Experimental Design of an Energy-Saving Egg Incubator System Using Fuzzy-PID Controller

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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. Incubation conditions depend on the hatchability of the birds. Inappropriate temperature and humidity levels result in unwanted conditions during incubation. 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 investigated and a new energy-saving egg incubator has been proposed. 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 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 the Fuzzy-PID controller can save 14.5 kWh more energy than conventional and save 3.19 kWh more energy than the PID Controller is more energy efficient than a conventional controller. 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 instead of PID and conventional controllers.

Keywords:
Temperature, Arduino UNO Micro Controller, Energy saving, Fuzzy-PID, Egg Incubator.

Introduction
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 (Nur and Rahman, 2022) For the growth of protein, poultry farming is one of the necessary ingredients for the current purpose. So the farmers and scientists are paying attention to the production and development of poultry farming (Mariani 2021). In 2016, the global annual meat production estimated by the UN Agricultural Outlook had reached 320.7 million tons of meat and poultry, totaling 12.7 million tons (Okonkwo 2012). 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 (Gabriel 2019). Natural Incubation performed by broody hens has low efficiency. The global yearly meat expenses per person are increasing 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 (Akintade, Olasunkanmi 2015). Sustainable poultry farming can promote the sustainable improvement goals of ending hunger, improving nutrition, achieving food security, and promoting sustainable agriculture. In our countries, poor farmers and non-farmers live in poultry farming (Mansury 2015). It is a regular income source for the poor farmers and village entrepreneurs.

For an automatic egg incubator, an artificial environment allows for the necessary temperature, humidity, regular turning of the eggs, and ventilation (Forson Peprah 2022). 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. Some eggs get spoiled when several factors such as temperature, egg turning, and humidity are not maintained properly (Idoko Emanual 2019). 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 this research aims 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.

1.1 Fuzzy Logic Controller

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. (Mizanur and Islam 2021). 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 into play when partial truths are mixed up, ranging from fulfilled truths to complete false (Isizoh A. N. 2012). 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 are '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 (Jiang and Xuchu 2012). The Fuzzy Controllers understand the output control, which is stable and improved. It has a longer settling time than the PI controller and removes the overshoot present in the PI Controller. Fuzzy-adaptive PID control is one kind of system that has effective and self-directing control of Fuzzy PID parameters It can sustain, manipulate, and control the data of an incubator. 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 (Qin and Yanni 2013). The PID controller has various applications for fuzzy controller improvement around the world in many different types of industries. 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 (Okide S. 2011).

1.2 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 lets the fetus inside the eggs grow without the mother hen needing to be present to provide warmth. There are two types of incubators available: conventional Egg incubators and Automatic Egg incubators.

1.3 Objectives

i. To design a Fuzzy-PID controller-based temperature control system for an egg incubator
ii. Comparison between new and old temperature control system
iii. To develop the temperature control strategy for energy-saving operations.

Literature Reviews

Several authors have done research on temperature control in egg incubators 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.
S. A. Rahman and Z. Aldeen proposed a smart incubator based on a PID controller. In his research work, he used the Arduino board ATmega1280 and set the temperature to 37°C and the humidity to 62%. In his research, he could use PWM technology for PID output voltage for the humidity and heat source (Zain-Aldeen and S.A. Rahman 2017). A.A. Sunday and Ogunbode proposed 100-egg hatching capacity-based egg incubator systems for small-scale farmers. For the temperature control of this system, the author used an 89C51 microcontroller. The authors set the temperature and humidity between 37°–39°C and 55%, respectively (Sunday and Ogunbode 2020). Frimpong Kyeremeh proposed an Arduino microcontroller based on (75*60*40) inch incubator that can operate 14000 quail eggs or 4500 equivalent chicken eggs hatching and uses 3 incandescent 200W bulbs as a heat source (Frimpong and Pepra 2017). M. Mariani et al. proposed an Arduino Uno R3, AT Mega 328 microcontroller-based Two incandescent bulbs (25 watts) were used to provide a 36 to 38°C temperature inside the incubator (Mariani 2018).. Pallavi Bhosale et al. had proposed an Arduino microcontroller-based 20–25-egg smart egg incubator. The author controls the temperature between 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 (Bhosale and Zagriti 2020). Shehzad and Rehman had developed their hatching incubator, and an 80-watt light bulb was installed in the box for the heat source. The authors used 6 eggs for the incubation. Maintain the temperature at 37–38 °C (Shehzad and Rehman 2016). W.S. Mada Sanjaya et al. proposed an Arduino microcontroller-based (100*70*43) cm. 4 pieces of 5-watt lamps and 2 pieces of blower fans were used inside the incubator. 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 (Sanjaya 2018). Adegbulugbe T. A. et al. proposed a 540-hatching capacity-based Egg Incubator. They used four 60-watt filament bulbs as the heating source for the incubator. Humidity was set at 58%–60%, and temperatures ranged from 37°–39° centigrade (Adegbulugbe and Atere 2013). Dr. Sunitha H. D. et al. propose a "Universal Egg Incubation System for Hatching using Atmega328P, Proteus Design Tool, and IoT." In their research, they used an Arduino Uno Atmega328P. Two 60-watt filament bulbs are used in this system. The temperature range of 36°C–37°C and humidity kept 57% for the first 18 days, then increased by 70% during the 21 days of incubation (Niranjan and Sunitha 2020). Adam Faroqi et al. proposed their method "Design of Arduino Uno-Based Duck Egg Hatching Machine With Sensor DHT22 and PIR Sensor".

