DESIGN AND DEVELOPMENT OF ENERGY EFFICIENT TEMPERATURE CONTROL OF AN EGG INCUBATOR SYSTEM

MASTER OF SCIENCE IN ENERGY TECHNOLOGY
M.Sc Engg. (ET)

Submitted by

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.

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Design and Development of Energy Efficient Temperature Control of an Egg Incubator System

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APPROVAL BY THE SUPERVISOR

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DEDICATION

Dedicated to

My Father and Mother

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ABSTRACT

To meet the high demand for poultry production, artificial egg hatching is needed. An incubator is a device that is used to successfully hatch fertile eggs under suitable environmental conditions by regulating the temperature and humidity of the enclosure. Temperature and humidity are the parameters that are controlled in hatching egg incubators in the poultry industry worldwide. There are two types of incubators: conventional and automatic egg incubators. Incubation conditions depend on the hatchability of the birds. Inappropriate temperature and humidity levels result in unwanted conditions during incubation. So, temperature and humidity control in an incubator are critical during incubation. The source of power in an incubator is electrical energy. The proper use of energy is an important factor. Controlling the temperature of an egg incubator system can reduce electrical energy consumption. In this research, different kinds of incubators have been discussed, and a new energy-saving egg incubator has been introduced. The possibility of the most suitable temperature for hatching an egg is about 35–40 °C; however, the optimum temperature should be kept at 37.5°C and humidity should be kept at 55%–60% during the 21 days of incubation. A normal conventional controller is usually used in the local poultry farms. The power consumption was about 56.08 kWh during the 21 days of incubation. For energy savings, a PID Control System was used with an Arduino UNO AT Mega 328P Microcontroller. Power consumption was recorded at 44.77 kWh during the 21 days of Incubation. For further development of the temperature control of this system, a fuzzy-PID controller is used and simulated, which has improved the temperature rise time and settling time compared to the conventional egg incubator. During the experimental operation, the power consumed was about 41.58 kWh for 21 days of Incubation. The result shows that PID control is more energy efficient than conventional controllers. However, Fuzzy-PID is more energy efficient than a PID Controller. Finally, it is found that a lot of energy has been saved because of the use of Fuzzy-PID and PID controllers instead of conventional controller.

সারাংশ

পোল্ট্রি উৎপাদনের উচ্চ চাহিদা মেটাতে কৃত্রিম ডিম ফুটানো প্রয়োজন। ইনকিউবেটর হল এমন একটি যন্ত্র যা ঢের তাপমাত্রা এবং আর্দ্রতা নিয়ন্ত্রণ করে উপযুক্ত পরিবেশগত পরিস্থিতিতে সফলভাবে উর্বর ডিম ফুটতে ব্যবহৃত হয়। তাপমাত্রা এবং আর্দ্রতা হল সেই পরামিতি যা বিশ্বব্যাপী পোল্ট্রি শিল্পে ডিমের ইনকিউবেটর হ্যাচিংয়ে নিয়ন্ত্রিত হয়। দুটি ধরণের ইনকিউবেটর রয়েছে: প্রচলিত এবং স্বয়ংক্রিয় ডিম ইনকিউবেটর। ইনকিউবেশন অবস্থা পাখির হ্যাচবিলিটির উপর নির্ভর করে। ইনকিউবেশনের সময় অনুপযুক্ত তাপমাত্রা এবং আর্দ্রতার মাত্রা অবাঞ্ছিত অবস্থার সৃষ্টি করে। সুতরাং, ইনকিউবেশনের সময় ইনকিউবেটরে তাপমাত্রা এবং আর্দ্রতা নিয়ন্ত্রণ গুরুত্বপূর্ণ। ইনকিউবেটরে শক্তির উৎস হল বৈদ্যুতিক শক্তি। শক্তির সঠিক ব্যবহার একটি গুরুত্বপূর্ণ বিষয়। ডিম ইনকিউবেটর সিস্টেমের তাপমাত্রা নিয়ন্ত্রণ বৈদ্যুতিক শক্তি খরচ কমাতে পারে। এই গবেষণায়, বিভিন্ন ধরণের ইনকিউবেটর নিয়ে আলোচনা করা হয়েছে, এবং একটি নতুন শক্তি-সাশ্রয়ী ডিম ইনকিউবেটর চালু করা হয়েছে। ডিম ফোটার জন্য সবচেয়ে উপযুক্ত তাপমাত্রার সম্ভাবনা প্রায় 35-40 ডিগ্রি সেলসিয়াস; তবে, ইনকিউবেশনের 21 দিনের মধ্যে সর্বোত্তম তাপমাত্রা 37.5 ডিগ্রি সেলসিয়াস এবং আর্দ্রতা 55%-60% রাখতে হবে। একটি সাধারণ প্রচলিত নিয়ামক সাধারণত স্থানীয় পোল্ট্রি খামারগুলিতে ব্যবহৃত হয়। 21 দিনের ইনকিউবেশনের সময় বিদ্যুত খরচ ছিল প্রায় 56.08 kWh। শক্তি সঞ্চয়ের জন্য, একটি পিআইডি কন্ট্রোল সিস্টেম একটি Arduino UNO AT Mega 328P মাইক্রোকন্ট্রোলারের সাথে ব্যবহার করা হয়েছিল। ইনকিউবেশনের 21 দিনের সময় বিদ্যুত খরচ 44.77 kWh রেকর্ড করা হয়েছিল। এই সিস্টেমের তাপমাত্রা নিয়ন্ত্রণের আরও উন্নয়নের জন্য, একটি অস্পষ্ট-পিআইডি নিয়ামক ব্যবহার করা হয় এবং সিমুলেট করা হয়, যা প্রচলিত ডিম

ইনকিউবেটরের তুলনায় তাপমাত্রা বৃদ্ধির সময় এবং নিষ্পত্তির সময়কে উন্নত করেছে। পরীক্ষামূলক অপারেশনের সময়, 21 দিনের ইনকিউবেশনের জন্য প্রায় 41.58 kWh বিদ্যুৎ খরচ হয়েছিল। ফলাফল দেখায় যে পিআইডি নিয়ন্ত্রণ প্রচলিত কন্ট্রোলারের চেয়ে বেশি শক্তি দক্ষ। যাইহোক, ফাজি-পিআইডি একটি পিআইডি কন্ট্রোলারের চেয়ে বেশি শক্তি দক্ষ। অবশেষে, দেখা গেছে যে প্রচলিত কন্ট্রোলারের পরিবর্তে ফাজি-পিআইডি এবং পিআইডি কন্ট্রোলার ব্যবহারের কারণে প্রচুর শক্তি সঞ্চয় করা হয়েছে।

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NOMENCLATURE

Symbol	Meaning
A	Current
AC	Alternative Current
°C	Degree Celsius
DC	Direct Current
e	Error
ec	Changing Error
FLC	Fuzzy logic Control
K_P	Proportional Gain
K_I	Integral Gain
K_D	Derivative Gain
LED	Light Emitting Diodes
PCC	Pearson Co-relation Coefficient
PID	Proportional Integral Derivatives
PWM	Pulse width Modulation
USB	Universal Serial Bus
V	Voltage
W	Watt

CHAPTER- I

INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

Bangladesh is a densely populated country with 160 million people and a total area of 147,570 square kilometers. National population growth is high, so the demand for protein sources is necessary for health and well-being [1]. For the growth of protein, poultry farming is one of the necessary ingredients for the current purpose. So the farmer and scientist are paying attention to the production and development of poultry farming [2]. In 2016, the global annual meat production by UN Agricultural Outlooks had to reach 320.7 million metric tons meat and poultry has reached 12.7 million metric tons meat total [3]. To improve nutrition and food security for national demand, poultry farming is a good solution for the Sustainable Development Goal (SDG). It can improve the income capacity of rural entrepreneurs and contribute to the national economy [4]. Natural Incubation performed by broody hens has low efficiency. The global yearly meat expenses per person are developing day by day, and to reach the 35.3 kg retail weight equivalent by 2025, it will come from poultry sites. Poultry is one of the ways to acquire an excellent protein source [5-7]. Sustainable poultry farming can promote the sustainable improvement goals of ending hunger, improving nutrition, achieving food security, and promoting sustainable agriculture [8]. In our countries, poor farmers and non-farmers live in poultry farming [9]. It is a regular income source for the poor farmers and village entrepreneurs [10].

For an automatic egg incubator, an artificial environment allows for the necessary temperature, humidity, regular turning of the eggs, and ventilation [11]. Poultry farming helps sustain the development of the village economy and limits urban migration. The conception of eggs is one of the significant factors when operating a poultry farm. It is possible to hatch the eggs at home without the mother chick sitting on them. It takes about 21-days to incubate these chicken eggs with control over their temperature, humidity, and turning of the eggs. Some eggs get spoiled when several factors such as temperature, egg turning, and humidity are not maintained properly [12]. For the incubation of the fertile eggs and their hatching, a proper environment is needed. Conventional and automatic, two types of incubators are being used worldwide. The artificial incubator has two main types: forced air and still air. A conventional incubator cannot maintain temperature and humidity properly. So the poultry farmers cannot hatch the eggs properly.

The energy in the world is limited. The power source of an incubator system is electrical energy. The lack of electricity in our country is the main problem. So an energy-efficient incubator is needed. An energy-efficient egg incubator can minimize the energy consumption as well as the energy cost. So the aim of this research is to simulate and implement an energy efficient egg incubator system that can save energy compared to conventional incubator systems. By applying the fuzzy-PID control method, the system can save more energy than a conventional incubator system, and by controlling the temperature efficiently, it can increase hatching efficiency.

1.2 PID CONTROLLER

PID control systems are manually optimized and exact control systems that are used to regulate different parameters like temperature, speed, and pressure at expected values. A PID controller can calculate the error value, which is measured as the difference between a process variable and the desired set point. The controller has tried to minimize the error by adjusting the proportional, integral, and derivative values, denoted P, I, and D. This kind of error is continuously calculated until the process has stopped. Temperature Control is the best example to understand the control of PID.

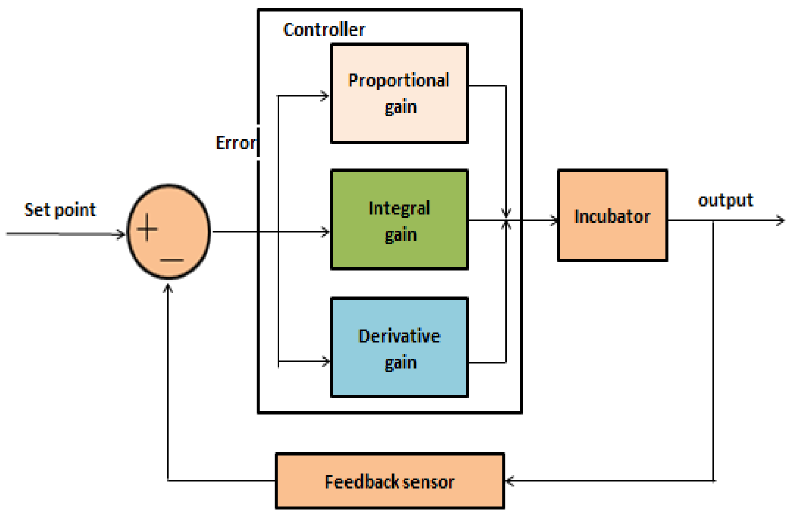

Figure: Block Diagram of PID Control Monitoring Process

The PID control system has been utilized to regulate the temperature and produce the effects for all economic and commercial processes.

The Mathematical function of PID Controller can be given as

$$u(t)= K_P\, e(t) + K_I e(t)dt + K_D \frac{de(t)}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Here, K_P, K_I, K_D is the coefficient of Proportional, Integral and Derivative gain in PID control system

1.2.1 Proportional Controller:

The Proportional gain generated an output value that is a proportional value, which is the current error. The improved proportional gain has big changes in the output due to the changing error. If the proportional gain is too high, then the system will become volatile. A proportional controller is one that can maintain a stable proportional gain by multiplying the error by a constant KP.

$$P= K_P\, e(t) \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

1.2.2 Proportional Integral Controller:

An integral controller can eliminate the steady-state error that occurs with a proportional gain. The principle function of the integral action is to make sure that the process of output agrees with the set point in a steady state. The integral gain function is developed as follows:

$$PI= K_P\, e(t) + K_I e(t)dt \ldots\ldots\ldots\ldots\ldots (3)$$

1.2.3 Proportional Derivative Controller:

The objective of the derivative function is to promote a closed-loop system. The control system will be late in correcting errors. The objective of a control system is proportional gain, and derivative gain can be explained if the control system is made of proportional gain calculated for the output process where the calculation is expected. The derivative gain function is developed as follows:

$$PD= K_P\, e(t) + K_D \frac{de(t)}{dt} \ldots\ldots\ldots\ldots (4)$$

1.3 FUZZY LOGIC CONTROL

For controlling the temperature, various kinds of techniques have been applied worldwide, including artificial intelligence techniques such as conventional PID, fuzzy self-tuning PID, fuzzy logic control, etc. [14]. Fuzzy logic has valuable logic where the quality is real numbers lying between 0 and 1. In the conventional method, 0 is considered an entire false while 1 is considered an entire truth. Thus, fuzzy logic comes in the presence where the partial truth is mixed up, ranging from fulfilled truth to complete false [15]. Fuzzy logic is important for the improvement of AI techniques so that software is presented on an unfamiliar task. It can find the solution just like a human being. Fuzzy logic is around the same as a human reasoning system. It can involve the possibilities between a Digital 'YES' or 'NO'. The transformation computer easily realizes precise inputs, which is 'YES' if 1 and 'NO' if 0. A relative study was done between the PI and Fuzzy controller discussions where the design is implemented using Fuzzy logic [16]. The Fuzzy Controllers understand the output control, which is stable and improved. It has been requires the settling time than the PI controller and removes the overshoot present on the PI Controller. An instant switch was setup to discard the fuzzy logic during an emergency situation. Simulation was done on the MATLAB Simulink to experiment with the FLC design and temperature control consequently. Fuzzy-adaptive PID control is one kind of system that has effective and self-directing control of Fuzzy PID parameters [17]. It can sustain, manipulate, and control the data of an incubator.

For the temperature control in the system, fuzzy tuning PID is using an all-over-the-world algorithm that is active and completes easily. There is unlimited solicitation by the FLC. Various researchers had claimed that fuzzy logic is an adjacent knowledge all over various types of logic control [18]. FLC has IF-THEN fuzzy rules that are controlled for decision making. FLC design is completed by the system error, which is determined by using computer simulations. PID controllers have various applications for fuzzy controller improvement around the world in many different types of industries [19-21]. FLC is the control system that can use IF-THEN fuzzy rules for decision making. The FLC system can determine the error and change the error via MATLAB simulation [22].

This research mainly focuses on designing a new temperature control for the incubator using a fuzzy self-tuning PID algorithm. The objective of this system is to develop temperature control and minimize fluctuation. Fuzzy logic controllers are the principle branch of temperature control. It has mainly combined the mathematical model with human experience of the proposed system. It controls the temperature inside the incubator. It can help promote the various active concepts for the development of reliability control in the incubator. The system has settling time, Rise time, and overshoot have been minimized compared to conventional PID by using fuzzy tuning PID.

1.4 INCUBATOR

The incubator is a device that is used to regulate environmental conditions such as humidity, temperature, fresh air flow, and turning eggs at regular intervals in an enclosure to hatch the fertile eggs successfully. Incubators recreate the role that a broody hen plays in nature. It is a mechanical machine that controls temperature to around 37.5°C and humidity to create the ideal conditions that allow the chick to grow inside the fertile eggs without a broody hen. The incubator is used for hatching bird eggs in an insulated, warm container for the hatching eggs, which artificially performs a role that the broody hen plays in nature. It lets the fetus inside the eggs grow without the mother hen needing to be present to provide warmth condition. [23]. There are two types of incubators available: conventional Egg incubators and Automatic Egg incubators.

There are two types of incubators mostly used in Bangladesh: conventional and automatic egg incubators. Regional Poultry Farm is a well-known poultry farm in Chattogram that is located at pahartoli, Khulsi. The following data was obtained from this poultry farm. There are two setters and one hatcher. Each setter contains 33600 eggs. Temperature and humidity are maintained at 37.78°C and 80–85%, respectively, for the first 18 days. There are 12 heaters, 2 fans, and one cooler. A candelar is used for testing the embryos of the eggs after 7 days. Trays are turned 45° via a gear motor after one hour. After 18 days, during the hatching time (3 days), the temperature is kept at 36.67°C and the humidity is kept at 75%. They had used one fan in the hatcher. The hatchery contains 16800 eggs. The hatching efficiency is 80%. A generator is used during power failures. The system can increase the temperature using a heater, but the temperature can't be reduced. In the summer, if the room temperature rises above 100 °F, egg trays are manually removed from the incubator and ventilated [25].

1.4.1 Fertilized Eggs

Fertile eggs are those that contain both ova and sperm, and will develop into a baby chick if incubated. The process of hatching chicks requires good quality fertilized eggs when a hen and a cock/rooster mate [26]. Only fertile eggs will hatch into chicks. To achieve high hatch rates, only use fertile eggs that are less than 7 days old from the day they were laid. The difference between infertile and fertile eggs contents if you have very sharp eyes

1.4.2 Ideal Incubation Temperature and Humidity

The temperature should be kept between 37°C and 38°C, but the optimum temperature is 37.5°C. The ideal incubation temperature is 37.5°C [27]. The humidity should be kept at 55%–60%. The temperature reading usually lights up at the front of the incubator. The temperature variations between 36°C and 38°C are normal and fine for incubation.

1.4.3 Incubation Period

Chicken eggs take 21 days to hatch. From the day fertile eggs are placed in an incubator, expect the chicks to come out on Day 21 [28]. For instance, if the fertile eggs were placed in the incubator on the 7th day of the month, chicks should hatch starting on the 27th day and be left in the incubator for another 24 hours until the 28th day. All chicks should have hatched out of their shells, and their feathers should be properly dried.

1.4.4 Egg Setting

On Day 1, eggs are placed into the setter, where they will remain until the 18days. The egg setter is the part of the incubator that has a mechanism where the eggs can be turned automatically after one hour [29]. The egg turner tilts the eggs from side to side at continuous intervals. For manual setters, egg turning should have done at least

8 times a day. The purpose of turning eggs is to ensure that the egg contents (embryos) do not stick to the inside wall of the shell inside the egg, as this results in the chick's failure to hatch.

1.4.5 Candling

It is not always possible to tell if an egg is fertilized or not just by looking at it. Fertilized and non-fertilized eggs look the same from the outside in terms of egg shape and color. After 7 days, it is possible to know if the eggs are fertile or not using the candling process. On day 7 and again on day 12, look at embryonic development by holding eggs over a true bright light, a candling torch, or your phone’s torch [30]. Candling is better at night or in a dark room. With the pointed part facing down, you place the egg on top of the light source so that the light will shine through the egg. Healthy embryos will have veins resembling a spider’s web. Healthy embryos should show up dark and cover two-thirds of the egg on day 12. Bright, glowing eggs with no visible veins should be removed from the incubator as they are not fertile. Try to always sanitize your hands before touching the eggs to avoid contamination. Candling helps to identify the eggs with thin spots, cracks, and double yolks, and these kinds of eggs should be removed from the incubator.

1.4.6 Egg Transfer to the Hatcher

The eggs must be transferred from the setter to the hatcher, which is found in the incubator on Day 18. The hatcher is a part of the incubator where the eggs lie for 3 days of the incubation phase. The airflow and humidity are slightly higher in the hatchery. The hatcher is creating a stable environment for the eggs hatching [31]. The chick comes out of the egg shell. The hatching period is the most critical and sensitive stage. It should be avoided to open the incubator unnecessarily, and the power supply should not be interrupted. On Day 21, the chicks will start coming out of their shells. Chicks can be left inside the incubator for up to 24 hours after they have hatched. This will help them dry out and develop some downy feathers.

1.5 Specific Objectives and Possible Outcomes

1. To design a new fuzzy PID temperature control of an incubator.
2. Comparison between designed new and old temperature control system.
3. To develop temperature control strategy for energy saving operation.
4. To design a new fuzzy-PID Humidity control of an Egg Incubator.

Possible outcomes:

The following outcomes can be achieved with the help of this project:

1. Minimize the cost and energy consumptions of existing incubator system
2. Provide high performance of energy saving solution.
3. To delivered the proper humidity in the Egg Incubator

1.6 THESIS OUTLINE

Chapter-1: The introduction chapter contains background on the PID Controller, fuzzy-logic Control, incubator, and objectives and possible outcomes of the study.

Chapter-2: Literature Review consist of Temperature Control in the Egg Incubator

Chapter-3: Materials and Methodology consists of research study sites and equipment collection, designed components of equipment, experimental setup and methodology, fuzzy PID experiments, and simulation.

Chapter-4: Results and Discussion

Chapter-5: Conclusion and Recommendations

Chapter- II

LITERATURE REVIEWS

Several authors have done research on temperature control in the egg incubator in many ways. The sub-section presented some related research on battery-powered, solar-powered, biogas-powered, and grid-powered egg incubators. Several researchers have worked on Egg incubators for their hatching efficiency. They made incubators of various types and sizes and maintained the temperature control strategy in many ways.

Shehzad Zareen et al. (2016) [32] developed their hatching incubator with an 80 watt light bulb installed in the box as the heat source. They used a digital temperature control circuit that consists of a temperature sensor, a relay that turns on and off a 220V AC bulb and CPU fan, and a display unit to set the desired temperature. Humidity is controlled manually with a soaked cloth. The CPU fan and AC bulb are connected to the same port. A thermohygrometer is used for the measurement of temperature and humidity inside the incubator. The result shows that when the temperature exceeds 38 degrees centigrade, the temperature control circuit triggers the AC bulb to turn off. Humidity between 60% to 90% is maintained on a daily basis by filling the system with water. The authors used 6 eggs for the incubation. Two gray partridge eggs were found unfertilized. The hatching has been completed for 22 days.

Zain-Aldeen et al. (2017) [33] proposed a smart incubator based on a PID controller. In his research work, he used the Arduino board ATmega1280, Atmel AVR brain, which can be run by IDE software in C programming language via the Universal Serial Bus port. He also used the DHT-11 sensor for humidity sensing and the LM35 for temperature sensing. The Author showed the real-time calculated data, which included the humidity and temperature control in the egg incubator. In his research, he could use PWM technology for PID output voltage for the humidity and heat source. The author set the temperature at 37°C. And humidity is set to be 62%. In the experimental period, the total current drawn by the controller is 148 mA, and the maximum level voltage is 5 volts DC.

Salawu Ganiyat et al. (2020) [34] proposed the design of a portable solar powered solar incubator. The authors used a 200W, 12V battery, a DC to AC converter, a solar system, two pieces of tungsten 100-watt electric bulbs, including portable fan and egg turning trays which holding 30 eggs that the rotate trays 46.58° in the incubator. The experiment result shows that, the authors try to regulate the temperature to 37 °C to heat up the eggs during hatching. A water tray was used to maintain the humidity control in this research. The average humidity was 56.15°C. The authors attempted to fully hatch 95% of the eggs.

Frimpong Kyeremeh et al. (2017)[35] proposed the design and Construction of an Arduino microcontroller-based EGG Incubator. In their research, they created an incubator with dimensions of (75*60*40) inches, which can hatch 14000 quail eggs or 4500 equivalent chicken eggs. The system was designed via an Arduino microcontroller and used 3 incandescent 200-watt bulbs as heat sources, and fan for air circulation, water tray used for humidity control inside the incubator. Turning trays were used through the relays. The authors showed the result 94% hatch ability rate through this system.

S.K. Mousavi, et al. (2017) [36] have developed an incubator with the fuzzy logic controller. In this research work, he used fuzzy parts such as Temperature, oxygen, and moisture, which are the main parts in the incubator. They had attempted to express their good ability in expression with the born the eggs with an exact control of three fuzzy parts. In their research, they designed an incubator that can hatch 5000 quail eggs or 3500 equivalent chicken eggs. The system was designed via Arduino microcontroller and used 4 filament bulbs for heat sources and a fan for air circulation. A water tray was used for humidity control inside the incubator. The authors showed an 86% hatch ability rate through this system.

A.A. Sunday et al. (2020) [37] proposed the design and construction of an automated egg incubator for small scale poultry Farmers**.** In their research, the authors used 100-eggs hatching capacity incubator systems for small scale farmers. For the temperature control of this system, the author used an 89C51 microcontroller, and an LM35 is used for sensing the heat inside the incubator. A stepper motor is used for rotating the egg through an iron rod. A fan is used for proper air ventilation inside the incubator and humidity control throughout the system. A water tray is used at the bottom line of this system. The authors set the temperature and humidity between 37°–39°C and 55%, respectively. The ambient humidity and temperature are 42% and 33 °C, respectively. The result showed 95 fertile Eggs, 5 infertile eggs, 85 hatched eggs, and 84.89% hatchability after incubation.

M. Mariani et al, (2018) [38] proposed a design modification of a cost-efficient microcontroller-based egg incubator. In their research, the authors tried to make a cost-efficient egg incubator. The authors used an Arduino Uno R3, and an AT Mega 328 Microcontroller is used for operating the system. Two incandescent bulbs (25 watts) were used to provide a 36 to 38°C temperature inside the incubator. If the temperature falls below 36 degrees, the relay switch is automatically turned on; if the temperature has been rising above 38 degrees, the relay is turned off. A fan is used to circulate the air inside the incubator. The DHT11 sensor is used for temperature and humidity control, and the relay is used for switching the circuit. The authors used the same number of duck and chicken fertile eggs: 60 (both). The result found that 56 out of 60 duck eggs and 48 out of 60 chicken eggs hatched. The hatching efficiency range is 80–93%.

Pallavi Bhosale, et al. (2020) [39] had proposed the Development of a smart egg incubator system using Arduino. The authors are used 20–25 eggs were hatched in a smart egg in the incubator. In this system, an Arduino Uno board, two tungsten bulbs, each containing 40 W, provide temperature inside the incubator. A fan is used for air circulation, and a water tray is used for humidity control inside the incubator. The DHT11 sensor is used for measuring temperature. The author used 35–37 °C. When the temperature exceeds 37 degrees, the bulb is automatically turned off and the fan is on. When the temperature is below 35 °C, the bulb is automatically on and the fan is off. The author used a microSD card, and a DC motor was used for rotating the iron rod for positioning the egg. The authors showed a 92% hatch ability rate through this system.

Pascalin Tiam Kapen et al. (2020) [40] have proposed the design and prototyping of a low-cost, energy-efficient egg incubator in developing countries: A case study of Cameroon, The authors used a 600-capacity incubator. The Arduino Mega 2560 board's main circuit board is used to control the other modules based on SIM900 SIMCOM GSM in this system. Power supply, which receives 220V input and gives

12V, 5Vdc, and 30A of output power. An ultrasonic humidifier is used to generate humidity, and a DHT-22 sensor is used to sense temperature and humidity in the system. Maple software was used for numerical simulation in this system. The result found that eggs were incubated at 37°C and 45.5% humidity, and the hatching ability was 87.27%.

W.S. Mada Sanjaya et al. (2018) [41] proposed "The Development of Quail Egg Smart Incubator for Hatching System Based on Microcontroller and Internet of Things." In their research, the authors used 490 quail eggs for hatching in an incubator. Temperature, humidity, and the reversal of the egg were automatically controlled through an Arduino microcontroller. The incubator box was designed at 100*70*43 cm. 4 pieces of 5-watt lamps, 2 pieces of blower fans were used inside the incubator. Two DHT11 sensors were used for sensing the temperature and humidity data. A heater was used to fill it with water. The temperature and humidity ranges used were 36.5°C to 38.5°C and 55%-65%RH, respectively. A synchronous motor was used to turn the egg after 4 hours from right to left. The result found that the hatching rate was 85.55% during 17 days of incubation.

Susmita M. Chougule et al. (2021) [42] proposed a smart egg incubator. In their research, they used the Arduino Uno AT Mega168 and AT Mega328p, which have 28 pins and operate at 5V/40ma. For temperature and humidity control, they used LM35 and HS220. A stepper motor is used to rotate the egg at a 45 degree angle every 5 minutes. The systems are controlled via IOT. The temperature and humidity ranges are 98°F–102°F and 85-89%, respectively. The result found that hatching rate ability is 88.5%, defected eggs are 0.41%, 1.84% hatch but are dead, and 9.20% do not hatch out of 490 quail eggs during the 21-day incubation process.

Adegbulugbe T. A. et al. (2013) [43] proposed the development of an Automatic Electric Egg incubator. In their research, they made a 540-egg hatching capacity incubator. They used four 60-watt filament bulbs as the heating source for the incubator. For the turning trays with a 40° horizontal angle, every hour lasted 4 minutes. They used an electric gear motor (0.5 HP). Humidity was set at 58%–60% and temperatures ranged from 37°–39° centigrade during 18 days, but 37.5° centigrade was set for the best result until hatching. The result found that, the hatching ability was 84.06% out of 420 clean, healthy eggs during the 21-day incubation process.

Adam Faroqi et al. (2020) [44] proposed their method "Design of Arduino Uno-Based Duck Egg Hatching Machine With Sensor DHT22 and PIR Sensor". In their research, they used the Arduino Uno AT Mega328p microcontroller, which has 14 Uno pins. They used DHT22 for temperature and humidity, and a PIR sensor is used for measuring body temperature. In this system, temperatures range from 38°C to 40°C, and humidity is around 60–70%. The result found that the hatching ability was 95% during the 25 to 28-day hatching process.

