parameters. The primary goal of this study is to show the advancement in greenhouse performance achieved by implementing an intelligent control system based on fuzzy logic controllers. By integrating error-based analysis and considering transient response criteria, the proposed system significantly enhances the overall efficiency of Ethiopian greenhouse production. The designed controller aims to reduce modeling error while also reducing settling error and overshoot. The controllers were developed and simulated using MATLAB/Simulink to evaluate the efficacy of the suggested control approaches. By using trial-error method the response shows the result have been compared with the PID controller. Under varied psychrometric circumstances throughout the summer, the set point tracking and disturbance rejection performance tests were run. Utilizing criteria like overshoot, settling time, recovery time, and perturbance peak values, the performance of the controllers is evaluated. The tracking test focuses on analyzing the indoor temperature result to carry out the parameters. which the plant using the temperature as set-point 26°C and 20% of the interior air humidity, so the performance measure result for temperature rise time 2.080 min, settiling time 2.861min,overshoot 1.073min and IAE 6.666, and for humidity rise time 2.498 settiling time 3.598 min,overshoot 0.592 min and IAE 8.014. Overall, the performance metrics obtained from both performance tests consistently demonstrated that the FLC controller for indoor temperature and humidity out performs the PID controller in the designed system.

Key-words: *Greenhouses, Fuzzy logic inference system, humidity and temperature.*

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LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
CSMC	Conventional Slide Mode Control
DIS	Disturbance
EHDA	Ethiopian Horticulture Development Agency
FL	Fuzzy Logic
FLC	Fuzzy Logic Controller
FRBSs	Fuzzy Rule-Based Systems
GH	Green House
IAE	Integral Absolute Error
IMC	Internal Model Control
KB	Knowledge Base
LDPE	Low-Density Polyethylene
MBPC	Model Based Predictive Control
MIMO	Mult Input Mult Output
PI	Proportional Integral
PID	Proportional Integral Derivative
SP	Set Point
USD	United States Dollar

LIST OF SYSTEM MODEL SYMBOL

A	Area of Surface
C_O	Greenhouse thermal capacity
C_p	The air specific heat
W_I	Indoor humidity ratio
W_o	Outdoor humidity ratio
Sa	Solar radiation
H_c	Heat loss through conducted the wall
H_e	Due to water evaporation the heat loss
H_{fog}	Deu to fog the heat loss
H_h	By the floor heating the heat emanated
H_s	Entering solar energy in the greenhouse
H_v	Deu to ventilation the heat loss
h%fog	The maximum capacity percentage of the fog
P	Interceped solar radiant energy
T_I	Inside air temperature
T_O	Outside air temperature
t	Time
T_v	Air changes of number in per unit time
V_G	The humidity volume of actively mixing air
V_R	Rate of ventillation

V_T	Active mixing volume of temperature
U	Enclosure heat tarncfer cofficient
$W_{air,I}$	Tranfer rate of moisture from the inside leaving GH
$W_{air,O}$	Tranfer rate of moisture from the outside air enteringthe
M_e	Due to evaporation water from the floor rate of moisture
W_{fog}	The fog system of water capacity
α	The shading and leaf index of aver all cofficient

CHAPTER ONE

INTRODUCTION

1.1. Background

The role that agriculture plays in a nation's economy and in providing food security and stability is crucial. It must adhere to an increasing number of environmental and quality laws. To overcome these obstacles, the agro-alimentary industry may use innovative technologies (del Sagrado et al., 2016). Globally, sustainable food and energy supply is a major challenge (Dagdougui et al., 2018). The world's ability to feed itself may be improved by greenhouse farming, a method of intensive and sustainable food production (Yano and Cossu, 2019). The challenges to the transition to precision and sustainable agriculture may be overcome by encouraging the heavy use of greenhouses in agriculture. According to Bersani et al. (2020), a sustainable smart strategy might promote the preservation of energy and water resources, the reduction of environmental impacts, the improvement of quality of life, the creation of local socio-economic and environmental advantages, and the reduction of the effects of climate change. The primary goal of a greenhouse is to provide the best conditions possible for crop cultivation (Chen et al., 2019). In order to raise agricultural yields and enhance production quality, greenhouses offer the right conditions for plant growth (Cuce et al., 2016).

The greenhouse offers a regulated climate that promotes greater plant growth and food production, as is widely known. Globally, there are thought to be 3.64 million hectares of greenhouses, according to the most recent statistics (Lewis et al., 2017). However, in the majority of nations, greenhouses account for the majority of the energy used in agriculture. However, according to Koppenborg and Hanssen (2021), emissions from agricultural production now make up 14% of all global greenhouse gas emissions and have increased since 2000. With the expansion of greenhouse areas, the challenge of greenhouse energy consumption and cleaner production will dramatically increase in the coming years.

In Ethiopia, a variety of vegetable crops are grown using irrigation and/or rain-fed systems (Emana et al., 2015). Hot and sweet peppers, Ethiopian Mustard/kale, onion (Allium cepa), (chili C/chinense), carrot, garlic (A.Sativum), cabbage, and flowers are among the most economically significant vegetables. Ethiopian Investment Agency (2013) reports that in 2013, the country made $438 million in revenue and exported 220,213 tons of vegetables.

Since its founding in 1980, Ethiopian Horticulture Development Agency (EDHA) has been engaged in horticulture crop production and marketing activities (Temesgen et al., 2014).

The growth of state farms and private investment in the industry by domestic and foreign businesspeople have both contributed to an increase in the commercial production of horticulture products, especially vegetables, in recent years. For optimal growing circumstances over various seasons, the majority of vegetables have their specific temperature and humidity range.

- Hot semi-arid regions are where hot season vegetables like tomato, hot pepper, and snap beans are grown.
- Vegetables that grow well in cooler climates include Ethiopian mustard, cabbage, potatoes, garlic, onions, shallots, carrots, and beets (Emana et al., 2015).

The role of vegetables in human nutrition and health, particularly their ability to provide antioxidants like vitamins A, C, and E that are critical in scavenging free radicals (oxidants) known to cause cancer, cataracts, heart disease, hypertension, stroke, and diabetes, has received more attention in recent years from public health advocacy in Ethiopia. It has something to do with the increased cost of livestock goods like milk, meat, and eggs. Increased vegetable consumption therefore contributes to the battle against undernutrition and concealed hunger. Vegetables and fruits are also used as raw materials by the local processing industries.

The state's goal of raising household income and improving nutrition is somewhat supported by improved horticulture products, which also encouraged private investment. However, there is a dearth of knowledge about modern production methods and marketing in Ethiopia, particularly in the humid tropics that were the target region.The fundamental understanding of the production system, marketing channels, and growth potential will contribute significantly to the increasing population and decreasing land area (Ito, 2012).

The most prevalent international diseases and pests affect Ethiopian horticulture crops. However, in order to control illnesses and insect pests, the country has primarily relied on cultural control measures as well as the usage of resistant crop varieties. In light of the current food crop shortfall caused by harsh weather conditions and high population pressure, the urge to develop new commodities and technologies to raise population and productivity in both high and low-potential areas is persistent (Fikir, 2019).

It has only just started to gather traction for Ethiopia to diversify its exports into non-traditional horticultural products such as cut flowers, ornamentals, fruits, roses, and vegetables. Many foreign investors are drawn to this sector, which is predominantly based in the Oromia area and produces a variety of products relating to flowers. These enterprises, which include Maranque Plants, Desa Plants, Ethiopian cutting, Floresis Ethiopia, Floresis

Abyssinia, Joy Tech Fresh, and Red Fox, use modern regulating mechanisms like as Scada and other distribution controls. Other for-profit firms, such as ZK Flower PLC, use natural resources to control the temperature and humidity within their structures. However, these traits alone are insufficient to stabilize the system and provide a higher-quality output.

Figure: 1.1. Greenhouse model (Kumar and Byregowda, 2017).

1.1.1. System description

The inputs (heating, cooling, ventilation, fog supply, light intensity, and CO2 injection) and outputs (air temperature, air humidity, CO2 concentration, PAR radiation, and soil humidity/nutrient) of a greenhouse climate management system typically contain these elements. (Outdoor air temperature, output air humidity, CO2 concentration, wind speed and direction, and sun radiation) are some of the system disturbances. The schematic representation of a greenhouse climate control system is shown in Figure 1.2.

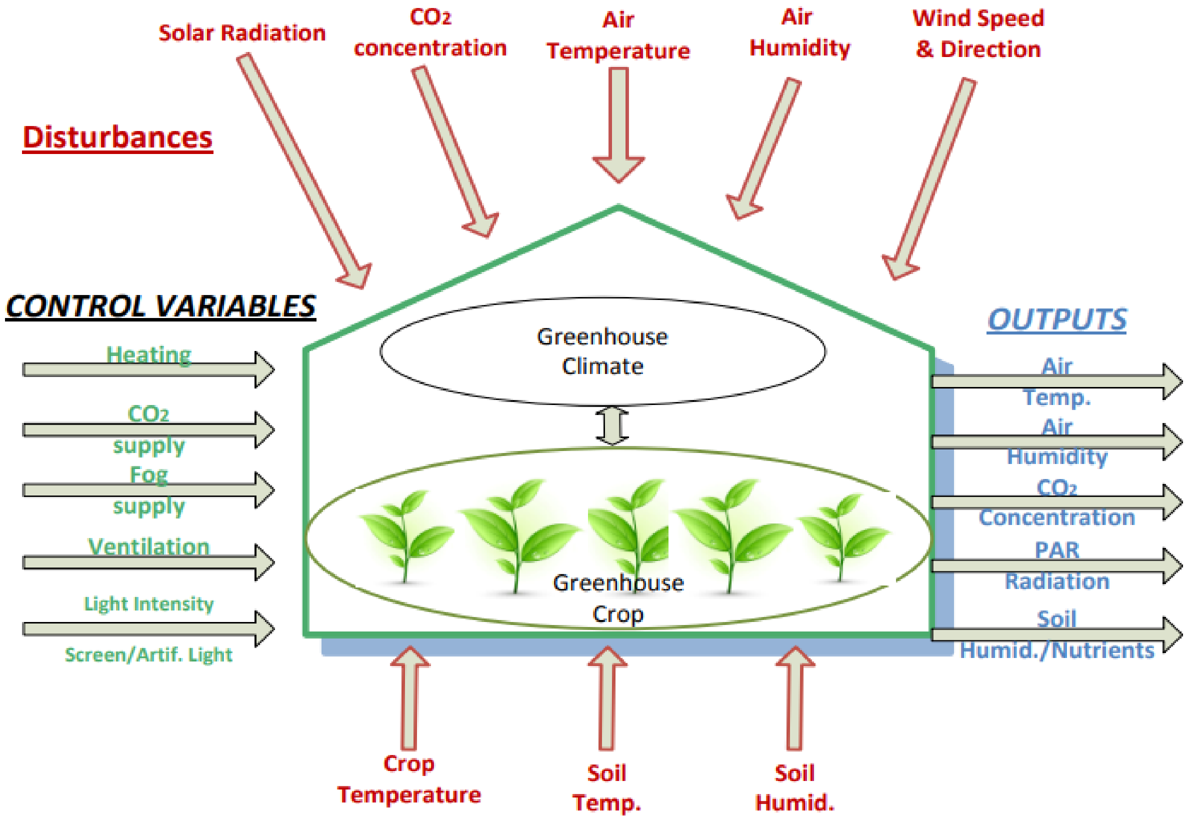


Figure: 1.2.Greenhouse climate control system schematic (Gurban, 2014).

1.2. Statement of the Problem

1.2.1. why the quality of production is low in ethiopian greenhouse?

Currently there are many greenhouse plants in diffrenet parts of Ethiopia. Most of them are found in Oromia region around Mojo, Bishofitu, Ziway and other areas. Eventhough, most of them are engagged on production of flowers, some are still producing different relish and seedling as their private investiments.

Many greenhouses are using different indoor environment controlling mechanisms which are manual and traditional controlling ways for cooling, heating, humidification and dehumidification; which are the main causes of lower production and non competitive quality.

The effectiveness and efficiency of a greenhouse as a whole in growing crops is measured by its performance. This performance can be affected by many factors. Some of them are Pests and diseases, Environmental factors, and management practices. This study mainly focuses on environmental factors mainly temperature and humidity as a factor in improving Performance of the Greenhouse by using fuzzy logic controller.

Even though, flower is ranked as the second level of countries' export items; it is one of the well-known main economic drivers. Among the major reasons seasonal variations of weather condition and its quality defect compared to other countries flower products. Ethiopia's weather has been shifting dramatically recently, which is unfavorable for local horticultural productions. Nowadays, greenhouse facilities are becoming more widespread all over the world. Controlling the internal environment is still a common challenge. This environment is influenced by a wide range of factors, including temperature, humidity, light intensity, and carbon dioxide content. According to Ethiopia's horticulture development, most of the gardens are irrigation based with season-based natural rain. The internal environment of the greenhouse is essentially better for higher-quality plant growth.

Most of the Ethiopian greenhouses are using traditional way of internal climate controlling system. Both Temperature and humidity are controlled by traditional way. To control inside temperature of the greenhouse by using of two models cooling and heating, for cooling model they simply use open the tent and wall of the greenhouse, for heating not use any other mechanism just it by nature. This exposes the flower to external air, pest and diseases. Humidity is tried to be controlled by using drip irrigation for humidification system, but that does not determine the exact moisture of the soil it's also the problem for dehumidification system. Due to these and other drawbacks, there is a significant declining in production and quality. Generally, there is no scientific measurement to control both temperature and humidity level of the indoor environment of the greenhouse in most Ethiopian GH.

The dynamic model of the greenhouse is particularly non-linear, and complexity behavior cooling and humidification of the air in the greenhouse is difficult, by applying the cooling and fogging system for regulating the excess temperature and less humidity respectively. The cooling and humidification mechanism is very important for increasing production quality of greenhouse. Since the cooling system employs less sophisticated technology. By use of an artificial intelligence concept, fuzzy logic control based system is used to improve greenhouse performance. Among other things, the system does not require an exact mathematical model and it works for nonlinear systems without changing of system state.

1.1. Objective

1.2.2. General Objective

Improving performance of the greenhouse by using fuzzy logic control system in case of Ethiopian greenhouses.

1.2.3. Specific Objective

- Assessing the stracture and characteristics of Etiopian Greenhouse system.
- Modeling and studying greenhouse system characteristics.
- Introducing the fuzzy logic control system to greenhouses using MATLAB/SIMULINK.
- Desgining the greenhouse system by fuzzy logic control system on MATLAB/SIMULINK.
- Test and evaluate the performance of the GH system control by fuzzy logic control system and PID controller.
- Comparison of the proposed method with previous work.

1.2. Significance of the Study

The dynamic model is highly non-linear, interactive (coupled), and complex because of the fluctuating weather conditions in greenhouses, making it difficult to regulate with conventional (classical) controllers. This work contributes by using an artificial intelligent to model and control the greenhouse climate for Ethiopian greenhouses, together with the parameters of air temperature and humidity characteristics. More effective regulating controller is fuzzy logic controller to address this problem.

1.3.Scope of theThesis

The analysis, modeling, and simulation design of greenhouse environmental systems are the main topics of this thesis. The proposed controller was implemented using a fuzzy logic controller to achieve the desired outcome. In terms of air temperature and humidity in the indoor greenhouse, then performance of the suggested plant is evaluated.

1.4.Motivation for the Study

The majority of the world's countries now have greenhouse industries where various plants, including vegetables, fruits, grains, ornamental plants and flowers can be grown in different weather conditions throughout the world. In our country, most greenhouses company works with manual methods so that is the cause for the quality reduction in different condition. With the use of cutting-edge control methods, greenhouse operators can improve quality control and boost plant development in regulated environments.

1.5.Limitations of the Study

Making the prototype was to hard because of my limited time, the complexity of the system, and the high cost of the materials needed for the research. The focus of this thesis project is thus restricted to simulation utilizing the MATLAB/Simulink program. Therefore, this job is only applicable to activities during the summer days. Although the greenhouse has several environmental controls, this study just uses the internal air temperature and humidity. The greenhouse microclimate may be affected by a variety of external disturbances. Proposed method only considers the three instabilites of intercepted solar radiation energy, outside temperatureso and external humidity. The various set point circumstances of the cutting flower are also used to execute the set point tracking test. Consequently, since each plant has varied needs for temperature and humidity, the thesis is only relevant for cutting flowers.

1.6.Structure of the Thesis is Organized as Follows

Chapter Two: presents review literatures, related works on background of greenhouses also classification of greenhouses based on the different methods and cooling system.

Chapter Three: presents the materials used for this thesis, the methodology follows for the work and develops of the mathematical model of the system.

Chapter Four: describes in detail the explanation of the proposed fuzzy logic controller also the design, construction and use of the PID controller for comparison.

Chapter Five: describes the Results, Discussions, and Implementation of the greenhouse model on Matlab/Simulink and its effects on the controlled parameters.

Chapter Six: presents the Conclusion, recommendation,on the greenhouse controlling system.

CHAPTER TWO

LITERATURE REVIEW

2.1. Greenhouse Overview and Literature Review

Essentially, there are five primary sections covered in this chapter. A comprehensive review of greenhouse systems is presented in the first part. The main classifications of greenhouses based on structure, glazing, and environmental management are presented in the second half of this article. Components that determine greenhouse performance are explained in detail in the third section. Part of the fourth section goes into great length on the psychrometric chart and how to read it. The final portion The final section presents a review of works that are closely related, notably those dealing with greenhouse interior climate regulation and various control systems, as well as their benefits and drawbacks.

Greenhouse technology offers a means to cultivate crops throughout the year within a controlled and favorable environment. By protecting crops from harsh winter conditions, scorching summer heat, and heavy monsoon rains, this technology enables year-round cultivation. While it is commonly used in tropical regions to regulate temperature and provide cooling, it can be beneficial in various climatic zones. Plant cultivation is a combination of art and science, and historically, most crops have been grown in open fields. However, humans have developed techniques to cultivate crops in unfavorable climates and locations. Greenhouse technology is critical in enhancing crop value by providing a suitable environment and protecting plant life from harmful weather climatic factors such as wind, cold, extreme radiation, intense heat, mosquitoes, and diseases. Greenhouses are commonly built or inflated buildings covered in transparent or translucent materials.These buildings are designed to be spacious enough to accommodate crops and facilitate their optimal growth and productivity. In summary, greenhouse technology offers a controlled environment that shields crops from adverse weather conditions, resulting in enhanced crop development and productivity. It is a vital tool in modern agriculture, enabling year-round cultivation and protection from various environmental challenges.