In this system, temperatures range from 38°C - 40°C, and humidity is around 60–70%. The result found that the hatching ability was 95% during the 25 to 28 days of the hatching process (Farouqi and Effendi 2020). Siriluk, S. et al. had developed (47×48×41) cm cabinet, which was made from zinc sheet acrylic plastic outside the wall, with a 30 egg capacity-based automatic egg Incubator. The author used two halogen 60W lamps to control the temperature range of 38°C–40°C and the humidity of 60–70%. (Siriluk. S 2011). Okpagu, et al, developed a 450 chicken egg incubator with an Arduino microcontroller-based air-forced egg incubator. The author developed the temperature control in the egg Incubator using a PID control system. The author had designed (0.60×0.52×0.35)m egg Incubator that has a 200W filament bulb, a 16*2 character LCD display, The temperature and humidity ranges were used 36.5°C–38.5°C & 55%–65% RH, respectively (Okpagu 2016). Fasanmi et al, proposed a 540 hatching capacity egg Incubator. The author had designed (0.36×0.45×0.32) m cabinet, 4 filament bulbs (60 watts) as heating sources for the incubator. Humidity was set at 58%–60% and temperature at 37°–39° centigrade for 18 days. DHT11 is used for sensing temperature and Humidity (Fasanmi 2013). Olaoye had developed a 100-egg capacity. The incubator box was designed at (120*70*40) cm. The author had used a 100-watt bulb as a Heat source. 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 (Olaoye 2018).

3. Membership function and Fuzzy logic Rules

The membership function of the fuzzy control system mappings the set of input variables is called fuzzy sets and the value of fuzzy set is called fuzzification. The FLC method can also organize the analog inputs which are 0, 1.The fuzzy sets were classified into two input variables 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 [NB, NM, NS, ZO, PS, PM, PB] and the domain

outputs are [NB, NM, NS, ZO, PS, PM, PB]. All of the membership functions in FLC were taken in straight line which is a triangular shape. The input value range of (K_P, K_I, K_D) range is [-20 40] & the output value range of (K_P, K_I, K_D) is [0 40]. The fuzzification and defuzzification method of a fuzzy function has been used to quantify the philological terms which can plotted by changing the temperature.
The membership function is given in Figure 1 and fuzzy logic rules are given on Table 1, Table 2, Table 3

Table 1: Fuzzy logic Rules for KP

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 2: Fuzzy logic Rules for KI