Dr. Sunitha H. D. et al. (2020) [45] propose a "Universal Egg Incubation System for Hatching using Atmega328P, Proteus Design Tool, and IoT." In their research, they used an Arduino Uno (Atmega328P, a DHT 11 sensor for temperature and humidity control, and a Node MCU (ESP8266) for monitoring the overall system via a smart phone. Two 60-watt filament bulbs are used in this system. A low-speed DC motor is used for rotating the egg trays at a 45° angle. Temperature range 36°C–37°C and humidity kept 57% for the first 18 days, then increased 70% during the 21 days of incubation. The result found that the hatching ability was 93% out of 56 eggs.

Abu Musa Bin Mohammad Adid (2013) [46] developed his 20–25 egg capacity based smart egg Incubator system. The author had used PIC 18F4550 for controlling the system. The incubator was designed with a 39*48.4*48.4 cm wide incubator and four lamps 5W is used for temperature control in the chamber. A DC motor is used for rotating the egg roller fan, which is used for circulating the temperature through the Incubator. An LCD display is also used in this system. The result found that hatching rate ability is 88.5%, defected eggs are 0.31%, 1.50% hatch but are dead, and 8.20% do not hatch out of 25 quail eggs during the 21-day incubation process.

Siriluk, S. et al. (2011) [47] had developed a 30 egg capacity-based automatic egg Incubator. The author had designed (47×48×41) cm cabinet that was made from zinc sheet acrylic plastic outside the wall. The author used two halogen 60-watt Lamps, and two small fans were installed for air ventilation. AP104 is installed to control the temperature and humidity inside the incubator. In this system, temperatures range from 38°C to 40°C, and humidity is around 60–70%. For temperature and humidity control, they used LM35 and HS220. A stepper motor is used to rotate the egg at a 45-degree angle every 5 minutes. The result found that the hatching ability was 92% during the 21-day hatching process.

Ogunwande et al. (2015) [48] Development of a wooden frame still-air type incubator that uses fuel from biogas and supplies heat through the burner. The authors had reported irregular internal temperatures and lower hatchability in the egg incubator. It would be great if the biogas could continuously provide gas to sustain the incubator. The incubator was designed with a (39 cm*45 cm*48.4) cm wide chamber, and two 60 W lamps are used as heat sources through the chamber. In this system, temperatures range from 37°C to 39°C, and humidity is around 65–70%. A DC motor is used for rotating the egg roller fan, which is used to circulate the temperature through the Incubator. An LCD display is also used in this system. The DHT11 sensor is used for humidity and temperature control, and a relay is used for switching the circuit. The number of fertile chicken eggs used by the authors was 60. The results revealed that 52 out of 60 chicken eggs hatched. The hatching efficiency range is 80–88%.

Peprah et al. (2017) [49] developed their research about a 4500 chicken egg capacity air-forced egg incubator using an Arduino microcontroller. In his research work, he designed an incubator with dimensions of (60*50*40) inches. Four 200-watt lamps and two blower fans were used inside the incubator. Two DHT11 sensors were used for sensing the temperature and humidity data. A heater was used to fill it with water. The temperature and humidity ranges used were 36.5°C to 38.5°C and 55%–65% RH, respectively. A synchronous motor was used to turn the egg after 4 hours from right to left. The result found that the hatching rate was 87.55% during 21 days of incubation.

Fasanmi et al. (2013) [50] proposed the development of an automatic electric egg incubator. In their research, they made a 540-egg hatching capacity incubator. The author had designed (0.36×0.45×0.32) m cabinet, which was made from zinc sheet outside the wall. They had used four 60-watt filament bulbs as a heating source for the incubator. Humidity was set at 58%–60% and temperature was 37°–39° centigrade during 18 days. But 37.5°C was set for the best result until hatching. They had used DHT11 for sensing the Temperature and Humidity in the Incubator. A DC motor is used for rotating the egg roller, and a fan is used for circulating the temperature through the Incubator. An LCD display is also used in this system. The result found that the hatching rate was 82%–86.4% during 21 days of incubation.

Olasunkanmi et al. (2015) [51] had developed a 60-egg capacity-based egg incubator using GSM technology. The author had designed (48×36×36) cm cabinet, which was made from zinc sheet acrylic plastic outside the wall. The author used two halogen 60-watt lamps, Two small fans were installed for air ventilation. They had used a real-time clock unit, a PIC18F4550 microcontroller, an LCD Display, a DHT11 sensor, and a M1306B GSM modem for communication and control. They had Four 57.6 W filament Bulbs used as a heat source for temperature. The result found that the hatching rate was 90% during 21 days of incubation.

Chukwuezie et al. (2012) [52] had developed a 375 capacity PV-powered poultry egg incubator. The author had designed (36×24×28) inches cabinet, which was made from zinc sheet acrylic plastic outside the wall. The author used 4 halogen 60W lamps, Two small fans were installed for air ventilation using a 2 cm thickness of wood wrapped with tarpaulin sheet and galvanized metal sheet with galvanized coting or cleaning to avoid moisture absorption. The result found that the hatching rate was 88% during 21 days of incubation.

Okpagu et al. (2016) [53] developed their research about a 450-chicken egg capacity air-forced egg incubator using an Arduino microcontroller, The author had developed their temperature control in the egg Incubator using a PID control system. The author had designed (0.60×0.52×0.35) m egg Incubator. The author used an AT89C52 Microcontroller for the entire control of this system. The author also used a 200-watt filament bulb, a 16*2 character LCD display, The following temperature and humidity ranges were used: 36.5°C -38.5°C & 55%-65%RH. A DC motor was used for rotating the iron rod to rotate the egg position automatically, and an LM35 Sensor was used for temperature and Humidity measurement in this system. The result found that the hatching rate was 89.25% during 21 days of incubation.

Olaoye (2018) [54] had developed a 100-egg capacity electrical appliance cabinet type incubator using mild steel. The incubator box was designed at (120*70*40) cm. The author had used a 100-watt bulb as a Heat source, and two blower fans were used inside the incubator. Two DHT11 sensors were used for sensing the temperature and humidity data. A heater was used to fill it with water. The temperature and humidity ranges used were 37°C to 38.5°C and 60%-65%RH, respectively. A synchronous motor was used to turn the egg after 1 hour from right to left. The result found that the hatching rate was 89.75% during 21 days of incubation.

Okonkwo et al. (2017) [55] designed a 375-egg capacity photovoltaic-powered poultry egg incubator using solar modules and an inverter system. The author had designed (0.45×0.44×0.44) m cabinet, which was made from zinc sheet outside the wall. The author used three halogen 100-watt lamps. Two small fans were installed for air ventilation. HSM20G is installed to control the temperature and humidity inside the incubator. In this system, temperatures range from 37°C to 39°C, and humidity is around (67-77)%.A stepper motor is used to rotate the egg at a 45-degree angle every hour. The result found that the hatching ability was 92% during the 21-day hatching process.

M.A. Aziz, et al. (2018) [59] proposed "The Development of Quail Egg Smart Incubator for Hatching System Based on Microcontroller and Internet of Things." In their research, the authors used 490 quail eggs for hatching in an incubator. Temperature, humidity, and the reversal of the egg were automatically controlled through an Arduino microcontroller. The incubator box was designed at 100*70*43 cm. 4 pieces of 5-watt lamps, 2 pieces of blower fans were used inside the incubator. Two DHT11 sensors were used for sensing the temperature and humidity data. A heater was used to fill it with water. The temperature and humidity ranges used were 36.5°C to 38.5°C and 55%-65%RH, respectively. A synchronous motor was used to turn the egg after 4 hours from right to left. The result found that the hatching rate was 85.55% during 17 days of incubation.

Jimoh N. et al. (2008) [56] had developed a GSM-based DC-powered egg incubator. The author used a PIC18F4550 microcontroller, a DHT-11 sensor, a low power DC motor, a humidifier, a ventilation fan, and a DC heater to regulate the Temperature inside the incubator. The Temperature was maintained at 37–38 °C, and the humidity was 32%–35% during incubation and 60%–65% during the hatching period.

A.A. Sunday et al. (2020) [57] have developed a 100-egg capacity-based egg Incubator. The incubator was designed as (39*48.4*48.4) cm wide incubator, and two halogen 60-watt bulbs are used for temperature control through the chamber. A DC motor is used for rotating the egg roller fan, which is used to circulate the temperature through the Incubator. An LCD display is also used in this system. The author can control the temperature at 37°–39° and maintain a humidity of 55% in the Egg Incubator. The eggs were turned at an angle of 40° either side of horizontal at every hour. The LM 35 sensor is used for the temperature and humidity measurements of the egg Incubator. The result found that the hatching efficiency was 89.47% during 21 days of incubation.

Agidi et al. (2014) [58] have developed the design, performance, and construction evaluation of an automatic egg incubator with a turning mechanism. The author kept the temperature at about 36–39° centigrade and the humidity at 50%–70%. The author had used 15 Fertile eggs to hatch. The Result found that 5 eggs were hatched out of 15 fertile eggs during 21 days of Incubation. The percentage of hatchability of the incubator was 33%

Table 2.1 ; Comparison with Different Controller

	Author name	**Proposed**	**Temperature**	**Humidity**	**ArduinUNO AT mega 328P microcontroller**	**PID Control**	**Fuzzy Logic Control**	**Fuzzy-PID Control**	**Limitation**
1	S.S.Danadekar et al (2019) [59]	Design of an Egg incubator for Bird using PID controller	37-38 °C		AT mega PIC18F 45K22	✓			They had not used FLC or Fuzzy-PID control
2	Okpagu et al,(2016) [43]	Development and Temperature control of smart Egg Incubator system for various types of Eggs	35--40°C	58-60%	AT89C52 Microcontroller	✓			They had not used FLC or Fuzzy-PID Control System

	Author name	Proposed	Temperature	Humidity	ArduinUNO AT mega 328P microcontroller	PID Control	Fuzzy Logic Control	Fuzzy-PID Control	Limitation
4	Zain-Aldeen et.al (2017) [33]	Smart incubator based on PID controller.	37°C	62%	Arduino ATmega 1280	✓			They had not used FLC or Fuzzy-PID control
5	S.Safiuddin et al(2018) [60]	Monitoring System and Temperature controlling on PID based Poultry hatching Incubator	37-38°C		✓	✓			They had not used FLC or Fuzzy-PID data
6	Firdaus Fathurrohman et al,(2022) [61]	Egg Incubator Temperature and Humidity Control Using FLC	35-40°C	50-60%	✓		✓		They had not used PID or Fuzzy-PID control
7	N.N Prince, (2023) [62]	Application of Fuzzy Logic Control in Design and Implementation of Digital Egg Incubator	37.5-38.8°C	59-65%	AT89C52 microcontroller		✓		They had not used PID, or Fuzzy-PID control

	Author name	Proposed	Temperature	Humidity	ArduinUNO AT mega 328P microcontroller	PID Control	Fuzzy Logic Control	Fuzzy-PID Control	Limitation
8	Edin mujcic et al (2020) [63]	Design and implementation of fuzzy control system for egg incubator based on IoT technology	37-38°C	55-60%	✓		✓		They had not used PID, or Fuzzy-PID control

The various researchers worked on temperature control using various techniques. Some researchers used only the Arduino Uno microcontroller; others used a PID controller. Some used fuzzy logic controllers. But none had worked on temperature control using a fuzzy-PID controller in an egg incubator. A detailed analysis of the temperature control and energy-saving techniques is indispensable, but none has been reported in the open literature. Therefore, in this research, the brightness of the bulb as well as the temperature are controlled using a fuzzy-PID controller in the egg incubator system to save energy, and a comparison of different controllers is done. Humidity is also effectively controlled using Fuzzy-PID compared with other controllers.

CHAPTER-III

METERIALS AND METHODOLOGY

3.1 MATERIALS

3.1.1 Bulb

An incandescent bulb has a filament wire that heats it until it glows. The filament wire is enclosed in clear glass to protect it from oxidation and inert gas. Current is supplied to the filament wire by terminals embedded in it. A socket provides electrical and mechanical support. Incandescent bulbs are manufactured in wide ranges of sizes and voltage ratings, from 1.5 volts to 300 volts and above. It has a low manufacturing cost and works equally well on either AC or DC. As a result, it can be widely used in household lighting, commercial areas. It can also be used in table lamps, flashlights, car headlamps, advertising, and decorative lighting. The bulb is essential as a heat source in the Egg Incubator. A 200-watt bulb is used as a heat source in the egg Incubator. Due to this research, when the bulb is on, heat is absorbed in the incubator. The bulb heats the chamber using fuzzy-PID control using Arduino programming.

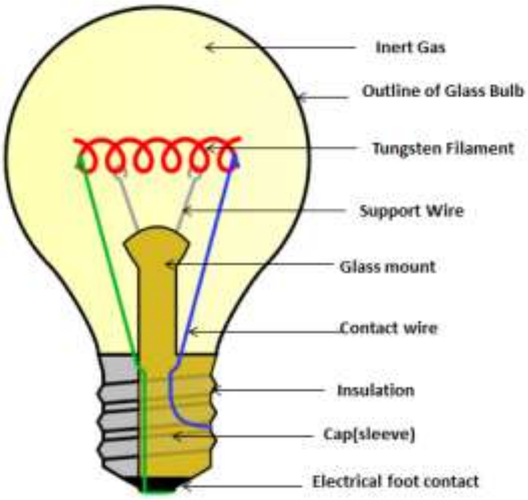

Figure 3.1: 200 Watt Incandescent Light Bulb

3.1.2 Humidifier:

This is a colorful ultrasonic humidifier that has 12 luminous LED mist makers that can add a stunning mist effect to the pond or water tank without adding a bad smell. The dreamy colors will change color automatically via electronic and ultrasonic technology. It can operate at 24 volts with a maximum evaporation rate of 350 ml/hour. It has a working depth of 4-9cm in water, a mist dia of approximately 4.5 cm, and a water consumption of 80ml/hour.

Figure 3.2: Color Changing Ultrasonic Water Humidifier

Power supply to this system The input voltage is about 100–240 volts, the input power is 20 watts, and the output voltage is 24 volts. Automatic mist is generated in huge amounts of droplets, and the service life of the atomizer is long. It can be used in the egg incubator to control the humidity inside the incubator. It can help droplet water inside the incubator, thus adding humidity to this system. A humidifier is used to increase the humidity in the egg Incubator for hatching. Here, the humidifier is controlled in the egg Incubator using the fuzzy-PID Method.

3.1.3 Temperature and Humidity Sensor Module

The HSM-20G is an analog humidity and temperature sensor that can sense the relative humidity and temperature inside the incubator. It has a current rating of 2mA, an input voltage of DC 5.0, and an output voltage of 3.19volt. It can operate in the relative humidity range of 20%–95%. Operating temperature is 0–50 °C. Relative humidity is the percentage of moisture in the air at a particular temperature. It can be used for air conditioners, Humidity data loggers, and automatic climate control. It can also be used as a humidifier and dehumidifier in the Egg Incubator system.

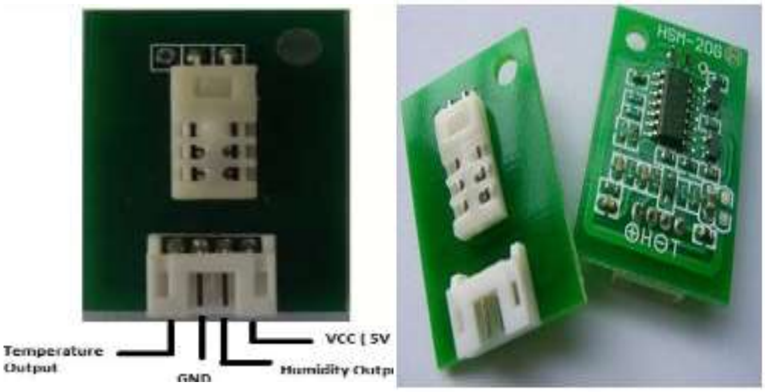

Figure 3.3: Temperature and Humidity Sensor Module HSM-20G

3.1.4 Synchronous Gear Motor

It is a 60 KTYZ synchronous AC motor that can operate at 220 volts and delivers a 14 Watt power supply to this system. It can rotate at 2.5 rpm. Frequency rate: 50 Hz. The diameter of the output shaft is 8 mm, and it supports two ball bearings. The axial sway is less than 0.3mm, and the motor runs smoothly with low noise. This motor can work continuously. The ambient temperature is 15 °C, and the maximum shell temperature is 48°C. This motor has been extensively used in low-speed machines. It can also be used to rotate the egg tray at a 45° angle every hour in the egg incubator, and its performance is reliable and stable. This motor is used for moving the Egg Tray at a 45°angle after one hour using fuzzy PID control.

Figure 3.4: Synchronous AC Gear Motor

3.1.5 USB Fan

USB fan can operate 0.32A current, 5V DC voltage. Fan dimension is (140*140*25) mm. It can delivered 59.61CFM airflow and 1200 rpm rated speed. It has power consumption1.6W

Figure 3.5: USB Fan

Power consume through the operation. It can use for circulating the air inside the Egg Incubator using Fuzzy-PID controlling method.

3.1.6 Egg Tray:

Egg Tray is used for setting the egg in the Incubator. There are various kind of Egg Tray in the local market. Here in our research we used 100 capacity based Egg Tray in our Egg Incubator.

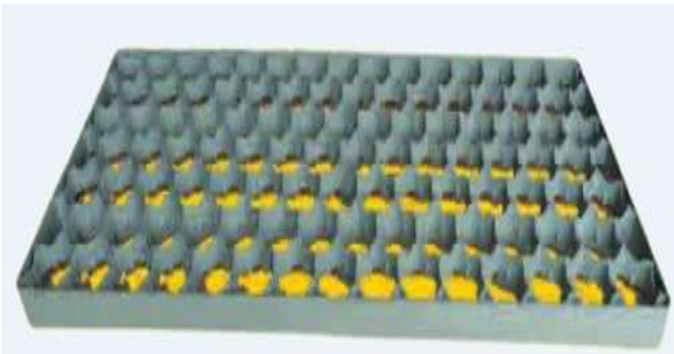

Figure 3.6: Egg Tray

3.1.7 Arduino UNO R3, Pin Diagram, Specification

Arduino UNO R3 is used in a microcontroller board**.** The major control on this board is the microcontroller. The major features include a DIP, detachable, and AT

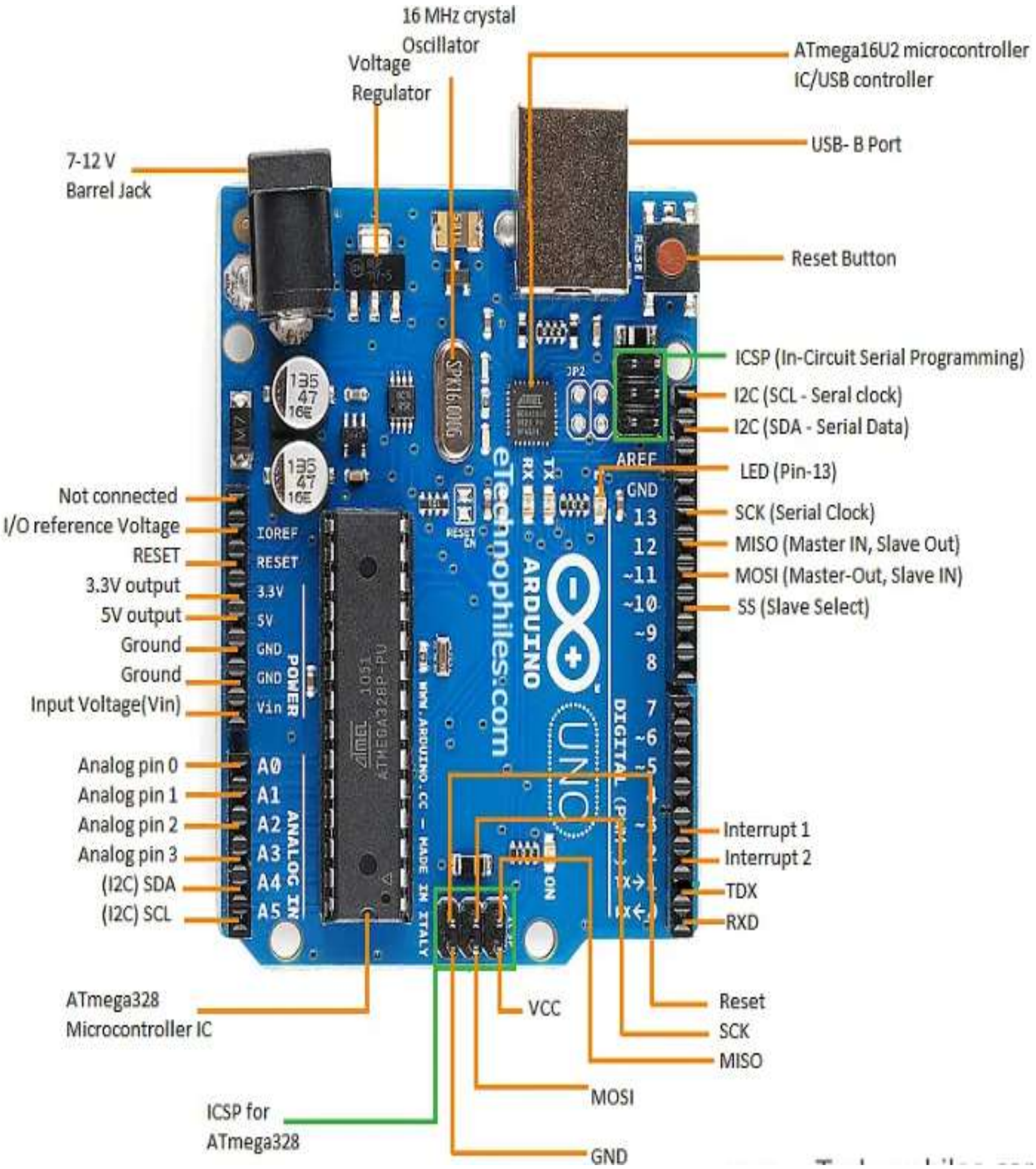

Figure 3.7: Arduino UNO R3 ATmega328p Diagram

Mega 328P microcontroller. This board can be used for Arduino programming. This board is used for many applications. The Arduino Uno ATmega328P is based on a microcontroller. The reference versions are the IDE software and the Arduino board. The board is used as the initial in a sequence of Arduino USB boards.

Here the table 3.1 the specification of Arduino UNO R3 is given below

Table 3.1: Specifications of the Arduino UNO R3

Board	**Name**	Arduino UNO R3
	SKU	A000066
Microcontroller	ATmega328P	
USB connector	USB-B	
Pins	**Built-in the LED Pin**	13
	Digital I/O Pins	14
	Input of Analog pins	6
	PWM pins	6
Communication	**UART**	Yes
	I2C	Yes
	SPI	Yes
Power	**I/O Voltage**	5V
	Input voltage (nominal)	7-12V
	DC Current I/O Pin	20 mA
	Power Supply Connection	Barrel Plug
Clock speed	**Main Processor**	ATmega328P 16 MHz
	USB-Serial Processor	ATmega16U2 16 MHz
Memory	**ATmega328P**	2KB SRAM, 32KB FLASH, 1KB EEPROM
Dimensions	**Weight**	25 g
	Width and Length	53.4 mm and 68.6mm

Power Supply

The power supply of an Arduino can be an external power supply via USB Connection. For External power supplies, such as 6V to 20V, are principally included in a battery or an AC to DC converter. The battery can be placed with the pins of Vin as well as ground. The **Arduino board** can include the following.

Vin: The input voltage in Arduino is from an external source of power, opposite to the voltage from the USB connection**.** This pin can use the voltage supply in the system.

5 Volts: RPS can be used as a power supply on the components that are used for the Arduino board. This can be obtained from the input voltage through the regulator.

Input and Output

We know that the Uno R3 includes 14 digital pins that use input and output functions, which are pin Mode (), digital Write(), and digital Read(). These pins can be operated at 5 volts, and every type of digital pin can give or receive 20 mA, including resistors. The maximum current is 40 mA, which cannot be exceeded to avoid damage.

Serial Pins

Arduino board has a serial pins of RX (0) and TX (1) pins and these types of pin can be used to transfer data. The connection of equivalent pins ATmega8 U2 USB to TTL chip.

External Interrupt Pins

The external interrupted pins on the board are 2 and 3, and these pins can be used to activate the interrupt on a rising or otherwise falling edge, a low-value modification in value.

PWM Pins

The Arduino has PWM pins 3, 5, 6, 9, 10, and 11, The output of the PWM function is an 8-bit analog Write ().

Serial Peripheral Interface Pins

The SPI pins have 10, 11, 12, 13, namely MOSI, SS, SCK, and MISO, and with these, the SPI will maintain communication with the help of the SPI library.

LED Pin

An Arduino board is built on digital pin 13. When the digital r pin is high, the LED will glow; otherwise, it will not glow.

TWI Pins

The TWI pins are A4, SDA, SCL, and A5, which can support the communication of the TWI with the help of the Wire library.

AREF Pin

An analog pin in Electrical voltage with an analog input using functions like analog reference

Reset Pin

The reset pin, given low line resetting for the microcontroller, is very helpful for RST button use toward the shields, which can block the Arduino R3 board.

Communication

The communication protocol with the Arduino Uno included I2C, SPI, and UART serial communication.

UART

The Arduino Uno has two functions, like the receiver digital pin 0 and transmitter digital pin 1, and These pins are used in UART TTL serial communication.

I2C

The Arduino UNO board employs the SDA A4 and A5 pins. For communication, SCL is used for the I2C communication library.

SPI Pins

The SPI has communication included in MISO, MOSI, and SCK.

MOSI (Pin11)

Master and slave are the pins used to transmit data to the devices.

MISO (Pin12)

The pin is used as a CLK pulse, and serial CLK will be optimized for transmission by the master.

SCK (Pin13)

This CLK synchronizes transmission data that is created by the master. The pins are in the SPI library, which is employed for communication. The ICSP header of utilities for the programming of the AT Mega microcontroller by the boot loade

3.2 METHODOLOGY (SIMULATION)

This research mainly aims to simulate an energy-efficient egg incubator. In this research, we can control the Temperature through a fuzzy-self tuning PID algorithm [64]. We have used the fuzzy PID method combined with conventional PID and fuzzy logic. The time error "e" and the changing time error "ec" are the inputs, and K_P, K_I, and K_D are the outputs of this fuzzy control system. In a PID controller, voltage is the input parameter and temperature is the output parameter. The fuzzy rules for tuning K_P, K_I, and K_D can be constructed with multiple requirements on the PID monitoring process. Here, 38°C is the set temperature, and 1 second is used as a transport delay to regulate the system. This design monitors the temperature control process of this system. And reduce the fluctuation, minimize the overshot, improve the rise time and settling time, and save the energy consumption of this system compared to the conventional egg incubator.

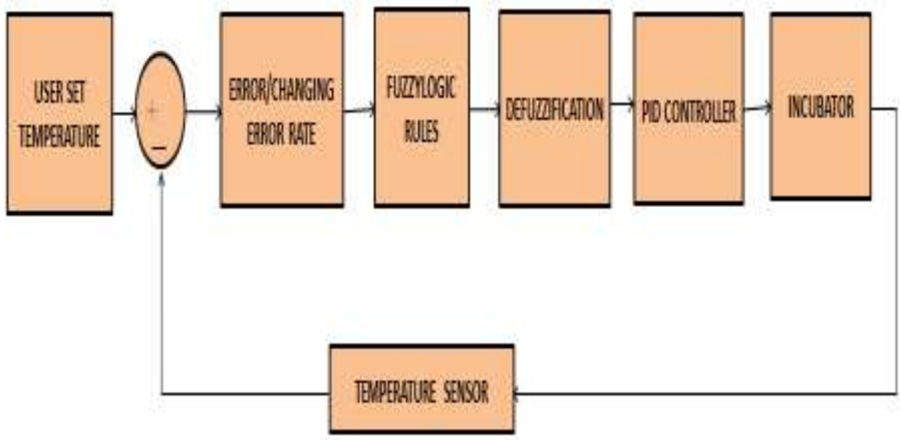

Figure 3.8: Simplified Block Diagram of a Temperature Control System

In Figure 3.8, Temperature is used as a feedback sensor. The difference between set temperature and sensor temperature is the error 'e, and by dividing the error by a fixed time, we can get the changing error rate 'ec'. Error 'e' and the changing error rate 'ec' enter the fuzzy inference system, and after defuzzification, the values of K_P, KI, and K_D enter the PID control system.

The law of traditional PID controls is given below.

The main parameters of the PID controller are:

(1) When **'e'** is big, K_P is big, but K_D is little.

(2) When **‘e’** and **‘ec’** are moderate, then the overshoot is small.

(3) When **‘e’** and **‘ec’**are little, then K_P, and K_I are big.

(4) When **‘ec’** is small, then K_D is big.

(5) When ‘ec’ is big, then K_D is little.