With the help of greenhouse technology, crops may grow year-round in a controlled and suitable environment. Crops are protected from winter cold, summer heat, and monsoon rain using this technology. Unlike in Europe, where the average temperature is high, technology is primarily used to cool the environment in tropical areas (Pandey et al., 2015). Both art and science go into growing plants. Most plants, whether used for food or commercial crops, are produced in open fields about 95% of them. Man has known since the beginning of time how to grow plants in their natural habitat. Man has developed techniques for producing some high in temperate areas where the climate is extremely unfavorable and no crops can be grown. Crop value is consistently increased by using greenhouse technology, which protects crops from extreme coldIn order to give plants a good habitat, greenhouse technology is used. Instead, it serves to safeguard plants from hazardous environmental conditions like wind, cold, precipitation, intense radiation, extreme heat, insects, and diseases. Moreover, it is crucial (Pandey et al., 2015). For the optimal crop development and productivity, greenhouses must be sufficiently sized, framed, or inflated structures wrapped with clear or translucent material. The cultivation of crops in a greenhouse system is typically influenced by the prevailing climate conditions. Fruits and vegetables have specific seasons during which they naturally thrive. The main purposes of a greenhouse are the cultivation of ornamental plants and food crops. A greenhouse is a building with a roof and side walls made of glass or plastic. It can be utilized either on a seasonal basis or throughout the year. The greenhouse itself is covered with transparent materials, allowing sunlight to penetrate.

Thanks to greenhouse technology, farmers now have the capability to cultivate a wide range of fruits, ornamental plants, and vegetables regardless of the season. This technological advancement has revolutionized crop production, enabling the availability of various vegetables throughout the year. It is possible to mimic the ideal growing conditions by regulating elements like temperature, humidity, and light within the greenhouse. This ensures that crops can be grown and harvested consistently, regardless of the external climate.

In summary, greenhouse technology has transformed crop cultivation by providing a means to grow fruits, ornamental plants, and vegetables in any season. By harnessing the power of controlled environments, farmers can now cultivate a diverse range of crops and ensure a consistent supply throughout the year.

Crop cultivation in greenhouses is typically heavily influenced by the local climate in normal condition. Every fruit and vegetable can be grown during a specific season. A greenhouse that building with a glass or plastic roof, side walls, and other features that can be used to grow ornamentals and food crops seasonally or year-round. It is a building covered with a transparent shell. Farmers can grow almost any fruit, flowering plant, or vegetable year-round because to greenhouse technology. Now that this method has been developed, all vegetables can be consumed year-round (Fikir, 2019).

1.3. Greenhouses Types

1.3.1. Based on cost investment greenhouse types

In order to meet demand in 2050, the global food production have to increase by 70%, claims FAQ 2020. To produce crops year-round, humans have developed technical methods. In this respect, the employment of greenhouse technology may be the only means of regulating the local temperature in order to increase crop productivity per unit area and crop production in terms of quantity and quality, both of which are impractical on open fields. Technology for greenhouses has gained a lot of appeal in this technical advancement over time. Progressive farmers are currently cultivating high-value vegetables and flowers under commercial protection(Maitra et al., 2021). Materials that are transparent or translucent, like glass or plastic, are used in one of two ways: in a fully controlled environment or in a partially controlled environment.

1.3.1.1. Greenhouses of low-technology

Farms with low levels of technology are used by a very tiny percentage of farmers. The low technology greenhouses are generally no taller than 3 meters. Since tunnel homes lack vertical walls, they have inadequate ventilation and are the most popular low-tech greenhouse style. Because there is little to no automation employed in this sort of structure, it is quite affordable. However, compared to open-field farming, this sort of structure offers fundamental advantages for crop production. Crop management can be difficult, and the growing environment continues to limit agricultural potential. Low-tech greenhouses frequently provide an unfavorable environment for growing, leading to lower yields and a negligible decrease when it comes to disease and pest occurrence. A more affordable way to enter the agricultural sector is, however, through low-tech greenhouses (Dalai et al., 2020).

1.3.1.2. Greenhouses of medium technology

Vertical walls are a defining characteristic of greenhouses with medium technology. The average height of the medium technology greenhouse is greater than 2 meters, less than 4 meters, and less than 5.5 meters altogether. The side walls or roofs of these greenhouses can be used to increase ventilation. Additionally, they provide medium-level greenhouses that are more effective at growing crops. Usually, single or double-skinned glass or plastic film is used. Hydroponic systems increase the water's effectiveness of use. The potential of greenhouse horticulture is Despite more potential to employ non-chemical pest and disease management strategies, realization is still challenging (Dalai et al., 2020).

1.3.1.3. Greenhouses of high level technology

High-level greenhouses can have roof peaks that are up to 8 meters above the ground, and their walls must be at least 4 meters tall. These structures provide superior agricultural output while being environmentally friendly. Both side wall vents and enough roof ventilation are present in this building. The cladding of high-level greenhouses is made of glass, polycarbonate sheeting, or plastic film (single or double-layer). The environment is managed automatically. Economic and environmental sustainability are strong possibilities for these buildings. Also less drastically reduced as the use of insecticides. In general, high-tech structures are stunning to see, and they are becoming more and more involved in global agribusiness potential. Although these greenhouses need a significant cash investment, they present a highly productive, environmentally friendly option for a developed fresh produce business. Decisions on investments should, whenever possible, Consider putting in high-tech greenhouses (Dalai et al., 2020).

1.3.2. Based on shape greenhouse type

When categorizing greenhouses, it is possible to take into account how unique their cross sections are. The most common greenhouse kinds, according to shape, are shown below.

- Greenhouse with a lean-to
- Greenhouse of the even –span type
- Greenhouse with uneven-spans
- Greenhouse Ridge and furrow type
- Greenhouse with Sawtooth
- Greenhouse of the Quonset

1.3.2.1. Greenhouse with a lean-to

Lean-to greenhouses are linked to a house or other structure, making it simpler to access services like electricity and water. One can also A lean-to greenhouse has the benefit of being close to your home, which mak es it easier to keep an eye on your plants. A lean-to greenhouse's restricted access to sunlight is a disadvantage.It typically faces south. Only single- or double-row plant benches with a total of 7 to 12 feet in width are permitted in lean-to greenhouses https://thehouseofgreen.weebly.com/greenhouse-types.html.

Figure: 2.1. Greenhouse with a lean-to.

1.3.2.2. Greenhouse of the even-span type

The even–span is the standard type and full-size structure The sides of the even span greenhouse are evenly pitched much like those of a home. The even span greenhouse has the benefit of being widespread and having even spacing.Even-span greenhouses have the drawback of having overlapping panes, which increases the likelihood of leakage. Lean-to greenhouses are less expensive, whereas even-span greenhouses have more design flexibility and plant space https://thehouseofgreen.weebly.com/greenhouse-types.html.

Figure: 2.2. Greenhouse of the even-span type.

1.3.2.3. Greenhouse with uneven-spans

This kind of greenhouse is built on a hilly site. Because it cannot be automated, this kind of greenhouse is no longer frequently utilized. The structure can be adapted to the side slopes of hills because the roofs are of different widths http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124111.

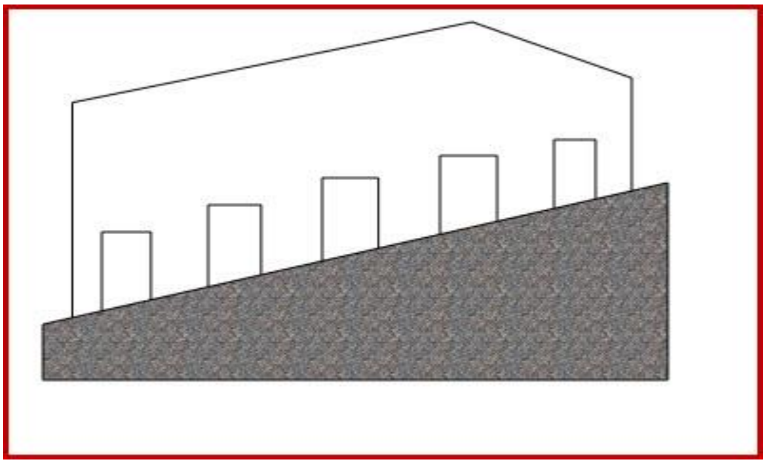


Figure: 2.3. Greenhouse with uneven-spans.

1.3.2.4. Greenhouse Ridge and furrow type

In such plans, the eaves' length is used to link two or more A-frame greenhouses. The eave functions as a gutter or furrow to catch snowmelt and rain. The side wall separating the greenhouses is taken down, exposing a building with a single, enormous interior. Interior space consolidation saves labor expenses, lowers the cost of automation, enhances personal management, and reduces fuel consumption because there is less exposed wall surface through which heat can escape. Snowfall must be taken into account when designing the frame specifications of these greenhouses since it cannot slide down the roofs as it would in a single greenhouse. Ridge and furrow greenhouses are still working despite substantial snowfall. These designs are carefully tailored to the situation because they use two or more connected A-frame greenhouses, which are successfully used in northern European and Canadian countries http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124111.

Figure: 2.4. Greenhouse Ridge and furrow type.

1.3.2.5. Greenhouse with Sawtooth

Similar to ridge and furrow greenhouses, but with one important difference it features a saw-tooth design for natural ventilation. The saw tooth vent can be closed to improve the growing room's climate management or opened to allow continuous circulation to lower the interior temperature. In addition to the side ventilation, the roof ventilation contributes for 25% of the overall ventilation of the covered area. The design of the arches allows for good light transmission (Dalai et al., 2020). This greenhouse form is similar to ridge and furrow kinds, but it features a saw-tooth shape for natural ventilation. The saw tooth vent can be closed to optimize growth room climate management or opened to allow continuous circulation and lower interior temperature. In addition to side ventilation, roof ventilation accounts for 25% of overall ventilation in the covered area. The shape of the arches allows for adequate light transmission (Dalai et al., 2020).

Figure: 2.5. Greenhouse with Sawtooth.

1.3.2.6. Greenhouse of the quonset

A Quonset greenhouse is a specific type of greenhouse based on its structure. The trusses in this style of greenhouse are maintained by pipe purling that extends the entire length of the greenhouse. Polyethylene is employed as the enclosure material in such a greenhouse. It is less expensive and desirable in a particular tiny, constrained region when compared to greenhouses connected to gutters. In these greenhouses, the two most common connection types are standing and interlocking. When houses are interlocked, it is necessary to grow vegetation between the overlapping truss members that connect the overlapping portions of the adjoining homes. For a group of dwellings in this type, there is a single, sizable cultural space. This approach is more suitable for automating and moving labor (Kidist, 2021).

Figure: 2.6. Greenhouse of the quonset.

1.3.3. Based on Utility the type of greenhouse

Depending on their uses and capabilities, greenhouses can be categorized. More expensive and complex artificial heating and cooling systems are used in greenhouses. Based on their usage of artificial cooling and heating, greenhouses are categorized as either active heating or active cooling systems (Dalai et al., 2020).

1.3.3.1. Greenhouses active heating system

The greenhouse's inside becomes cooler at night. There must be a certain level of heat present to shield plants from the cold bite brought on by freezing. The volume of heat lost to the environment dictates the volume of heat needed to heat the greenhouse. The use of double-layer polyethylene, thermo pane windows (two layers of factory-sealed glass with dead air space), thermo pane windows, or heating systems such unit heaters, central heating, radiant heat, and solar heating systems are all options for reducing heat losses (Dalai et al., 2020).

1.3.3.2. Greenhouses active cooling system

Greenhouse temperatures should be lower than surrounding air temperatures for efficient crop development throughout the summer. Thus, the greenhouse is correctly modified to allow for the introduction of significant amounts of cooled air. This greenhouse uses evaporative cooling or has a cooling pad with a fan. This greenhouse's design permits a 40%, and in certain cases, nearly 100%, roof openness (Dalai et al., 2020).

1.3.4. Greenhouse Type Based on Construction

Although the covering material also has an effect, the structural material largely determines the sort of structure. To develop tissues with a longer span, stronger materials and more structural components should be used. For short spans, simple patterns like hoops can be used. As a result, greenhouses can be classified as follows based on their construction.

- Structure of the Wooden framed
- Structure of the Pipe framed
- Structure of the Truss framed.

1.3.4.1. Structures of wooden framed

On the whole only wooden-framed buildings with spans less than 6 m are used for greenhouses. Side supports and columns are constructed from wood without the need of a truss. Considering that pine wood is both affordable and strong, it is frequently employed. For construction, it is also possible to use locally accessible wood that has good strength, durability, and machinability.

Figure: 2.7.Wooden framed greenhouses. https://sturdi-built.com/greenhouse-styles-sizes/greenhouse-kits-garden-sunroom/

1.3.4.2. Structures pipe framed

Pipes are used in the construction of greenhouses with a clear span of around 12 meters. The side pillars, columns, cross ties, and purlins are typically constructed from pipes. This type does not employ trusses..

http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124111.

Figure: 2.8. Pipe framed greenhouse structures.

1.3.4.3. Structures of the truss framed

When a greenhouse span exceeds or equals 15 meters, truss frames are used. Welding flat steel, tubular steel, or angular iron together produces a truss consisting of rafters, chords, and struts. While chords support members in tension, struts support components that are compressed. To an angle iron purlin that runs the length of the greenhouse, each truss is bolted. Columns are only used in extraordinarily wide 21.3 m or larger truss frame homes http://ecoursesonline.iasri.res.in/mod/page/view.php?id=124111.

Figure: 2.9. Structures of truss framed.

1.3.5. Based on Covering Material Greenhouse Type

The greenhouse's primary structural component is its covering materials. They directly affect the greenhouse effect's interior component by controlling the air temperature inside the greenhouse. There are a variety of frame styles and fastening options depending on the covering material. According to the type of covering material used, greenhouses can be divided into three categories: glass, plastic film, and rigid panel greenhouses (Dalai et al., 2020).

1.3.5.1. Glass greenhouses

Before 1950, there was just one glass greenhouse that had glass employed as the covering material. The interior lighting is enhanced, which is one benefit of choosing glass as a covering material. These greenhouses' higher air infiltration rates reduce internal humidity, which enhances disease prevention by reducing the risk of illness. Glass greenhouses are built using ridge and furrow, even span, lean-to, and other architectural principles. Glass is the most conventional greenhouse glazing material. This type of greenhouse, as suggested by its name, uses glass as a glazing material. It is more effective in the winter than it is in the summer. The high midday temperatures in the summer are the cause of this. It is not advisable to build a greenhouse with glass windows because of the high cost of installation, the difficulty of building, and the frequent glass breakage caused by strong winds (Sara Abdelgadir Saeed, 2017).However, due to its durability, the best type of glass glazing is double-pane tempered glass. In the event of damage, it also lessens the chance of injury by breaking into little square pieces, and those pieces won't hurt your plants (Sara Abdelgadir Saeed, 2017).

Figure: 2.10. Glass greenhouses (Dalai et al., 2020).

1.3.5.2. Greenhouses plastic film

This type of greenhouse's covering is comprised of a flexible polyethylene plastic sheet, polyester, and polyvinyl chloride. Plastic has been a popular choice for greenhouse covers since it is less expensive and requires less heating than glass. The main problem with plastic films is their short lifespan. For instance, the best ultraviolet (UV) stabilized film has a four-year lifespan maximum. Both gutter-connected and quait designs can make use of this covering material.

http://agrimenia.blogspot.com/2018/05/greenhouse-type-based-on-covering.html

Figure: 2.11. Polyethylene film greenhouse.

1.3.6. Classification Based on Environmental Control

Numerous elements, including temperature, solar radiation, carbon dioxide, and humidity, have an impact on the greenhouse environment. Thus these factors must be properly controlled. Every greenhouse has a mechanism in place to regulate the environment. This approach aids in creating a controlled atmosphere that is uniform. Numerous issues arise in plants when the environment is not uniform, including potential infections, consequences of hormonal or nutritional treatments that cannot be cured, and variations in plant growth rates. As a result, controlling the plant's production system is challenging.

The primary problem of the greenhouse environment control system during the summer months is an increase in a significant amount of heat. Incoming solar radiation and heat obtained from air exchange are the main sources of this heat. Thus, the amount of heat in the greenhouse can be increased by limiting such heat sources and raising the percentage of energy partitioned into latent heat. can be decreased. shade and Whitewash nets are the most effective ways to minimize sun radiation. Additionally, ventilation during cold outside temperatures removes any additional heat created airflow between the interior and exterior. Evaporative cooling is the alternative popular method. By raising the latent heat component of the dissipated energy, this technique lowers the perceptible heat load (Choab et al., 2019). The following provides a thorough overview of cooling systems, ventilation, and other topics.

1.3.6.1. Ventillation

In a greenhouse, There are two types of ventilation used. They either use mechanical ventilation or natural ventilation. When mechanical ventilation is used, exhaust fans, inlet holes, and power are used to run the fans (Tronchin et al., 2018). To achieve sufficient cooling under a variety of environmental circumstances, a good design is necessary. The two primary natural ventilation phenomena that depend on these phenomena are thermal buoyancy and the wind effect. Ventilation has an impact on greenhouse interior temperature when incident solar radiation is high. Openings in the framework of the greenhouse permit natural ventilation to control the humidity and temperature within. Additionally, it can deliver adequate air exchange. The greenhouse has effective ventilation thanks to the combination of fans, roof vents, and front doors. The benefit of better ventilation is a practical way to lessen the temperature differential in the air between inside and outside.

Figure: 2.12. Greenhouse with natural ventilation (Kidist, 2021).

1.3.6.2. Cooling System

When the ventilation system's cooling capacity is no longer sufficient to maintain the greenhouse's temperature, an extra cooling system may be necessary. Fog systems and pad-fan cooling systems are further water-evaporating cooling solutions. High pressure is used in fogging systems to propel tiny water droplets into the atmosphere above the plants (Kittas et al., 2012). As a result, more of the water's surface comes into touch with the atmosphere. The relative humidity rises when the greenhouse's interior is cooled during the fogging process. The sentences that follow provide descriptions of these two cooling methods.

A. Evaporative Cooling: A technique called evaporative cooling uses fans and/or pads to lower the air's temperature. The temperature is lowered as water evaporation from the pads consumes electricity. The ideal distance between the pad and fans should be taken into account while installing one of the systems. The size of the greenhouse and your plants' endurance for high temperatures are important considerations. You can place additional space between the two when the plants' tolerance range is wider.

https://thehouseofgreen.weebly.com/greenhouse-heating-and-cooling.html.