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: Fuzzy logic Rules for KD

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

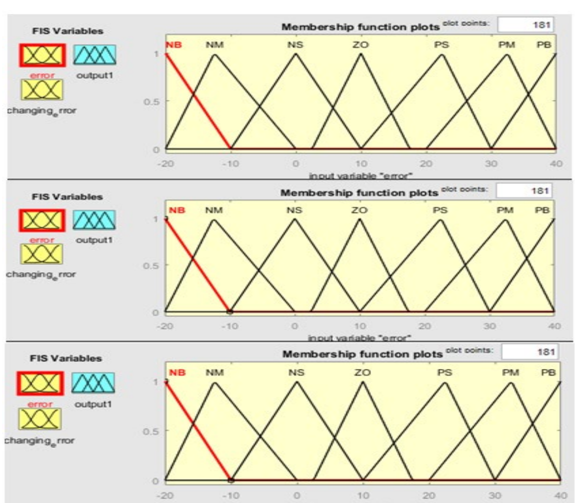

Figure 1. Membership Function

Methodology

To implement the system, there are three basic designs: mechanical, electronic, and software. On the Mechanical site, the incubator box is built on a steel structure covered with a layer of anti-rust and has a size of (22 ×24 ×36) Inches in such a way as to avoid any kind of heat loss and preserve the static temperature inside the incubator. The box constructed was built on a four-layered wall. On the Electronic site, a 200-watt bulb is used as a heat source, a fan is used for the temperature circulation, and a humidifier is used for the humidity in the enclosure. Ventilation holes are provided to replenish the humidity and air in the circumference. Clear glass with windows was used on this box to observe the interior of the circumference during the incubation. Arduino Uno AT Mega 328P is used during the experimental work in the incubator, which has 14 input Pins and 6 analog input pins.
A circuit diagram of Temperature control is given on Figure 2 and an Experimental image of temperature control of an Egg incubator is given on Figure 3

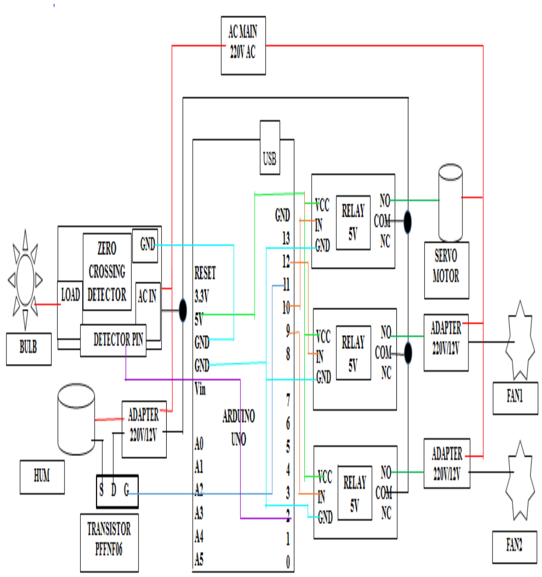

Figure 2. Circuit Diagram of Temperature Control of an Egg Incubator Model.

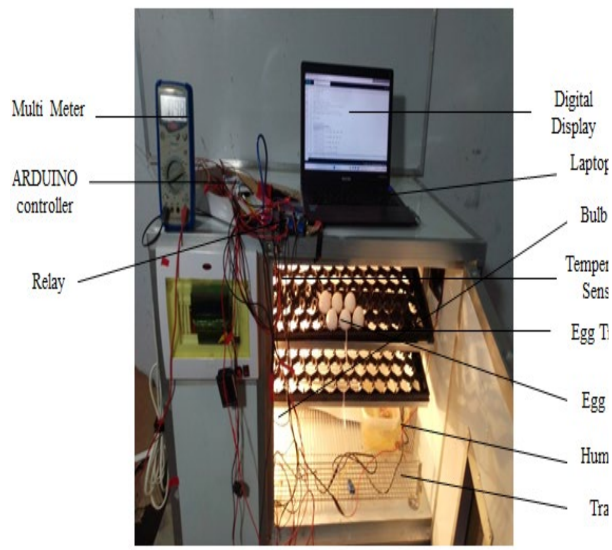

Figure 3. The Experimental Image of Temperature Control of an Egg Incubator

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. A zero-crossing detector is used for the brightness of the bulb, as well as the voltage and temperature control in the egg incubator. For temperature 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 as well as control the temperature inside the egg incubator.
Flowchart of the Temperature and Humidity Control in egg incubator system is given on figure 4.