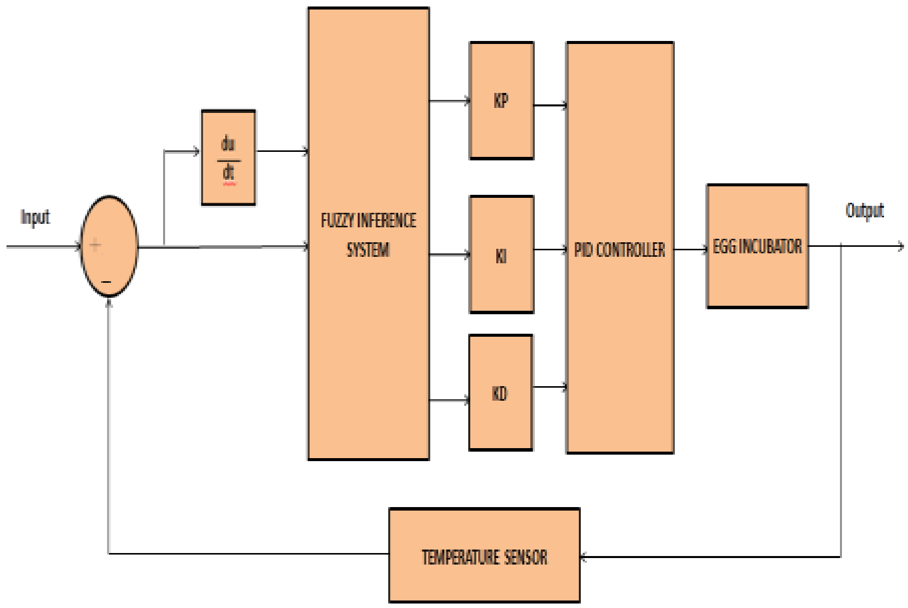

Figure 3.9: The Schematic Diagram of Temperature Control using Fuzzy Adaptive PID Monitoring Process

In Figure 3.9, the supply voltage is used as an input and is connected to the fuzzy inference system. A temperature sensor is used as a feedback sensor. The difference between set temperature and sensor temperature is the error ‘e, and by dividing the error by a fixed time, we can get the changing error rate ‘ec’. Error ‘e’ and the changing error rate ‘ec’ are the inputs of the fuzzy inference system, and after defuzzification, the values of K_P, KI, and K_D are the inputs of the PID control system. The temperature is the output of the system.

In the design of a fuzzy logic system, the input and output variables are defined with fuzzy sets, and the fuzzy rules are obtained via testing. In this system, the error "e" and changing error "ec" are calculated with the fuzzy-pid controller through different parameters of the FLC system. The fuzzy monitoring tables K_P, KI, *and* K_D are calculated by the error and changing error rate via the fuzzy inference system.

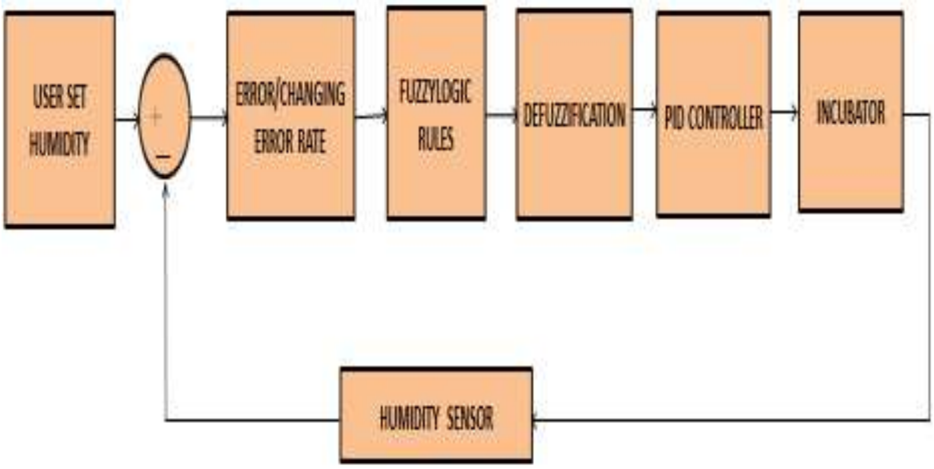

Figure 3.10: Block Diagram of Humidity Control System

In Figure 3.10, a humidity sensor is used as a feedback sensor. The difference between set humidity and sensor humidity is the error ‘e’ and by dividing the error by a fixed time, we can get the changing error rate ‘ec’. Error ‘e’ and changing error rate ‘ec’ enter the fuzzy inference system, and after defuzzification, the values of Kp, Ki, and Kd enter the PID control system.

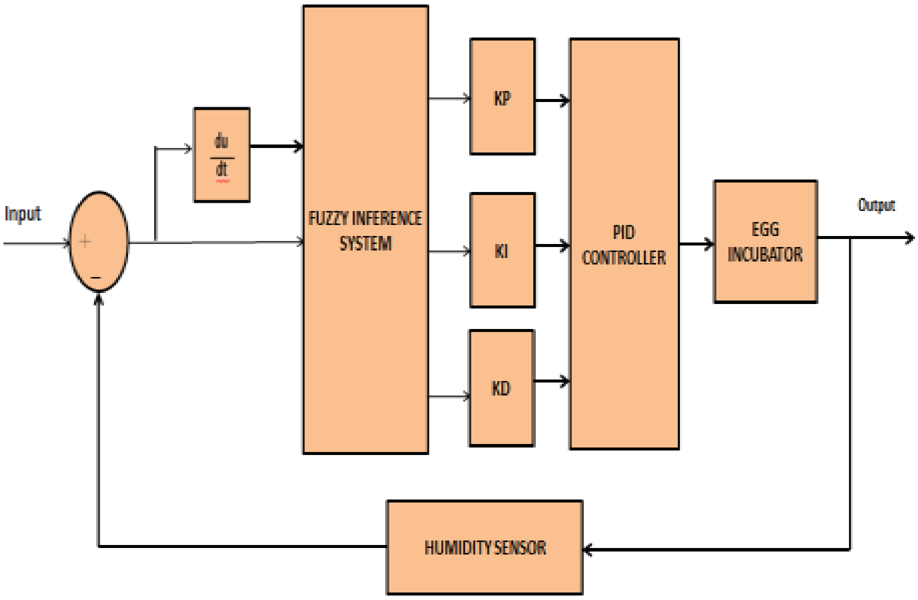

Figure 3.11: The Schematic Diagram of Humidity Control using Fuzzy Adaptive PID Monitoring Process

In Figure 3.11, supply voltage is used as an input connected to the fuzzy inference system. A humidity sensor is used as a feedback sensor. The difference between set humidity and sensor humidity is the error ‘e, and by dividing the error by a fixed time, we can get the changing error rate ‘ec’. Error ‘e’ and the changing error rate ‘ec’ enter the fuzzy inference system, and after defuzzification, the values of K_P, KI, and K_D enter the PID control system. After simulation, we get humidity as an output from this system.

1.2.1 Membership function

The membership function of a fuzzy control system maps the set of input variables is called fuzzy sets, and the value of a fuzzy set is called fuzzification [64]. The Fuzzy subsets were defined with different crisp sets. The fuzzy sets are completely perceived by the membership functions. The FLC method can also organize the analog inputs, which are 0 and 1, into its fuzzy operation, which can either be one or another value [65]. The fuzzy sets were classified into two input variables, like error 'e' and the changing error 'ec, and the temperature is defined as the output variable of this egg incubator system. The input and output domains are defined with seven fuzzy subsets. Errors are: [NB, NM, NS, ZO, PS, PM, PB]. The Changing error is [NB, NM, NS, ZO, PS, PM, PB], and the domain outputs are [NB, NM, NS, ZO, PS, PM, PB]. The values of input and output parameters were fuzzified by converting the membership function corresponding to the seven subsets [66]. All of the membership functions in FLC were taken in a straight line, which is a triangular shape. The input value range of (K_P, K_I, K_D) is [-20 40] and the output value range of (K_P, K_I, K_D) is [0 40]. The fuzzification and defuzzification methods of a fuzzy function have been used to quantify the philological terms that can be plotted by changing the temperature.

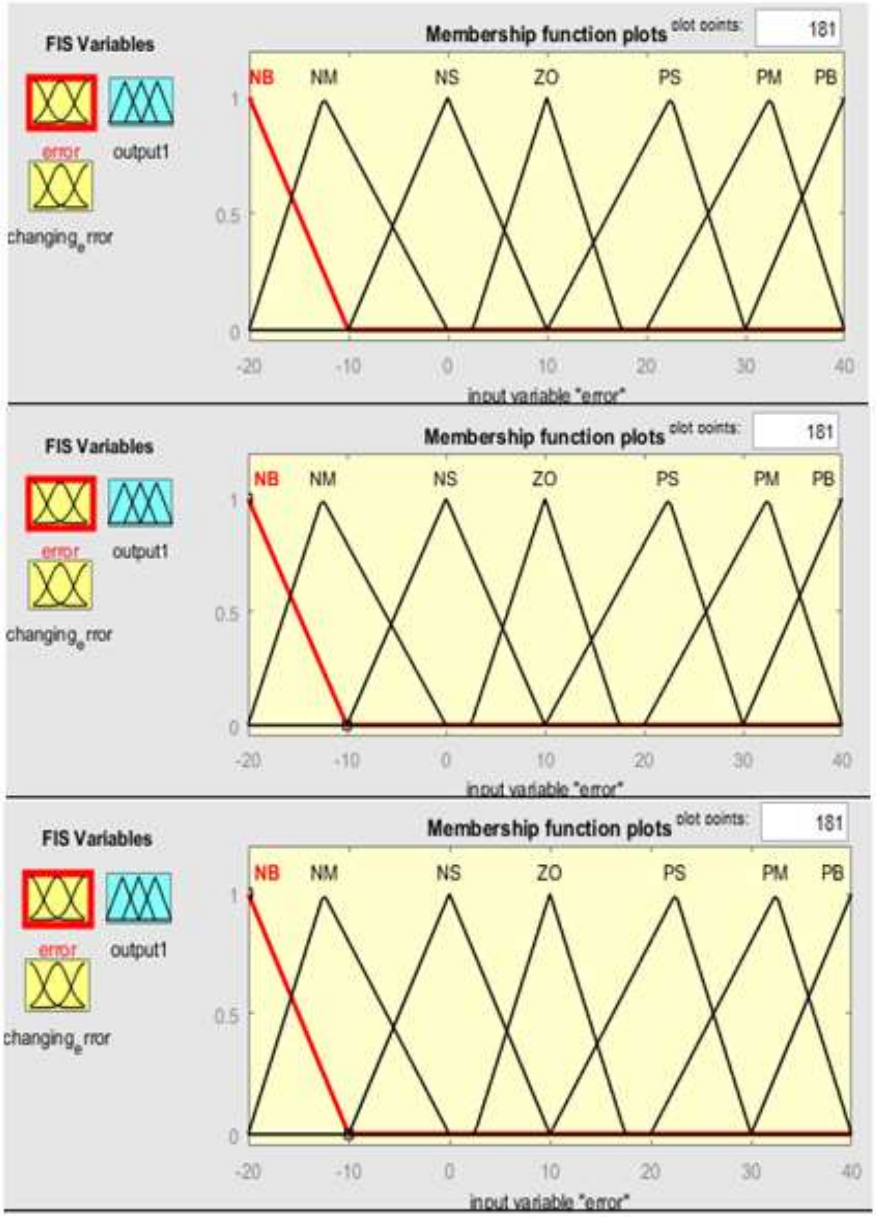

Figure 3.12: Membership function of KP, KI and KD

In Figure 3.12, the membership function of KP, KI, and KD has two inputs: Error 'e' and changing Error 'ec, whose range is [-20 40] and output, which range is [0 40]. Seven fuzzy subsets are taken, which are NB, NM, NS, ZO, PS, PM, and PB. All the membership functions are triangular shape.

In Table 3.2, the Membership functions of K_P, KI, and K_D have seven subsets: NB,NM,NS,ZO,PS, PM, and PB, and the error "e" changing error "ec" ranges are given on the table.

Table 3.2: Table of the Membership Function

	Membership function	Error 'e'	Changing error 'ec'	Output
K_P	NB	[-30 -20 -10]	[-30 -20 -10]	[-6.773 -0.104 6.56]
	NM	[-20 -12.5 0.0025]	[-20 -11 0.0025]	[0 6.665 13.33]
	NS	[-10 0.0025 10]	[-10 0.0025 10]	[6.665 13.33 20]
	ZO	[2.5 10 17.5]	[4 10 16]	[13.33 20 26.67]
	PS	[10 22.5 30]	[10 17.5 30]	[20 26.67 33.35]
	PM	[20 32.5 40]	[20 29 40]	[26.67 33.35 40]
	PB	[30 40 50.02]	[30 40 50.02]	[33.35 40 46.68]
K_I	NB	[-30 -20 -10]	[-30 -20 -10]	[-6.773 -0.104 6.561]
	NM	[-20 -12.5 0.0025]	[-20 -11 0.0025]	[0 6.665 13.33]
	NS	[-10 0.0025 10]	[-10 0.0025 10]	[6.665 13.33 20]
	ZO	[2.5 10 17.5]	[4 10 16]	[13.33 20 26.67]
	PS	[10 22.5 30]	[10 17.5 30]	[20 26.67 33.35]
	PM	[20 32.5 40]	[20 29 40]	[26.67 33.35 40]
	PB	[30 40 50.02]	[30 40 50.02]	[33.35 40 46.68]
K_D	NB	[-30 -20 -10]	[-30 -20 -10]	[-6.773 -0.104 6.561]
	NM	[-20 -12.5 0.0025]	[-20 -11 0.0025]	[0 6.665 13.33]
	NS	[-10 0.0025 10]	[-10 0.0025 10]	[6.665 13.33 20]
	ZO	[2.5 10 17.5]	[4 10 16]	[13.33 20 26.67]
	PS	[10 22.5 30]	[10 17.5 30]	[20 26.67 33.35]
	PM	[20 32.5 40]	[20 29 40]	[26.67 33.35 40]
	PB	[30 40 50.02]	[30 40 50.02]	[33.35 40 46.68]

3.2.2 Fuzzy logic Rules

The FLC method consists of an input term, processing term, and output term of the system [63]. The input term of a FLC system is the error 'e' and the changing error 'ec'. The output term is the temperature of the system, and the processing term is based on fuzzy logic rules (if-than statements), where the if statement is known as 'precursory' and the then statement is known as 'pursuant. [67] In the fuzzification process, we can get fuzzy sets, and in the defuzzification process, we get three parameters with improved PID operation. FLC rule is familiar with manufacturing the output variables KP, KI, and K_D for this system. [68] The fuzzy logic rules are demonstrated below in Tables 3.3, 3.4, and 3.5.

Table 3.3 Fuzzy logic Rules for [K_P]

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

Table 3.4 Fuzzy logic Rules for [K_I]

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

Table 3.5 Fuzzy logic Rules for [K_D]

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

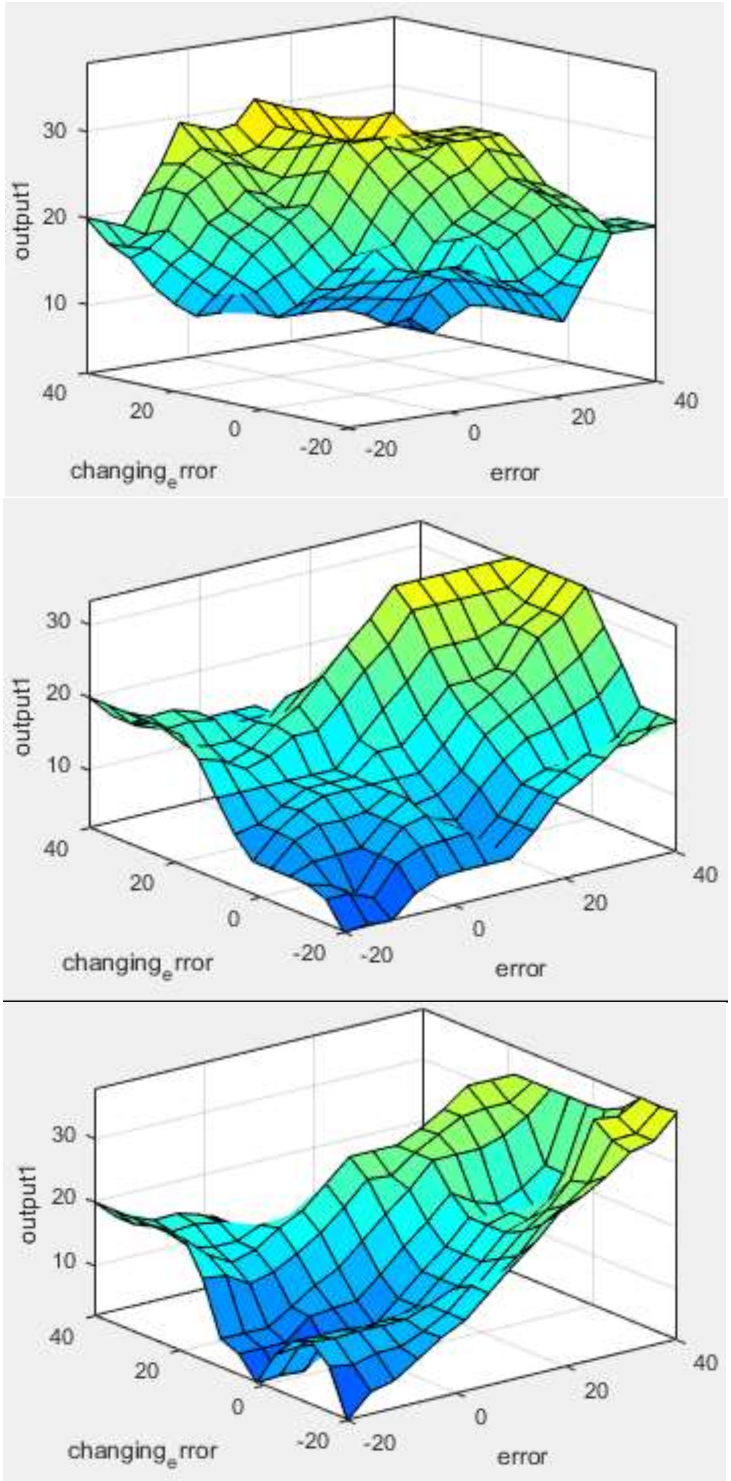

Figure 3.13: View of the surface K_P, K_I, K_D

After the fuzzification, a view of the surfaces K_P, KI, and K_D is given in Figure 3.13. In surface view, according to error and the changing error rate, the output (values of KP, KI, and K_D) are shown.

3.2.3 Temperature Control

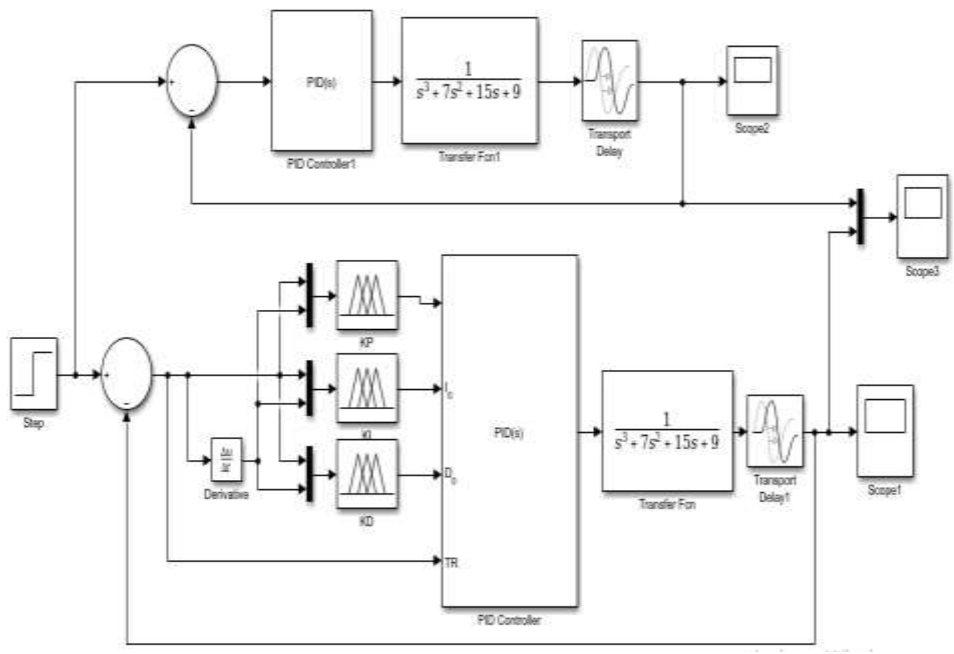

Figure 3.14: Simulink Block Diagram for Temperature control

In an energy-efficient egg incubator system, temperature control is the most important part. For energy savings, we have controlled the temperature by using fuzzy adaptive PID via the MATLAB toolbox. The simulation in MATLAB was adapting the arrangement of membership functions for fuzzy rules [69]. The application of fuzzy-PID is, to maintain the heating and control the air temperature in the incubator. This system can reduce overshoot and undershoot and give a better response. The transfer function [70] of the Simulink model is:

$$\frac{1}{s^3 + 7s^2 + 15s + 9}$$

Comparing the simulation results of fuzzy PID and conventional PID control, the simulation results show that fuzzy PID has improved the rise time and settling time, reduced the overshoot and undershoot, and is more energy efficient.

The Simulink block diagram is given in Figure 3.14. In the Simulink block diagram, the step-response allows the fundamental step signal detection and the reaction of the progressive system. The FLC system is essential to selecting the appropriate error ‘e’ and changing error ‘ec’ [71]. For better temperature performance, the FLC is used in this system. The error ‘e’ and the changing error ‘ec’ determine the parameters *Kp*, *Ki, and Kd.*

If the system of error ‘e’ is large, then overshoot is large and the mode of alteration will be extended. If ‘ec’is big, then Kd is big. The overshoot will be reduced, and the speed reaction will slow. The set temperature is 38 °C. The step time of the system is 0, and the final value is 38° centigrade. 60 seconds have been taken for the simulation process. And 1 second has been used as a transport delay. During the simulation time, the rise time and settling time improved, and overshoot was reduced, which is energy efficient for this system compared to a conventional egg incubator.

Table 3.6 Value of PID Parameter for Temperature

Parameters	Value
K_P	10.55
K_I	10.2
K_D	5.5

3.2.4 Simulation Graph:

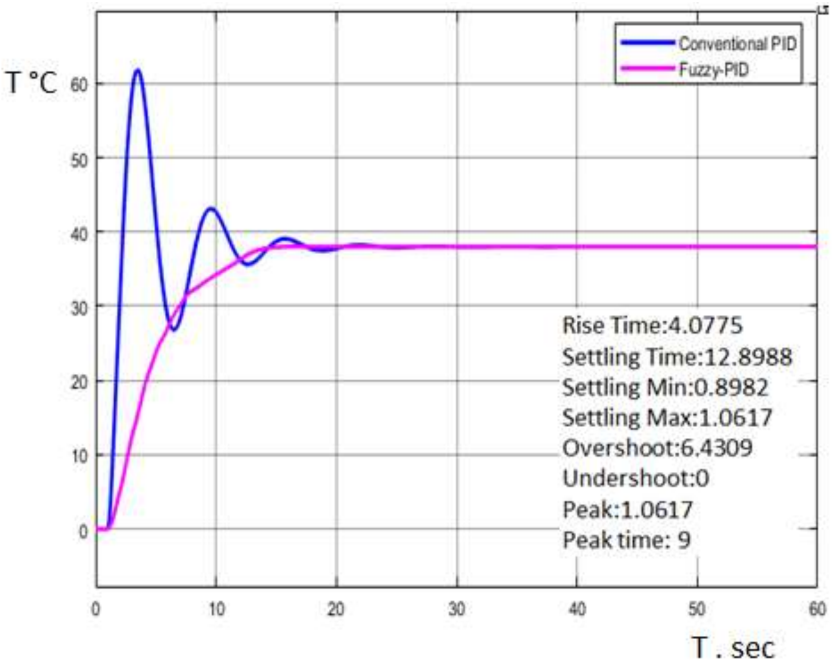

Figure 3.15: Conventional PID and Fuzzy- PID control monitoring process

Here, the PID control values (K_P, KI, and K_D) do not change with time automatically. So in figure 3.15, we see that PID control has fluctuated and is stable at 16.5450 sec above. On the other hand, fuzzy PID control changes with time automatically. That's why the fuzzy PID has never fluctuated and generated a smooth curve during MATLAB simulation. The rise time, settling time, and overshoot have been minimized compared to the PID control graph.

3.2.5 Humidity Control

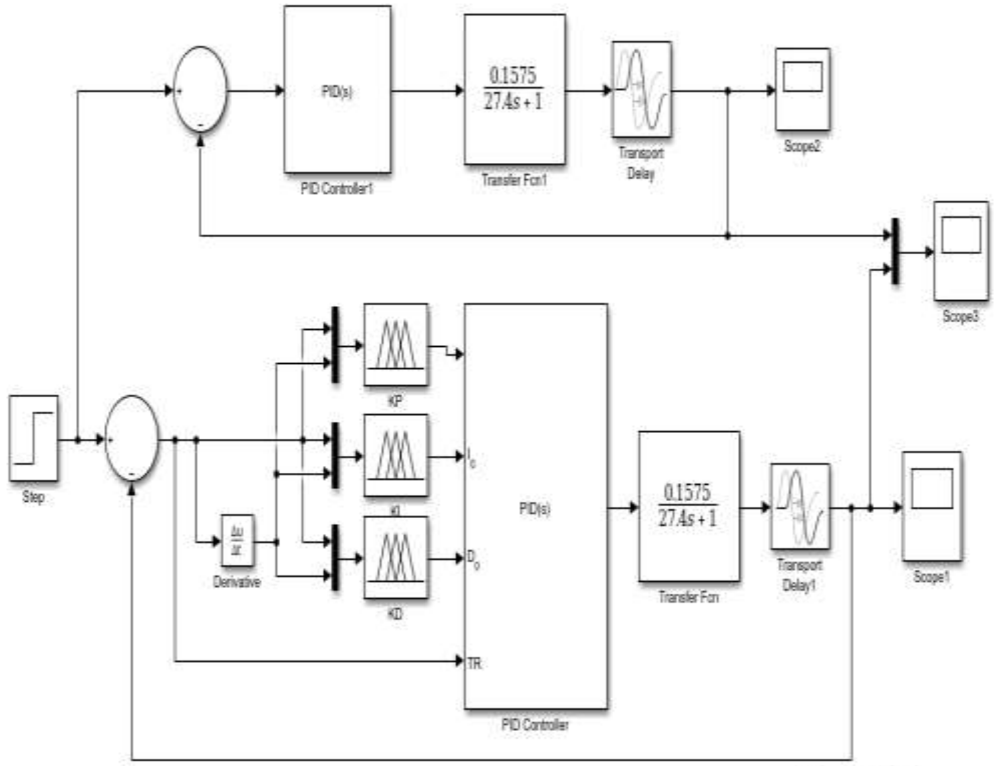

Figure 3.16: Simulink Block Diagram for Humidity Control

The most crucial component of this system is humidity management, which is required to operate the energy-efficient egg incubator. We suggested using the MATLAB toolbox to control the humidity of this system using a fuzzy adaptive PID in order to save energy. The adaptation feature for the fuzzy rules of the membership functions in MATLAB is simulation. Fuzzy-PID is used to keep the incubator's humidity under control. This approach improves the responsiveness to undershoot while reducing overshoot. The Simulink model's transfer function [72] is as follows:

$$\frac{0.1575}{27.4s+1}$$

The simulation result shows that it has improved the rise time and settling time, reduced the overshot and undershot, and is more effectively controlled than a conventional system.

Figure 3.16, shows the block diagram for Simulink. The step-response feature in the Simulink block diagram enables the detection of the basic step signal and the progressive system's response. The FLC system is necessary for modifying error 'ec' and choosing the right error 'e'. The FLC is utilized in this system for improved humidity management. The parameters Kp, Ki, and Kd are determined by the error 'e' and the changing error 'ec'.

The overshoot will be large and the method of alteration will be extended if the system of error, "e," is large. Kd is large if 'ec' is large. The speed reaction will slow, and the overshoot will be reduced. The set humidity is 55%–60%. The step time of the system is 0, and the final value is 60%. 400 seconds have been taken for the simulation process. The simulation result shows that it has improved the rise time and settling time, reduced the overshot and undershot, and is more effectively controlled than a conventional system.

Table 3.7 Value of PID Parameter Humidity

Parameters	Value
K_P	15.8
K_I	15.8
K_D	08

3.2.6 Simulation Graph

Here, the PID control values (K_P, KI, and K_D) do not change with time automatically. So in figure 3.17, we see that PID control has fluctuated and is stable at 300 seconds above. On the other hand, fuzzy-PID control changes with time automatically.

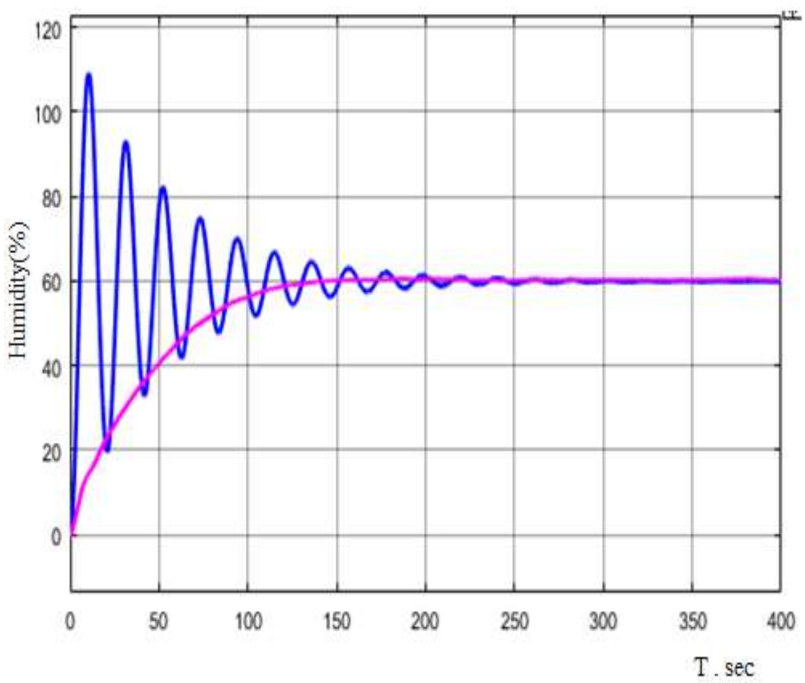

Figure3.17: Conventional PID and Fuzzy- PID control monitoring process

That's why the fuzzy PID has never fluctuated and generated a smooth curve during MATLAB simulation. The rise time, settling time, and overshoot have been minimized compared to the PID control graph.