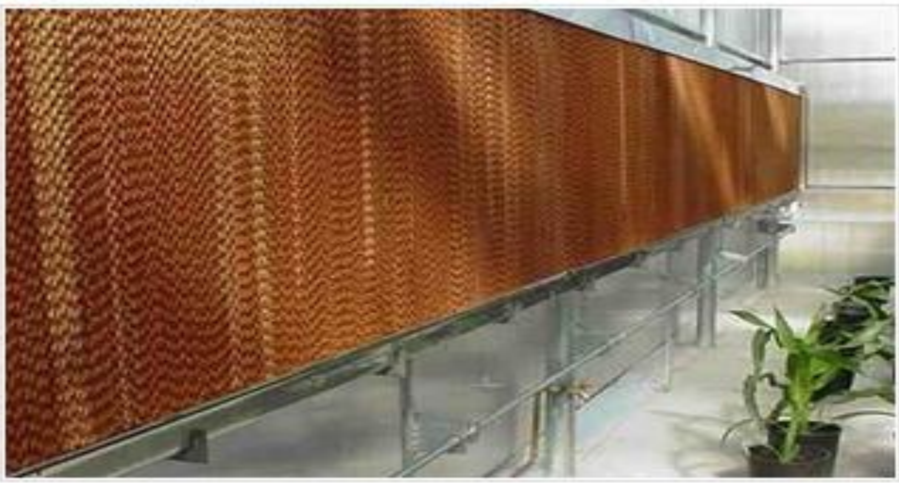


Figure: 2.13. greenhouse evaporative cooling system with fans and pads.

B. Fog System: The two major components of the greenhouse's fogging system are a pump unit and fogging lines. The pump unit is made up of a valve, a pressure-adjusting regulator, a water softener, a fine filter, and a pump, the main pipeline, distributor line, and LDPE pipe (Choab et al., 2019). Using a high-pressure pumping apparatus, tiny water droplets that are part of the fog are created. Due to their tiny size, these droplets can remain suspended in the air while evaporating. When fog covers the greenhouse, the air is chilled throughout. This method is also utilized for seed germination and seedling growth.

Figure: 2.14. Fogging systems for cooling a greenhouse (Kidist, 2021).

1.3.6.3. Shading

Are also known as blankets, Screens, and shades. Whatever name they go by, they are built by movable plastic film or fabric panels that are utilized to both conceal and reveal the space inside a greenhouse. Curtains can be used to cover spaces of any size, from a single seat to an entire acre. Generally speaking, smaller systems are moved by hand, but bigger systems are typically propelled by a motor. Systems for internal shading are mounted to the greenhouse's frame beneath the rigid or film exterior. less than 1% of the incident light is transmitted through the covering material., they are utilized to alter day duration, block out light, retain heat, and provide shade (and its cooling effect). Mobile external curtains are now possible because of advancements in the motor system and shade cloth technologies.

Shading is one method for cooling the greenhouse. Its use reduces the amount of solar energy that reaches plants. The air temperature differential is lessened by lowering the greenhouse's solar load, bringing the absolute air temperatures there closer to those outside (Choab et al., 2019). In greenhouses, heat uptake is mostly caused by direct sun radiation. Shading may have an impact on greenhouse plants' development and photosynthesis because of the reduction of light and possible effects on the ventilation rate. Therefore, consideration must be given to the type of shading and related control methods (Choab et al., 2019). Crop yields can be increased with the right choice and use of shed nets production during or in locations with unfavorable weather conditions, especially during the summer. By shielding the plants in the greenhouse system from intense sun radiation, the shading plays a significant function (Holcman and Sentelhas, 2012).

Figure: 2.15. Aluminum shade net for greenhouse (Kidist, 2021).

1.4. Components that determine greenhouse performance

A. Sky temperature: Long-wave heat exchanges are one of the primary routes for gain and loss in the greenhouse because of the vastness of the roof surface and the poor thermal efficiency of the greenhouse shells.

B. Photosynthesis and respiration: By utilizing CO_2 and water, photosynthesis transforms light energy into sugar energy. Generally speaking, the crop doesn't need the full range of sun radiation to thrive. The three sections of the sun's spectrum that are most beneficial for crop growth are ultraviolet (UV), the photosynthetically active region (PAR), and near infrared (NIR).

C. Transpiration: Transpiration is the term for the process of losing water by the evaporation of water vapor, primarily from leaves and stomata. For two key reasons, transpiration is essential to the growth of the plant. It enables the plant to cool off and moves nutrients from the roots to the sections of the plant that are on the surface.

D. Condensation: The greenhouse's relative humidity is consistently high because of the crops' transpiration. Moisture on the greenhouse shell condenses into water droplets when the surface temperature is lower than the air's dew point temperature. A normal greenhouse cover is either entirely or partially wet 50% of the time, and the greenhouse shell has 100l/m2 of condensation on it. Because it reduces internal humidity, this condensation is important for keeping a good balance of moisture. Additionally, by releasing energy from evaporative cooling to the shell, the condensation heats the cover and slightly lowers the greenhouse's demand for heating.

E. Ventilation control: By absorbing solar energy during the day, the greenhouse warms up due to the so-called greenhouse effect. This phenomenon leads to high air temperatures within the greenhouse, which are bad for crop development and quality. If the greenhouse's interior temperature rises above a specified point, the crop develops distorted leaves, its leaf growth is delayed, and it finally sustains harm or dies.High temperature is another important factor in the decreasing.

It is possible to naturally or artificially reduce the temperature and relative humidity of the air in greenhouses by using outside air. Because the relative humidity outdoors is frequently lower than the humidity inside, ventilation is the greatest approach for regulating humidity in a greenhouse. Independent of the wind speed outside the greenhouse, mechanical ventilation operates. Mechanical ventilation is a more efficient method of dehumidification than natural ventilation since it exchanges air near to the crop.

F. Humidification: The greenhouse's relative humidity falls too low as crop transpiration increases. Nutrient shortages develop when only the water transports the nutrients or minerals to the leaves in this situation. Additionally, the crop rapidly loses moisture as a result, wilting. Low relative humidity eventually leads to a drop in crop quality and quantity.The high-pressure fogging system in the greenhouse is used to increase the humidity. This system sprayed water into the internal air to increase humidity and decrease temperature. The control system can regulate both the water flow and the timings of the activation. Both the moisture balance and the energy balance are directly impacted by the use of evaporative cooling and the rise in vapor.

G. Control of artificial lighting: Given that light contains solar radiation, it has a significant impact on how crops develop and thrive. Nevertheless, depending on the time of year, different quantities of sun radiation are available. It is necessary for the crop to be able to absorb adequate PAR radiation in order to generate good, high-quality harvests. when the crop doesn't get enough PAR radiation. The energy balance is significantly impacted by artificial lights. A relatively small amount of light is used to create PAR radiation, which is used to increase agricultural productivity. Most of what is still present is converted to long-wave radiation and used to increase the temperature within the greenhouse. Since the summertime PAR radiation shortfall is the greatest, lights are used to heat greenhouses.

H. Control of screens: Three main types of screens are used: block, shade, and thermal, depending on the needs of the greenhouse. The following screen control goals:Crops can be harmed by high sun radiation.The length of the day needs to be changed for flowering.Reduce the requirement for winter cooling.Blocking summer heat loss is a good idea.

I. Water: is one of the most important components of plant cells and is necessary for cellular processes like photosynthesis, the movement of nutrients, and the integrity of plant tissue. Water typically makes up between 80 and 95 percent of the bulk of growing plants.

For a plant to produce one gram of organic matter, 500 grams of water are required. Since plants lose water to the atmosphere through transpiration, maintaining turgor pressure requires a significant amount of water since some species of plants transpire 100 times their mass in water through their leaves throughout the course of their existence. Since losing water reduces the efficiency of many cellular processes, maintaining this water balance is essential. The degradation of the root zone is one of the additional problems brought on by over watering (Taiz and Zeiger, 2010).

There is a rising need for water as a result of population growth, economic activity, and the requirement for agricultural irrigation. The balance between water supply and demand becomes unstable in areas with a water scarcity. The excessive use of non-rechargeable groundwater for irrigation in arid areas reduces the amount of water that is available to other users. 2014's Abulobaida.

irrigation systems that are closed or open. While closed nutrient solutions are recirculated and not allowed to enter the environment, open nutrient solutions are allowed to pass through the root system. For plants cultivated in plug trays with tiny cells, regular hydration is crucial.

The greenhouse may be irrigated at various rates thanks to an automatic boom system. These gadgets, which are quite adaptable, will eliminate the majority of manual watering.
Additional greenhouse irrigation techniques include misting for propagation zones, overhead watering for mature crops, and drip irrigation for crops planted in ground beds and hanging baskets. The main benefit of employing capillary irrigation mats may be for bench-grown potted plants.

- When frequent watering and nutrient solution confinement are sought, such as in bench or floor systems, irrigation with ebb and flood is becoming more popular. Methods of Common Irrigation.Hand Sprinklers for WateringIrrigation Booms for DripBench for Ebb and Flow
- Consequently, to sustain the water scarcity caused by the use of the greenhouse system Drip irrigation, a local form of irrigation, limits the soil soaking body per unit plow layer and hence the formation of agricultural roots. (2017) (Zhao et al.).

- Flowering plants can be categorized as short-day, long-day, or day-neutral plants depending on how much darkness is needed for flowering.
- When the day is shorter than 12 hours, a plant known as a short-day (long night) plant will begin to bloom.
- Plants with long days and short nights produce flowers when the length of the day exceeds 12 hours. While
- Day-neutral plants produce flowers no matter the length of the day.

1.5. Psychrometric Chart

atmospheric air is made up of a variety of gases, water vapor, and impurities. Prior to processing the air, it is essential to filter out these contaminants. As a result, both dry and wet air are present in the final air mixture. The thermal and physical properties of this damp air are examined in the discipline of psychrometry.

A psychrometric chart shows the thermodynamic characteristics of moist air graphically. A psychrometric chart, seen in Figure 2.16, is distinguished by its distinctive and detailed design. The features and attributes of moist air are extensively covered in this chart. Solutions to problems with air temperature and humidity can be developed by utilizing the information and insights offered by the psychrometric chart.

It offers a visual tool for examining and comprehending the connections between many air-related factors, including temperature, humidity, dew point, enthalpy, and specific volume. The dry bulb temperature, or air temperature, is shown by the horizontal axis on a psychrometric chart. The mass of water vapor present in the air per unit mass of dry air is represented by the vertical axis as the humidity ratio or specific humidity.

The saturation lines on the graph, which are curved, show how much moisture the air can contain at a given temperature. Temperature and humidity data are used to depict a specific point on the graph, allowing for the determination of attributes like relative humidity, dew point temperature, specific volume, and enthalpy. Psychrometric charts are widely used in fields such as HVAC (heating, ventilation, and air conditioning), meteorology, and building science to analyze air conditioning systems, determine air properties, and assess the thermal comfort of indoor environments.

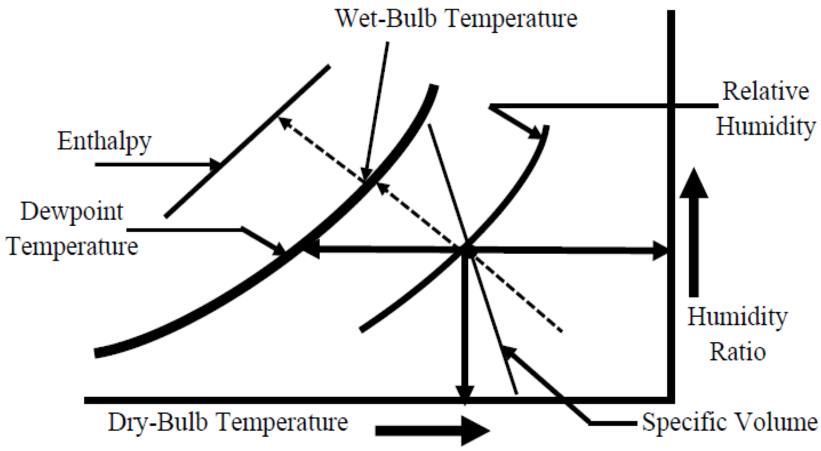


Figure: 2.16. Psychrometric chart representation.

1.6. Review of Previous Works

Greenhouses are an example of MIMO systems, which are extremely nonlinear and strongly coupled. Performance of greenhouses is significantly influenced by actuators, the moistening cycle, as well as the external environment (wind speed, outdoor temperature, and humidity). Many complex control strategies were proposed decades ago. Many greenhouses employ a standard PID control to achieve the control goal, however because there are many interdependent components in a greenhouse, this control method may not be sufficient to ensure the required performance. Numerous improved control-based methods have been developed to meet the issues of temperature regulation in greenhouses as a result of the limits of linear control techniques. Model predictive control has recently been used to evaluate nearby field experiments (Ito, 2012).

The findings showed the effectiveness of the control system by improving disturbance rejection and temperature stabilization in contrast to conventional controllers like PI, PID, and others. The optimal solution provided by this controller, however, exposed the system to a temporal delay because it relied on a brute-force method and took longer to compute.
In the system of moral corporate governance in the floriculture business, sustainability considerations for the benefit of people, the environment, and economic gain have developed as a novel idea. Sectoral sustainability in Ethiopia, however, is still a relatively new issue. Due to its poor cultivation, which gravely harms both the environment and societal well-being, the floriculture sector is today the subject of a lot of criticism.

In order to explain any differences, the industry must evaluate new discoveries in sustainability research. The sustainability challenges facing the floriculture industry and their impacts on the environment and society have been thoroughly analyzed. A approach to cut back on water use was suggested in the literature (Lijun et al., 2018) and is based on adaptive feedback linearization of greenhouse temperature. The study shows that the proposed method provides an appropriate set point for evaluating the effectiveness of indoor temperature control with efficient energy inputs.

The technology does not replicate disturbance situations or take into consideration internal humidity regulation. These problems could be viewed as a limitation on investigation. The authors Zeng et al. (2012) suggested combining an RBF network with a conventional PID controller to create a hybrid control approach. The PID gains were adaptively identified and adjusted using the RBF network. The results show how highly resilient, adaptable, and set-point tracking the suggested system is. The suggested method used the gradient descent algorithm to reduce the error. Given the length of the training process using the gradient descent method, it is difficult to obtain a speedy response during any set point change.

The findings showed the effectiveness of the control system by improving disturbance rejection and temperature stabilization in contrast to conventional controllers like PI, PID, and others. The optimal solution provided by this controller, however, exposed the system to a temporal delay because it relied on a brute-force method and took longer to compute. A system that integrates MPC with a genetic algorithm to decrease water use has also been created (Blasco et al., 2007). Irrigated agriculture, which is practiced on only a small amount of land, played a significant role in yield growth, which sustained a significant portion of output gains over the past few decades. Irrigated agriculture enhanced land production by a factor of about two, according to Smith et al.'s (2017) study.

One shortcoming of the research literature is the lack of discussion of the controller's capability to reject perturbations in a greenhouse environment. Given the significant impact that external disturbances have on greenhouse operations both throughout the summer and winter seasons, the designed control approach must exhibit high disturbance rejection capability. The literature does not address important performance measures including settling time, overshoot, and integral absolute error. This thesis proposes a fuzzy logic inference control system approach to get around these limitations. In addition to utilizing the advantages already present, this technique combines intelligent controller performance reviews for indoor climate control in a greenhouse scenario.

In a variety of domains, including greenhouse climate management, fuzzy logic controllers, or FLCs, have been extensively researched and used. The following is an overview of some of the earlier studies that have applied FLCs in various settings:

Greenhouse Climate Control: - Using FLCs to improve greenhouse climate control has been the subject of several studies. In these projects, FLCs that control ventilation, humidity, and temperature are designed.

Irrigation Control: - To maximize water use and preserve soil moisture levels, FLCs have been used to regulate irrigation systems. FLCs may control irrigation schedules and amounts to minimize water wastage and prevent over- or under-watering by taking into account variables including weather, soil moisture, and crop water requirements.

Energy Management: - Energy management systems for greenhouses have made use of FLCs. In order to maximize energy consumption, these tasks entail managing the ventilation, heating, and cooling systems. Temperature variations, meteorological conditions, and energy costs can all be taken into account by FLCs to modify control operations in a way that optimizes energy use and lowers operating costs.

These previous works demonstrate the versatility and effectiveness of FLCs in improving greenhouse performance and sustainability. They highlight the potential of FLCs in optimizing various aspects of greenhouse management, including climate control, resource utilization, pest management, energy efficiency, and decision-making support. Continued research and development in this field can further enhance the application of FLCs in greenhouse systems.

CHAPTER THREE

METHODOLOGY

3.1. Materials

To organize this thesis work by using different materials for different purposes, first for writing and editing of the document though out this thesis work Microsoft Word 10, for reference citations Endnote X7. Secondly, developing and writing different equations and formulas of the mathematical model of the greenhouse system by using math type 6.0 throughout this thesis work. Finally Matlab 2018a/Simulink toolbox used for simulation of greenhouse system model. That suggested controller for controlling and fogging greenhouse system.

3.2. Method

Before modeling and design phase of the proposed system, it is necessary to complete several basic tasks. These include accompanying a comprehensive review of relevant literature, collecting data and analyzing it. By revewing related papers and literature that are closely related to greenhouse temperature and humidity control system, the literature review seeks to provide a better knowledge of these systems.

The numerous performance The testing for tracking and disturbance rejection principal target of this study, the observed site from Ethiopin Green house has provided the goal values for indoor temperature and humidity during various psychrometric procedures. The values about these factors are gathered through examination of recorded data and conducting interviews with relevant individuals to enhance understanding of the greenhouse and its control system. The organization also provides values for solar intercepted energy and outdoor temperature.

Considering that the business focuses on the production of cut flowers, the proposed method is applicable specifically to such flowers due to variations Floresnsis Ethiopia PLC in indoor air temperature and humidity requirements across different plant species. The parameter values for the greenhouse model are derived from existing literature. The thesis work employs both primary and secondary data collection methods. The collected data undergo mathematical and graphical analysis to facilitate the development of system modeling. Both modeling and simulation are applied to analyze the indoor climate control system of the greenhouse.

Additionally, fuzzy inference system The interior humidity and temperature can be properly standardized thanks to the controller's design. The system's final simulation results are contrasted with those attained by utilizing a PID controller. MATLAB software is used to implement the complete system.

3.3. Mathematical Model for Greenhouse

3.3.1. System descripion

The Floresnis Ethiopia PLC system incorporates a variety of sensors and actuators and is built as a multi-input and multi-output (MIMO) system. The greenhouse's internal temperature and humidity, as well as the ventilation (VR), fogging (Qfog), and heating (Qheater) systems, serve as the system's inputs. External variables that affect the system's activity include sun radiation, temperature, and humidity outside the greenhouse. The cooling and heating model are the two models for the glasshouse system. As the greenhouse's interior temperature is extremely low at night and throughout the winter, a heating system is very crucial.

In other side, a cooling model is required when the inside temperature is extremely increase because this could harm the plants during the daytime in the summer. Ventilation model is one of the most crucial elements of glasshouse whose goals are to maintain the temperature at the ideal level, to provide a fresh air supply for photosynthesis and plant respiration, and to assure air moment. However, the ventilation model and the heating and cooling model are merged in this work (Manonmani et al., 2016).