3.3 METHODOLOGY (EXPERIMENTAL)

3.3.1 Enclosure of the incubator

The egg incubator is built on a steel structure covered with a layer of anti-dust and has a size of (22 ×24 ×36) Inches to make it solid so as to withstand the weight of the eggs during the incubation period. The incubators were built on this steel structure in such a way as to avoid any kind of heat loss and preserve the static temperature inside the incubator. Ventilation holes are provided to renew the humidity and air in the circumference. The box is built on four multi-layered walls. Clear glass with windows was used on this box to observe the interior of the circumference during the incubation. A 200W bulb is used as the heat source, and a fan circulates the air in the enclosure to keep the temperature stable in the incubator. During the experimental work, we use an Arduino Uno AT Mega 328P in the incubator. Which has 14 input Pins and 6 analog input pins. Three 5V DC relays were used for the servo motor, fan

1, and fan 2. The servo motor and adapter are connected to the relays at the point. The Arduino has provided 5 volts in the system.

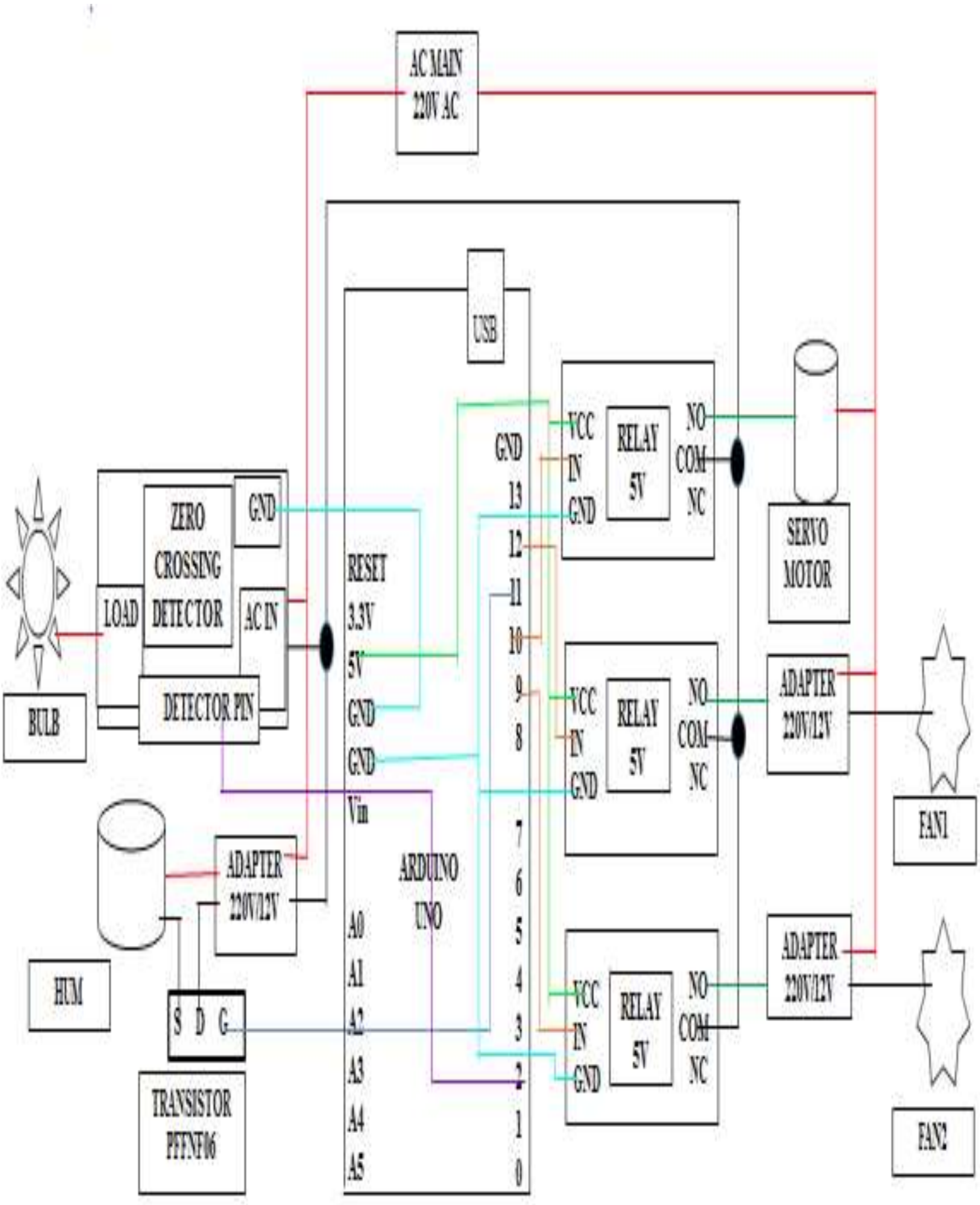

Figure 3.18: Experimental Circuit Diagram of Temperature and Humidity Control of an Egg Incubator Model.

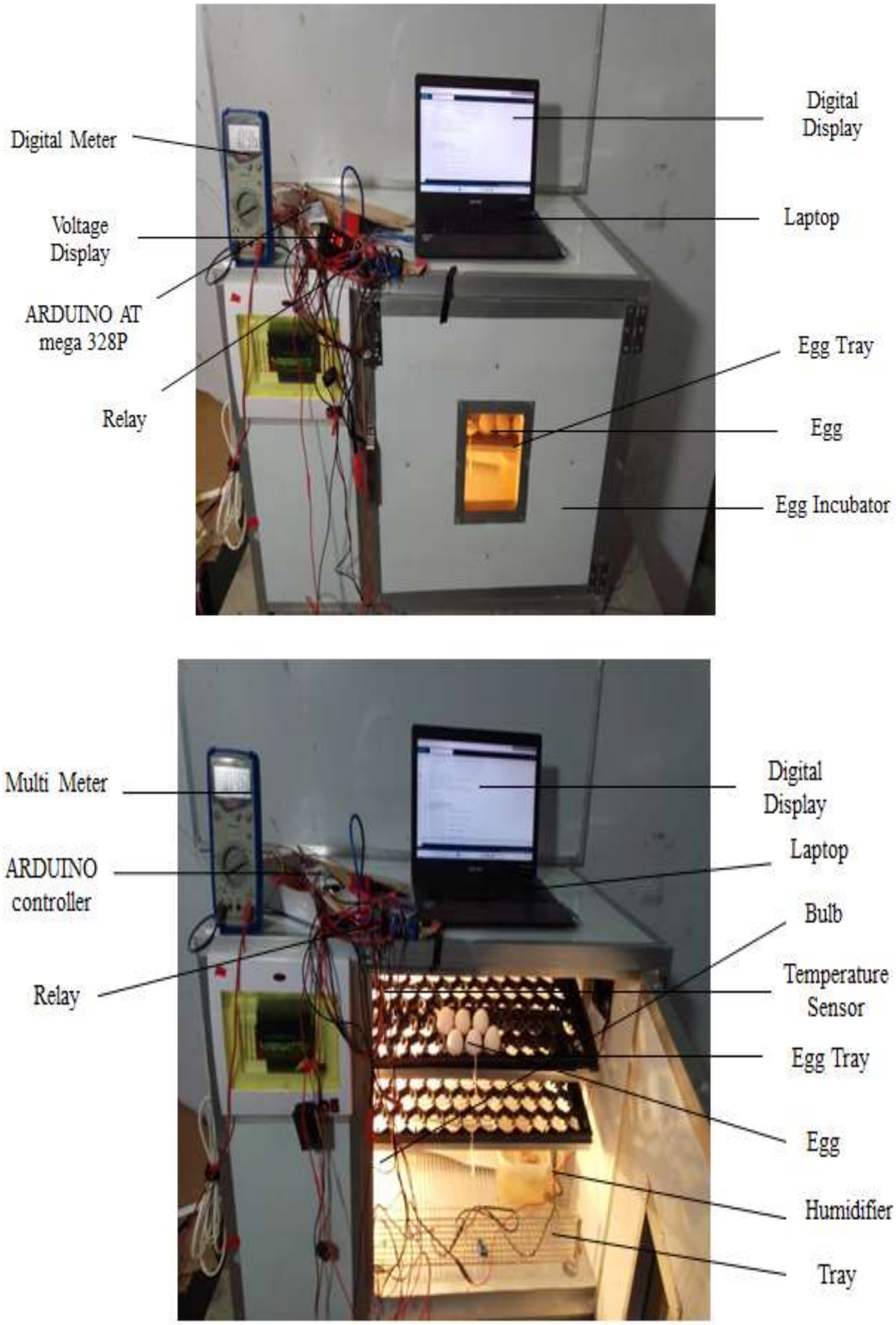

Figure 3.19: The Experimental Image of Temperature and Humidity Control of an Egg Incubator

A zero-crossing detector is used for the bulb, which is the heat source in the incubator. It can help to control the voltage in the Incubator. A Humidifier is used in the Incubator to control the humidity in the Incubator. For temperature and humidity control in the incubator, we use PID and Fuzzy-PID coding through the Arduino UNO ATmega 328P microcontroller.

In a conventional egg incubator, there is no zero-crossing detector circuit, which is why the brightness of the bulb cannot be controlled. But after installing the zero crossing, we can control the brightness of the Bulb. In a conventional Egg incubator system, there is no transistor in the humidifier circuit. That's why the water spray cannot be regulated properly. But in our proposed system, we used a P55NF transistor in the humidifier circuit, so the water spray can be controlled with a PID or Fuzzy-PID control system.

3.3.2 Working Principle:

To implement the Egg incubator, there are three basic designs: mechanical, electronic, and software. On the Mechanical site, we made an incubator box that is built on a steel structure covered with a layer of anti-rust and has a size of (22 ×24 ×36) Inches to make it solid so as to dispute the weight of the eggs during the incubation period. The box constructed was built on a four-layered wall. On the Electronic site, we built the system circuit with a 200-watt bulb used as a heat source, a fan used for the temperature, and a humidifier used for the humidity in the enclosure. A relay is used to run the servo motor in the Incubator. For Sensing the Temperature and Humidity in the incubator, we use HSM20G. Then we set up the Arduino Uno AT Mega 328P microcontroller in the system. For Temperature and humidity control through the incubator, we built PID and Fuzzy PID coding, which was run by the Arduino software. When the temperature exceeds 38 °C, the bulb is off and the fan is on. When the temperature falls to 38 °C, the bulb is on and the fan is off. Similarly, for controlling the humidity, When the humidity exceeds 58%, then fan 2 is on. If the humidity falls below 58%, then the fan is off.

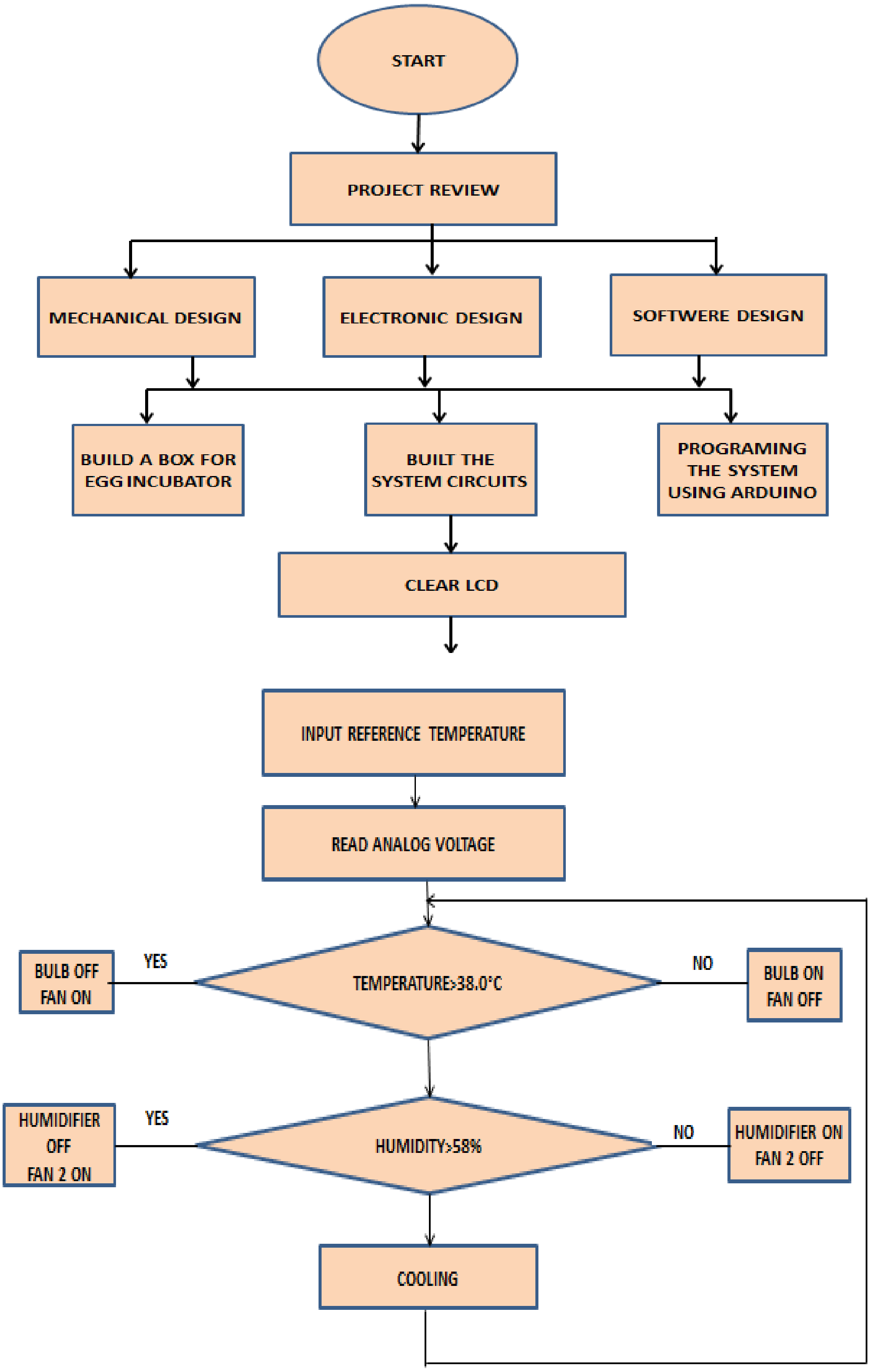

Figure 3.20: Flow Chart of Temperature and Humidity Control of an Egg Incubator

CHAPTER- IV

RESULT AND DISCUSSION

4.1 Experimental Results using Conventional, PID & Fuzzy PID Controller

For the natural incubation of eggs, Temperature and Humidity are the most important factors. The temperature for egg incubation should be between 37° to 38°C. The set temperature has been taken at 38° centigrade, and humidity should be 55–60% centigrade. During the experimental work, the Arduino Uno AT Mega 328P microcontroller and the HSM20G are used for the temperature and Humidity sensors, and a 200-watt filament bulb is used as the heat source in the incubator. When the temperature rises to 38° centigrade above, the bulb is off, and when the temperature falls to 37°centigrade, the bulb is automatically on. For experimental work, collect the Conventional, PID, and Fuzzy-PID controller data for 1 hour in the Egg Incubator. The Experimental data has been given below.

4.1.1 Temperature Data

For controlling the temperature in an egg incubator system, there are three different kinds of controllers: conventional, PID, and fuzzy-PID Control systems are used to collect the temperature data (°C) for the egg incubator system. The Temperature experimental data is given in Appendix A.1.

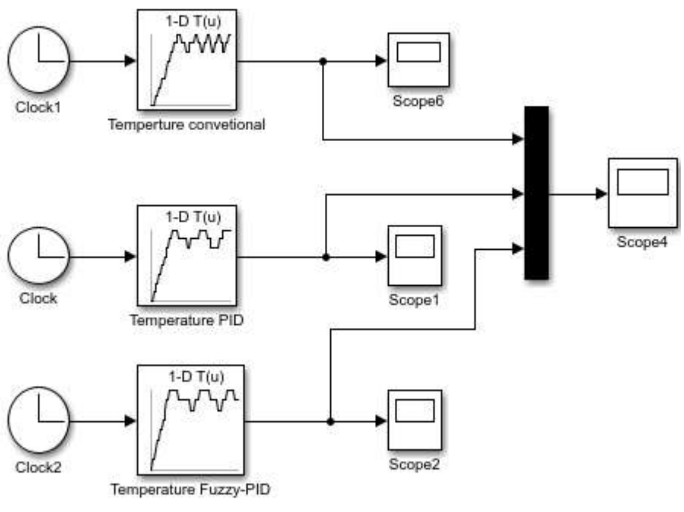

Figure 4.1: Simulink Model of Temperature

Simulink is the most important part of Matlab, which is used for the calculation of the practical data of the Egg Incubator System. The Temperature changes with Time using the Simulink model in the Matlab Software. Simulink blocks produce conventional, PID, and Fuzzy-PID Control data to make the graph change with time. Here the clock is used for set the time during the operation of this system. Scope is used for viewing the Temperature data graph change with time in the egg incubator system and comparing the conventional, PID, and Fuzzy-PID graphs simultaneously.

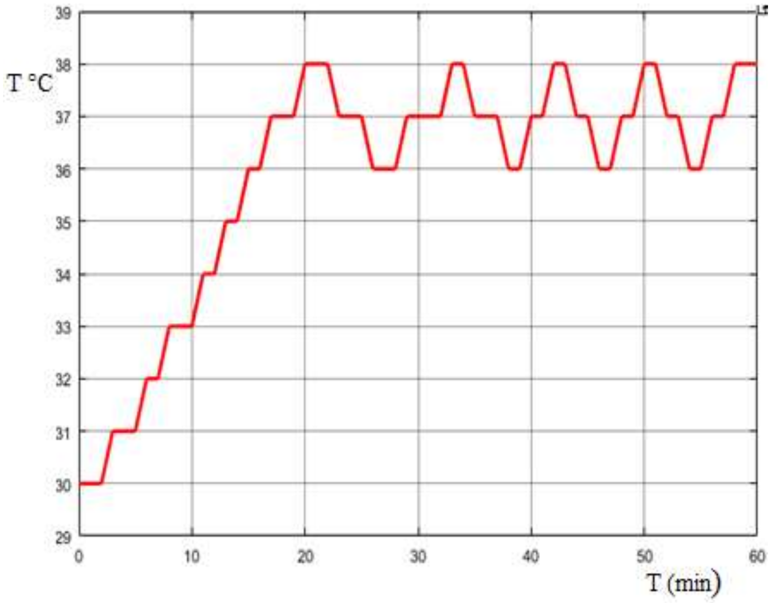

Figure 4.2: Change Temperature with Time Using Conventional Control Monitoring Process

During the experimental work, 60-minute Experimental temperature data is collected for the conventional Egg Incubator. In Figure 4.2, we can see that Temperature has been increasing and decreasing with respect to time. When the temperatures rise to 30–38°CC it takes 20 minutes, and when the temperatures fall to 38–36°CC, it takes 5 minutes. The result shows that conventional controllers have huge power consumption compared to conventional Egg incubators.

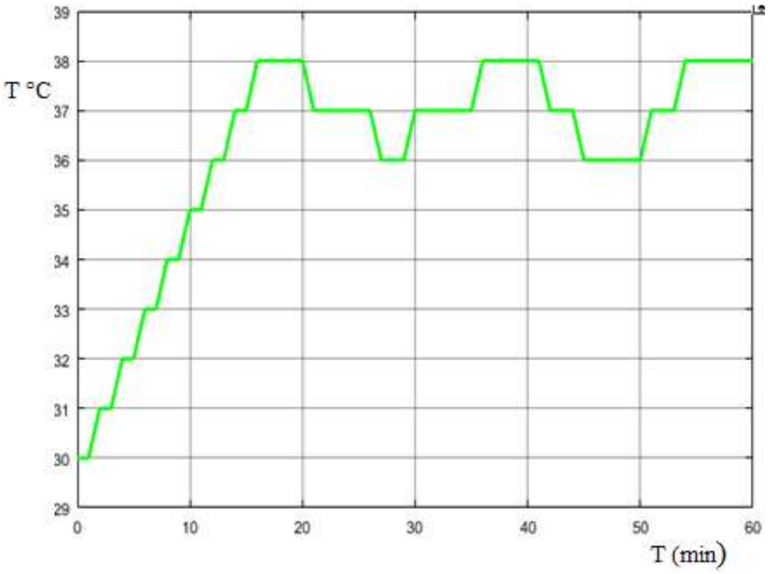

Figure 4.3: Change Temperature with Time Using PID Control Monitoring Process

During the experimental work, 60-minute Experimental temperature data for the Egg Incubator using a PID control system through Arduino PID coding. In Figure 4.3 shows that the temperature has been increasing and decreasing with respect to time. The temperature rises to 30–38°CC It has taken 15 minutes on the PID control system. When the temperatures fall to 38–36 °C, it takes 7 minutes. The result shows that PID control systems are more energy efficient than conventional egg Incubator systems.

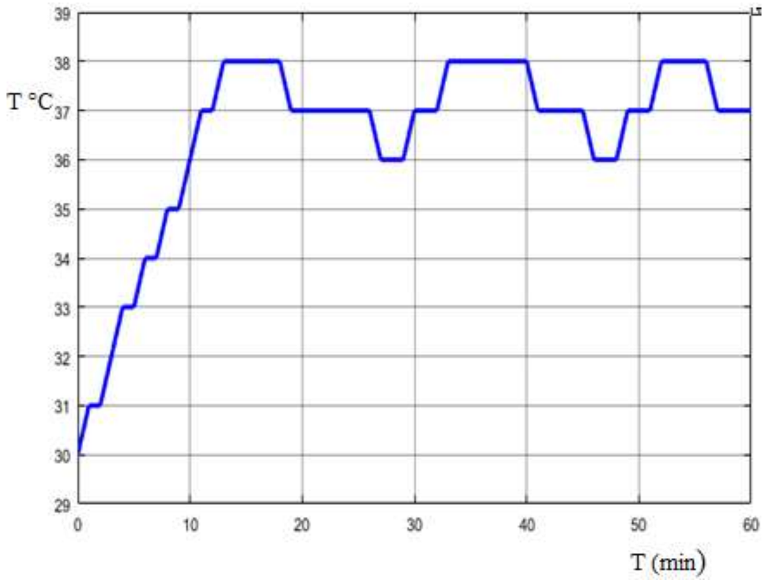

Figure 4.4: Change Temperature with Time Using Fuzzy-PID Control Monitoring Process

During the experimental work, 60-minute Experimental temperature data for the Egg Incubator using a PID control system through Arduino PID coding In Figure 4.4 shows that Temperature has been increasing and decreasing with respect to time. When the temperature rises to 30–38° C. It has taken 12 minutes on the conventional control system. When the temperature falls to 38–36 °C,, it has taken 8 minutes. The result shows that Fuzzy-PID control systems are more energy efficient than PID and conventional egg Incubator systems.

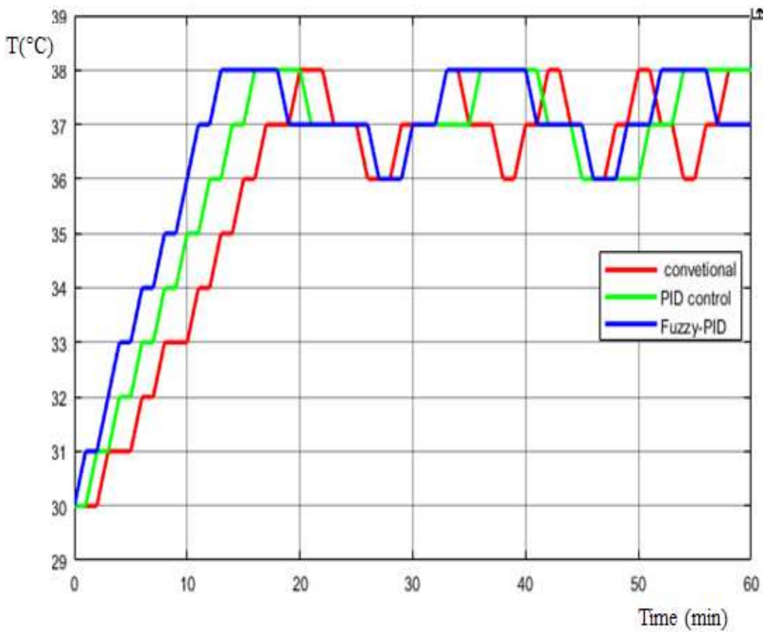

Figure 4.5: Change Temperature Variation with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

During the experimental work, 60 minutes of experimental temperature data were collected for the proposed Egg Incubator system. There are three different kinds of controllers, like Conventional, PID, and Fuzzy-PID control systems, used in the egg Incubator. The experimental data had been inserted into the Matlab Simulink model. Simulink blocks that produce the graph change with time. Figure 4.5 shows that the red curve is denoted as conventional Control, the green curve is denoted as PID control, and the blue curve is denoted as a fuzzy-PID control system. For comparison, we can see that a conventional controller can raise temperatures from 30°C to 38°C in 20 minutes, PID control can take 16 minutes, and Fuzzy PID can take 12 minutes. Then Temperatures fall from 38 °C to 36°C. Conventional controllers can take 5 minutes, PID controllers can take 7 minutes, and fuzzy-PID controllers can take 8 minutes. As temperature rises early in fuzzy-PID compared to other controllers. Power has lower consumption and energy savings than PID and conventional controllers. The result shows that Fuzzy-PID has improved temperature and saved more energy than conventional PID control systems.

4.1.2 Humidity Data

For controlling the Humidity in egg incubator system there are three different kinds of controllers conventional, PID, and fuzzy-PID Control systems are used and collected the humidity data (%) for egg incubator system. The humidity experimental data is given in Appendix A.2.

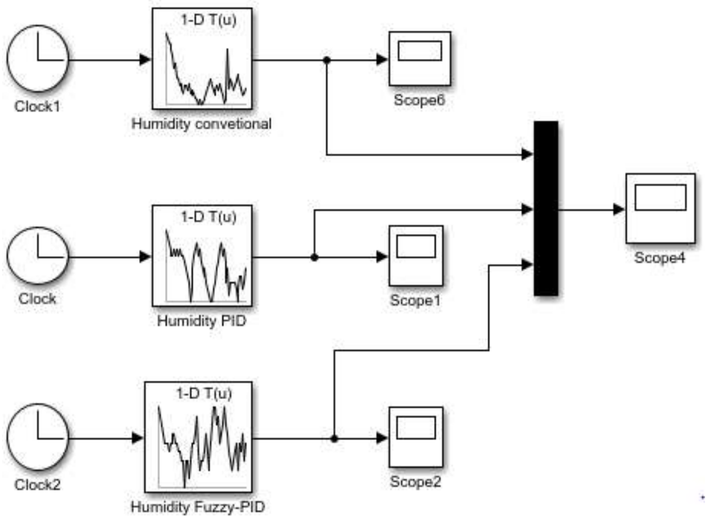

Figure 4.6: Simulink Model of Humidity

The most crucial component of Matlab is Simulink, which is utilized to compute the real-world data for the Egg Incubator System. With the help of the Simulink model in the Matlab software, the Humidity fluctuates over time. To make the graph alter over time, Simulink blocks generate conventional, PID, and fuzzy-PID Control data. Here, the system's clock is utilized to set the time while it is in operation. Scope is used to compare the conventional, PID, and Fuzzy-PID graphs simultaneously while monitoring the humidity data graph change with time in the egg incubator system.

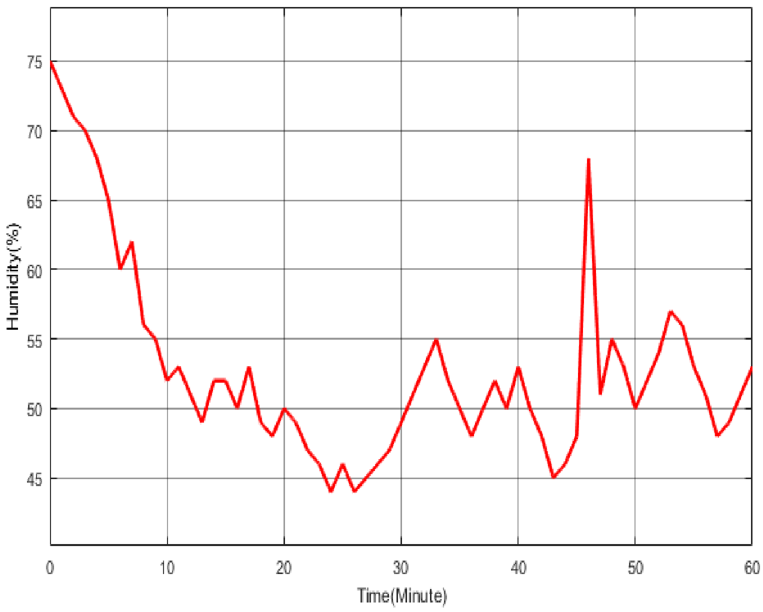

Figure 4.7: Change Humidity with Time Using Conventional Control Monitoring Process

We have been given 60-minute Experimental data for the conventional Egg Incubator. In figure 4.7, we can see that Humidity has been increasing and decreasing with respect to time. In this figure, we can see that the humidity is not controlled properly in the convention system. The result shows that the conventional controller has been fluctuating the humidity change with time accordingly.