However, the heating and cooling models are combined with the ventilation model, the Qheater is set to zero when operating in summer mode. Both temperature and humidity inside can be controlled in the climate model given by adjusting the ventilation (Vr) and fogging (Qfog) processes. These variables (T_I and G_I) are controlled by cooling/ventilation and heating Qheat (t) in the summer when Qfog becomes zero (off). As a result, ventilation is widespread in both seasons (Fikir, 2019).

Regulation interior Temperature

The building is essential as a means of maturation and crop breeding. Fruit quality and size drop as a result of overcooling or overheating, which results in harvest losses. excellent regulation of temperature enables the production of crops in the off-season and even multiple harvests annually.

Controlling interior humidity

Controlling interior humidity, together with controlling the outside temperature, is the cornerstone of glasshouse farming. The humidity must be balanced and at the right amount to prevent plant diseases and insect infestations.

The glasshouse can be modeled using numerous techniques. The most common among others on which this study relay is physical modeling.

Physical modeling: This model portrays the flow and mass transfer resulting from control, exogenous energy and mass inputs, or the interior and exterior air's mass and energy contents differ. On the foundation of the state space form depicted below, the majority of analytical models for the analysis and control of the glasshouse environment have been developed. x = f(t, u, v), where u represent state variables such as the indoor temperature and humidity and x represent control inputs such as energy from the heating system, fogging system, ventilation system, etc. Sun radiation, outdoor temperature, and humidity are examples of external disturbances; t stands for time; and the non-linear function is represented by the symbol f (,).The state variable's dynamic behavior is explained by the two differential equations that follow for control purposes using a simplified glasshouse climate model (Manonmani et al., 2016). A system with a strong relationship between temperature and humidity is depicted in the following dynamic model. The breathing rate affects both output parameters.

The system behaves nonlinearly in the glasshouse because it incorporates a variety of physical and biological phenomena (Nazir et al., 2019). A MIMO system with a glasshouse that contains numerous state parameters such the inside temperature, the interior humidity, and is shown in Figure 3.1. A few physical pieces of equipment are used for spraying and ventilation to control a few state variables. Without carefully chosen glazing, shading, and other disturbance rejections, the glasshouse system is extremely susceptible to disturbance from the outside. Solar radiation, the temperature, humidity, and wind speed of the immediate surroundings are a few examples of the disruptions (Nazir et al., 2019).

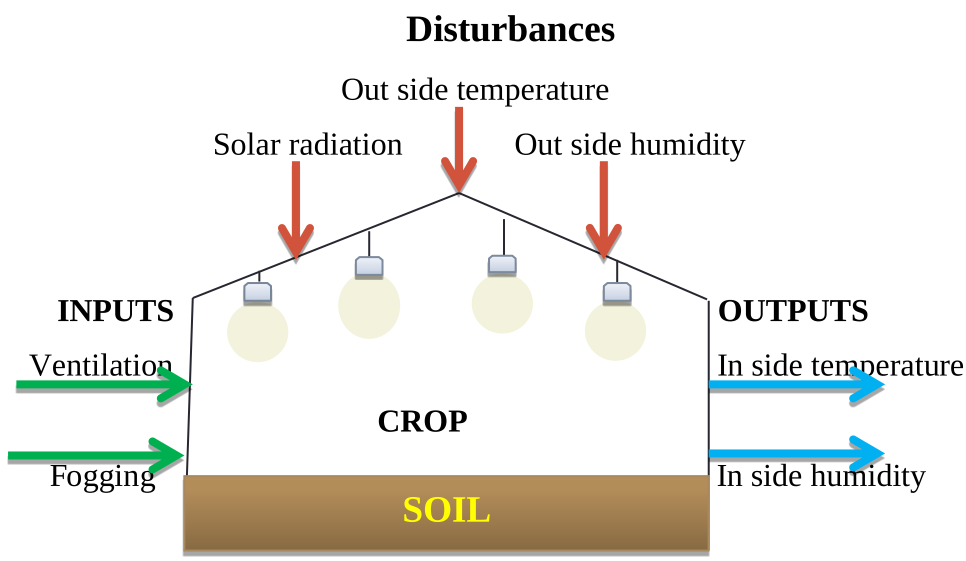


Figure: 3.1. Structure of proposed greenhouse climate control system.

3.3.2. Heat balance

The basis for calculating Equations for energy balance and mass transfer determine how dynamically the greenhouse model behaves. (Hu et al., 2014; Sapounas et al., 2020).

When modeling this complex dynamic system, the heat balance and water balance differential equations are taken into account. The greenhouse climate system's mathematical model, which is the subject of this study, has been used by the majority of researchers (Hoshi et al., 2018; Nazir et al., 2019). The state space form is used to describe the greenhouse climatic system. The equation below is used to calculate internal heat balance.

$$\rho C_p V_t \dot{T}_I(t) = H_s + H_h - H_v - H_c - H_e - H_{fog} \tag{3.1}$$

Where (Riahi et al., 2020).

ρ Density air (kgm^{-3})

C_p Air specific heat of ($Jkg^{-1} K^{-1}$)

V_T active mixing volume of the temperature (m^3)

H_c Heat loss through conducted the wall

H_e Due to water evaporation the heat loss

H_{fog} Due to fog the heat loss

H_h By the floor heating the heat emanated

H_s Entering solar energy in the greenhouse

H_v Due to ventilation the heat loss

T_I is the indoor air temperature in (°C) and

t is Time (min)

Each above parameter has their own calculate value so a natural technique to replace heat lost from dawn till dusk is through solar gain become in Equation (3.2) can be used to calculate the solar energy that enters the glasshouse (Riahi et al., 2020).

$$H_S = P_i(t) = \alpha_C \tau_C AI \quad (3.2)$$

Where: A is the surface area,

α_C is the cover absorptivity of the solar radiation,

I Solar radiation (W),

τ_C Cover transmittance

P is intercepted solar radiant energy (W), (Nazir et al., 2019).

Q_h Value is changed to zero for the summer operation in Equation (3.1), are a linear function of the temperature differential between the interior and exterior environment. and reflects the heat ventilation losses Q_v, as well as V_r in (m^3/min) and Q_c is the conductive heat losses can be express in Formula (3.3) and (3.4) respectively (Daskalov et al., 2006; Gao et al., 2014).

$$H_v = f_v(T_{in}, T_{out}, V_r) \approx \rho C_p V_r (T_{in}(t) - T_{out}(t)) \quad (3.3)$$

$$H_C = f_C(T_{in}, T_{out}) \approx U(T_{in}(t) - T_{out}(t)) \quad (3.4)$$

due to the fog system's heat losses Equation (3.5) expresses Qfog as a function of the water capacity of the fog system (rate of water vaporization by the fog system) (Daskalov et al., 2006).

$$H_{fog} = \lambda h_{fog}(t) \quad (3.5)$$

Where U is the enclosure's heat transmission coefficient (W/K) and U is the latent heat of vaporization.

In this system, the heat losses resulting from water evaporating off the floor Qe are insignificant and have minimal impact on the internal climate of the greenhouse system's thermal and moisture processes. All heat balance variables, i.e., the heat gain and loss parameters, are now substituted, and the proposed model's general heat balance equation (3.1) is changed to equation (3.6).

$$\rho C_p V_T \dot{T}_I(t) = P_i(t) - \rho C_p V_r(t)(T_I(t) - T_O(t)) - U(T_I(t) - T_O(t)) - \lambda h_{fog} \quad (3.6)$$

3.3.3. The water balance

The dynamics of the humidity inside the greenhouse must be modeled after the heat balance. Based on Equation (3.7), this.

$$\rho V_h \dot{G}_{in}(t) = G_{fog} + G_e - G_I - G_O \quad (3.7)$$

Where is (Revathi et al., 2017)

V_G Humidity actively mixing air volume (m3)

G_{in} Humidity ratio in inside (g H2O/kg of dry air)

G_{out} Humidity ratio in outside (g H2O/kg of dry air)

G_{fog} The fog system water capacity of (g [H2O] s-1)

G_{Oair} From the outside air entering the GH rate of moisture transfer (g [H2O] s-1)

G_{Iair} Moisture transfer from inside air rate the leaving greenhouse (g [H2O] s-1)

G_e Rate of moisture due to evaporation water from the floor (g [H2O] s-1)

Now calculate water balance equation for each parameters and final substitute their value to get general formula of inside humidity model of the GH.

Equation (3.8) is used to represent the water vapor of the floor that has been absorbed by dampness. The evapotranspiration rate and energy of solar radiation intercepted are also related in the following way by equation (3.8):

$$G_e = f(P_i(t), G_I(t)) = \alpha \frac{P_i}{\lambda} - \beta_T G_I(t) \quad (3.8)$$

Where: α is an overall coefficient to take into account shade and the dimensionless leaf area index, whereas T is an overall coefficient to take into account thermodynamic constants and other variables affecting evapotranspiration, such as stomata and air motion. (Ahmed et al., 2014; Daskalov et al., 2006). According to Vr, Hin (interior humidity), and Hout, the rates of moisture transport between outside air (GO,air) and inside air (GI,air) are similarly linear functions. (Outdoor humidity) (Daskalov et al., 2006).

$$G_{O,air} = f_O(V_r, G_O) \approx V_r(t)G_O(t) \quad (3.9a)$$

$$G_{I,air} = f_I(V_r, G_I) \approx V_r(t)G_I(t) \quad (3.9b)$$

Now substitute the above all water balance variables in equation (3.7) for develop The differential equation for the greenhouse's interior humidity can be rewritten as (3.10) (Ahmed et al., 2014; Gurban and Andreescu, 2012).

$$\rho V_G \dot{G}I(t) = q_{fog}(t) + \alpha \frac{P_t(t)}{\lambda} - \beta_T G_I(t) - V_r(t)(G_I(t) - G_O(t)) \quad (3.10)$$

Depend on equations of (3.6) and (3.10) describing the mathematical model of the heat and moisture (water) processes of the GH's indoor climate was expressed as (3.11A),(3.11B) (Daskalov et al., 2006).

$$\dot{T}_I = F_T(S_i, T_I, V_r, T_o, q_{fog}) \quad (3.11a)$$

$$\dot{G}_I,air = f_G(S_i, G_I, V_r, G_o, q_{fog}) \quad (3.11b)$$

The coupled energy and water vapor mass balances' general system differential equations are defined below: consider $C_o=1/\rho CpV_t$ reflects the greenhouse's thermal capacity. (Ahmed et al., 2014; Daskalov et al., 2006).

$$\dot{T}_I(t) = \frac{1}{C_o}[S_i(t) - \lambda q_{fog}(t)] - \frac{\rho C_p V_p(t)}{C_o}(T_I(t) - T_o(t)) - \frac{U}{C_o}(T_I(t) - T_o(t)) \quad (3.12a)$$

$$\dot{G}_I(t) = \frac{1}{\rho V_G} q_{fog}(t) + \frac{\beta_T}{\lambda \rho V_G} G_I(t) - \frac{V_r}{\rho V_G}(G_I(t) - G_o(t)) \quad (3.12b)$$

3.4 Representation of the State Space

Figure 3.3 shows a two-input, two-output system with three external disturbances for the greenhouse described in Section 3.2. It was designed for the sweltering summer daytime. In order to vary the greenhouse's internal climate during that season as a result of variations in the ambient temperature, sunlight, ventilation, and fog spray are used (Chhipa, and Somwanshi, 2019). Linked nonlinear equations explain the physical model of the greenhouse in a manner similar to Equation (3.13). The interior temperature Tin and interior humidity Hin can be effectively represented of variations in the ambient temperature, sun radiation, ventilation, and fog spray are the control variables. Furthermore, the disruptions di(t), i

$$\dot{x}1(t) = -\frac{U}{c_0}x_1(t) - \frac{1}{t_v}x_1(t)u_1(t) - \frac{\lambda}{c_0}u_2(t) + \frac{1}{c_0}d_1(t) + \frac{U}{c_0}d_2(t) + \frac{1}{t_v}u_1(t)d_2 \qquad (3.13a)$$

$$\dot{x}2(t) = -\frac{1}{t_v}x_2(t)u_1(t) + \frac{1}{v}u_2(t) + \alpha d_1(t) - \frac{1}{t_v}u_1(t)\,d_3(t) \qquad (3.13b)$$

Where:

t_v Inverse of the number of air changes per unit time represent

$q\%_{fog}$ The maximum capacity of the fog system defined as a percentage

λ' is a product of λ and q_{fog}, max

$V' = V_G/qfog$, max is greenhouse volume per unit of the maximal fog water supply

$\alpha' = 1/\alpha V_G$ which is the contribution of evapotranspiration to the balance of the absolute humidity (Sapounas et al., 2020).

Figure: 3.3. shows the Temperature and humidity Simulink model with their parameters.

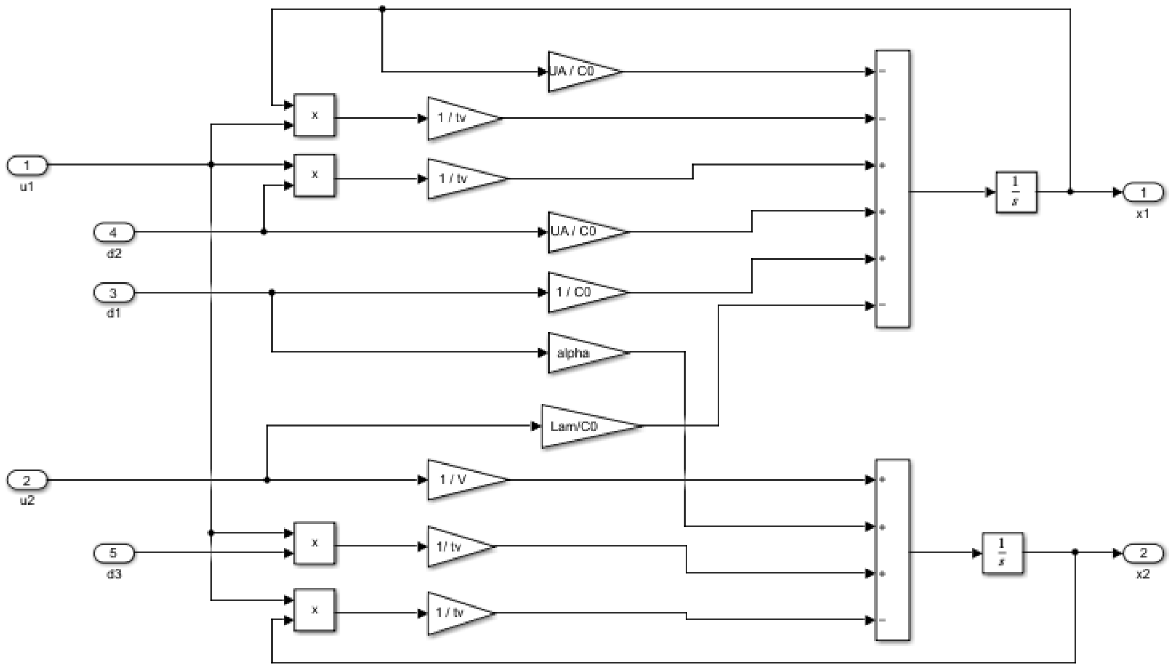


Figure: 3.3. Temperature and humidity Simulink model.

3.5 Mathematical model of DC motor

DC motors may vary their speed, torque, and even rotational direction at any time to adjust to changing conditions since they have the ability to control speed. The analysis and design of physical systems often start with mathematical modeling. DC motors are being used by more and more people. Considering that the input voltage and rotation in DC motors are linearly related. One of the first devices created to transform electrical power into mechanical power was the DC motor. The DC motor allow for easier fan speed adjustments, and electronic circuits last longer (Emhemed and Mamat, 2012)

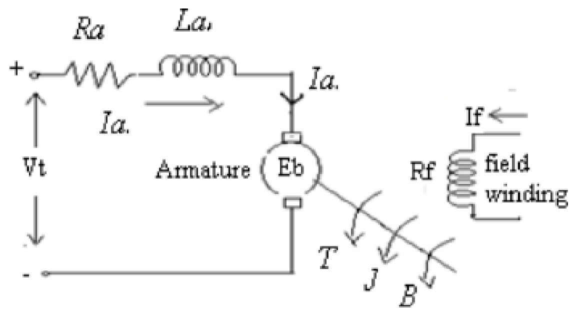


Figure: 3.4 The rotor's free body schematic and electric circuit for a DC motor with PC-based PID speed control.

$$V_a = Raia + Ladia + kbw$$
$$V_a = RaIa + LasIa + Kbw$$
$$V_a - Kbw = Ia\left(Ra + Las\right) \tag{3.14}$$

Armature current equation

$$Ia = \frac{Va - Kbw}{Ra + Las} \tag{3.15}$$

Electromagnetic torque,

$$Te = J\frac{dw}{dt} + Bw \tag{3.16}$$

Where

$$Te = kbIa$$

$$kbIa = J\frac{dw}{dt} + Bw \tag{3.17}$$

$$Kb\left(\frac{Va - Kbw}{Ra + Las}\right) = (Js + B) \tag{3.18}$$

$$kbVa - Kb^2 w = (Ra + Las)(Js + B)w$$
$$kbVa = ((Ra + Las)(Js + B) + Kb^2)w \tag{3.19}$$

Speed equation

$$\frac{w}{Va} = \frac{kb}{(Ra + Las)(Js + B) + Kb^2} \tag{3.20}$$

Table: 3.1. Parameter of DC motor.

Parameters	Unit and value
Inertia (J)	$0.0465 \mathrm{kgm}^2$
Armature resistance (Ra)	1Ω
Torque constant (Kb)	$0.112V/(rad/s)$
Friction of coefficient (B)	$0.005N.m.s$
Armature Voltage (Va)	$6V$
Armature Inductance (La)	$0.032H$

The system transfer function

$$G(s) = \frac{\omega(s)}{Va(s)} = \frac{1}{0.001488s^2 + 0.04666s + 0.01254} \tag{3.21}$$

CHAPTER FOUR

CONTROLLER DESIGN

4.1. Introduction

Controller for fuzzy logic In the field of artificial intelligence known as fuzzy logic, reasoning algorithms are employed to simulate human thought and decision-making in computers. These methods are utilized in scenarios where binary representation of the process data is not possible. For instance, "he is young" and "the air feels cool" are not separate assertions. These kinds of ambiguous statements are interpreted using fuzzy logic to make sense. Since the time of Aristotle, who created the law of the excluded middle, there has been fuzzy logic. Aristotle emphasized that there is no room for intermediate ground in the art of logical reasoning; assertions can either be true or incorrect. When FLCs were created, the discrete logic they used was based on antiquated logic. such as (i.e., ON or OFF) all other values were excluded.

Independent of Bertrand Russell, a Polish logician by the name of Jan Lukasiewicz began research on multivalued logic, which produced fractional binary values between logic 1 and logic 0. Fuzzy logic violates the law of the excluded middle in FLC circa the 1920s. Max Black, a quantum philosopher, used this multivalued logic to create the first set of fuzzy curves for ambiguous sets in a 1937 essay in Philosophy of Science. a fresh approach to automatic control since L. A. Zadeh introduced fuzzy sets in 1965. As complexity increases, exact statements lose meaning while meaningful ones get less precise, according to Zadeh " might be used to sum up its justification.

Fuzzy control is an effort to address the issues posed by the complexity of the processes that need to be regulated and the problems that automatic control systems must solve. Control that is fuzzy may be useful.

• The process that needs to be controlled displays a clear nonlinear characteristic.

• Expert Knowledge is essential for managing the process and should be gained and used for automatic control; • No mathematical model of the process is available because the modeling effort is excessively large or the process is poorly understood.

An illustration of a multidimensional nonlinear connection that should be expressed in a way that makes it simple to understand and modify is a control law. Fuzzy control systems can be seen from several angles: It is possible to think of a fuzzy controller as a nonlinear controller that uses language rules rather than differential equations to describe it.

Alternately, a fuzzy control system might be thought of as the application of a human expert's control technique. Fuzzy logic and control theory are important concepts to understand in order to comprehend how fuzzy control systems work, including how they process information and interact with the plant and other automatic control system components (Bryan and Bryan, 2003).

According to Auliciems and Dedear (1984) and Zadeh (1965), fuzzy logic control (FLC) is a well-known artificial intelligence-based control method. The past familiarity the functionary has with the intended system is utilized. The three basic FLC processes of fuzzification, decision-making, and defuzzification must be applied to the inputs before the output can be produced. During the fuzzification phase, the input variable is transformed into a linguistic variable by using predefined membership functions (MFs). The output that has been fuzzified according to the established ruleset is then produced using the output from the fuzzification phase. Finally, during the defuzzification stage, the fuzzified output is transformed into the imperative output required for system control.

The most exciting feature of the FLC is that it does not require the exact model of the system during building. The FLC has several uses in the realm of machine control for systems with high levels of uncertainty and nonlinearity (Joyo et al., 2013).

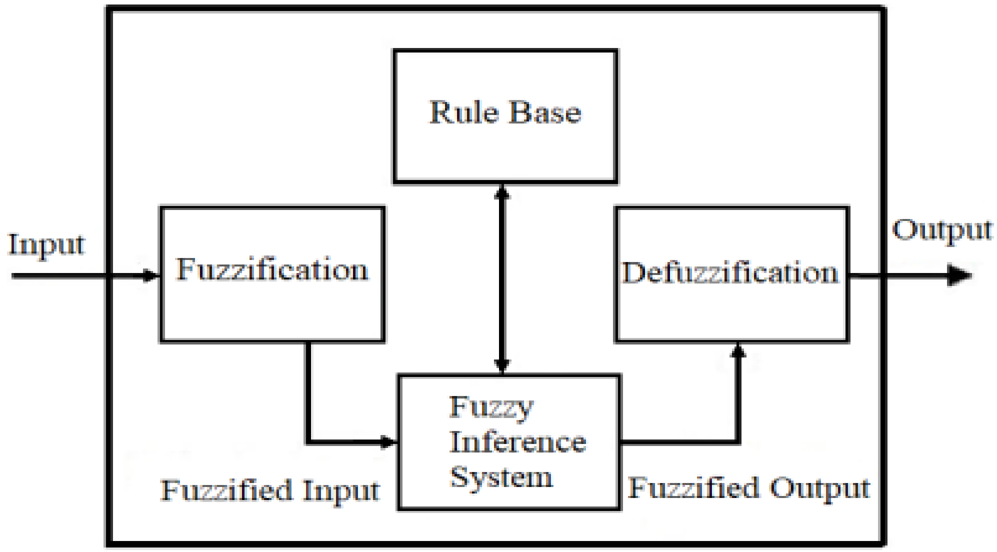


Figure: 4.1. The fuzzy logic controller system structure (Karaburun and Köse)

4.2. Fuzzy logic control system for greenhouse

The FLC of the agricultural greenhouse is shown in Figure 4.2The structure of the controller is formed by the input and output variables of a decision-making unit. Most input variables, including Temperature and Humidity, are Error and Error change variables. The output variable depends on the state of the system. The sensors, which detect the temperature and humidity inside the plant, will provide these readings to the controller.

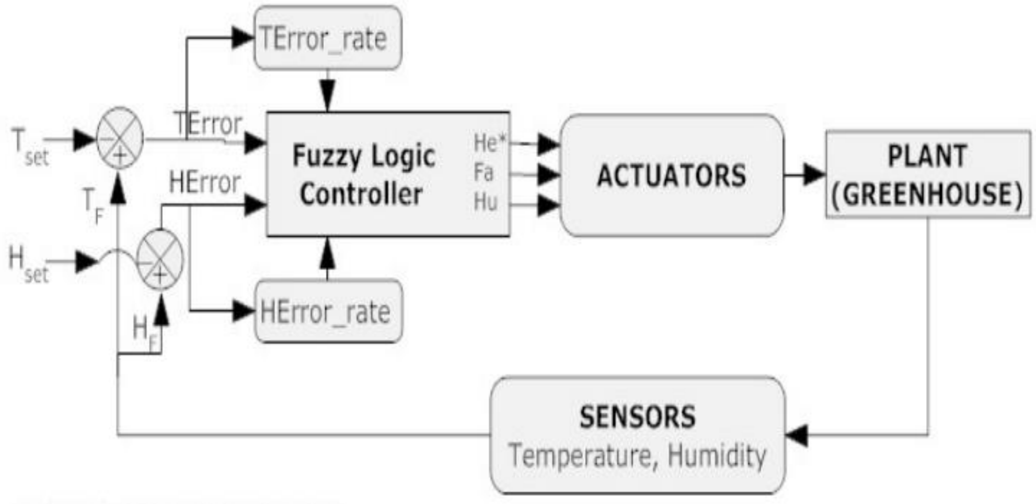


Figure: 4.2. Fuzzy control system of greenhouse (Salim, 2017).

4.3. Design the fuzzy logic membership function of the system

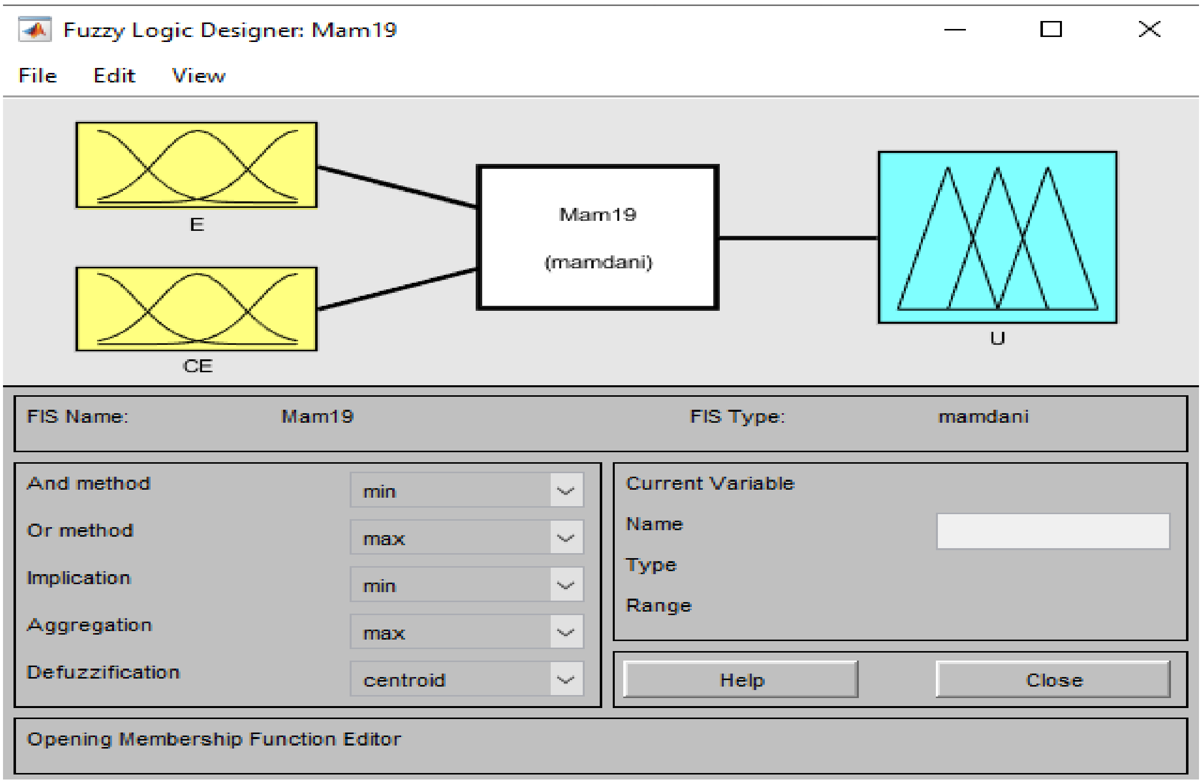


Figure: 4.3. Fuzzy logic designer toolbox for the given greenhouse system.

4.3.1. Input Variables

For the suggested greenhouse system of this thesis, there are two input parameters: error and error change. These two factors influence the greenhouse's temperature and humidity level. which the system's output shares with both of its input parameters. The membership function is depicted in the picture below along with the linguistic values of the two input parameters.

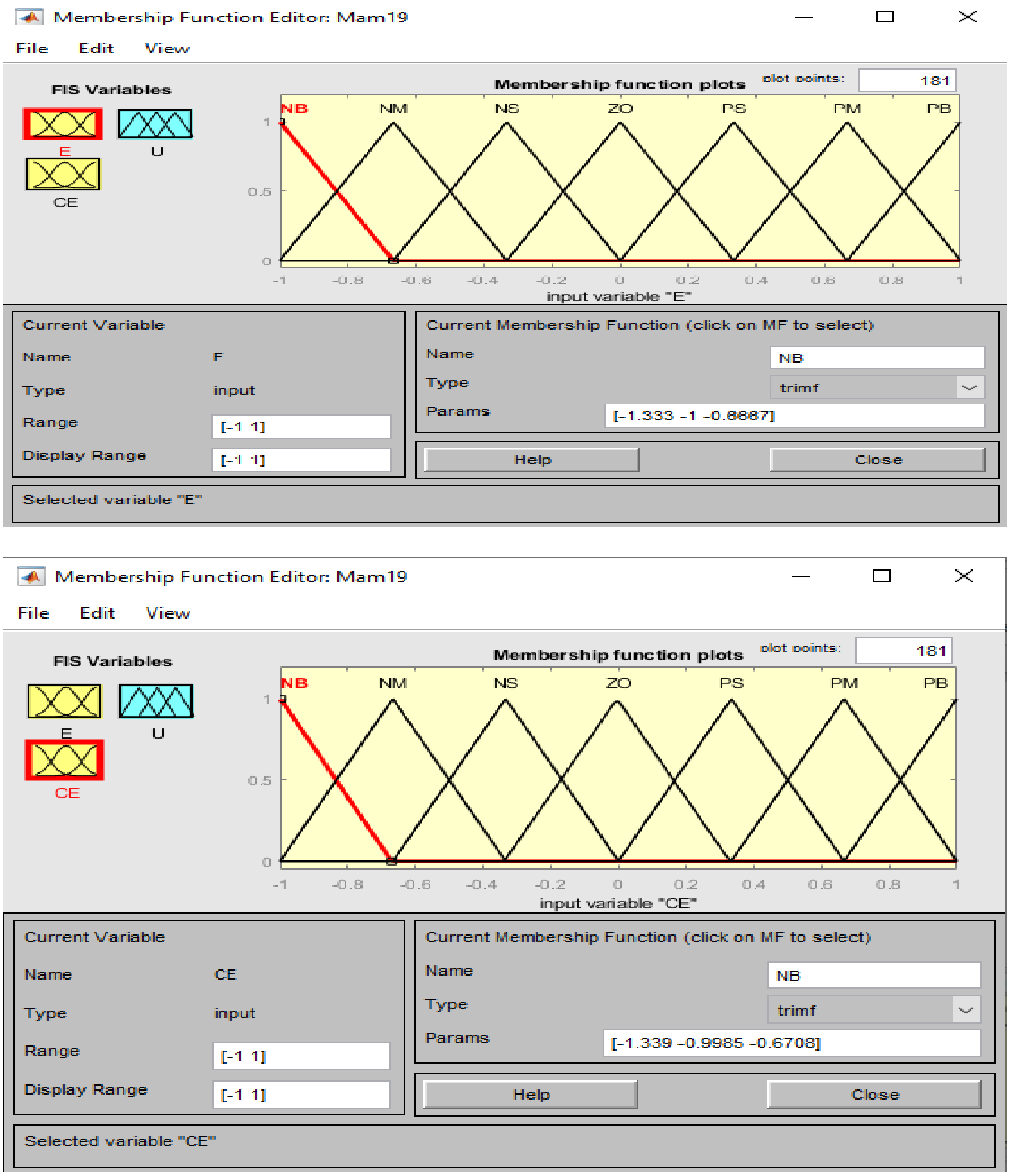


Figure: 4.4. The membership function of input parameters for error and error change.

Table: 4.1. Membership functions for input variables with their range.

Linguistic variable of inputs (e), (ce)	Crisp value of (e)	Crisp value of (ce)
Negetive Big (NB)	(-1.333 -1 -0.6667)	(-1.339 -0.9985 -0.6708)
Negetive Medium (NM)	(-1 -0.667 0.3333)	(-1 -0.6667 0.3333)
Negetive Small (NS)	(-0.6667 0.3333 -5.55e-17)	(-0.6667 0.3333 -5.55e-17)
Zero (ZO)	(-0.3333 0 0.3333)	(-0.3333 -0.4228 -0.3333)
Positive Small (PS)	(-5.55e-17 0.3333 0.6667)	(-5.55e-17 0.3333 0.6667)
Positive Medium (PM)	(0.3333 0.6667 1)	(0.3333 0.6667 1)
Positive Big (PB)	(0.6667 1 1.333)	(0.6667 1 1.333)

4.3.2. Output variables membership function regarding the suggested system

For the suggested greenhouse system assign two input and one output variables which both input variables use as common for one output of the system the membership function of the output variable with their linguistic value are showed at figure below. Ventilation rate and foging rate are output variables of the greenhouse.

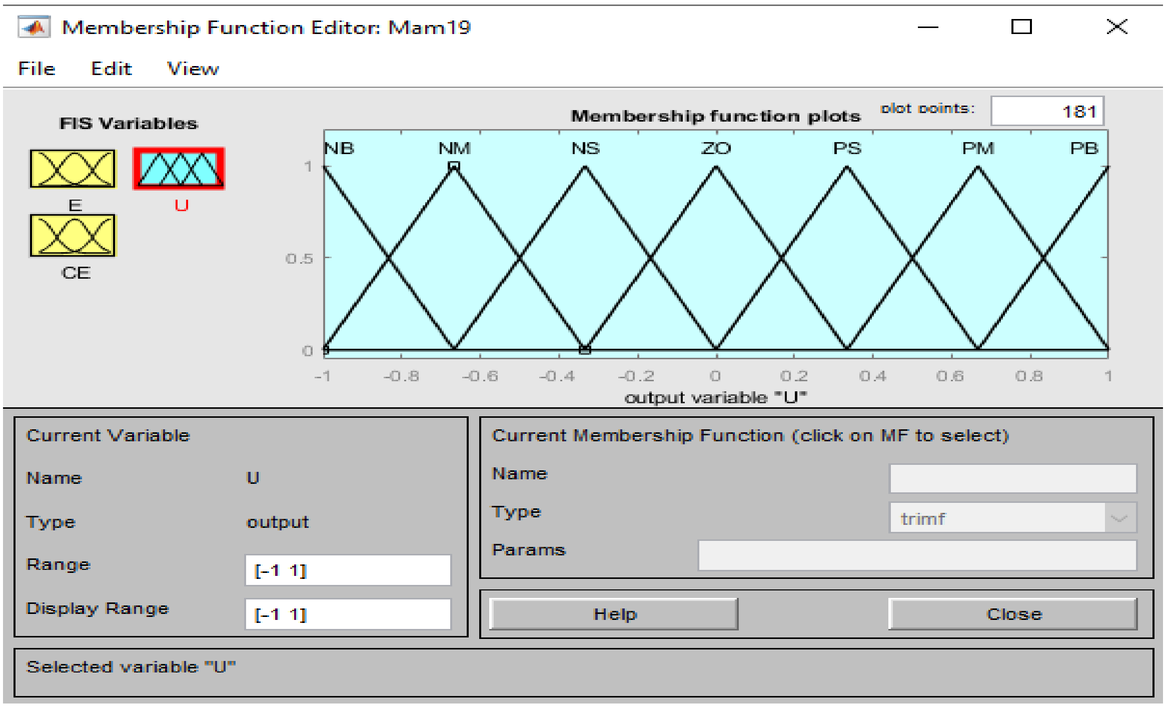


Figure: 4.5. Output membership function of the proposed system.

Table: 4.2. Membership functions of output variables with their range.

Linguistic variable of output (U)	Crisp value of (U)
Negetive Big (NB)	(-1.3333 -1 -0.6667)
Negetive Medium (NM)	(-1 -0.6667 0.3333)
Negetive Small (NS)	(-0.6667 0.3333 -5.55e-17)
Zero (ZO)	(-0.3333 0 0.3333)
Positive Small (PS)	(-5.55e-17 0.3333 0.6667)
Positive Medium (PM)	(0.3333 0.6667 1)
Positive Big (PB)	(0.6667 1 1.3333)

4.4. Fuzzy Rule of the system

One of the most significant subfields of fuzzy sets theory in terms of applications is fuzzy rule-based systems (FRBSs). These types of rule-based systems go beyond traditional rule-based systems by taking into account IF-THEN rules whose antecedents and consequents are formed of fuzzy logic (FL) statements rather than ones of classical logic. A rule-based system known as a FRBS uses fuzzy sets and FL to convey various types of information about the current situation while usually modeling the interactions and relationships between its variables. One of the key components of the rules, fuzzy statements, allow any potential uncertainty in the represented knowledge to be captured and controlled.

The introduction of fuzzy logic, on the other hand, has increased the versatility and accuracy of inference techniques. These qualities have allowed FRBSs to be successfully used to a number of problems in a range of sectors where ambiguity and vagueness present themselves in a variety of ways. The use of linguistic variables and their linguistic values, which are decided by context-dependent fuzzy sets with meanings given by progressive membership functions, improves knowledge representation in FRBSs. Thus, FL offers a distinctive computational basis for inference in rule-based systems. This idea maintains that knowledge and reasoning, two notions that are obviously distinct, are included in FRBSs. The knowledge base (KB) and processing structure depicted here indicate how knowledge and reasoning are significantly separated from one another, which is a key characteristic of knowledge-based systems and processing structure depicted in Figure:4.6.