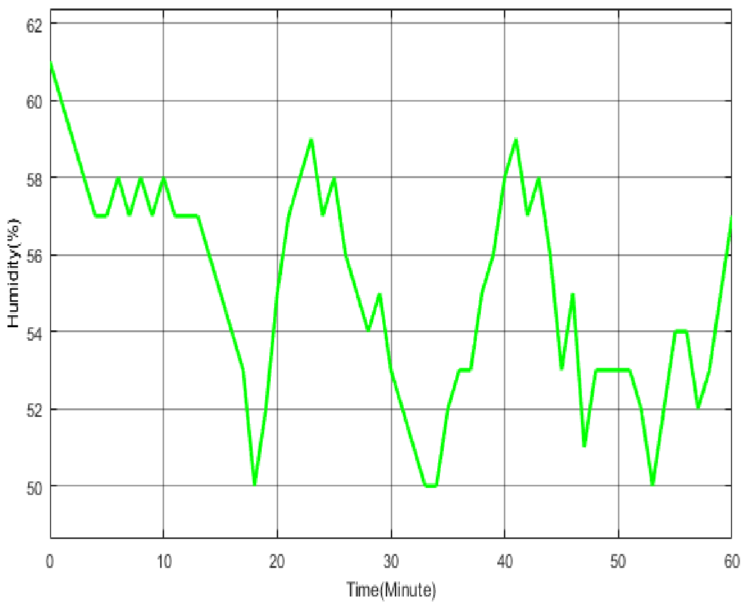

Figure 4.8: Change Humidity with Time Using PID Control Monitoring Process

We have taken 60 minutes of experimental data for the proposed Egg Incubator. In the experimental work, we used a PID control system for better Humidity control in the egg Incubator. In figure 4.8, we can see that Humidity has been changed with time, and we have controlled the humidity 50–60% accordingly. The result shows that it has better Humidity improvement than the conventional system.

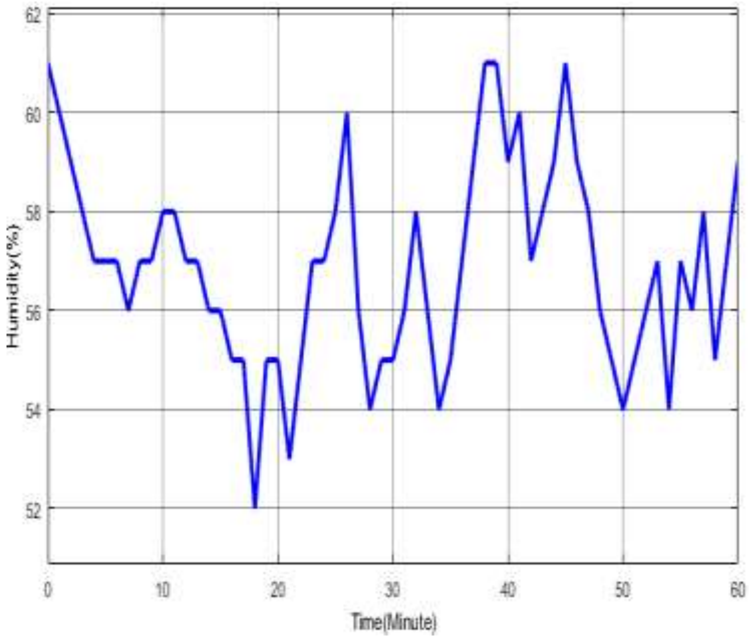

Figure 4.9: Change Humidity with Time Using Fuzzy-PID Control Monitoring Process

We have taken 60 minutes of experimental data for the proposed Egg Incubator. In the experimental work, we used a fuzzy-PID control system for better performance in the egg Incubator. In figure 4.8, we can see that Humidity has changed with time. The humidity had been controlled by 55–60% in our proposed system using the fuzzy-PID control method. The result shows that Fuzzy-PID has better performance than PID controllers and conventional control systems.

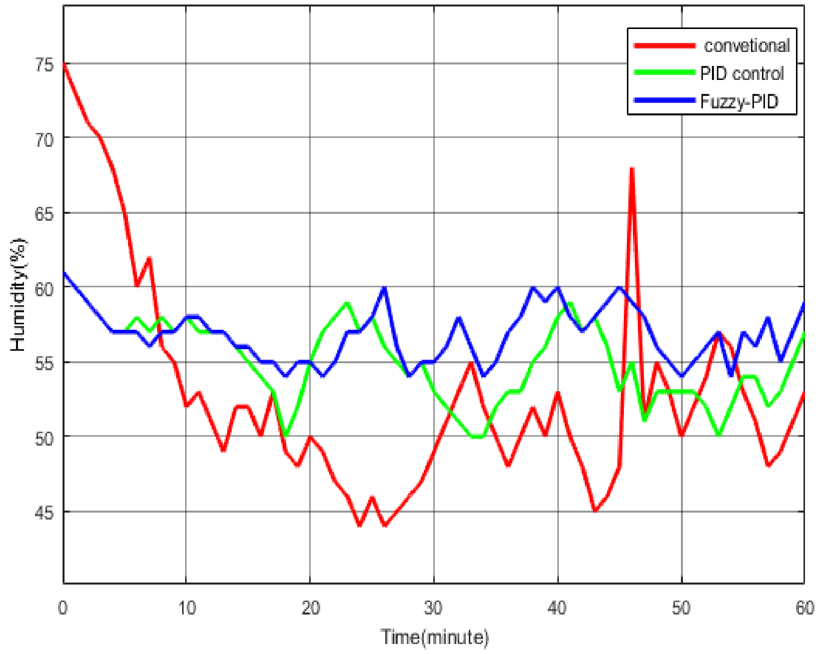

Figure 4.10: Humidity Variation with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

We have taken 60 minutes of experimental data for the proposed Egg Incubator system. In the experimental work, we used different kinds of controllers, like Conventional, PID, and Fuzzy-PID control systems, in the egg Incubator. The experimental data had been inserted in the Matlab Simulink model, which produced the graph changing with time. In Figure 4.10, we can see that the red curve is denoted as conventional Control, the green curve is denoted as PID control, and the blue curve is denoted as a fuzzy-PID control system. For our proposed incubator, humidity should be maintained at 55–60%. We have used different controllers, like conventional, PID, and fuzzy-PID control systems. Here we can see that in conventional control, the humidity does not maintain itself properly, and PID can control 50% to 60%. With a fuzzy-PID control system, the humidity can be maintained at 55 to 60%. The result shows that Fuzzy-PID has improved humidity control over conventional PID control systems.

4.1.3 Voltage Data

During the experiment in the egg incubator, we used conventional, PID, and fuzzy-PID Control systems. We had collected the Voltage (V) data using Conventional, PID, and Fuzzy-PID Control data in the egg incubator. The experimental Voltage (V) data is given in Appendix A.3.

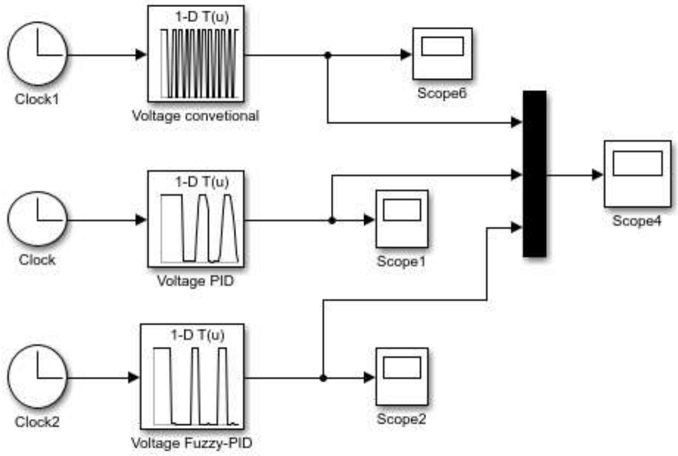

Figure 4.11: Simulink Model of Voltage

Simulink is a Matlab tool that is used for calculating the Practical data in the egg incubator system. The Voltage changes with time. Simulink blocks Producing Conventional, PID, and Fuzzy-PID control data graphs change with time accordingly. We have used a clock function for setting the time during the operation. Scope is used for viewing the voltage data graph change with time in the egg incubator system and comparing the conventional, PID, and Fuzzy-PID graphs simultaneously.

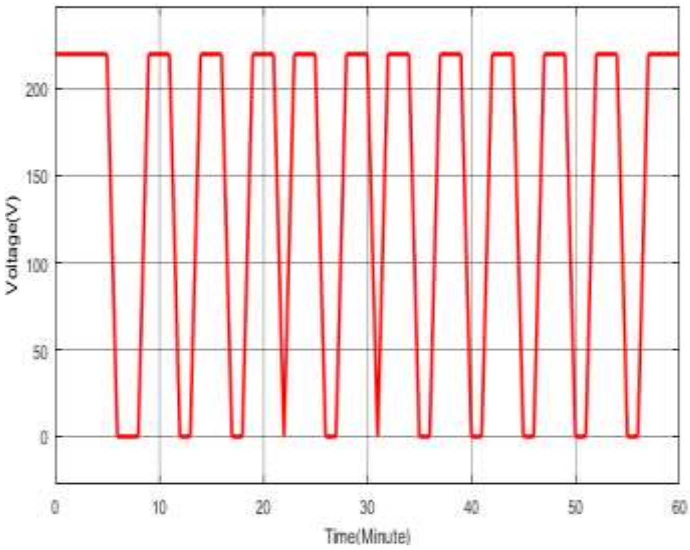

Figure 4.12: Change Voltage with Time Using Conventional Control Monitoring Process

We have taken 60 minute Experimental data for the conventional Egg Incubator. In figure 4.12, we can see that Voltage has been increasing and decreasing with respect to time. Initially, the 220 volt system took 5 minutes to start, 2 minutes for the voltage to drop, and 1 minute for the voltage to rise. The result shows that conventional controllers have huge power consumption compared to conventional Egg incubators.

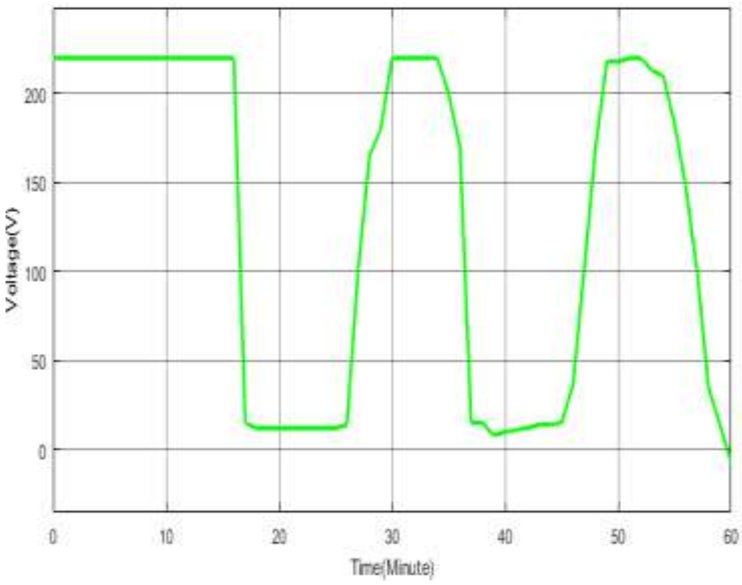

Figure 4.13: Change Voltage with Time Using PID Control Monitoring Process

We have taken 60-minute Experimental data for the Egg Incubator using a PID control system through Arduino PID coding. In figure 4.13, we can see that Voltage has been increasing and decreasing with respect to time. At first, the 220 volt had taken 15 minutes to start, but after 10 minutes, the voltage was lower, and since then, the voltage has been increasing with respect to time. The result shows that PID control is better than conventional controllers.

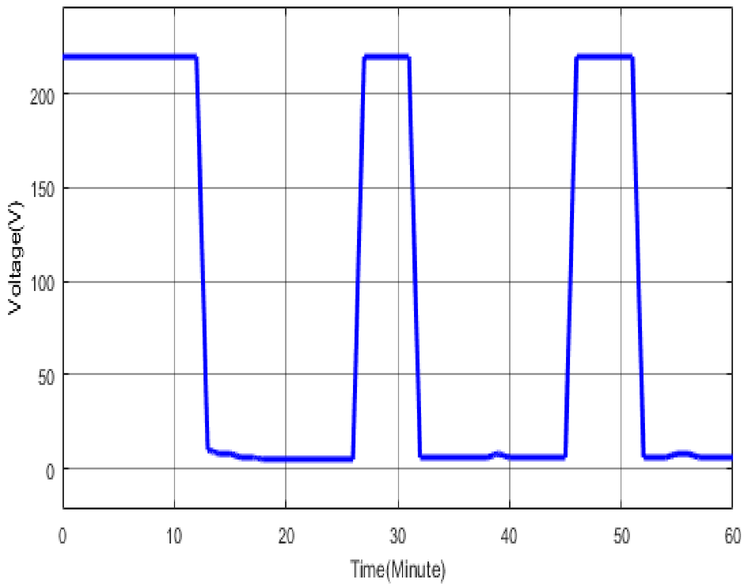

Figure 4.14: Change Voltage with Time Using Fuzzy-PID Control Monitoring Process

We have taken 60-minute Experimental data for the Egg Incubator using a fuzzy-PID control system through Arduino PID coding. In figure 4.14, we can see that Voltage has been increasing and decreasing with respect to time. At first, the 220 volts took 11 minutes to start, but after 14 minutes, the voltage was lower, and since then, the voltage has been increasing with respect to time. The result shows that Fuzzy-PID control is better than PID and conventional controllers.

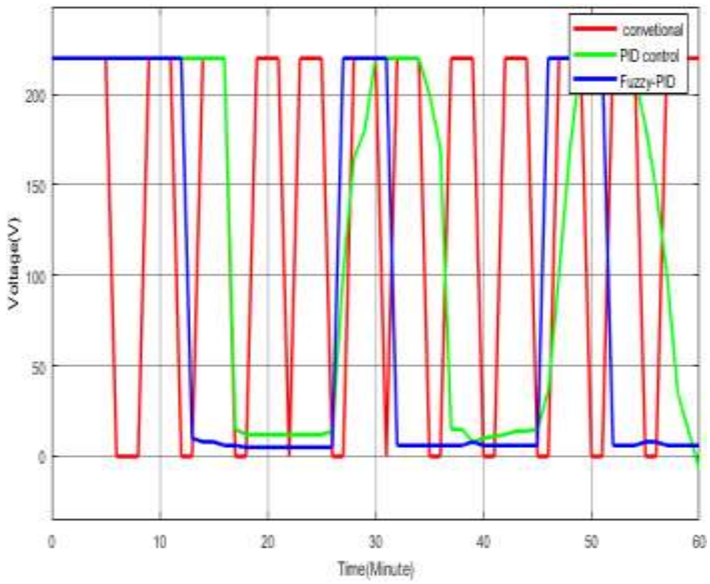

Figure 4.15: Voltage Variation with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

We have taken 60 minutes of experimental data for the proposed Egg Incubator system. In the experimental work, we used different kinds of controllers, like Conventional, PID, and Fuzzy-PID control systems, in the egg Incubator. The experimental data had been inserted into the Matlab Simulink model. Simulink blocks producing the graph change with time. In figure 4.5, we can see that the red curve is denoted as conventional Control, the green curve is denoted as PID control, and the blue curve is denoted as a fuzzy-PID control system. For comparison, we can see that conventional controllers take much more fluctuation, that’s why voltage consumption is much higher than PID Control. On the other hand, PID control had less fluctuation than Conventional control systems. So PID control consumes less voltage than Conventional Control. Further, Fuzzy-PID had a comparatively less fluctuation voltage than Conventional and PID control systems. The result shows that Fuzzy-PID consumes comparatively less voltage and saves energy than PID and the conventional control system.

4.1.4 Current Data

During the experiment in the egg incubator, we used conventional, PID, and fuzzy-PID Control systems. We had collected the Current (A) data using Conventional, PID, and Fuzzy-PID Control data in the egg incubator. The experimental Current (A) data is given in Appendix A.4.

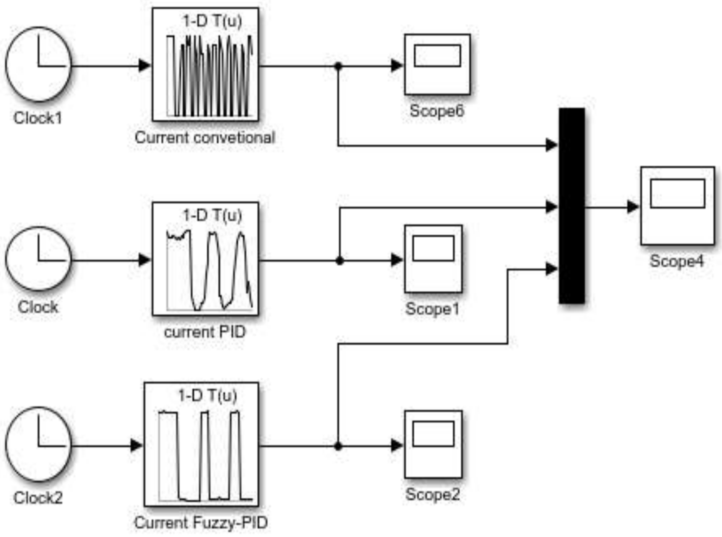

Figure 4.16: Simulink Model of Current

Simulink is the most important part of Matlab, which is used for the calculation of the practical data of the Egg Incubator System. For the Current variation, change with Time using the Simulink model in the Matlab Software. Simulink blocks produce conventional, PID, and Fuzzy-PID Control data to make the graph change with time using Arduino coding. Here, we can use the clock to set the time during the operation of this system. Scope is used for viewing the data graph variation with time for the egg incubator system. Scope is used for viewing the Current data graph's variation with time, and Scope 4 is used to compare the conventional, PID, and Fuzzy-PID graphs simultaneously.

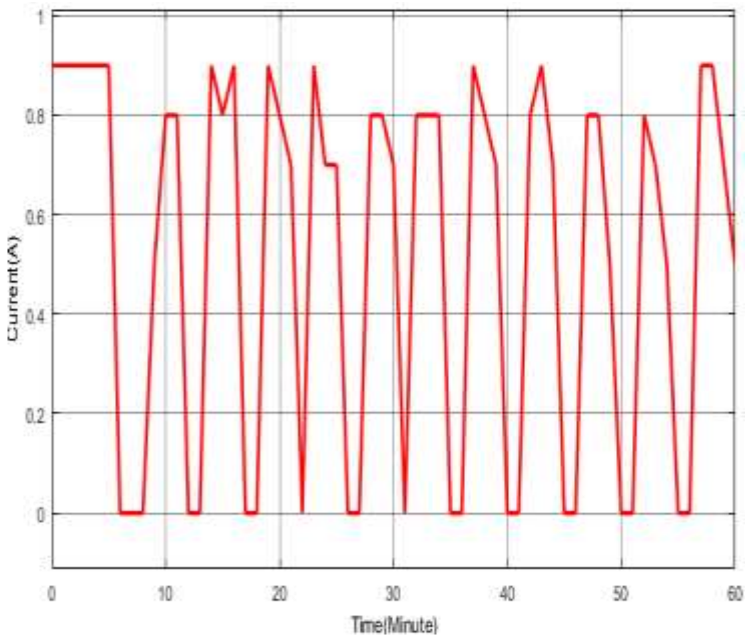

Figure 4.17: Change Current with Time Using Conventional Controller

We have been given 60-minute Experimental data for the conventional Egg Incubator. In figure 4.17, we can see that the current has been increasing and decreasing with respect to time. At first, the 0.9A had taken 5 minutes to begin, and after 2 minutes, the Current had 0 and then the current rise on 1 minute of conventional system. The result shows that conventional controllers have huge power consumption compared to conventional Egg incubators.

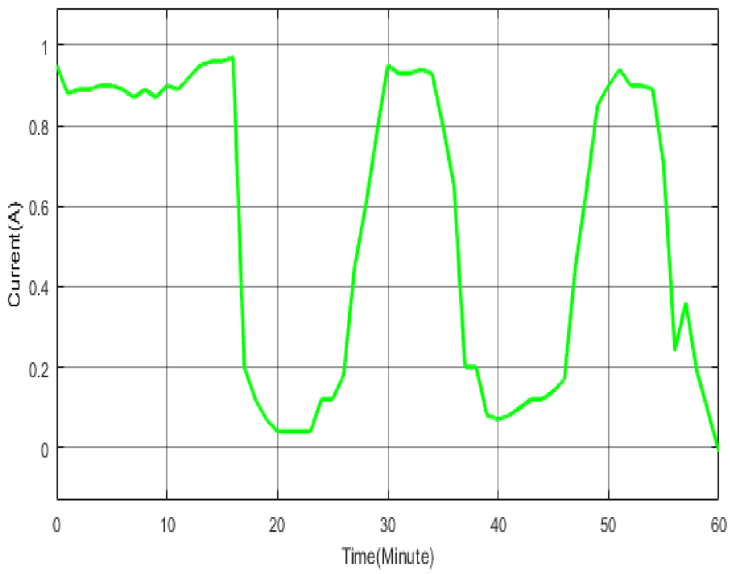

Figure 4.18: Change Current with Time Using PID Control Monitoring Process

We have taken 60-minute Experimental data for the Egg Incubator using a PID control system through Arduino PID Coding. In figure 4.18, we can see that the current has been increasing and decreasing with respect to time accordingly. The result shows that PID control is better than conventional controllers.

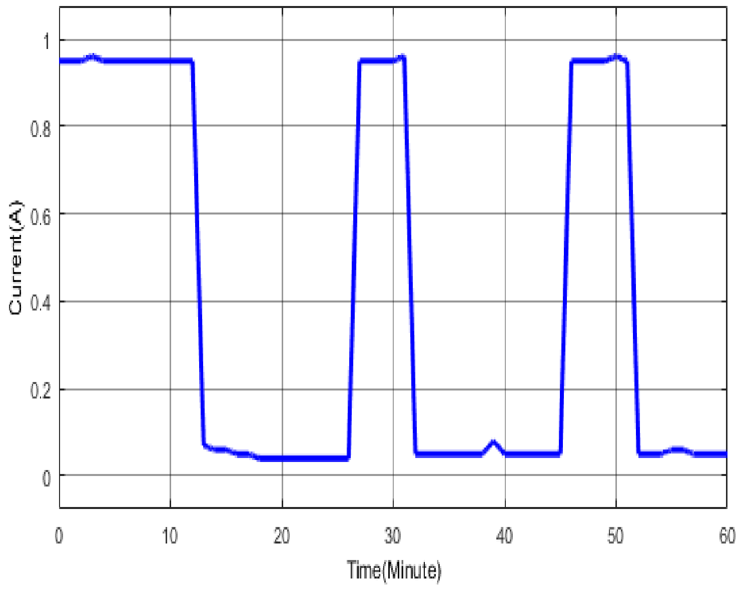

Figure 4.19: Change Current with Time Using Fuzzy-PID Control Monitoring Process

For the proposed egg incubator, 60-minute experimental data have been provided to us. For improved performance in the egg incubator, we implemented a fuzzy-PID control system during the experimental work. Here, the figure 4.19 current (A) has been updated in line with the passage of time. The outcome demonstrates that Fuzzy-PID performs better than a PID Controller.

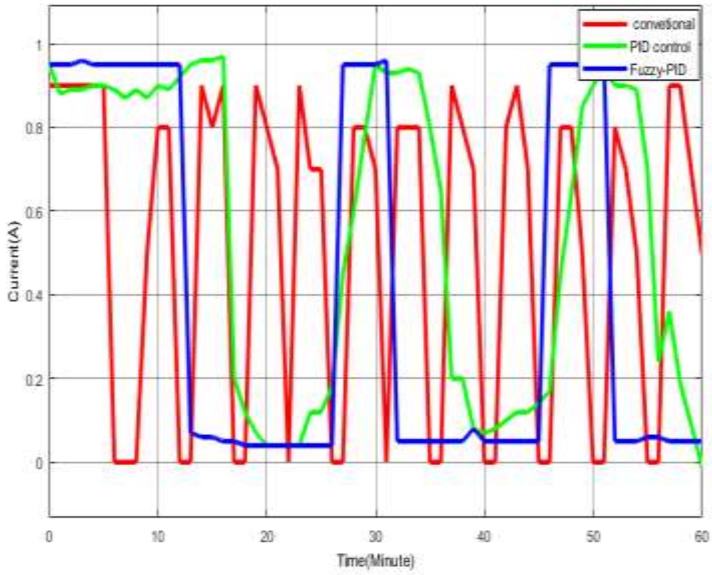

Figure 4.20: Current Variation with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

We have been given 60-minute Experimental data for the proposed Egg Incubator system. In the experimental work, we used different kinds of controllers, like Conventional, PID, and Fuzzy-PID control systems, in the egg Incubator. The experimental data had been inserted into the Matlab Simulink model. Simulink blocks that produce the graph change with time. In Figure 4.20, we can see that the red curve is denoted as conventional Control, the green curve is denoted as PID control, and the blue curve is denoted as a fuzzy-PID control system. For comparison, we can see that conventional controllers take much more fluctuation, which is why current consumption is higher than PID Control. On the other hand, PID control had less fluctuation than Conventional control systems. So PID control consumes less Current than Conventional Control. Further, Fuzzy-PID had taken Comparatively less fluctuation current than Conventional and PID control systems. The result shows that, Fuzzy-PID consumes comparatively less current and saves energy than PID and conventional control systems.

4.1.5 Power Data

During the experiment in the egg incubator, we used conventional, PID, and fuzzy-PID Control systems. We had collected the Power (W) data using Conventional, PID, and Fuzzy-PID Control data in the egg incubator. The experimental Power (W) data is given in Appendix A.5.

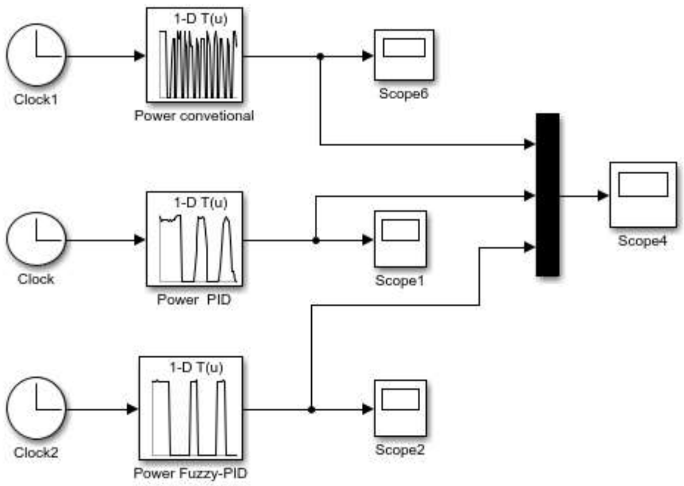

Figure 4.21: Simulink Model of power

The most crucial component of Matlab is Simulink, which is utilized to compute the real-world data for the Egg Incubator System. Simulink blocks in the Matlab program create traditional, PID, and fuzzy-PID Control data, which are used by Arduino code to update the graph over time as the Power variation changes with time. Here, the clock is used to set the time for this system's operation. For the system of the egg incubator, the scope is utilized to view the Power data graph change over time. Additionally, scope 4 is used to simultaneously compare the traditional, PID, and fuzzy-PID graphs.

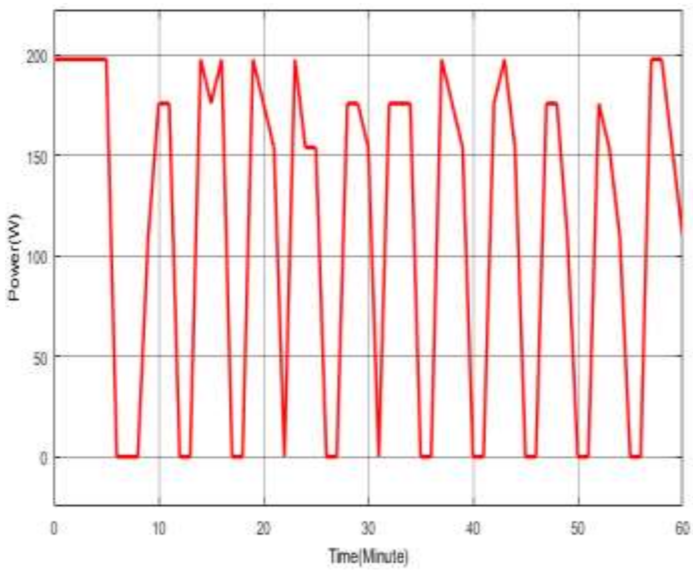

Figure 4.22: Change Power with Time Using Conventional Control Monitoring Process

We have taken 60-minute Experimental data for the Egg Incubator using conventional control systems through Arduino PID coding. In figure 4.22, we can see that power has been increasing and decreasing with respect to time. At first, the 200W power consumed about 6 minutes from beginning to end. After 2 minutes, the power had been consumed 0 and then the power increased with respect to time. The result shows that PID control is better than conventional controllers.

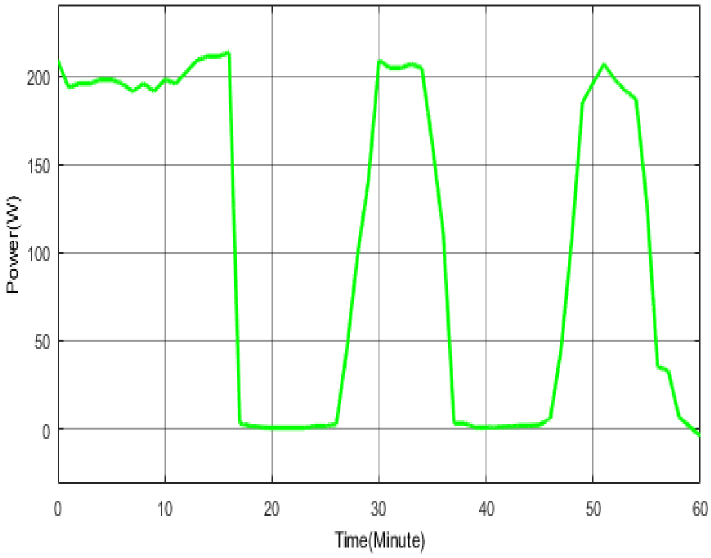

Figure 4.23: Change Power with Time Using PID Control Monitoring Process

With the help of Arduino PID coding, we collected experimental data for the Egg Incubator over a period of 60 minutes. Figure 4.23 shows how Power (W) has changed throughout time, increasing and decreasing. It has taken 16 minutes to use the power, and 9 minutes to fall on. The outcome demonstrates that PID control is better than conventional controllers.

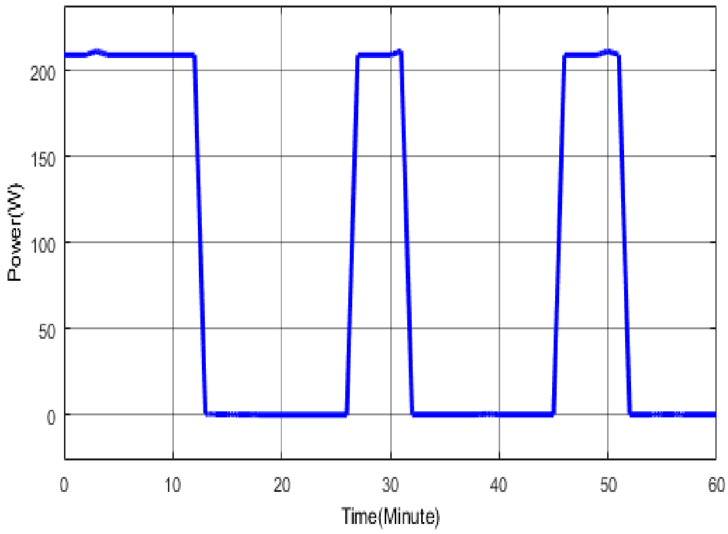

Figure 4.24: Change Power with Time Using Fuzzy-PID Control Monitoring Process

For the proposed egg incubator, 60-minute experimental data have been provided to us. In the experiment, we used a variety of factors in the egg incubator, including conventional, PID, and fuzzy-PID control systems. We employed a fuzzy-PID Control system in the egg incubator to improve performance. See figure 4.24 below. With relation to time, power has been used appropriately. The power had been used for 12 minutes prior to the temperature increase. It takes 12 minutes when the temperature drops. As a result, Fuzzy-PID outperforms PID and the traditional system in terms of improvements.

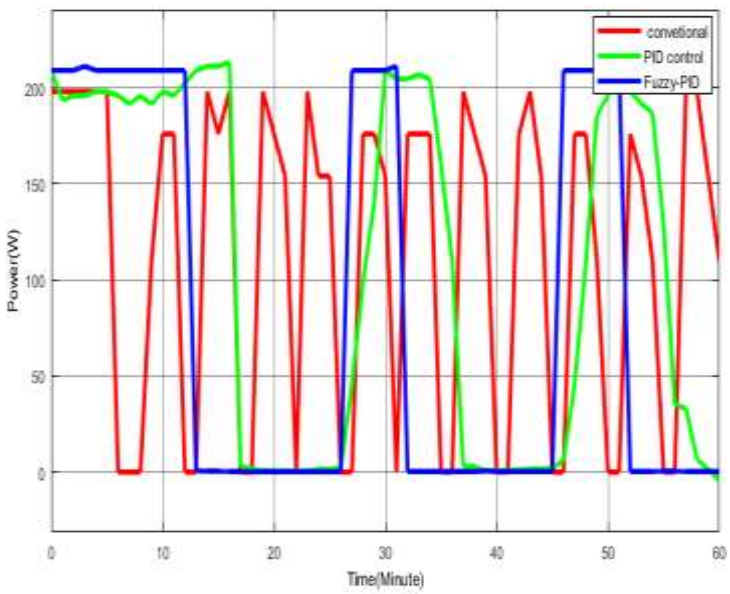

Figure 4.25: Power Variation with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

For the proposed Egg Incubator system, 60-minute Experimental data have been provided. Different types of controllers, including conventional, PID, and fuzzy-PID control systems, were utilized in the experiment in the egg incubator. The Matlab Simulink model had been updated to include the experimental data. The Simulink blocks used to create the graph evolve over time. Figure 4.25 shows three different types of control systems: conventional control (represented by the red curve), PID control (represented by the green curve), and fuzzy-PID control (represented by the blue curve). In contrast, we can observe that conventional controllers are far more tolerant of variation, which accounts for the increased power usage compared to PID Control. PID control, however, displayed less fluctuation than conventional control methods. So PID control consumes less power than Conventional Control. Further, Fuzzy-PID had comparatively less fluctuation power than Conventional and PID control systems. The result shows that, Fuzzy-PID consumes comparatively less current and saves energy than PID and conventional control systems.

4.1.6 Power Consume in different Parameter

The most crucial component of Matlab, which is used to compute the real-world data for the Egg Incubator System, is Simulink. Utilizing the Simulink model in Matlab software, the power fluctuates over time. To make the graph alter over time, Simulink blocks generate conventional, PID, and fuzzy-PID Control data.

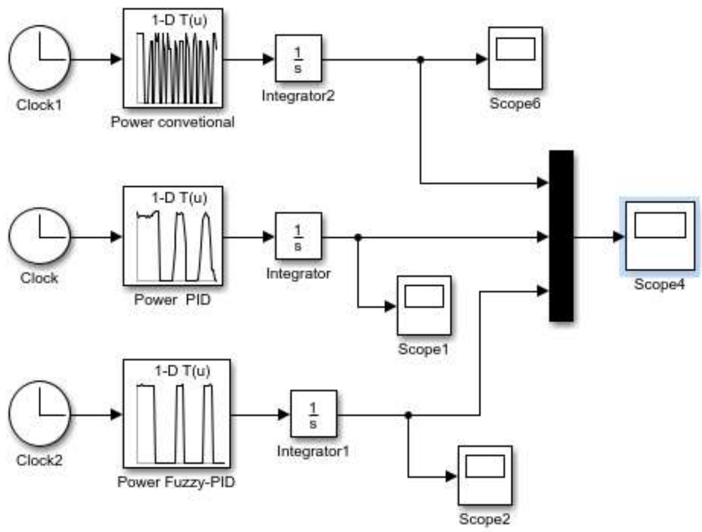

Figure 4.26: Simulink of power Consumption Model

The time is set using a clock in this case so that the system can function. Utilizing Scope, one can simultaneously compare the conventional, PID, and Fuzzy-PID graphs to see how the power consumption data graph changes over time in the egg incubator system.

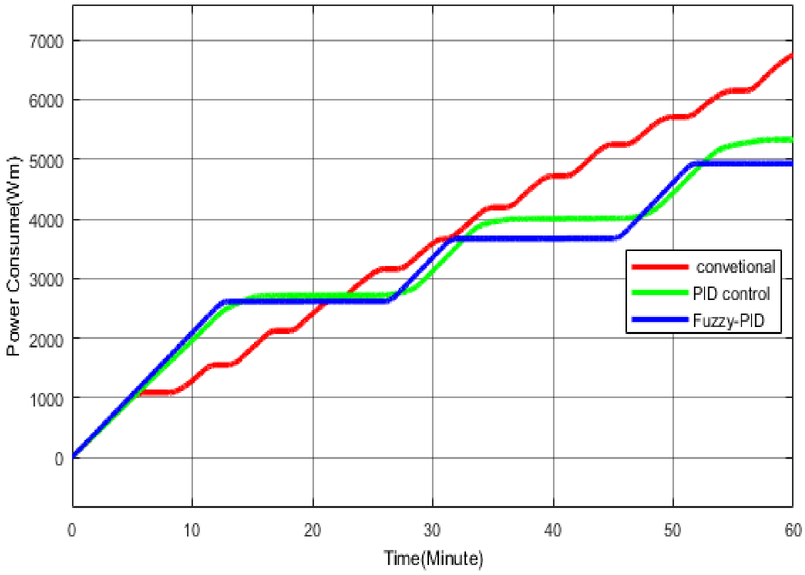

Figure 4.27: Power Consumed with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

During the experimental work, 60-minute Experimental Power consumption data were collected for the proposed Egg Incubator system. In the experimental work, there are three different kinds of controllers, like Conventional, PID, and Fuzzy-PID control, in the egg Incubator. The experimental data had been inserted in the Matlab Simulink model, which can produce a Power consumption graph changing with time. Figure 4.27 shows that the red curve is denoted as conventional Control, the green curve is denoted as PID control, and the blue curve is denoted as a fuzzy-PID control system. For comparison, conventional controllers consume much more power in the system compared to PID and Fuzzy-PID Control systems. Here, the integrator is used for the calculation of Power consumption for this system. The figure shows that a conventional controller consumed 6667 W of power per minute during operation. On the other hand, the PID controller had been taken at 5330 W per minute and the fuzzy-PID had been taken at 4945 W per minute during 1 hour of operation. The result shows that Fuzzy-PID consumes comparatively less power and saves more energy than PID and conventional control systems.

4.2 Energy Calculation of Conventional Controller

During the Experimental work we had collected 60 minutes data for Convention Egg Incubator. After integration through the Matlab Simulink the power had consumed 6667 W minutes

The Energy consumption = 6667 Watt minute

$= \frac{6667}{60}$ Watt hour

= 111.117W hour

For 24/ 1 day , the energy consumption of egg Incubator is = (111.117 × 24) W hour

= 2666.8 Whour

For 21 days incubation energy consumption of egg Incubator is = 2666.8 Watt hour× 21

=56002.8 Watt hour

$= \frac{56002.8}{1000}$ kWh

= 56.0028 kWh

4.3 Energy Calculation of PID Control System

During the Experimental work we had collected 60 minutes data for PID control Egg Incubator. After integration through the Matlab Simulink the power had consumed 6667 W minutes

The Energy consumption = 5330 Watt minute

$= \frac{5330}{60}$ Watt hour

= 88.83W hour

For 24/ 1 day , the energy consumption of egg Incubator is = (88.83× 24) W hour

= 2132 Whour

For 21 days incubation energy consumption of egg Incubator is = 2132 Watt hour× 21

=44772Watt hour

$= \frac{44772}{1000}$ kWh

= 44.772 kWh

Now the energy saving of PID control compared to the Conventional Controller

$$= \frac{Conventional - PID}{Conventional}$$

$$= \frac{56.0028 - 44.772}{56.0028} \times 100$$

= 20.05%

During the experimental work, the conventional controller consumed more power than the PID. The result shows that PID controllers are more energy efficient than conventional controllers.

4.4 Energy Calculation of Fuzzy-PID Control System

During the Experimental work we had collected 60 minutes Fuzzy-PID data for Egg Incubator. After integration through the Matlab Simulink the power had consumed 4945 W minutes

The Energy consumption = 4945 Watt minute

$= \frac{4945}{60}$ Watt hour

= 82.42W hour

For 24/ 1 day , the energy consumption of egg Incubator is = (82.42 × 24) W hour

= 1978 Whour

For 21 days incubation energy consumption of egg Incubator is =1978 Watt hour× 21

= 41538 Watt hour

$=\frac{41538}{1000}$ kWh

= 41.538 kWh

The Energy Calculation result shows that Fuzzy-PID has better Power saving in the Egg incubator than PID and the Conventional system.

Now the energy saving of Fuzzy-PID compared to the Conventional Controller

$$= \frac{Conventional - Fuzzy - PID}{Conventional}$$

$$= \frac{56.0028 - 41.538}{56.0028} \times 100$$

=25.83%

During the experimental work, the conventional controller consumed more power than the PID, and fuzzy-PID consumed less power than the PID, saving energy by

25.83%. The result shows that Fuzzy-PID is more energy efficient than PID and conventional controllers.

4.5 Comparison of Power Consumption between Conventional, PID and fuzzy-PID

During the experimental work, three different kinds of controllers, like conventional, PID, and Fuzzy-PID, are used to control the temperature in the egg incubator system. Figure 4.29 shows that the red column is denoted as a conventional system, the green column is denoted as a PID control system, and the blue column is denoted as a fuzzy-PID control system. After the experiment, total power consumption in 21 days of incubation was 56.0028 kWh. After using a PID controller, the total power consumption was 44.772 kWh. For further energy savings, a fuzzy-PID controller is used in the incubator. During the experimental work, total power consumption was 41.538 kWh during 21 days of incubation.

The result shows that the conventional controller consumes more power than the PID Controller. On the other hand, Fuzzy-PID has less power consumption than PID and conventional systems and saves energy compared to PID and conventional systems.

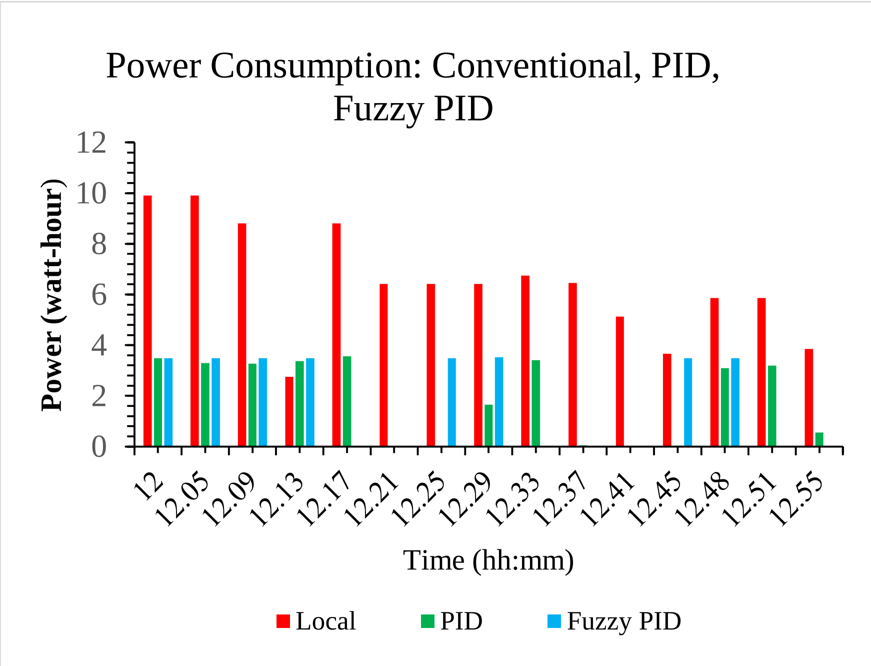

Figure 4.28 Power Consumption with time in Conventional, PID and Fuzzy-PID Monitoring Process

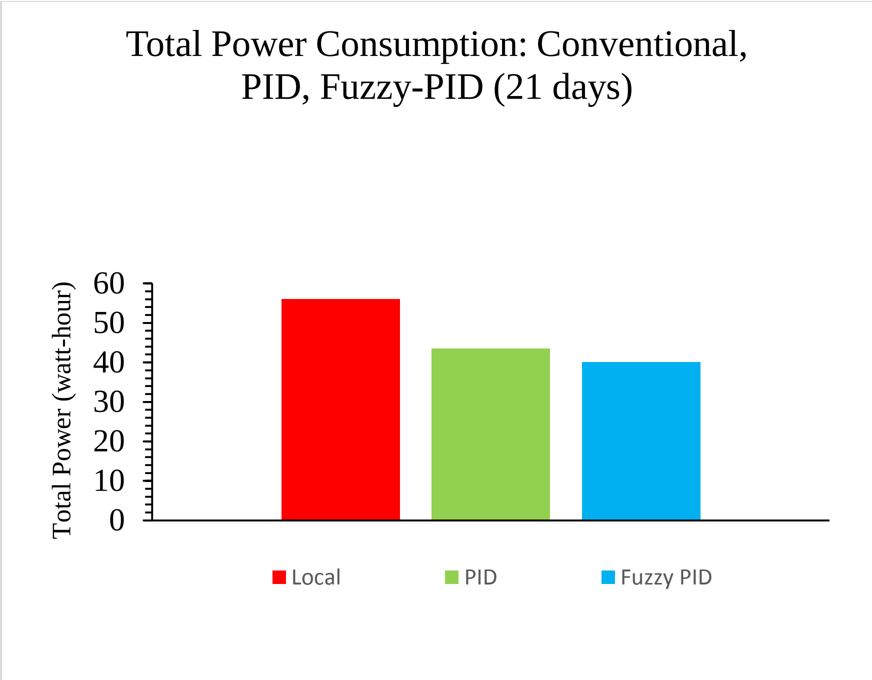

Figure 4.29 Power Consumption Variation with time in Conventional, PID and Fuzzy-PID Monitoring Process

4.6 Pearson Correlation Coefficient

The Pearson correlation is a measurement of the strength of a linear relationship between two variables. Here, the values of -1 to 1 mean a total negative linear correlation, while + 1 means a total positive correlation. 0 means there is no correlation between two variables [70]. Pearson correlation is the mean of two variables, like X and Y. If the relation between X and Y is 0.75 to 1, then the values of X and Y are strongly correlated. These values of X and Y are valid for the system. For calculating the Pearson correlation with respect to voltage, Current, Power, temperature, and Humidity, The Pearson correlation Coefficient equation is given below.

$$r_{xy} = \frac{\sum(xi-\bar{x})(yi-\bar{y})}{\sqrt{\sum(xi-\bar{x})^2(yi-\bar{y})^2}} \quad \text{............(5)}$$

r = Pearson Correlation coefficient

xi= The samples of x variable

$\bar{x}$ = the value of mean in x variable

yi= The sample of y variable

$\overline{y}$= The value of mean in y variable

4.6.1 Pearson Correlation Coefficient of Conventional Current-Voltage

For calculating the mean of both X (Current) and Y (Voltage) values. the difference between the individual X and Y values and calculated the sum of the last three columns. Now put the values into the formula for the Pearson Correlation coefficient. The Table of Pearson Correlation The coefficient of the conventional controller for Current-Voltage data is given in Appendix 6. After using Conventional Current and Voltage data, the Correlation is

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 \, (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{248.805}{\sqrt{80412.75 * 0.7971}} = 0.98$$

The Pearson Correlation Coefficient turns out to be 0.98. Since this value is close to 1, this indicates that Current (X) and voltage (Y) are strongly positively correlated. As the value of X increases, the value of Y also increases, which is exactly predictable.

4.6.2 Pearson Correlation Coefficient of Conventional Current- Temperature

For figuring out the average of the numbers for both X (Current) and Y (Temperature). calculated the sum of the final three columns and the difference between the individual X and Y values. Put the values into the Pearson Correlation Coefficient calculation now. The Pearson Correlation Table Appendix 7 contains the coefficient of the traditional controller for Current-Temperature data. The correlation is determined by conventional current and voltage measurements.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 \, (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{214.8125}{\sqrt{5.4875 * 8577.188}} = 0.98$$

The Pearson Correlation Coefficient turns out to be 0.98. Since this value is close to 1, this indicates that Current (X) and Temperature (Y) are strongly positively correlated. As the value of X increases, the value of Y also increases, which is exactly predictable.

4.6.3 Pearson Correlation Coefficient of Conventional Current- Humidity

in order to determine the average of the X (current) and Y (humidity) values. calculated the sum of the final three columns and the difference between the individual X and Y values. Put the values into the Pearson Correlation Coefficient calculation now. The Pearson Correlation Table Appendix 8 contains the coefficient of the traditional controller for Current-Voltage data. the correlation is determined by conventional current and humidity measurements.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 \, (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{399.58409}{\sqrt{5.379539 * 29903.44}} = 0.99$$

It turns out that the Pearson Correlation Coefficient is 0.99. Since this number is nearly 1, it means that the correlation between current (X) and humidity (Y) is very strong. It is precisely foreseeable that as the value of X rises, the value of Y also rises.

4.6.4 Pearson Correlation Coefficient of PID Controller of Current-Temperature

in order to calculate the average of the values for both the current and the temperature, X and Y. computed the difference between the individual X and Y values and the sum of the last three columns. Now calculate the Pearson Correlation Coefficient using the values. The PID controller's coefficient for current-temperature data can be found in the Pearson Correlation Table in Appendix 9. Measurements of conventional current and voltage are used to determine the correlation.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{8.4}{\sqrt{0.8154 * 110.4}} = 0.89$$

It turns out that the Pearson Correlation Coefficient is 0.89. The fact that this number is so near to1shows that the correlation between current (X) and temperature (Y) is very strong. It is precisely foreseeable that as the value of X rises, the value of Y also rises.

4.6.5 Pearson Correlation Coefficient of PID Controller of Current- Humidity

X and Y computed the difference between the individual X and Y values and the sum of the last three columns in order to determine the average of the values for both the Current and the Humidity. Now use the values to compute the Pearson Correlation Coefficient. The Pearson Correlation Table in Appendix 10 contains the coefficient for the PID controller for Current-Humidity data. The correlation is ascertained using conventional current and voltage measurements.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 \, (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{1.47}{\sqrt{0.0064 * 347.8}} = 0.9853$$

It turns out that the Pearson Correlation Coefficient is 0.98. Since this number is nearly 1, it means that the correlation between current (X) and humidity (Y) is very strong. It is precisely foreseeable that as the value of X rises, the value of Y also rises.

4.6.6 Pearson Correlation Coefficient of PID Controller of Current- Voltage

For figuring out the average of the numbers for both X (Current) and Y (voltage). calculated the sum of the final three columns and the difference between the individual X and Y values. Put the values into the Pearson Correlation Coefficient calculation now. The Pearson Correlation Table Appendix 11 contains the coefficient of the PID controller for Current-voltage data. The correlation is determined by conventional current and voltage measurements.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 \, (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{222.59}{\sqrt{0.2402 * 6059.045}} = 0.9814$$

The Pearson Correlation Coefficient is 0.98, as it turns out. This value's proximity to 1 demonstrates how strongly current (X) and voltage (Y) are correlated. It is predictable that as the value of X increases, the value of Y will follow suit.

4.6.7 Pearson Correlation Coefficient of Fuzzy-PID Controller of Current-Voltage

For calculating the X (current) and Y (voltage) figures' averages. computed the difference between the individual X and Y values and the sum of the last three columns. Now calculate the Pearson Correlation Coefficient using the values. The PID controller's coefficient for current-voltage data can be found in Appendix 12, the Pearson Correlation Table. Measurements of Fuzzy-PID current and voltage are used to determine the correlation

$$.r_{xy} = \frac{\sum(xi-\bar{x})(yi-\bar{y})}{\sqrt{\sum(xi-\bar{x})^2(yi-\bar{y})^2}}$$

$$r_{xy} = \frac{1524.686}{\sqrt{6.5408*356402.3}} = 0.99$$

It turns out that the Pearson Correlation Coefficient is 0.99. Since this number is nearly 1, it means that the correlation between current (X) and Voltage (Y) is very strong. It is precisely foreseeable that as the value of X rises, the value of Y also rises.

4.6.8 Pearson Correlation Coefficient of Fuzzy-PID Controller of Current-Temperature

Initial determined the average of the data for X (Current) and Y (Temperature). The value and difference between the distinct X and Y values and their various meanings have then been determined. The last three columns' sum was then determined. Now that the values have been entered, the Pearson Correlation coefficient formula may be used.

The Pearson Coefficient On A.13, the fuzzy-PID controller of current-temperature data's coefficient is provided. When current and temperature data are combined with fuzzy-PID data, the correlation is

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 \, (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{203.8352}{\sqrt{5.86352 * 8236.264}} = 0.93$$

It comes out that the Pearson Correlation Coefficient is 0.93. Given that this value is nearly 1, this shows a strong positive correlation between temperature (Y) and current (X). It is precisely foreseeable that as the value of X rises, the value of Y also rises.

4.6.9 Pearson Correlation Coefficient of Fuzzy-PID Controller of Current-Humidity

To calculate the average value of the voltage and current data. calculated the difference between the separate X and Y values as well as the sum of the final three columns. Enter the data into the calculation of the Pearson Correlation Coefficient right away. The PID controller's coefficient for current-Humidity data is found in the Pearson Correlation Table Appendix 14. Fuzzy-PID current and Humidity measurements are used to determine the correlation

$$.r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2 (yi - \bar{y})^2}}$$

$$r_{xy} = \frac{393.41456}{\sqrt{6.897156 * 27630.63}} = 0.90$$

The Pearson Correlation Coefficient is 0.90, as it turns out. Since this value is so close to 1, there is a significant link between current (X) and humidity (Y). The value of Y will increase as the value of X increases, which is precisely what is expected to happen.

4.6.10 Pearson Correlation Coefficient of Fuzzy-PID Controller of Power-Humidity

To get the average values of X (power) and Y (humidity) calculated the difference between the individual X and Y values as well as the sum of the final three columns.

Now calculate the Pearson Correlation Coefficient using the data. The Fuzzy-PID controller's coefficient for Current-Voltage data can be found in the Pearson Correlation Table Appendix 11. Standard current and voltage measurements are used to determine the correlation.for Current-Voltage data can be found in the Pearson Correlation Table Appendix 15. Standard current and voltage measurements are used to determine the correlation.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2\,(yi - \bar{y})^2}}$$

$$r_{xy} = \frac{85894.0208}{\sqrt{339366.1 * 27630.63}} = 0.89$$

The Pearson Correlation Coefficient was found to be 0.89. The fact that this value is so close to 1 indicates a strong correlation between the variables power (X) and humidity (Y). It is clearly predictable that as X's value increases, Y's value will follow suit.

4.6.11 Pearson Correlation Coefficient of Fuzzy-PID Controller of Power-Temperature

to calculate the average value of the power and temperature data calculated the difference between the separate X and Y values as well as the sum of the final three columns. Enter the data into the calculation of the Pearson Correlation Coefficient right away. The PID controller's coefficient for current-voltage data is found in the Pearson Correlation Table Appendix 16. Fuzzy-PID power and temperature measurements are used to determine the correlation.

$$r_{xy} = \frac{\sum(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum(xi - \bar{x})^2\,(yi - \bar{y})^2}}$$

$$r_{xy} = \frac{51091.05}{\sqrt{339404.7 * 10394.38}} = 0.87$$

It turns out that 0.87 is the Pearson Correlation Coefficient. The close proximity of this value to one indicates a significant connection between the variables power (X) and temperature (Y). The value of Y will increase as the value of X increases, as is precisely predictable.

4.7 Regression Analysis of Conventional Controller

Table 4.1 shows the regression analysis of the conventional controller. We have used the regression analysis in Excel to calculate the estimated value, and then we have relations between two or more variables. There are two terms, such as dependent and independent variables. The regression Analysis of the conventional controller is given below.

Table 4.1 : Regression Analysis of Conventional Controller

Regression Analysis of Power (P,watt) with voltage (v,volt), current(i,amp),temperature (T,°centigrade), Humidity(%)						
Model No.	Form of Equation	Equation Constants		Multiple R	R Square	Adjusted R Square
		m_i	k_1			
1	$P_1 = m_1$v+k_1	$m_1 = 0.86$	-1.7907	0.9733	0.9473	0.9420
$\boldsymbol{P_1 = -1.7907 + 0.86}$**v**						
2	$P_2 = m_1$i+k_1	m_1=122.65	-90.8971	0.968	0.934	0.919
$\boldsymbol{P_2 = -90.8971 + 122.65}$**i**						
3	$P_3 = m_1T+k_1$	m_1=5.6538	3.6645	0.9332	0.89719	0.8749
$\boldsymbol{P_3 = 3.6645 + 5.6538}$**i**						
4	$P_4 = m_1H+k_1$	m_1=2.7881	1.779	0.9742	0.95719	0.9448
$\boldsymbol{P_4 = 1.779 + 2.7881}$**i**						
5	$P_5 = m_1$v+m_2i + k_1	m1=0.76 m2=308	-246.4	0.98941	0.9682	0.96872
$\boldsymbol{P_5 = -246.4 + 0.76}$**v+308i**						
6	$P_6 = m_1$v+m_2T + k_1	m_1=1.531353 m_2= -4.57381	-0.15086	0.9894	0.96824	0.95873
$\boldsymbol{P_6 = -0.15086 + 1.531353}$**v-4.57381T**						
7	$P_7 = m_1$v+m_2H + k_1	m_1=0.825503 m_2= 1.335823	-79.6826	0.980288	0.960964	0.952289
$\boldsymbol{P_7 = -79.6826 + 0.825503}$**v+1.335823H**						
8	$P_8 = m_1$v+m_2i + m_3T + $m4$H + k_1	m_1=-0.19087 m_2=776.8789 m_3= 5.577465 m_4= -0.70986	-579.385	0.98471	0.9696	0.9523
$\boldsymbol{P_8 = -579.385 - 0.19087v - 776.8789}$**i +5.577465T-0.70986H**						

In the conventional controller, the dependent variable is power, and the independent variables are voltage, current, temperature, and humidity. In the Tables, the Multiple R is a linear relationship between the dependent and independent variables for the measurement of the correlation coefficient. Here is the strong relationship measurement: 1 means a strong positive, -1 means a strong negative, and 0 means no relationship at all [73].