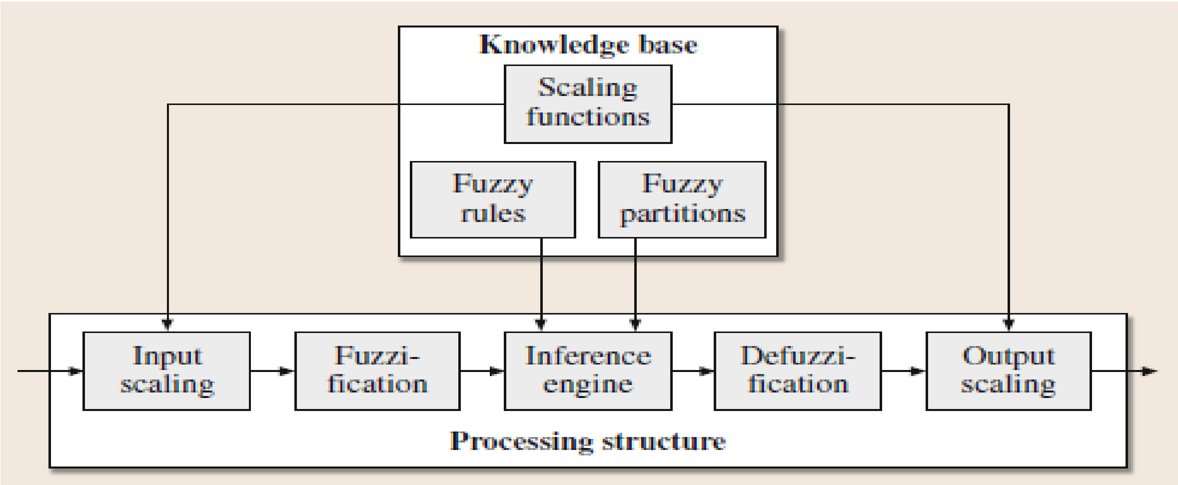


Figure:4.6. Mamdani FRBS structure.

Table: 4.3. Fuzzy rule base of the input variable and output variables of greenhouse system.

E / CE	NB	NM	NS	ZO	PS	PM	PB
NB				NB	NM		
NM				NM			
NS				NS	ZO		PM
ZO	NB	NM	NS	ZO	PS	PM	PB
PS	NM		ZO	PS			
PM				PM			
PB			PM	PB			

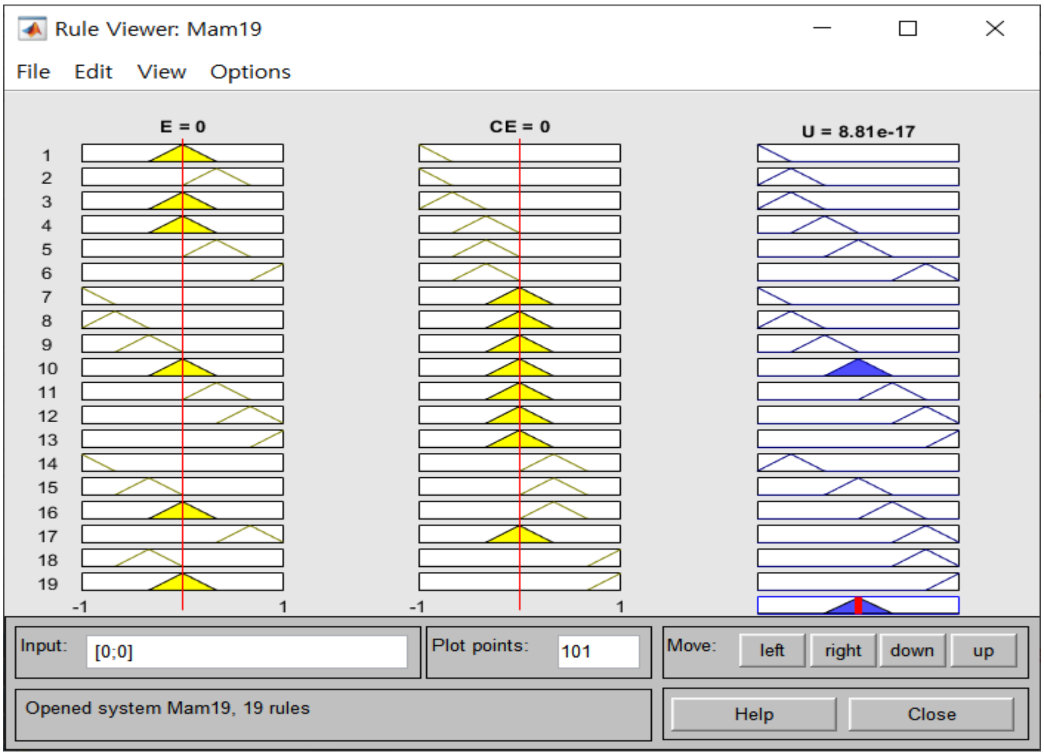


Figure: 4.7. Input output based rule viewer of the proposed system.

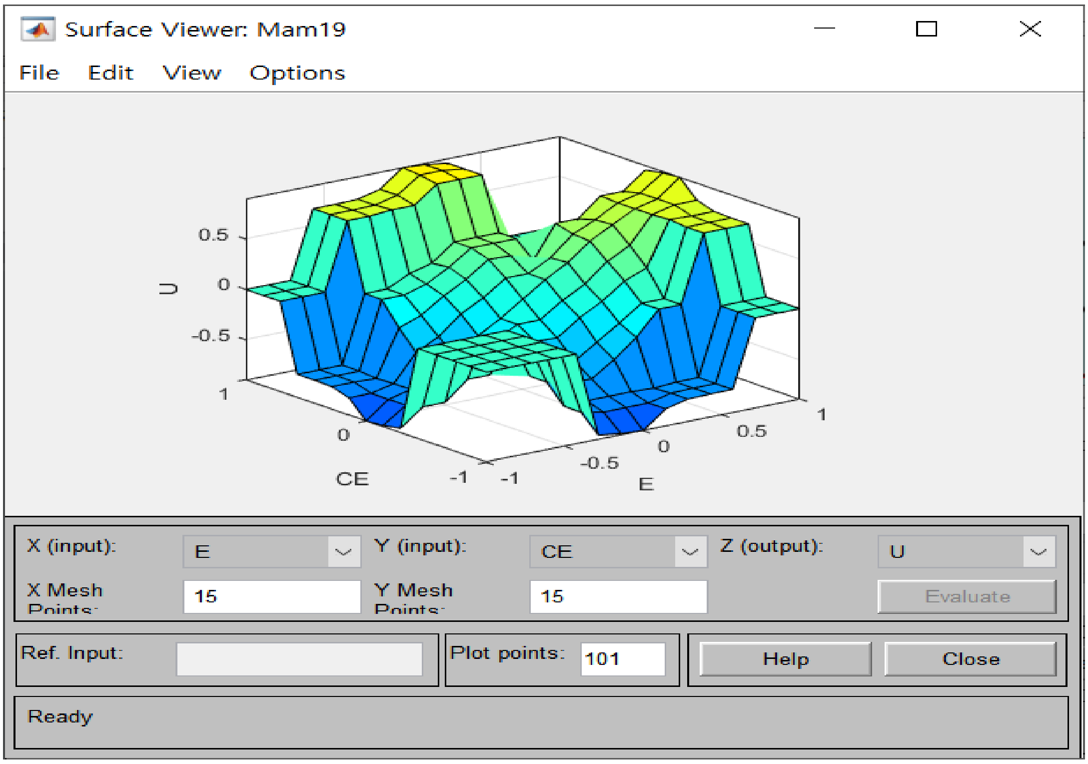


Figure: 4.8. Surface viewer of the proposed greenhose system.

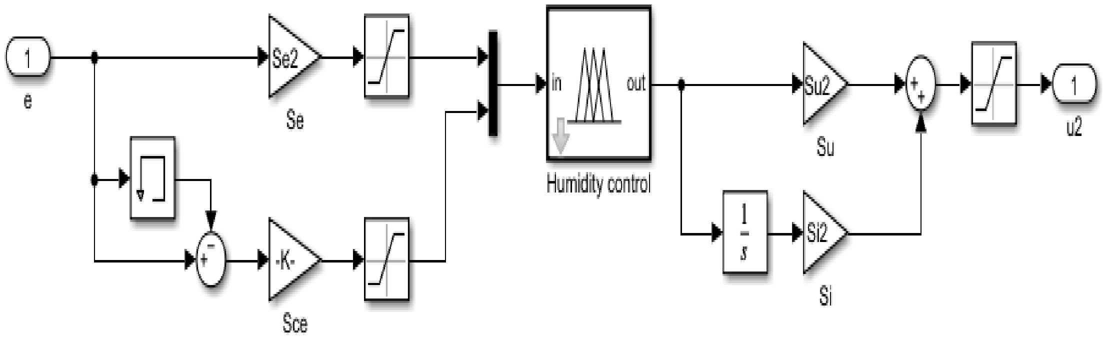


Figure: 4.9. Stracture of the fuzzy PID controller.

4.5. PID Controller for ventillation

In recent years, traditional (classical) proportional-integral-derivative (PID) controllers have arguably gained the most notoriety and popularity. According to statistics, more than 90% of the controllers used in businesses today are PID or PID-type controllers, making conventional (classical) proportional-integral-derivative (PID) controllers perhaps the most well-known and frequently used controllers in recent years.

In general, PID controllers have the advantages of being straightforward, dependable, and efficient; they are also very cost-effective and simple to use. PID controllers also offer outstanding set-point tracking performance and ensured stability for lower-order linear systems (plants, processes). As a result, PID controllers are widely used in practical applications.

Automated control systems enable the safe and efficient operation of complex industrial processes through the use of the Proportional-Integral-Derivative (PID) controller. They accomplish this by continuously monitoring process operating parameters like Temperature, Pressure, Level, Flow, and Concentration. Based on these measurements, decisions are then made regarding whether to open or close a valve, operate a pump more slowly or more quickly, or adjust the amount of heat generated (Vaco et al., 2012).

PID controllers frequently offer the benefits of being uncomplicated, dependable, and efficient; they use less energy but are still quite easy to operate. PID controllers also offer outstanding set-point tracking capabilities and stability assurance for lower-order linear systems (plants, processes). Therefore, PID controllers are frequently utilized in real-world settings.

$$G_{pid}(t) = k_p e(t) + k_i \int e(t) + k_d \frac{de(t)}{dt} \quad (4.1)$$

$$where\ k_i = \frac{k_p}{T_i} \text{ and } k_d = k_p T_d$$

The transfer function of the PID controller can be written as:

$$G_{pid}(s) = k_p + \frac{k_i}{s} + sk_d \quad (4.2)$$

Where: k_p proportional controller gain, k_i integral controller gain, and k_d derivative controller gain.

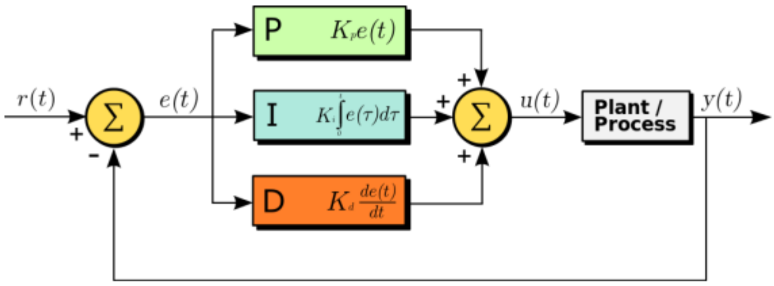


Figure: 4.10. Block diagram of PID controller.

In order to guarantee the system's performance and stability with little error, the proper parameters must be specified. There are several ways to modify the PID controller's parameters. However, in this study, three PID controller settings were a genetic algorithm with a particle swarm optimization.

In process industries, Given that PID controllers are the most often used family of intermediate value controllers, it is advantageous to have a fundamental understanding of the three (3) terms—Proportional (p), Integral (I), and Derivative (D)—that interact and regulate control.

Proportional Term – When calculating the planned set point is contrasted with "how far" the measured process variable has varied from it using the proportional term. A calculated number that the proportional term adds or subtracts at a predetermined interval of time is used to represent the error, or difference between the process' current location and the desired set point. Along with the error value, the amount added to or subtracted from the error also changes swiftly and proportionally.

Integral Term – When a process variable is "how long" away from the target set point, it is said to be integral. The integral term constantly integrates or accumulates errors over time. As a result, even a small amount of persistent inaccuracy that is estimated during the method will eventually add up to a significant amount.

Derivative Term – The derivative term considers the "rate of change" of the error value at a specific moment. The derivative calculation results in a rate of change or slope of the error curve. An inaccuracy that is changing quickly creates a substantial derivative regardless of how recently or for how long a dynamic event has been in progress.

Three settings of the PID controller needed to be tweaked. Proportional gain, or Kp in the proportional controller, was one of the parameters. The rising time and steady state error (SSE) are both decreased by this controller, however the system's overshoot (OS) percentage is significant. Ki, the integral gain in the integral controller, reduces the rising time (Tr), but it also gets rid of the system's SSE. Even though the mistake is eliminated, the OS % is rising, which will also have an impact on the Settling Time (Ts). Derivative gain, Kd in the derivative controller is introduced to boost the system's performance.

This controller will take action to increase the system's stability and transient specification.

Consider the feedback system architecture in Figure 4.13, which has a DC motor as the plant whose speed needs to be accurately controlled.

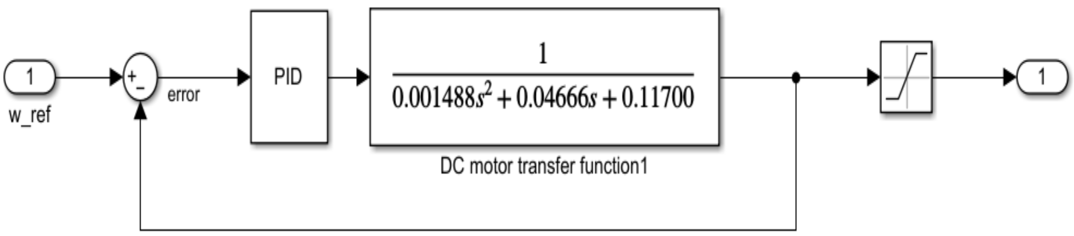


Figure: 4.11 feedback system architecture of PID with motor.

4.6. Proposed control system combining the FLC,PID controller for ventilation and greenhouse system.

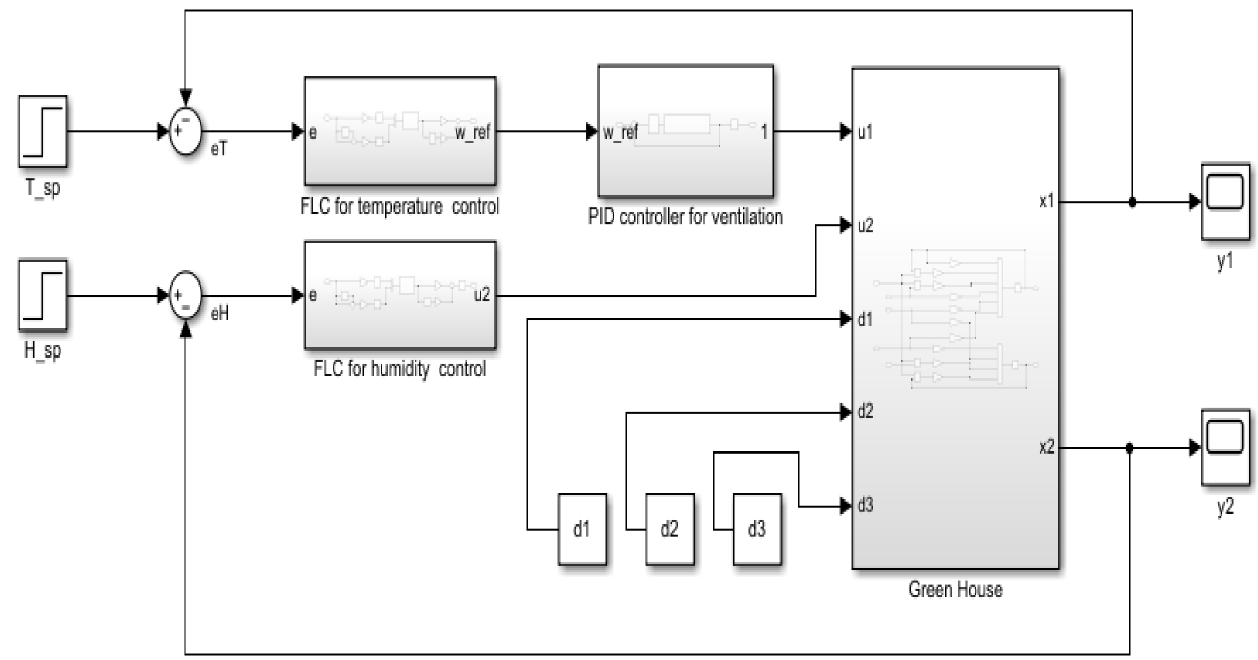


Figure: 4.12. Simulink block diagram of the general proposed greenhouse system.

CHAPTER FIVE

SIMULATION RESULT AND DISCUSSION

5.1. Performance test of the proposed controller for greenhouse system

Table 5.1 Parameter Setting of the Greenhouse Model and FLC System Parameter and Controller Parameters compiles the parameters and their values of the greenhouse climate system model at a nominal state for use in a variety of simulation operations.

Table: 5.1. Operation of the greenhouse system model's parameters and values (Hu et al., 2010).

Parameters	Values	Unit
Heat transfer coefficient of enclosure (U)	29.80	[W/°C^{-1}]
(Co)	-322	[minW/°C^{-1}]
The number of air changes per unit time Inverse (tv)	3.41	[min]
Maximum greenhouse volume per unit of fog water supply (V')	0.0752	[g/m3min]
Alpha (α)'	0.0033	[g/m3minW]
Lamda (λ)'	465	[W]
Fogging rate (q_{fog})	0 to 1	
Ventilation rate(V_r)	0 to 1	
Intercepted solar radiant energy (D_1)/S_i	300	[W]
Outside temperature (D_2)	35	°C
Outside humidity (D_3)	4	%

In this section, a number of simulation studies in accordance with the setpoint tracking and disturbance rejection tests of performance were carried out using MATLAB. When compared to PID controllers, It is assessed how effective the suggested controller is. Performance in tracking is gauged using a number of parameters, such as rise time (tr), settling time (ts), overshoot (Mp), and integral of absolute error (IAE).