In Table 4.1, there are eight correlations. We have calculated the multiple R value, the R square value, and the adjusted R value. We had been showing the 8 no model correlations, such as the correlation between power and voltage, the correlation

between power and current, and the correlation between temperature and humidity. In model 8, we have correlated power between voltage, current, temperature, and Humidity. The maximum value of Multiple R in Table 4.1 is 0.9894, and the minimum value is 0.9332, which indicates a good positive correlation. Here, the R Square means the determination of the coefficient shows the quality of fit. In our experiments, the R square value in Table 4.1 is between 0.8971 and 0.9996, which is a better fit. In other words, 91–99% of y values are dependent, and x values are independent variables. The adjusted R-squared value is a simplified version that has been adjusted for the number of predictors in a model. The adjusted R-squared value has been increased when a new factor is developed, which is more than expected by the change. It has decreased when a predictor develops the model by less than expected. Here, the value of the adjusted R-squared value is positive and not negative. It is always lower than the value of squared R. In Table 4.1, the minimum and maximum adjusted R square values are 0.8749 and 0.96872.

4.8 Regression Analysis of PID Controller

Table 4.2 shows the regression analysis of the PID Controller. We have used the regression analysis in Excel to calculate the estimated value, and then we have relations between two or more variables. There are two terms, such as dependent and independent variables. The regression Analysis of the PID Controller is given below.

Table 4.2: Regression Analysis of PID Controller

Model No.	Form of Equation	Equation Constants m_i	k_1	Multiple R	R Square	Adjusted R Square
Regression Analysis of Power (P,watt) with voltage (v,volt), current(i,amp),temperature (T,°centigrade), Humidity(%)						
1	$P_1 = m_1$v+k_1	$m_1 = 0.53$	1.39	0.9861	0.9790	0.9481
$\boldsymbol{P_1 = 1.39 + 0.53}$**v**						
2	$P_2 = m_1$i+k_1	m_1=45.25	0.79	0.9763	0.9821	0.9873
$\boldsymbol{P_2 = 0.79 + 45.25}$**i**						
3	$P_3 = m_1 T$+k_1	m_1=181.36	1.39	0.9642	0.9673	0.9534
$\boldsymbol{P_3 = 1.39 + 181.36}$**i**						
4	$P_4 = m_1 H$+k_1	m_1=2.79	18.67	0.9761	0.9686	0.9542
$\boldsymbol{P_4 = 18.67 + 2.79}$**i**						
5	$P_5 = m_1$v+m_2i $+ k_1$	m_1=1.031068 m_2=-123.68	87.28006	0.9760	0.9721	0.9978
$\boldsymbol{P_5 = 87.28006 + 1.03106}$**v+123.68i**						
6	$P_6 = m_1$v+m_2T $+ k_1$	m_1=1.018405 m_2= 2.214534	-92.3776	0.9982	0.9883	0.9868
$\boldsymbol{P_6 = -92.3776 + 1.018405}$**v+2.214534T**						
7	$P_7 = m_1$v+m_2H $+ k_1$	m_1=0.996681 m_2= -3.64087	196.2731	0.9719	0.9544	0.9280
$\boldsymbol{P_7 = 196.2731 + 0.996681}$**v-3.64087H**						
8	$P_8 = m_1$v+m_2i + m_3T + m4H + k_1	m_1=0.980584 m_2=2.570947 m_3= -1.09421 m_4= -4.72146	295.9699	0.96614	0.9899	0.9965
$\boldsymbol{P_8 = 295.9699 + 0.980584v + 2.570947}$**i – 1.09421T-4.72146H**						

In a PID controller, the dependent variable is power, and the independent variables are voltage, current, temperature, and humidity. In the Tables, the Multiple R is a linear relationship between the dependent and independent variables for the measurement of the correlation coefficient. Here is the strong relationship measurement if 1 means a strong positive, -1 means a strong negative, and 0 means no relationship at all [74].

In Table 4.2, there are eight correlations. We have calculated the multiple R value, the R square value, and the adjusted R value. We had been showing the 8 no model correlations, such as the correlation between power and voltage, the correlation between power and current, and the correlation between temperature and humidity. In model 8, we have correlated power between voltage, current, temperature, and Humidity. The maximum value of Multiple R in Table 4.2 is 0.9982, and the minimum value is 0.9642, which indicates a good positive correlation. Here, the R Square means the determination of the coefficient shows the quality of fit.

In our experiments, the R square value in Table 4.2 is between 0.9544 and 0.9899, which is a better fit. In other words, 91–99% of y values are dependent, and x values are independent variables.

The adjusted R-squared value is a simplified version that has been adjusted for the number of predictors in a model. The adjusted R-squared value has been increased when a new factor is developed in the model, which is more than expected by the change. It has decreased when a predictor develops the model by less than expected. Here, the value of the adjusted R-squared value is positive, and not negative. It is always lower than the value of squared R. In Table 4.2, the minimum and maximum adjusted R square values are 0.9280 and 0.9978.

4.9 Regression Analysis of a Fuzzy-PID Controller

Table 4.3 shows the regression analysis of the PID Controller. We have used the regression analysis in Excel to calculate the estimated value, and then we have relations between two or more variables. There are two terms, such as dependent and independent variables. The regression Analysis of the PID Controller is given below.

In a PID controller, the dependent variable is power, and the independent variables are voltage, current, temperature, and humidity. In the Tables, the Multiple R is a linear relationship between the dependent and independent variables for the measurement of the correlation coefficient. Here is the strong relationship measurement: 1 means a strong positive, -1 means a strong negative, and 0 means no relationship at all [74].

Table 4.3 : Regression Analysis of Conventional Controller

Regression Analysis of Power (P,watt) with voltage (v,volt), current(i,amp),temperature (T,°centigrade), Humidity(%)						
Model No.	Form of Equation	Equation Constants		Multiple R	R Square	Adjusted R Square
		m_i	k_1			
1	$P_1 = m_1$v+k_1	m_1 = 0.97	-6.50	0.9876	0.9886	0.9791
$\boldsymbol{P_1 = -6.50 + 0.97}$**v**						
2	$P_2 = m_1$i+k_1	m_1=245.8132	-23.7871	0.9963	0.9943	0.9890
$\boldsymbol{P_2 = -23.7871 + 245.8132}$**i**						
3	$P_3 = m_1T+k_1$	m_1=218.36	-14.26	0.9732	0.94719	0.9449
$\boldsymbol{P_3 = -14.26 + 218.36}$**i**						
4	$P_4 = m_1H+k_1$	m_1=0.630737	171.9318	0.9832	0.96719	0.9649
$\boldsymbol{P_4 = 171.9318 + 0.630737}$**i**						
5	$P_5 =$ m_1v+m_2i + k_1	m_1=0.417797 m_2=132.8834	-9.23293	0.9864	0.9982	0.96872
$\boldsymbol{P_5 = -9.23293 + 0.4177}$**v+132.8834i**						
6	$P_6 =$ m_1v+m_2T + k_1	m_1=0.971881 m_2= -0.32412	5.857871	0.9994	0.99879	0.97868
$\boldsymbol{P_6 = 5.8578 + 0.971881}$**v-0.32412T**						
7	$P_7 =$ m_1v+m_2H + k_1	m_1=0.625218 m_2= -0.481606	43.05162	0.950925	0.904258	0.880322
$\boldsymbol{P_7 = 43.05162 + 0.625218}$**v-0.481606H**						
8	$P_8 =$ m_1v+m_2i + m_3T + m4H + k_1	m_1=129.9516 m_2=-0.294197 m_3= - 0.2986 m_4= 0.264797	14.35803	0.96614	0.9899	0.9865
$\boldsymbol{P_8 = 14.35803 + 0.294197v + 129.9516}$**i - 0.2986T+0.264797H**						

In Table 4.3, there are eight correlations. We have calculated the multiple R value, the R square value, and the adjusted R value. We had been showing the 8 no model correlations, such as the correlation between power and voltage, the correlation between power and current, and the correlation between temperature and humidity. In model 8, we have correlated power between voltage, current, temperature, and Humidity. The maximum value of Multiple R in Table 4.3 is 0.9982, and the minimum value is 0.9642, which indicates a good positive correlation. Here, the R Square means the determination of the coefficient shows the quality of fit. In our experiments, the R square value in Table 4.3 is between 0.9544 and 0.9899, which is a better fit. In other words, 91–99% of y values are dependent, and x values are independent variables. The adjusted R-squared value is a simplified version that has been adjusted for the number of predictors in a model.

The adjusted R-squared value has been increased when a new factor is developed in the model, which is more than expected by the change. It has decreased when a predictor develops the model by less than expected. Here, the value of the adjusted R-squared value is positive and not negative. It is always lower than the value of squared R. In Table 4.3, the minimum and maximum adjusted R square values are 0.9280 and 0.9978.

CHAPTER-V
CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The Energy-saving egg incubator system has been investigated in this research by controlling the temperature and maintaining the humidity of the egg incubator system using a Fuzzy-PID controller. For energy-saving operation, the brightness of the bulb is controlled as well as the temperature in the egg incubator system.

In the experimental work, the following three controllers are used: Conventional, PID, and Fuzzy-PID controllers. The brightness of the bulb can't be controlled in a conventional system. Therefore, a PID and Fuzzy-PID controllers are used to regulate the voltage as well as the temperature and maintain the humidity in the egg incubator system.

The experiment involved gathering 60-minute temperature data for conventional, PID, and Fuzzy-PID controllers. The set temperature is 38°C. For 21 days of incubation, the conventional controller consumes 56.08 kWh; however, PID consumes 44.77 kWh, and Fuzzy-PID consumes 41.58 kWh. The PID has a significant amount of energy savings when compared to a conventional controller, which amounts to 20.05%. The energy savings of Fuzzy-PID compared to conventional controllers amount to 25.83%. The result shows that Fuzzy-PID controller has lower power consumption compared to other controllers. By controlling the temperature of the egg incubator, Fuzzy-PID is an effective method. It can help regulate the temperature of this system very efficiently.

The Co-relation of the Power, Voltage, Current, Temperature and Humidity for Conventional Control is $P_8 = -579.385 - 0.19087v - 776.8789i + 5.577465T - 0.70986H$. The Co-relation of the Power, Voltage ,Current, Temperature and Humidity for PID Control is $P_8 = 295.9699 + 0.980584v + 2.570947i - 1.09421T - 4.72146H$ and The Co-relation of the Power, Voltage ,Current, Temperature and Humidity for Fuzzy-PID Control is $P_8 = 14.35803 + 0.294197v + 129.9516i - 0.2986T + 0.264797H$

5.1.1 Key Findings

1. Temperature determines the power consumption of an energy-saving egg incubator system.
2. In an energy-saving egg incubator, the power consumption increases with temperature.
3. The settling time has been reduced using Fuzzy PID.
4. Fuzzy PID responds faster than PID and can save energy.

5.1.2 Limitations

1. This research has taken into account the power consumption for 1 hour out of 21 days of incubation.

2. A small-scale laboratory incubator has been developed from a practical viewpoint. The explanation of other parameters that may be present in the industry-grade egg incubator was not provided.

5.2 FUTURE WORK

This research will definitely help to develop the temperature control in the Egg Incubator system by utilizing a convolution neural network. Improving the settling time and rise time will make the system more energy efficient.

5.3 RECOMMENDATION

The author would like to propose the following recommendations, which are beneficial for future research:

1. In order to save power and prevent a high turning speed, the motor with the lowest rating should be used.
2. The bulb and egg tray motor power should be calculated according to the size of the incubator.

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Appendix

A.1 Experimental Data on Temperature using Conventional, PID and Fuzzy-PID Controller

Temperature(°C)			
Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.00	30.00	30.00	30.00
12.01	30.00	30.00	31.00
12.02	30.00	31.00	31.00
12.03	31.00	31.00	32.00
12.04	31.00	32.00	33.00
12.05	31.00	32.00	33.00
12.06	32.00	33.00	34.00
12.07	32.00	33.00	34.00
12.08	33.00	34.00	35.00
12.09	33.00	34.00	35.00
12.10	33.00	35.00	36.00
12.11	34.00	35.00	37.00
12.12	34.00	36.00	37.00
12.13	35.00	36.00	38.00
12.14	35.00	37.00	38.00
12.15	36.00	37.00	38.00
12.16	36.00	38.00	38.00
12.17	37.00	38.00	38.00
12.18	37.00	38.00	38.00
12.19	37.00	38.00	37.00
12.20	38.00	38.00	37.00
12.21	38.00	37.00	37.00
12.22	38.00	37.00	37.00
12.23	37.00	37.00	37.00

Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.24	37.00	37.00	37.00
12.25	37.00	37.00	37.00
12.26	36.00	37.00	37.00
12.27	36.00	36.00	36.00
12.28	36.00	36.00	36.00
12.29	37.00	36.00	36.00
12.30	37.00	37.00	37.00
12.31	37.00	37.00	37.00
12.32	37.00	37.00	37.00
12.33	38.00	37.00	38.00
12.34	38.00	37.00	38.00
12.34	37.00	37.00	38.00
12.35	37.00	38.00	38.00
12.36	37.00	38.00	38.00
12.37	36.00	38.00	38.00
12.38	36.00	38.00	38.00
12.39	37.00	38.00	38.00
12.40	37.00	38.00	37.00
12.41	38.00	37.00	37.00
12.42	38.00	37.00	37.00
12.43	37.00	37.00	37.00
12.44	37.00	36.00	37.00
12.45	36.00	36.00	36.00
12.46	36.00	36.00	36.00
12.47	37.00	36.00	36.00
12.48	37.00	36.00	37.00
12.49	38.00	36.00	37.00
12.50	38.00	37.00	37.00
12.51	37.00	37.00	38.00

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.52	37.00	37.00	38.00
12.53	36.00	38.00	38.00
12.54	36.00	38.00	38.00
12.55	37.00	38.00	38.00
12.56	37.00	38.00	37.00
12.57	38.00	38.00	37.00
12.58	38.00	38.00	37.00
12.59	37.00	37.00	37.00

A.2 : Experimental Data on Humidity using Conventional, PID and Fuzzy-PID Controller

Humidity (%)			
Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.00	75	61	61
12.01	73	60	60
12.02	71	59	59
12.03	70	58	58
12.04	68	57	57
12.05	65	57	57
12.06	60	58	57
12.07	62	57	56
12.08	56	58	57
12.09	55	57	57
12.10	52	58	58
12.11	53	57	58
12.12	51	57	57

Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.13	49	57	57
12.14	52	56	56
12.15	52	55	56
12.16	50	54	55
12.17	53	53	55
12.18	49	50	52
12.19	48	52	55
12.20	50	55	55
12.21	49	57	53
12.22	47	58	55
12.23	46	59	57
12.24	44	57	57
12.25	46	58	58
12.26	44	56	60
12.27	45	55	56
12.28	46	54	54
12.29	47	55	55
12.30	49	53	55
12.31	51	52	56
12.32	53	51	58
12.33	55	50	56
12.34	52	50	54
12.34	50	52	55
12.35	48	53	57
12.36	50	53	59
12.37	52	55	61
12.38	50	56	61

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.39	53	58	59
12.40	50	59	60
12.41	48	57	57
12.42	45	58	58
12.43	46	56	59
12.44	48	53	61
12.45	68	55	59
12.46	51	51	58
12.47	55	53	56
12.48	53	53	55
12.49	50	53	54
12.50	52	53	55
12.51	54	52	56
12.52	57	50	57
12.53	56	52	54
12.54	53	54	57
12.55	51	54	56
12.56	48	52	58
12.57	49	53	55
12.58	51	55	57
12.59	53	52	58

A.3 : Experimental Data on Voltage using Conventional, PID and Fuzzy-PID Controller

Voltage(V)			
Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.00	220	220	220

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.01	220	220	220
12.02	220	220	220
12.03	220	220	220
12.04	220	220	220
12.05	220	220	220
12.06	0	220	220
12.07	0	220	220
12.08	0	220	220
12.09	220	220	220
12.10	220	220	220
12.11	220	220	220
12.12	0	220	220
12.13	0	220	10
12.14	220	220	08
12.15	220	220	08
12.16	220	220	06
12.17	0	15	06
12.18	0	12	05
12.19	220	12	05
12.20	220	12	05
12.21	220	12	05
12.22	0	12	05
12.23	220	12	05
12.24	220	12	05
12.25	220	12	05
12.26	0	14	05
12.27	0	101	220

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.28	220	165	220
12.29	220	180	220
12.30	220	220	220
12.31	0	220	220
12.32	220	220	06
12.33	220	220	06
12.34	220	220	06
12.34	0	200	06
12.35	0	170	06
12.36	220	15	06
12.37	220	15	06
12.38	220	08	08
12.39	0	10	06
12.40	0	11	06
12.41	220	12	06
12.42	220	14	06
12.43	220	14	06
12.44	0	15	06
12.45	0	36	220
12.46	220	101	220
12.47	220	169	220
12.48	220	218	220
12.49	0	218	220
12.50	0	220	220
12.51	220	220	06
12.52	220	213	06
12.53	220	210	06

Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.54	0	183	08
12.55	0	147	08
12.56	220	100	06
12.57	220	35	06
12.58	220	14	06
12.59	220	15	05

A.4 : Experimental Data on Voltage using Conventional, PID and Fuzzy-PID Controller

Current(A)			
Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.00	0.90	0.95	0.95
12.01	0.90	0.88	0.95
12.02	0.90	0.89	0.95
12.03	0.90	0.89	0.96
12.04	0.90	0.90	0.95
12.05	0.90	0.90	0.95
12.06	0	0.89	0.95
12.07	0	0.87	0.95
12.08	0	0.89	0.95
12.09	0.5	0.87	0.95
12.10	0.80	0.90	0.95
12.11	0.80	0.89	0.95
12.12	0	0.92	0.95
12.13	0.	0.95	0.07
12.14	0.90	0.96	0.06

Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.15	0.80	0.96	0.06
12.16	0.90	0.97	0.05
12.17	0	0.20	0.05
12.18	0	0.12	0.04
12.19	0.90	0.07	0.04
12.20	0.80	0.04	0.04
12.21	0.70	0.04	0.04
12.22	0	0.04	0.04
12.23	0.90	0.04	0.04
12.24	0.70	0.12	0.04
12.25	0.70	0.12	0.04
12.26	0	0.18	0.04
12.27	0	0.45	0.95
12.28	0.80	0.60	0.95
12.29	0.80	0.78	0.95
12.30	0.70	0.95	0.95
12.31	0	0.93	0.96
12.32	0.8	0.93	0.05
12.33	0.8	0.94	0.05
12.34	0.8	0.93	0.05
12.34	0	0.80	0.05
12.35	0	0.65	0.05
12.36	0.90	0.20	0.05
12.37	0.80	0.20	0.05
12.38	0.70	0.08	0.08
12.39	0	0.07	0.05
12.40	0	0.08	0.05

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.41	0.80	0.10	0.05
12.42	0.90	0.12	0.05
12.43	0.70	0.12	0.05
12.44	0	0.14	0.05
12.45	0	0.17	0.95
12.46	0.80	0.45	0.95
12.47	0.80	0.64	0.95
12.48	0.50	0.85	0.95
12.49	0	0.90	0.96
12.50	0	0.94	0.95
12.51	0.80	0.90	0.05
12.52	0.70	0.90	0.05
12.53	0.50	0.89	0.05
12.54	0	0.70	0.06
12.55	0	0.24	0.06
12.56	0.90	0.36	0.05
12.57	0.90	0.19	0.05
12.58	0.70	0.09	0.05
12.59	0	0.10	0.04

A.5 Experimental Power data using Conventional, PID, and Fuzzy-PID Control System

Power(W)			
Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.00	198	209	209
12.01	198	193.6	209
12.02	198	195.8	209

Day Time (PM)	**Conventional Controller**	**PID Controller**	**Fuzzy-PID Controller**
12.03	198	195.8	211.2
12.04	198	198	209
12.05	198	198	209
12.06	0	195.8	209
12.07	0	191.4	209
12.08	0	195.8	209
12.09	110	191.4	209
12.10	176	198	209
12.11	176	198	209
12.12	0	198	209
12.13	0.	108	0.7
12.14	198	85	0.48
12.15	176	60	0.48
12.16	198	3	0.3
12.17	0	3	0.3
12.18	0	1.44	0.2
12.19	198	0.84	0.2
12.20	176	0.48	0.2
12.21	154	0.48	0.2
12.22	0	0.48	0.2
12.23	198	0.48	0.2
12.24	154	1.44	0.2
12.25	154	1.44	0.2
12.26	0	2.52	0.2
12.27	0	45.45	209
12.28	176	60	209
12.29	176	190	209

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.30	154	209	209
12.31	0	204.6	211.2
12.32	176	204.6	0.3
12.33	176	206.8	0.3
12.34	176	90	0.3
12.34	0	36	0.3
12.35	0	25	0.3
12.36	198	3	0.3
12.37	176	3	0.3
12.38	154	0.64	0.64
12.39	0	0.70	0.3
12.40	0	0.88	0.3
12.41	176	1.2	0.3
12.42	198	1.68	0.3
12.43	154	1.68	0.3
12.44	0	2.1	0.3
12.45	0	6.12	209
12.46	176	45.45	209
12.47	176	90	209
12.48	110	185.3	209
12.49	0	196.2	211.2
12.50	0	206.8	209
12.51	176	198	0.3
12.52	154	191.7	0.3
12.53	110	90	0.3
12.54	0	35	0.48
12.55	0	35.28	0.48

Day Time (PM)	Conventional Controller	PID Controller	Fuzzy-PID Controller
12.56	198	33	0.3
12.57	198	6.65	0.3
12.58	154	1.26	0.3
12.59	0	1.5	0.2

A.6 : Pearson Correlation Coefficient of Conventional Current-Voltage

X (Current) xi	Y1 (Voltage) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.9	220	0.31	85.5	26.505	0.0961	7310.25
0.9	220	0.31	85.5	26.505	0.0961	7310.25
0.9	220	0.31	85.5	26.505	0.0961	7310.25
0.9	220	0.31	85.5	26.505	0.0961	7310.25
0.9	220	0.31	85.5	26.505	0.0961	7310.25
0.9	220	0.31	85.5	26.505	0.0961	7310.25
0.8	220	0.21	85.5	17.955	0.0441	7310.25
0.8	220	0.21	85.5	17.955	0.0441	7310.25
0.8	220	0.21	85.5	17.955	0.0441	7310.25
0.8	220	0.21	85.5	17.955	0.0441	7310.25
0.8	220	0.21	85.5	17.955	0.0441	7310.25
0.156667				**248.805**	**0.7971**	**80412.75**

A.7 : Conventional Current –Temperature Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Temp) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.9	30	0.75	23.75	17.8125	0.5625	564.0625
0.9	31	0.75	24.75	18.5625	0.5625	612.5625

X (Current) xi	Y1 (Temp) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.9	32	0.75	25.75	19.3125	0.5625	663.0625
0.9	33	0.75	26.75	20.0625	0.5625	715.5625
0.9	34	0.75	27.75	20.8125	0.5625	770.0625
0.9	35	0.75	28.75	21.5625	0.5625	826.5625
0.8	36	0.65	29.75	19.3375	0.4225	885.0625
0.8	36	0.65	29.75	19.3375	0.4225	885.0625
0.8	36	0.65	29.75	19.3375	0.4225	885.0625
0.8	36	0.65	29.75	19.3375	0.4225	885.0625
0.8	36	0.65	29.75	19.3375	0.4225	885.0625
0.156667	**6.25**			**214.8125**	**5.4875**	**8577.188**

A.8 : Conventional Current –Humidity Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.9	75	0.743	62.33	46.31119	0.552049	3885.029
0.9	73	0.743	60.33	44.82519	0.552049	3639.709
0.9	71	0.743	58.33	43.33919	0.552049	3402.389
0.9	70	0.743	57.33	42.59619	0.552049	3286.729
0.9	68	0.743	55.33	41.11019	0.552049	3061.409
0.9	65	0.743	52.33	38.88119	0.552049	2738.429
0.8	60	0.643	47.33	30.43319	0.413449	2240.129
0.8	62	0.643	49.33	31.71919	0.413449	2433.449
0.8	56	0.643	43.33	27.86119	0.413449	1877.489
0.8	55	0.643	42.33	27.21819	0.413449	1791.829
0.8	52	0.643	39.33	25.28919	0.413449	1546.849

0.156667	**12.67**			**399.58409**	**5.379539**	**29903.44**

A.9 : PID Current –Temperature Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Temperature) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.94	30	0.17	-2.4	-0.408	0.0289	5.76
0.94	31	0.17	-1.4	-0.238	0.0289	1.96
0.92	32	0.15	-0.4	-0.06	0.0225	0.16
0.92	33	0.15	0.6	0.09	0.0225	0.36
0.9	34	0.13	1.6	0.208	0.0169	2.56
0.9	35	0.13	2.6	0.338	0.0169	6.76
0.9	36	0.13	3.6	0.468	0.0169	12.96
0.88	37	0.11	4.6	0.506	0.0121	21.16
0.25	38	0.57	5.6	3.192	0.3249	31.36
0.15	38	0.57	5.6	3.192	0.3249	31.36
0.77	**34.5**			**8.4**	**0.8154**	**110.4**

A.10 : PID Current –Humidity Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.94	61	0.17	8.8	0.352	0.0016	77.44
0.94	60	0.17	7.8	0.312	0.0016	60.84
0.92	59	0.15	6.8	0.272	0.0016	46.24
0.92	58	0.15	5.8	0.116	0.0004	33.64
0.9	57	0.13	4.8	0.096	0.0004	23.04

X (Current) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.9	57	0.13	4.8	0.096	0.0004	23.04
0.9	57	0.13	4.8	0.096	0.0001	23.04
0.88	56	0.11	3.8	0.038	0.0001	14.44
0.25	57	0.57	4.8	3.048	0.0001	23.04
0.15	57	0.57	4.8	3.048	0.0001	23.04
0.77	**52.2**			**1.47**	**0.0064**	**347.8**

A.11: PID Current –Voltage Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Voltage) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.94	220	0.17	39.5	6.715	0.0289	1560.25
0.94	220	0.17	39.5	6.715	0.0289	1560.25
0.92	220	0.15	39.5	6.715	0.0225	1560.25
0.92	220	0.15	39.5	6.715	0.0225	1560.25
0.9	220	0.13	39.5	6.715	0.0169	1560.25
0.9	220	0.13	39.5	6.715	0.0169	1560.25
0.9	220	0.13	39.5	6.715	0.0169	1560.25
0.88	220	0.11	39.5	6.715	0.0121	1560.25
0.25	30	-0.52	-150.5	78.26	0.2704	22650.25
0.15	15	-0.58	-165.2	90.016	0.3844	27390.25
0.77	**180**			**222.59**	**0.8204**	**62522.5**

A.12 : Fuzzy-PID Current –Voltage Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Voltage) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.96	220	0.78	179.4	139.9554	0.6084	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.95	220	0.77	179.4	138.1611	0.5929	32195.12
0.94	220	0.76	179.4	136.3668	0.5776	32195.12
0.94	220	0.76	179.4	136.3668	0.5776	32195.12
0.04	8	-0.14	-32.57	4.5598	0.0196	1060.805
0.06	6	-0.12	-34.57	4.1484	0.0144	1195.085
0.17566667	**40.566667**			**1524.686**	**6.5408**	**356402.3**

A.13 : Fuzzy-PID Current –Temperature Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Tempe rature) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.95	30	0.806	24.28	19.56968	0.649636	589.5184
0.95	31	0.806	25.28	20.37568	0.649636	639.0784

X (Current) xi	Y1 (Temperature) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.95	32	0.806	26.28	21.18168	0.649636	690.6384
0.96	33	0.816	27.28	22.26048	0.665856	744.1984
0.95	34	0.806	28.28	22.79368	0.649636	799.7584
0.95	35	0.806	29.28	23.59968	0.649636	857.3184
0.95	36	0.806	30.28	24.40568	0.649636	916.8784
0.95	37	0.806	31.28	25.21168	0.649636	978.4384
0.95	37	0.806	31.28	25.21168	0.649636	978.4384
0.12	38	-0.024	32.28	-0.77472	0.000576	1041.998
0.14467	**5.71667**			**203.8352**	**5.86352**	**8236.264**

A.14 : Fuzzy-PID Current –Humidity Using Pearson Co-relation Coefficient

X (Current) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.95	61	0.758	47.48	35.98984	0.574564	2254.35
0.95	60	0.758	46.48	35.23184	0.574564	2160.39
0.95	59	0.758	45.48	34.47384	0.574564	2068.43
0.93	58	0.738	44.48	32.82624	0.544644	1978.47
0.95	57	0.758	43.48	32.95784	0.574564	1890.51
0.95	57	0.758	43.48	32.95784	0.574564	1890.51
0.95	58	0.758	44.48	33.71584	0.574564	1978.47
0.95	57	0.758	43.48	32.95784	0.574564	1890.51

X (Current) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.95	58	0.758	44.48	33.71584	0.574564	1978.47
0.95	57	0.758	43.48	32.95784	0.574564	1890.51
0.95	58	0.758	44.48	33.71584	0.574564	1978.47
0.95	57	0.758	43.48	32.95784	0.574564	1890.51
0.07	57	-0.122	43.48	-5.30456	0.014884	1890.51
0.06	57	-0.132	43.48	-5.73936	0.017424	1890.51
0.191833	**13.51667**			**393.41456**	**6.897156**	**27630.63**

A.15 : Fuzzy-PID Power–Humidity Using Pearson Co-relation Coefficient

X (Power) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
209	61	167.1	47.48	7935.8072	27935.78	2254.35
209	60	167.1	46.48	7768.6672	27935.78	2160.39
209	59	167.1	45.48	7601.5272	27935.78	2068.43
211.2	58	169.3	44.48	7532.2432	28676.04	1978.47
209	57	167.1	43.48	7267.2472	27935.78	1890.51
209	57	167.1	43.48	7267.2472	27935.78	1890.51
209	58	167.1	44.48	7434.3872	27935.78	1978.47
209	57	167.1	43.48	7267.2472	27935.78	1890.51
209	58	167.1	44.48	7434.3872	27935.78	1978.47
209	57	167.1	43.48	7267.2472	27935.78	1890.51
209	58	167.1	44.48	7434.3872	27935.78	1978.47
209	57	167.1	43.48	7267.2472	27935.78	1890.51

X (Power) xi	Y1 (Humidity) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
0.7	57	-41.16	43.48	-1789.6368	1694.146	1890.51
0.6	57	-41.26	43.48	-1793.9848	1702.388	1890.51
41.8583333	**13.5166667**			**85894.0208**	**339366.1**	**27630.63**

A.16 : Fuzzy-PID Power–Temperature Using Pearson Co-relation Coefficient

X (Power) xi	Y1 (temp) yi	xi-x	yi-y	(xi-x)*(yi-y)	(xi-x)^2	(yi-y)^2
209	30	167.2	21.75	3635.5125	27939.12	473.0625
209	31	167.2	22.75	3802.6625	27939.12	517.5625
209	32	167.2	23.75	3969.8125	27939.12	564.0625
211.2	33	169.4	24.75	4191.4125	28679.42	612.5625
209	34	167.2	25.75	4304.1125	27939.12	663.0625
209	35	167.2	26.75	4471.2625	27939.12	715.5625
209	36	167.2	27.75	4638.4125	27939.12	770.0625
209	37	167.2	28.75	4805.5625	27939.12	826.5625
209	37	167.2	28.75	4805.5625	27939.12	826.5625
209	38	167.2	29.75	4972.7125	27939.12	885.0625
209	38	167.2	29.75	4972.7125	27939.12	885.0625
209	38	167.2	29.75	4972.7125	27939.12	885.0625
0.7	38	-41.15	29.75	-1224.2125	1693.323	885.0625
0.6	38	-41.25	29.75	-1227.1875	1701.563	885.0625
41.85833	**8.25**			**51091.05**	**339404.7**	**10394.38**

A.17 Experimental data using Conventional Controller

Day Time PM	Temperature (°C)	Humidity (%)	Humidifier	Bulb Condition	Voltage (V)	Current (A)	Power (W)
12.00	30.00	75	ON	ON	220	0.9	198
12.01	30.00	73	ON	ON	220	0.9	198
12.02	30.00	71	ON	ON	220	0.9	198
12.03	31.00	70	ON	OFF	0	0	0
12.04	31.00	68	ON	ON	220	0.9	198
12.05	31.00	65	ON	ON	220	0.9	198
12.06	32.00	60	ON	ON	220	0.9	198
12.07	32.00	62	ON	OFF	220	0	0
12.08	33.00	56	ON	ON	220	0.8	176
12.09	33.00	55	ON	ON	220	0.8	176
12.10	33.00	52	ON	ON	220	0.8	176
12.11	34.00	53	ON	OFF	220	0.5	110
12.12	34.00	51	ON	ON	220	0.8	176
12.13	35.00	49	ON	ON	220	0.8	176
12.14	35.00	52	ON	ON	220	0.8	176
12.15	36.00	52	ON	OFF	0	0	0
12.16	36.00	50	ON	ON	220	0.7	154
12.17	37.00	53	ON	ON	220	0.7	154
12.18	37.00	49	ON	ON	220	0.7	154
12.19	37.00	48	ON	OFF	0	0	0
12.20	38.00	50	ON	ON	220	0.7	154
12.21	38.00	49	ON	ON	220	0.7	154
12.22	38.00	47	ON	ON	220	0.7	154
12.23	37.00	46	ON	OFF	0	0	154
12.24	37.00	44	ON	ON	220	0.7	154
12.25	37.00	46	ON	ON	220	0.7	154
12.26	36.00	44	ON	ON	220	0.7	154

Day Time PM	Temperature (°C)	Humidity (%)	Humidifier	Bulb Condition	Voltage (V)	Current (A)	Power (W)
12.27	36.00	45	ON	OFF	0	0	0
12.28	36.00	46	ON	ON	220	0.8	176
12.29	37.00	47	ON	ON	220	0.8	176
12.30	37.00	49	ON	ON	220	0.8	176
12.31	37.00	51	ON	OFF	0	0	0
12.32	37.00	53	ON	ON	220	0.8	176
12.33	38.00	55	ON	ON	220	0.8	176
12.34	38.00	52	ON	ON	220	0.8	176
12.35	37.00	50	ON	OFF	0	0	0
12.36	37.00	48	ON	ON	220	0.7	110
12.37	37.00	50	ON	ON	220	0.7	154
12.38	36.00	52	ON	ON	220	0.7	154
12.39	36.00	50	ON	OFF	220	0.5	110
12.40	37.00	53	ON	ON	220	0.8	176
12.41	37.00	50	ON	ON	220	0.8	176
12.42	38.00	48	ON	ON	220	0.8	176
12.43	38.00	45	ON	OFF	0	0	0
12.44	37.00	46	ON	ON	220	0.8	176
12.45	37.00	48	ON	ON	220	0.8	176
12.46	36.00	68	ON	ON	220	0.5	110
12.47	36.00	51	ON	OFF	0	0	0
12.48	37.00	55	ON	ON	220	0.7	154
12.49	37.00	53	ON	ON	220	0.7	154
12.50	38.00	50	ON	OFF	0	0	0
12.51	38.00	52	ON	ON	220	0.9	198
12.52	37.00	54	ON	ON	220	0.9	198
12.53	37.00	57	ON	OFF	0	0	0
12.54	36.00	56	ON	ON	220	0.9	198
12.55	36.00	53	ON	ON	220	0.9	198

Day Time PM	Temperature (°C)	Humidity (%)	Humidifier	Bulb Condition	Voltage (V)	Current (A)	Power (W)
12.56	37.00	51	ON	OFF	0	0	0
12.57	37.00	48	ON	ON	220	0.8	176
12.58	38.00	49	ON	ON	220	0.8	176
12.59	38.00	51	ON	ON	220	0.8	176

A.18 Experimental data using PID Controller

DayTime (PM)	Tempt. (°C)	Humidity (%)	Fan condition	Humidifier	Servo Motor	Voltage (V)	Current (A)	Power (W)
12.00pm	30.00	61	On	On	On	220	0.95	209
12.01pm	30.00	60	On	On	Off	220	0.88	193.6
12.02pm	31.00	59	On	On	Off	220	0.89	195.8
12.03pm	31.00	58	On	On	Off	220	0.89	195.8
12.04pm	32.00	57	On	On	Off	220	0.90	198
12.05pm	32.00	57	On	On	Off	220	0.90	198
12.06pm	33.00	58	On	On	Off	220	0.89	195.8
12.07pm	33.00	57	On	On	Off	220	0.87	191.4
12.08pm	34.00	58	On	On	Off	220	0.89	195.8
12.09pm	34.00	57	On	On	Off	220	0.87	191.4
12.10pm	35.00	58	On	On	Off	220	0.90	198
12.11pm	35.00	57	On	On	Off	220	0.89	195.8
12.12pm	36.00	57	On	On	Off	220	0.92	202.4
12.13pm	36.00	57	On	On	Off	220	0.95	209
12.14pm	37.00	56	Off	On	Off	220	0.96	211.2
12.15pm	37.00	55	On	On	Off	220	0.96	211.2
12.16pm	38.00	54	On	On	Off	220	0.97	213.4
12.17pm	38.00	53	Off	On	Off	15	0.20	3
12.18pm	38.00	50	Off	On	Off	12	0.12	1.44
12.19pm	38.00	47	Off	On	Off	12	0.07	0.84

DayTime (PM)	Tempt. (°C)	Humidity (%)	Fan condition	Humidifier	Servo Motor	Voltage (V)	Current (A)	Power (W)
12.20Pm	38.00	45	Off	On	Off	12	0.04	0.48
12.21Pm	37.00	43	Off	On	Off	12	0.04	0.48
12.22Pm	37.00	42	Off	On	Off	12	0.04	0.48
12.23Pm	37.00	44	Off	On	Off	12	0.04	0.48
12.24Pm	37.00	47	Off	On	Off	12	0.12	1.44
12.25Pm	37.00	49	Off	On	Off	12	0.12	1.44
12.26Pm	37.00	50	Off	On	Off	14	0.18	2.52
12.27Pm	36.00	52	On	On	Off	101	0.45	45.45
12.28Pm	36.00	54	On	On	Off	165	0.60	99
12.29Pm	36.00	56	On	On	Off	180	0.78	140.4
12.30Pm	37.00	56	On	On	Off	220	0.95	209
12.31Pm	37.00	55	On	On	Off	220	0.93	204.6
12.32Pm	37.00	54	On	On	Off	220	0.93	204.6
12.33Pm	37.00	38	On	On	Off	220	0.94	206.8
12.34Pm	37.00	43	On	On	Off	220	0.93	204.6
12.34Pm	37.00	46	Off	On	Off	200	0.80	160
12.35Pm	38.00	47	Off	On	Off	170	0.65	110.5
12.36Pm	38.00	35	Off	On	Off	15	0.20	3
12.37Pm	38.00	36	Off	On	Off	15	0.20	3
12.38Pm	38.00	38	Off	On	Off	08	0.08	0.64
12.39Pm	38.00	38	Off	On	Off	10	0.07	0.70
12.40Pm	38.00	39	Off	On	Off	11	0.08	0.88
12.41Pm	37.00	40	Off	On	Off	12	0.10	1.2
12.42Pm	37.00	46	Off	On	Off	14	0.12	1.68
12.43Pm	37.00	50	Off	On	Off	14	0.12	1.68
12.44Pm	36.00	53	Off	On	Off	15	0.14	2.1
12.45Pm	36.00	48	Off	On	Off	36	0.17	6.12
12.46Pm	36.00	51	On	On	Off	101	0.45	45.45
12.47Pm	36.00	53	On	On	Off	169	0.64	108.16
12.48Pm	36.00	53	On	On	Off	218	0.85	185.3

DayTime (PM)	Tempt. (°C)	Humidity (%)	Fan condition	Humidifier	Servo Motor	Voltage (V)	Current (A)	Power (W)
12.49Pm	36.00	53	On	On	Off	218	0.90	196.2
12.50Pm	37.00	53	On	On	Off	220	0.94	206.8
12.51Pm	37.00	52	On	On	Off	220	0.90	198
12.52Pm	37.00	50	On	On	Off	213	0.90	191.7
12.53Pm	38.00	48	On	On	Off	210	0.89	186.9
12.54Pm	38.00	46	On	On	Off	183	0.70	128.1
12.55Pm	38.00	44	Off	On	Off	147	0.24	35.28
12.56Pm	38.00	43	Off	On	Off	100	0.36	33
12.57Pm	38.00	41	Off	On	Off	35	0.19	6.65
12.58Pm	38.00	35	Off	On	Off	14	0.09	1.26
12.59Pm	37.00	33	Off	On	Off	15	0.10	1.5

A.19 Experimental Data using Fuzzy-PID Control Monitoring Process

Day Time (PM)	Temp. (°C)	Humidity (%)	Fan condition	Humidifier	Servo Motor	Voltage (V)	Current (A)	Power (W)
12.00	30.00	61	On	On	On	220	0.95	209
12.01	31.00	60	On	On	Off	220	0.95	209
12.02	31.00	59	On	On	Off	220	0.95	209
12.03	32.00	58	On	On	Off	220	0.96	211.2
12.04	33.00	57	On	On	Off	220	0.95	209
12.05	33.00	57	On	On	Off	220	0.95	209
12.06	34.00	57	On	On	Off	220	0.95	209
12.07	34.00	56	On	On	Off	220	0.95	209
12.08	35.00	57	On	On	Off	220	0.95	209
12.09	35.00	57	On	On	Off	220	0.95	209
12.10	36.00	58	On	On	Off	220	0.95	209
12.11	37.00	58	On	On	Off	220	0.95	209

Day Time (PM)	Temp. (°C)	Humidity (%)	Fan condition	Humidifier	Servo Motor	Voltage (V)	Current (A)	Power (W)
12.12	37.00	57	On	On	Off	220	0.95	209
12.13	38.00	57	On	On	Off	10	0.07	0.7
12.14	38.00	56	Off	On	Off	08	0.06	0.48
12.15	38.00	56	On	On	Off	08	0.06	0.48
12.16	38.00	55	On	On	Off	06	0.05	0.3
12.17	38.00	55	Off	On	Off	06	0.05	0.3
12.18	38.00	52	Off	On	Off	05	0.04	0.2
12.19	37.00	48	Off	On	Off	05	0.04	0.2
12.20	37.00	47	Off	On	Off	05	0.04	0.2
12.21	37.00	45	Off	On	Off	05	0.04	0.2
12.22	37.00	45	Off	On	Off	05	0.04	0.2
12.23	37.00	46	Off	On	Off	05	0.04	0.2
12.24	37.00	47	Off	On	Off	05	0.04	0.2
12.25	37.00	47	Off	On	Off	05	0.04	0.2
12.26	37.00	49	Off	On	Off	05	0.04	0.2
12.27	36.00	50	On	On	Off	220	0.95	209
12.28	36.00	51	On	On	Off	220	0.95	209
12.29	36.00	53	On	On	Off	220	0.95	209
12.30	37.00	54	On	On	Off	220	0.95	209
12.31	37.00	55	On	On	Off	220	0.96	211.2
12.32	37.00	55	On	On	Off	06	0.05	0.3
12.33	38.00	56	On	On	Off	06	0.05	0.3
12.34	38.00	50	On	On	Off	06	0.05	0.3
12.34	38.00	47	Off	On	Off	06	0.05	0.3
12.35	38.00	43	Off	On	Off	06	0.05	0.3
12.36	38.00	35	Off	On	Off	06	0.05	0.3
12.37	38.00	36	Off	On	Off	06	0.05	0.3
12.38	38.00	38	Off	On	Off	08	0.08	0.64

Day Time (PM)	**Temp. (°C)**	**Humidity (%)**	**Fan condition**	**Humidifier**	**Servo Motor**	**Voltage (V)**	**Current (A)**	**Power (W)**
12.39	38.00	38	Off	On	Off	06	0.05	0.3
12.40	37.00	39	Off	On	Off	06	0.05	0.3
12.41	37.00	40	Off	On	Off	06	0.05	0.3
12.42	37.00	46	Off	On	Off	06	0.05	0.3
12.43	37.00	50	Off	On	Off	06	0.05	0.3
12.44	37.00	53	Off	On	Off	06	0.05	0.3
12.45	36.00	52	Off	On	Off	220	0.95	209
12.46	36.00	51	On	On	Off	220	0.95	209
12.47	36.00	53	On	On	Off	220	0.95	209
12.48	37.00	53	On	On	Off	220	0.95	209
12.49	37.00	54	On	On	Off	220	0.96	211.2
12.50	37.00	55	On	On	Off	220	0.95	209
12.51	38.00	56	On	On	Off	06	0.05	0.3
12.52	38.00	57	On	On	Off	06	0.05	0.3
12.53	38.00	52	On	On	Off	06	0.05	0.3
12.54	38.00	48	On	On	Off	08	0.06	0.48
12.55	38.00	45	Off	On	Off	08	0.06	0.48
12.56	37.00	43	Off	On	Off	06	0.05	0.3
12.57	37.00	41	Off	On	Off	06	0.05	0.3
12.58	37.00	38	Off	On	Off	06	0.05	0.3
12.59	37.00	42	Off	On	Off	05	0.04	0.2

Appendix-20

PID Coding

```
/**************
 *  RobotDyn
 *  Dimmer Library
 *  **************
 *
 *  The following sketch is meant to turn the lamp on/off with use of a button.
 *  pinMode(14, INPUT); button is connected to 14th pin
 *  void loop()  ON/OFF button evaluator of dimmer in dim4.setState(ON/OFF);
 *
 *
 *  ---------------------- OUTPUT & INPUT Pin table ---------------------
 *  +---------------+------------------------+-------------------------+
 *  |   Board       | INPUT Pin              | OUTPUT Pin              |
 *  |               | Zero-Cross             |                         |
 *  +---------------+------------------------+-------------------------+
 *  | Lenardo       | D7 (NOT CHANGABLE)     | D0-D6, D8-D13           |
 *  +---------------+------------------------+-------------------------+
 *  | Mega          | D2 (NOT CHANGABLE)     | D0-D1, D3-D70           |
 *  +---------------+------------------------+-------------------------+
 *  | Uno           | D2 (NOT CHANGABLE)     | D0-D1, D3-D20           |
 *  +---------------+------------------------+-------------------------+
 *  | ESP8266       | D1(IO5),    D2(IO4),   | D0(IO16),   D1(IO5),    |+

 *  |               | D5(IO14),   D6(IO12),  | D2(IO4),    D5(IO14),   |
 *  |               | D7(IO13),   D8(IO15),  | D6(IO12),   D7(IO13),   |
 *  |               |                        | D8(IO15)                |
 *  +---------------+------------------------+-------------------------+
 *  | ESP32         | 4(GPI36),   6(GPI34),  | 8(GPO32),   9(GP033),   |
```

```
 *  |               | 5(GPI39),   7(GPI35),   | 10(GPIO25), 11(GPIO26), |
 *  |               | 8(GPO32),   9(GP033),   | 12(GPIO27), 13(GPIO14), |
 *  |               | 10(GPI025), 11(GPIO26), | 14(GPIO12), 16(GPIO13), |
 *  |               | 12(GPIO27), 13(GPIO14), | 23(GPIO15), 24(GPIO2),  |
 *  |               | 14(GPIO12), 16(GPIO13), | 25(GPIO0),  26(GPIO4),  |
 *  |               | 21(GPIO7),  23(GPIO15), | 27(GPIO16), 28(GPIO17), |
 *  |               | 24(GPIO2),  25(GPIO0),  | 29(GPIO5),  30(GPIO18), |
 *  |               | 26(GPIO4),  27(GPIO16), | 31(GPIO19), 33(GPIO21), |
 *  |               | 28(GPIO17), 29(GPIO5),  | 34(GPIO3),  35(GPIO1),  |
 *  |               | 30(GPIO18), 31(GPIO19), | 36(GPIO22), 37(GPIO23), |
 *  |               | 33(GPIO21), 35(GPIO1),  |                         |
 *  |               | 36(GPIO22), 37(GPIO23), |                         |
 *  +---------------+-------------------------+-------------------------+
 *  | Arduino M0    | D7 (NOT CHANGABLE)      | D0-D6, D8-D13           |
 *  | Arduino Zero  |                         |                         |
 *  +---------------+-------------------------+-------------------------+
 *  | Arduino Due   | D0-D53                  | D0-D53                  |
 *  +---------------+-------------------------+-------------------------+
 *  | STM32         | PA0-PA15,PB0-PB15       | PA0-PA15,PB0-PB15       |
 *  | Black Pill    | PC13-PC15               | PC13-PC15               |
 *  | BluePill      |                         |                         |
 *  | Etc...        |                         |                         |
 *  +---------------+-------------------------+-------------------------+
 */

#include <RBDdimmer.h>//
#include <PID_v1.h>

#define PIN_INPUT 0
#define PIN_OUTPUT 3
```

```
//Define Variables we'll be connecting to
double Setpoint, Input, Output;

//Specify the links and initial tuning parameters
double Kp=5, Ki=4, Kd=2;
PID myPID(&Input, &Output, &Setpoint, Kp, Ki, Kd, DIRECT);

//#define USE_SERIAL  SerialUSB //Serial for boards whith USB serial port
#define USE_SERIAL  Serial
#define outputPin  6
#define zerocross  2 // for boards with CHANGEBLE input pins

//dimmerLamp dimmer(outputPin, zerocross); //initialase port for dimmer for
ESP8266, ESP32, Arduino due boards
dimmerLamp dimmer(outputPin); //initialase port for dimmer for MEGA, Leonardo,
UNO, Arduino M0, Arduino Zero

int buttonRed = 0;

void setup() {

 Setpoint = 37;
  //turn the PID on
  myPID.SetMode(AUTOMATIC);

  dimmer.begin(NORMAL_MODE, ON); //dimmer initialisation: name.begin(MODE,
STATE)
pinMode(A0,INPUT);//humidity
pinMode(A1,INPUT);//temperature
pinMode(9,OUTPUT);//relay servo motor
pinMode(10,OUTPUT);//relay
```

```
pinMode(11,OUTPUT);//relay
pinMode(12,OUTPUT);//relay
Serial.begin(9600);
}

void loop() {
 //temp and humidity reading and mapping starts here
float temp=analogRead(A1);
float humidity=analogRead(A0);
float temperature=map(temp, 0,1023,25,75);
float rh=map(humidity, 0,1023,0,140);
Serial.print("temperature=");
Serial.println(Input);
Serial.print("humidity=");
Serial.println(rh);
//temp and humidity reading & mapping ends here
//pid bulb starts here
Input = temperature;
  myPID.Compute();
 int bulb=map(Output,0,255,0,80);
  dimmer.setPower(bulb);
  //Serial.println(Output);
  //pid bulb ends here
  //humidifier,fan1 and fan2 starts here
  if(rh>=58)
{
digitalWrite(11,HIGH);//Humidifier

}
  else{digitalWrite(11,LOW);}
```

```
  if(temperature<=37)
{
digitalWrite(12,LOW);//Humidifier
digitalWrite(10,HIGH);//Humidifier
}
 else{digitalWrite(12,HIGH);
 digitalWrite(10,LOW);
 }
digitalWrite(9,1);//servo motor
//digitalWrite(10,1);// Fan 1
//digitalWrite(11,0);//Humidifier
//digitalWrite(12,0);//Fan 2
```

Appendix : 21

Fuzzy PID Coding

```
#include <RBDdimmer.h>
#include <PID_v1.h>
#include <Fuzzy.h>
Fuzzy* fuzzy = new Fuzzy();
float err=0;

#define PIN_INPUT 0
#define PIN_OUTPUT 3
//Define Variables we'll be connecting to
double Setpoint, Input, Output;

//Specify the links and initial tuning parameters
double Kp=5, Ki=4, Kd=2;
PID myPID(&Input, &Output, &Setpoint, Kp, Ki, Kd, DIRECT);

//#define USE_SERIAL  SerialUSB //Serial for boards whith USB
serial port
#define USE_SERIAL  Serial
#define outputPin  6
#define zerocross  2 // for boards with CHANGEBLE input pins

//dimmerLamp dimmer(outputPin, zerocross); //initialase port
for dimmer for ESP8266, ESP32, Arduino due boards
dimmerLamp dimmer(outputPin); //initialase port for dimmer for
MEGA, Leonardo, UNO, Arduino M0, Arduino Zero
```

```
int buttonRed = 0;

void setup() {
Serial.begin(9600);
 Setpoint = 37;
  //turn the PID on

  dimmer.begin(NORMAL_MODE, ON); //dimmer initialisation:
name.begin(MODE, STATE)
pinMode(A0,INPUT);//humidity
pinMode(A1,INPUT);//temperature
pinMode(9,OUTPUT);//relay servo motor
pinMode(10,OUTPUT);//relay
pinMode(11,OUTPUT);//relay
pinMode(12,OUTPUT);//relay

 // initilizing fuzzy papmeters
 FuzzyInput* e = new FuzzyInput(1);
 FuzzySet* enl = new FuzzySet(-40, -40, -20, -10);
 e->addFuzzySet(enl);
 FuzzySet* enm = new FuzzySet(-10, -10, -8, -6);
 e->addFuzzySet(enm);
 FuzzySet* ens = new FuzzySet(-8, -6, -6, 0);
 e->addFuzzySet(ens);
 FuzzySet* eze = new FuzzySet(-6, 0, 0, 20);
 e->addFuzzySet(eze);
 FuzzySet* eps = new FuzzySet(0, 20, 20, 40);
 e->addFuzzySet(eps);
 FuzzySet* epm = new FuzzySet(20, 40, 40, 60);
 e->addFuzzySet(epm);
 FuzzySet* epl = new FuzzySet(40, 60, 60, 80);
 e->addFuzzySet(epl);
 fuzzy->addFuzzyInput(e);
 // initilizing fuzzy papmeters
 FuzzyOutput* KP = new FuzzyOutput(1);
 FuzzySet* kpsm = new FuzzySet(1, 2, 2, 3 );
 KP->addFuzzySet(kpsm);
 FuzzySet* kpmd = new FuzzySet(2, 3, 3, 4);
 KP->addFuzzySet(kpmd);
 FuzzySet* kpbg = new FuzzySet(3, 4, 4, 5);
 KP->addFuzzySet(kpbg);
 fuzzy->addFuzzyOutput(KP);
 // initilizing fuzzy papmeters
 FuzzyOutput* KI = new FuzzyOutput(2);
 FuzzySet* kism = new FuzzySet(1, 2, 2, 3);
 KI->addFuzzySet(kism);
 FuzzySet* kimd = new FuzzySet(2, 3, 3, 4);
 KI->addFuzzySet(kimd);
```

```
 FuzzySet* kibg = new FuzzySet(3, 4, 4, 5);
 KI->addFuzzySet(kibg);
 fuzzy->addFuzzyOutput(KI);
 // initiating fuzzy rules
 FuzzyRuleAntecedent* if_e_pl = new FuzzyRuleAntecedent();
 if_e_pl->joinSingle(epl);
 FuzzyRuleConsequent* then_kpsm_and_kism = new
FuzzyRuleConsequent();
 then_kpsm_and_kism->addOutput(kpsm);
 then_kpsm_and_kism->addOutput(kism);
 FuzzyRule* fuzzyRule01 = new FuzzyRule(1, if_e_pl,
then_kpsm_and_kism);
fuzzy->addFuzzyRule(fuzzyRule01);
 FuzzyRuleAntecedent* if_e_pm = new FuzzyRuleAntecedent();
 if_e_pm->joinSingle(epm);
 FuzzyRuleConsequent* then_kpmd_and_kimd = new
FuzzyRuleConsequent();
 then_kpmd_and_kimd->addOutput(kpmd);
 then_kpmd_and_kimd->addOutput(kimd);
 FuzzyRule* fuzzyRule02 = new FuzzyRule(2,
if_e_pm,then_kpmd_and_kimd);
 fuzzy->addFuzzyRule(fuzzyRule02);
 FuzzyRuleAntecedent* if_e_ps = new FuzzyRuleAntecedent();
 if_e_ps->joinSingle(eps);
 FuzzyRuleConsequent* then_kpbg_and_kibg = new
FuzzyRuleConsequent();
 then_kpbg_and_kibg->addOutput(kpbg);
 then_kpbg_and_kibg->addOutput(kibg);
 FuzzyRule* fuzzyRule03 = new FuzzyRule(3, if_e_ps,
then_kpbg_and_kibg);
fuzzy->addFuzzyRule(fuzzyRule03);
 FuzzyRuleAntecedent* if_e_ns = new FuzzyRuleAntecedent();
 if_e_ns->joinSingle(ens);
 FuzzyRule* fuzzyRule04 = new FuzzyRule(4, if_e_ns,
then_kpbg_and_kibg);
fuzzy->addFuzzyRule(fuzzyRule04);
 FuzzyRuleAntecedent* if_e_nm = new FuzzyRuleAntecedent();
 if_e_nm->joinSingle(enm);
 FuzzyRule* fuzzyRule05 = new FuzzyRule(5, if_e_nm,
then_kpmd_and_kimd); fuzzy->addFuzzyRule(fuzzyRule05);
 FuzzyRuleAntecedent* if_e_nl = new FuzzyRuleAntecedent();
 if_e_nl->joinSingle(enl);
 FuzzyRule* fuzzyRule06 = new FuzzyRule(6, if_e_nl,
then_kpsm_and_kism);
fuzzy->addFuzzyRule(fuzzyRule06);
 FuzzyRuleAntecedent* if_e_ze = new FuzzyRuleAntecedent();
 if_e_ze->joinSingle(eze);
 FuzzyRule* fuzzyRule07 = new FuzzyRule(7, if_e_ze,
then_kpsm_and_kism);
```

```
fuzzy->addFuzzyRule(fuzzyRule07);
myPID.SetMode(AUTOMATIC);
}

void loop() {
 //temp and humidity reading and mapping starts here
float temp=analogRead(A1);
float humidity=analogRead(A0);
float temperature=map(temp, 0,1023,25,70);
float rh=map(humidity, 0,1023,0,100);
Serial.print("temperature=");
Serial.println(Input);
Serial.print("humidity=");
Serial.println(rh);
//temp and humidity reading & mapping ends here
//pid bulb starts here
Input = temperature;
err = Setpoint -temperature;
fuzzy->setInput(1, err);
 fuzzy->fuzzify();
 // Set output vlaue: outpu
 Kp = (double)fuzzy->defuzzify(1);
 Ki = (double)fuzzy->defuzzify(2)*3;
 myPID.SetTunings(Kp, Ki, Kd);
  myPID.Compute();
 int bulb=map(Output,0,255,0,80);
  dimmer.setPower(bulb);
  //Serial.println(Output);
  //pid bulb ends here
  //humidifier,fan1 and fan2 starts here
  if(rh>=58)
{
digitalWrite(11,HIGH);//Humidifier

}
else{digitalWrite(11,1);
digitalWrite(9,1);//servo motor
digitalWrite(10,1);// Fan 1
//digitalWrite(11,0);//Humidifier
digitalWrite(12,0);//Fan 2
}
}
```

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