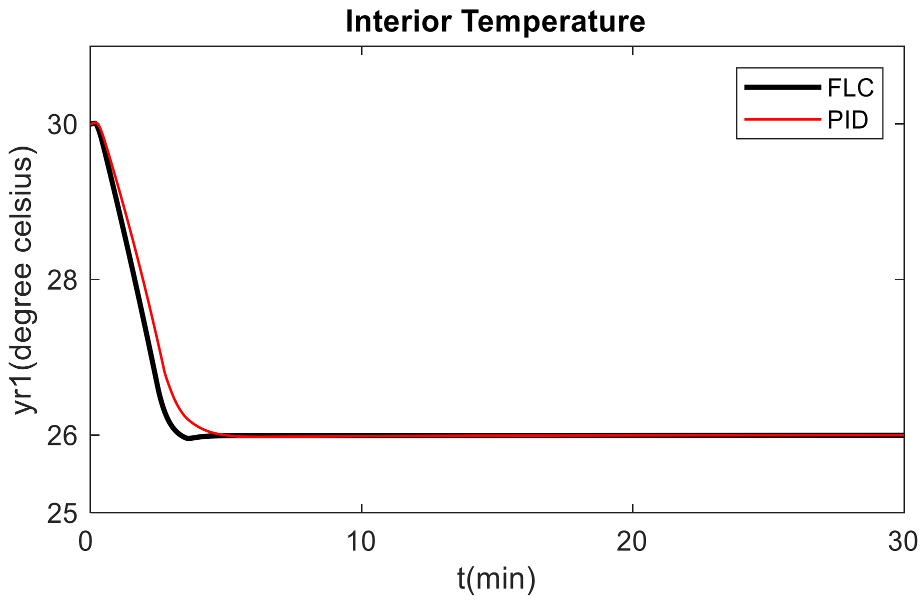
5.1.1. Setpoint Tracking Performance Test

The simulation starts with 300W, 35°C, and 4%, respectively, for the perturbations of the exterior air temperature, external humidity, and solar radiation energy intercepted. The temperature is initially set at 30 degrees Celsius, the relative humidity at 20%, and the ventilation and fog rates are likewise thought to be between 0 and 1. During the setpoint tracking tests, the values of yr1 and yr2, which stand for temperature in degrees Celsius and relative humidity rate in percentage, respectively, are modified while the disturbances are held constant. The simulation takes 30 minutes to complete.

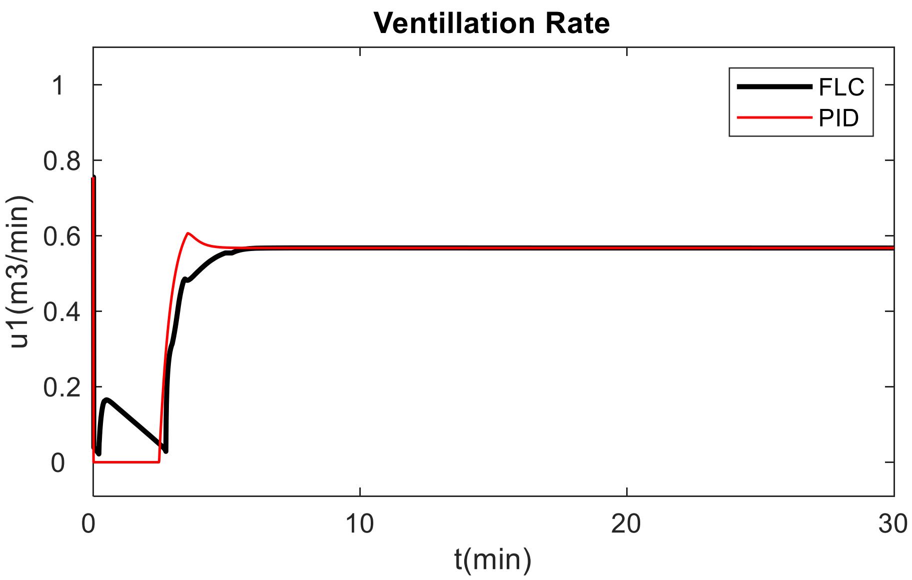
5.1.2. Case 1 of Indoor Humidity Simulation for Setpoint Change at Constant Temperature

Throughout summer, when bright sunshine causes it to rise, it is necessary to lower the interior air temperature to the range that is suitable for greenhouse plants. To achieve this, a realistic cooling procedure is employed. The target setpoint (yr2) for indoor humidity air is altered for 24% and 16% while the setpoint (yr1) for interior temperature remains fixed at 26 °C.

The satisfactory operation of both controllers is shown in Figure 5.1(a). The results show that the FLC maintains acceptable overshoot while responding to temperature setpoint changes more quickly compared to the PID controller. Table 5.2 provides an overview of the quantitative comparison of the control strategies. The rising and settling times are both faster with the FLC. It is crucial to drop the interior air temperature to the ideal range for greenhouse plants throughout the summer, when intense sunlight causes it to rise. A practical cooling process is used to accomplish this. While the setpoint (yr1) for interior temperature remains fixed at 26 °C, the target setpoint (yr2) for indoor humidity air is changed for 24% and 16% in this simulation. Figure 5.1(a) demonstrates that both controllers operate satisfactorily. The outcome demonstrates that the FLC responds more quickly to temperature setpoint changes than the PID controller while maintaining acceptable overshoot. Table 5.2 provides a summary of the quantitative comparison of the control approaches. Compared to the PID controller, the FLC provides a faster rise time, a faster settling time, and a smaller IAE.

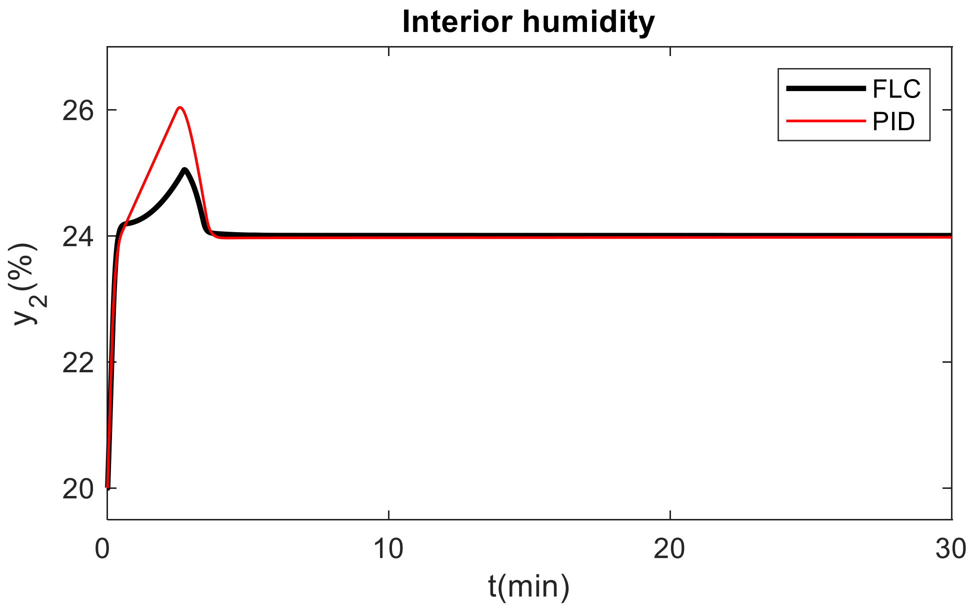


(a)

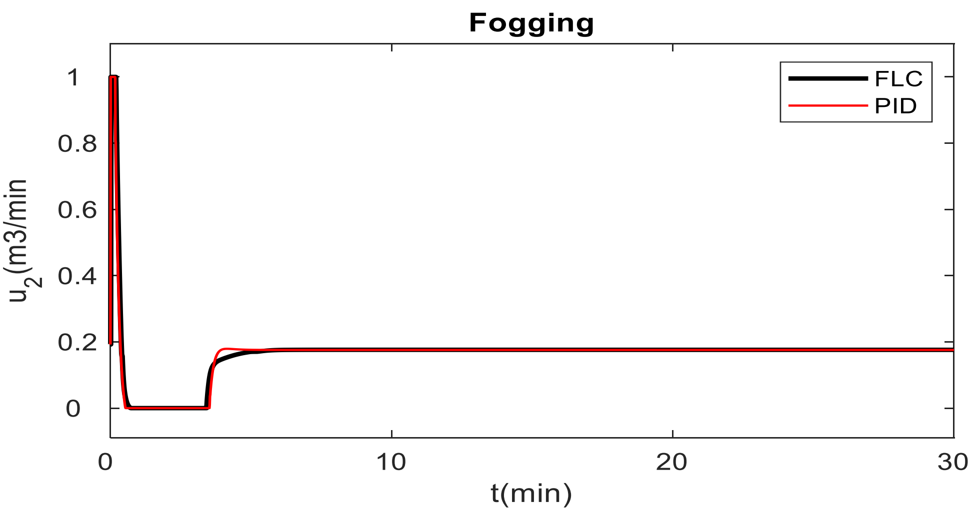


(b)

Figure: 5.1. FLC and the PID controllers for interior temperature and ventilation rate case1.



(c)



(d)

Figure: 5.2. FLC and the PID controllers for inside humidty (c) and fogging rate (d) for case 1.

Figure 5.2 (c) shows how indoor humidity reacts when yr1 is held constant while yr2 is increased from 20% to 24%. The figure shows that the FLC performs better in terms of regulation

Case 1 quantitative performance evaluations

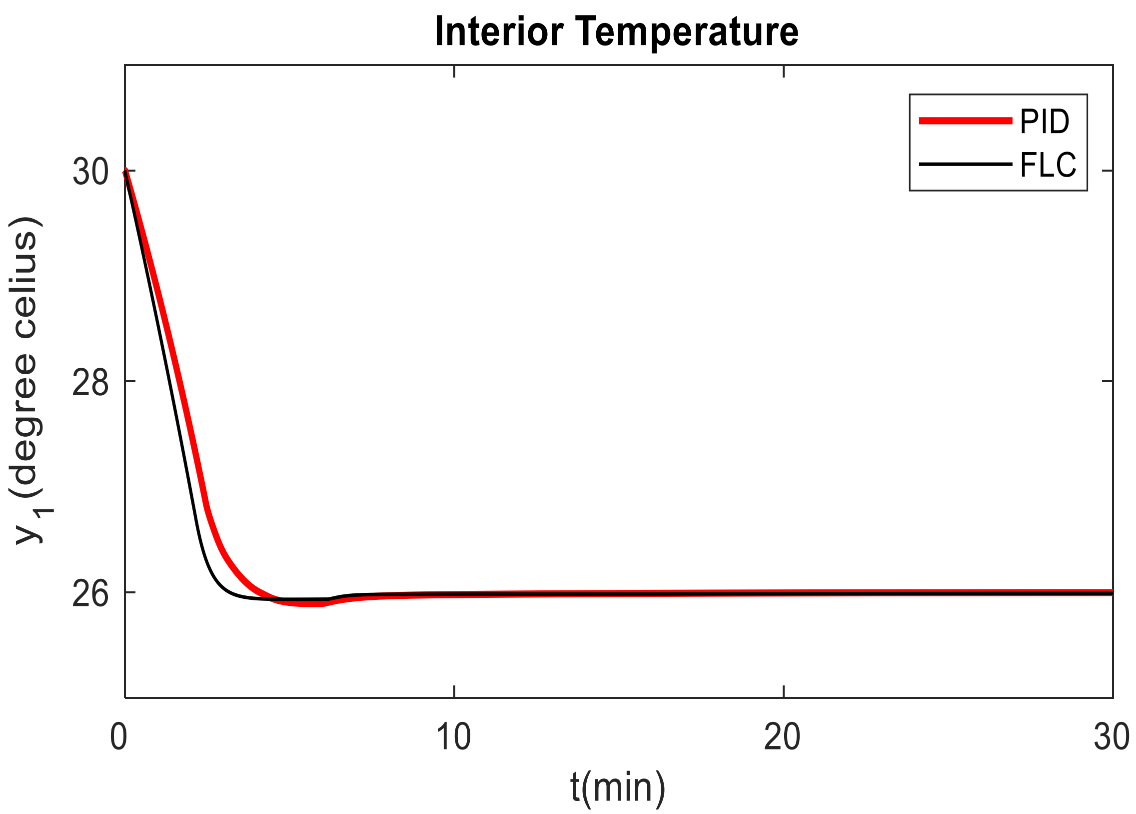
A quantitative performance test for a system is a methodological evaluation that involves measuring and assessing the system's performance using numerical metrics.

Table:5.2.Quantitative performance measures when yr1 is changed from 30℃ to 26℃ and the yr2 is from 20% to 24%.

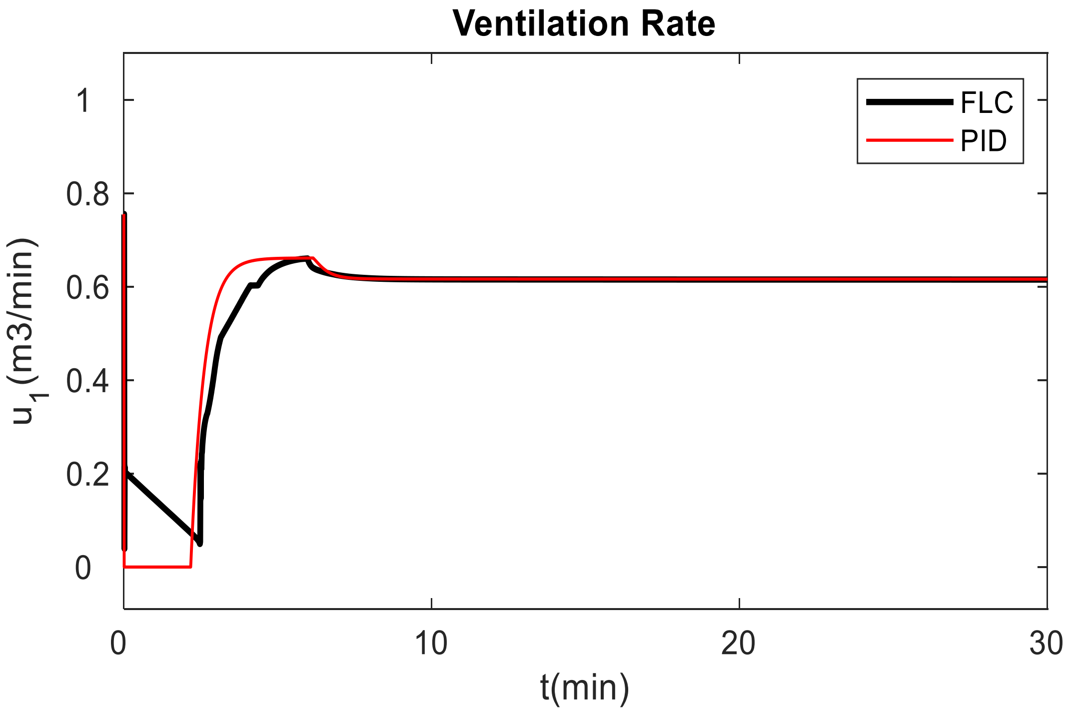
Performance Measure	Controller for Temperature		Controller for Humidity Rate	
	FLC	PID	FLC	PID
Rise time	2.080	2.498	0.256	0.293
Settiling time	2.861	3.598	3.429	3.567
Over Shoot	1.073	0.592	26.261	50.970
IAE	6.666	8.014	2.443	4.831

5.1.3. The simulation of a set point change of indoor humidity at constant temperature Case 2

During the summer season, when intense sunlight causes a rise in inside air temperature, it is essential to lower it to the optimal temperature for greenhouse plants. A smart cooling procedure is used to accomplish this. The desired setpoint (yr2) for interior humidity air is reduced from 20% to 16% in this scenario. it is decrease while the setpoint (yr1) for indoor temperature remains constant at 26 ℃.

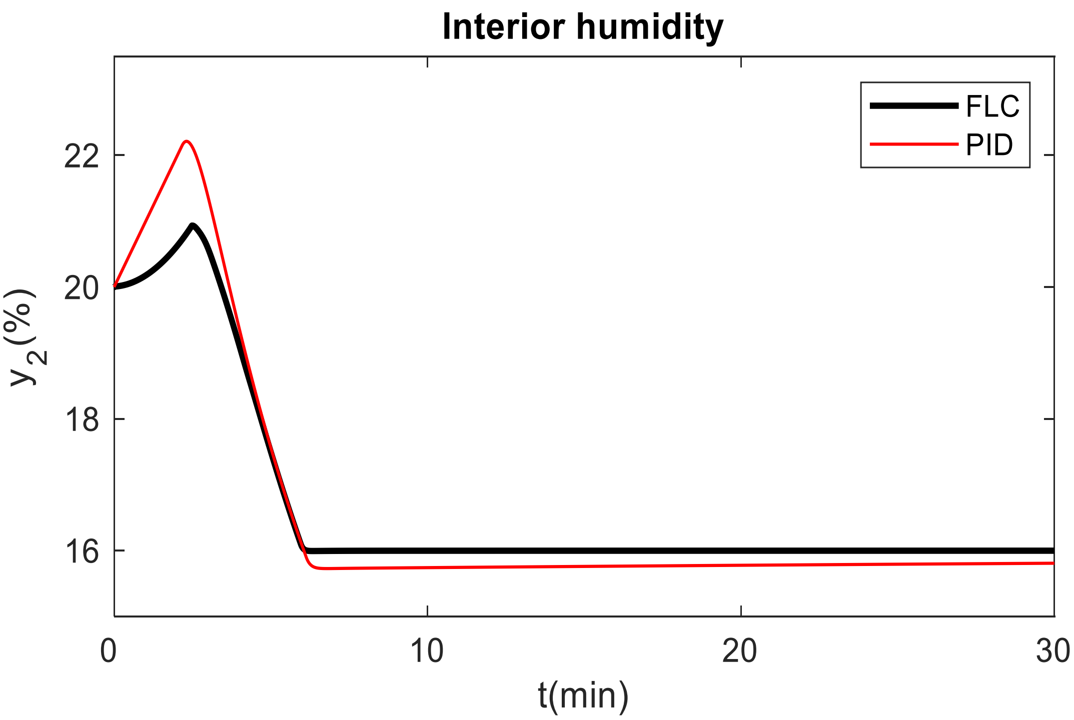


(a)

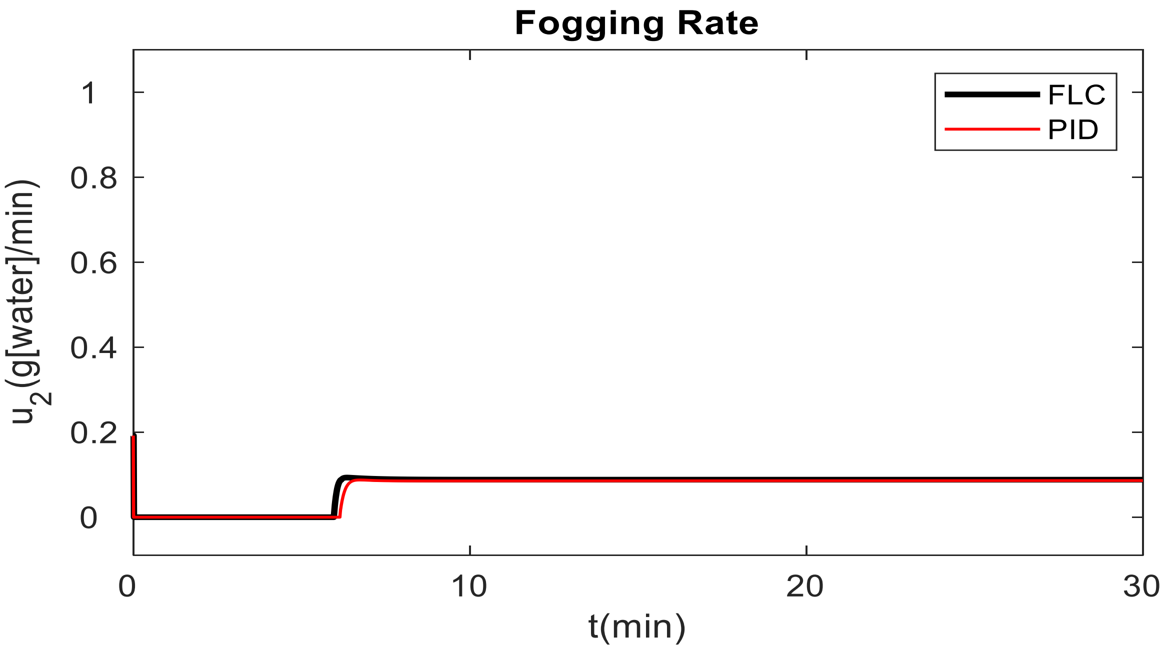


(b)

Figure: 5.3. FLC and the PID controllers for interior humidty (a) and fogging rate (b) case 2.



(c)



(d)

Figure: 5.4. FLC and the PID controllers for interior humidty and fogging rate case 2.

Quantitative performance tests for Case 2

A quantitative performance test for a system is a methodological evaluation that involves measuring and assessing the system's performance using numerical metrics.

Table:5.3.Quantitative performance test of temperature and humidity rate for case 2.

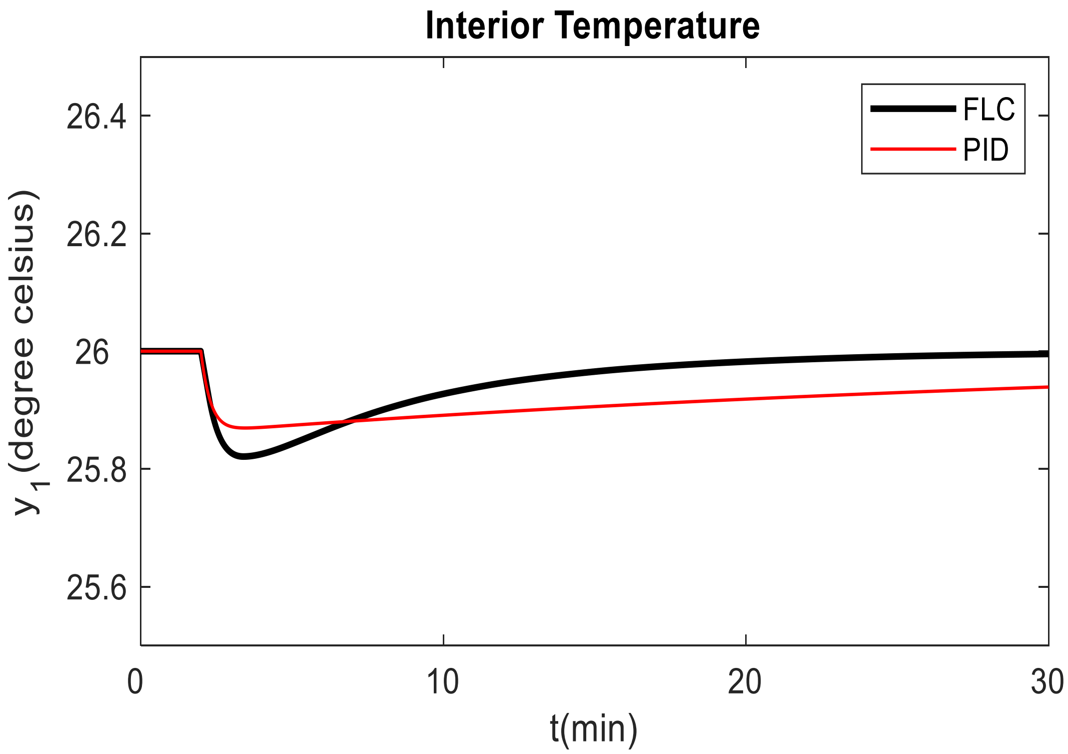
Performance Measure	Controller for Temperature		Controller for Humidity Rate	
	FLC	PID	FLC	PID
Rise time	2.090	2.590	2.052	1.886
Settiling time	2.615	3.376	5.848	5.827
Over Shoot	1.632	2.647	0.163	6.825
IAE	5.929	7.154	20.197	29.027

5.1.4. Case 3 Disturbance Rejection Performance Test

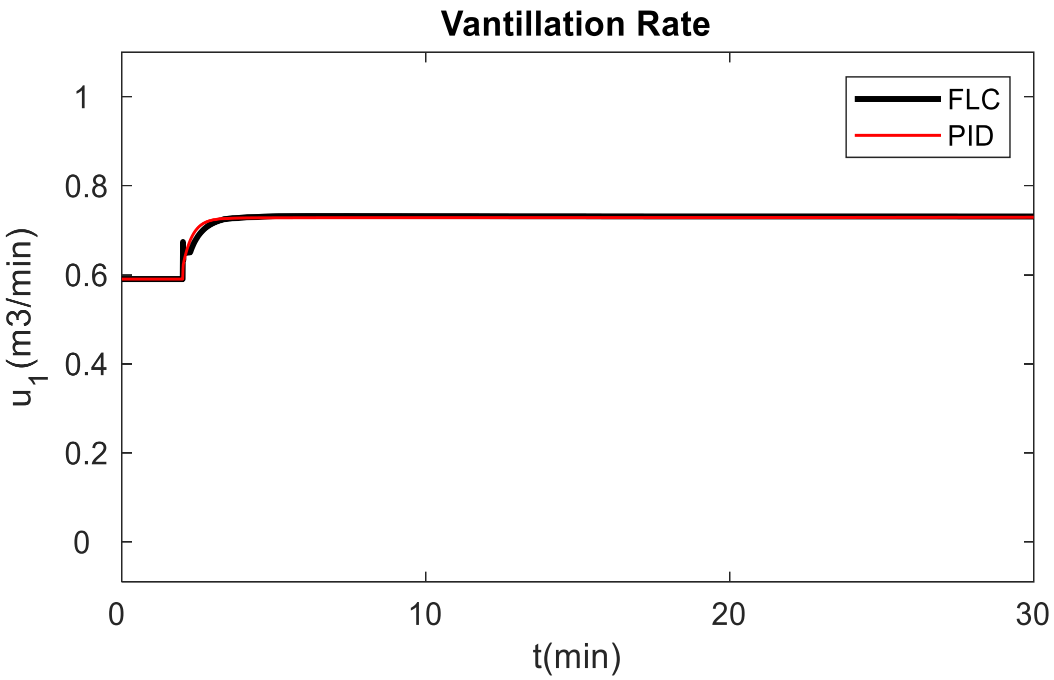
External disruptions have a substantial impact on greenhouse systems, especially solar radiation, outdoor temperature, and outdoor humidity, as one might anticipate. The greenhouse system is significantly influenced by solar radiation and ambient temperature, particularly during the summer. Using a variety of performance metrics, this thesis compares and contrasts PID controllers with the suggested controller's resilience in rejecting these disturbances. The simulation lasts for thirty minutes. The disturbances are altered while the setpoints stay the same, much like the setpoint tracking performance test.

5.1.5. Fixed inside temperature and humidity and for Disturbances Increase

Plants are unable to withstand the high temperatures brought on During the summer, heat is caused by sun radiation and the surrounding temperature. As a result, anytime the system is impacted by solar radiation and outside temperature in both disturbance parameters d1 from 300W to 500W and d2 from 35°C to 37° d3 are constant, the controller's duty is to maintain the ideal indoor temperature and humidity levels.



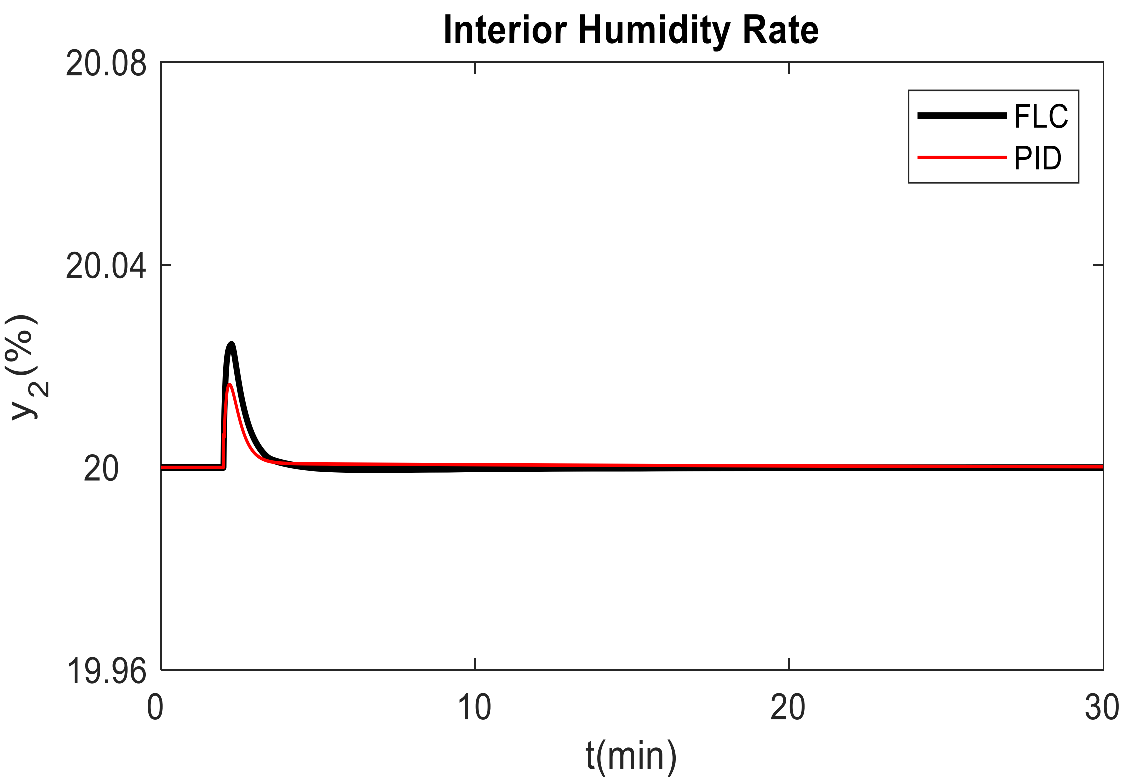
(a)



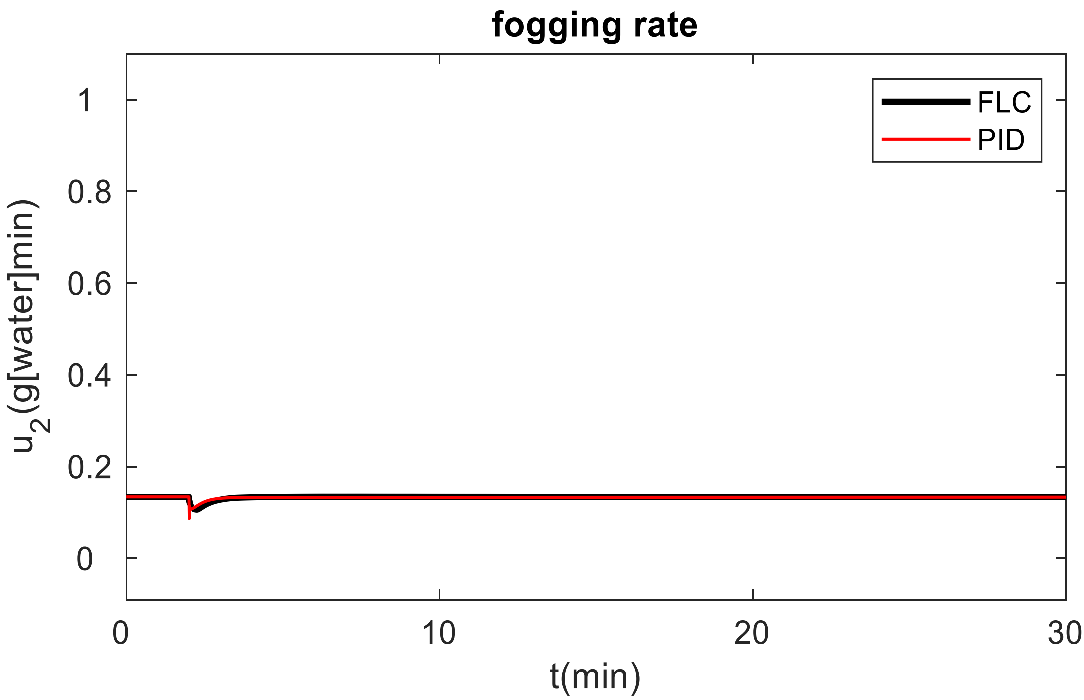
(b)

Figure: 5.5. FLC and the PID controller responses of interior Temperature (a) and vantillation rate (b) for case 1.

Figure:5.6 shows the disturbance rejection test for both controller performance test applied by some time.



(c)



(d)

Figure: 5.6. Disturbance rejection test of FLC and the PID controllers (a) for interior humidty and (b) fogging rate case 3.

CHAPTER SIX

SUMMARY AND RECOMMENDATION

6.1. Conclusion

Out of all of these variables, indoor air temperature and humidity have the biggest impact on greenhouse plant development and quality. For the purpose of generating a favorable climate that fosters plant growth, development, and overall crop quality, it is imperative to maintain appropriate temperature and humidity levels. The psychrometric law links these parameters together. In this work, fuzzy logic controllers are used for the first time to control the greenhouse's inside environment. The research gives a clear overview of the advantages of utilizing fuzzy logic to address issues that are challenging to examine using conventional analytical techniques but are amenable to being quickly resolved using linguistic variables.

The proposed greenhouse system is highly nonlinear and interacts (couples) with its parameters to demonstrate the complexity of the system model. Due to this issue, the greenhouse system's loss of performance is the cause of poor production quality, and it will eventually help in the construction of sophisticated control systems for various applications in industry for management.

The effectiveness of the suggested practical PID controller technique was also evaluated using the greenhouse's nonlinearity model.Determine PID parameters using the tria and error approach. The performance of the controller was assessed using a setpoint tracking test and a disturbance rejection test. Performance metrics are utilized in tracking tests, such as settiling time, overshoot, IAE, and rising time, to compare the performance of both controllers.

The controllers were developed and simulated using MATLAB/Simulink to test the efficacy of the suggested control approaches. The thorough results of this investigation reveal that the FLC controller performs better than other controllers when both In GH, there exist conditions for setpoint tracking and disturbance rejection.

6.2. Recommendation

However, given that the greenhouse system is coupled and has highly nonlinear features, more research must be done on the the effectiveness of greenhouses over an extended length of time. This is because this is a hot research field or concern for the system. Due of the substantial economic potential it holds for Ethiopia, this research has been done. The majority of greenhouse systems in the nation today use manual humidification and natural ventilation to control the internal climate. However, the majority of greenhouse facilities employ a manual technique to regulate temperature, heating rate, humidity, and fogging rate, which increases the possibility of mistakes and lowers the quality of the output. Horticulture organizations can gain from greater production, lower labor expenses, and improved system management by adopting this innovative technology.

Furthermore, the use of such sophisticated control systems paves the way for ongoing innovation and the possibility of future breakthroughs in greenhouse technology.

- Using multi-objective optimization methods, such as solar and geothermal systems, to reduce energy usage.
- It is necessary to continue putting new research findings into practice in the greenhouse industry.
- As far as we are aware, horticulture areas are mostly supported by private internal and foreign investment. The most resource-researched country is ours.The government works to include public investment for revenue production and to reduce the number of educated persons without jobs in this lucrative industry.

Research fund Acknowledgment

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APPENDIX

Proposed greenhouse system rule and model of fuzzy logic controller

[System]

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Type='mamdani'

Version=2.0

NumInputs=2

NumOutputs=1

NumRules=19

AndMethod='min'

OrMethod='max'

ImpMethod='min'

AggMethod='max'

DefuzzMethod='centroid'

[Input1]

Name='E'

Range=[-1 1]

NumMFs=7

MF1='NB':'trimf',[-1.333 -1 -0.6667]

MF2='NM':'trimf',[-1 -0.6667 -0.3333]

MF3='NS':'trimf',[-0.6667 -0.3333 -5.551e-17]

MF4='ZO':'trimf',[-0.3333 0 0.3333]

MF5='PS':'trimf',[-5.551e-17 0.3333 0.6667]

MF6='PM':'trimf',[0.3333 0.6667 1]

MF7='PB':'trimf',[0.667 1 1.33]

[Input2]

Name='CE'

Range=[-1 1]

NumMFs=7

MF1='NB':'trimf',[-1.33854334038055 -0.99854334038055 -0.67084334038055]

MF2='NM':'trimf',[-1 -0.667 -0.333]

MF3='NS':'trimf',[-0.6667 -0.3333 -5.551e-17]

MF4='ZO':'trimf',[-0.337528329809725 -0.00422832980972521 0.329071670190275]

MF5='PS':'trimf',[-5.551e-17 0.3333 0.6667]

MF6='PM':'trimf',[0.3333 0.6667 1]

MF7='PB':'trimf',[0.6667 1 1.333]

[Output1]

Name='U'

Range=[-1 1]

NumMFs=7

MF1='NB':'trimf',[-1.333 -1 -0.6667]

MF2='NM':'trimf',[-1 -0.6667 -0.3333]

MF3='NS':'trimf',[-0.6667 -0.3333 -5.551e-17]

MF4='ZO':'trimf',[-0.3333 0 0.3333]

MF5='PS':'trimf',[-5.551e-17 0.3333 0.6667]

MF6='PM':'trimf',[0.3333 0.6667 1]

MF7='PB':'trimf',[0.6667 1 1.333]

[Rules]

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4 2, 2 (1) : 1

4 3, 3 (1) : 1

5 3, 4 (1) : 1

7 3, 6 (1) : 1

1 4, 1 (1) : 1

2 4, 2 (1) : 1

3 4, 3 (1) : 1

4 4, 4 (1)

The Simulink model of the temperature and humidity controlling system