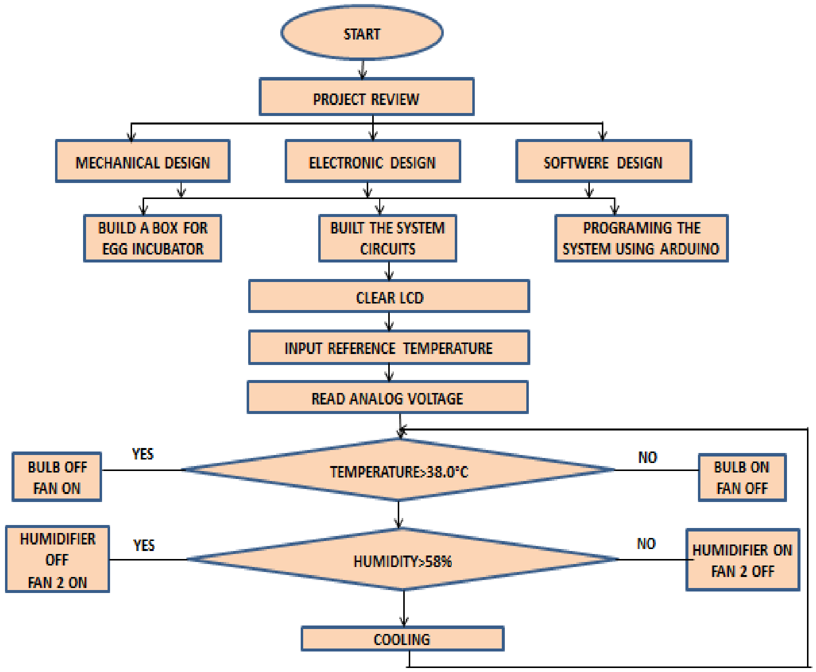

Figure 4. Flow Chart of Temperature and Humidity Control of an Egg Incubator

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 is greater than 58%, then fan 2 is on. If the humidity is less than 58%, then fan 2 is off.

Data Collection

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. For experimental work, collect the Conventional, PID, and Fuzzy-PID controller data for 1 hour in the Egg Incubator. The Experimental temperature (°C) data and power consumption (W) data has been given in table 4 and Table 5.

Table 4. Temperature(°C) Experimental Data

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

Table 5. Power(W) Experimental Data

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
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	38.00	37.00	37.00
12.22	38.00	37.00	37.00
12.23	37.00	37.00	37.00
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
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

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
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
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

5.1 Result and Discussion

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 Table 4 and the Power consumption data is given in the table

5.2 Graphical Result

The most crucial component of MATLAB is Simulink, which is utilized to compute the real-world data for the Egg Incubator System. Use the Simulink model in the Matlab software to simulate the temperature change over time. To have the graph alter over time, the Simulink block in Figure 5 generates conventional, PID, and fuzzy-PID Control data. Here, the clock is used to set the time during system operation, and Scope is used to observe the Temperature data graph change with time in the egg incubator system and compare the conventional, PID, and Fuzzy-PID graphs simultaneously. A Simulink model of the Temperature is given in Figure 5 and the Change in temperature variations with time is given in Figure 6

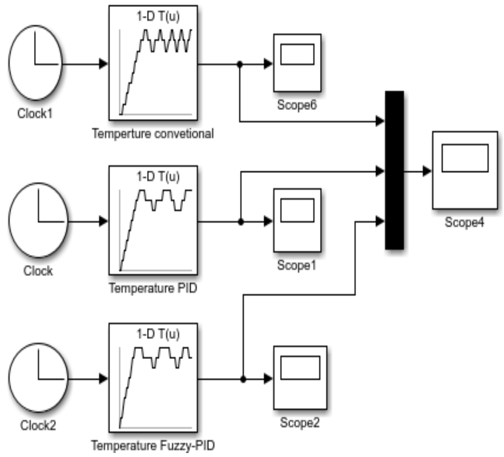

Figure 5. Simulink Model of Temperature

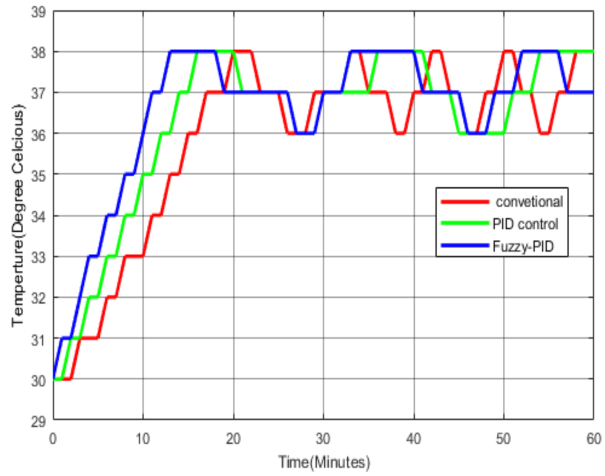

Figure 6. Change Temperature Variation with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

During the experimental work, 60 minutes of experimental temperature data were collected for the proposed Egg Incubator system. The experimental data had been inserted into the Matlab Simulink model. Simulink blocks produce the graph change with time. Figure 6 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.

Graphical Results

Simulink model of Power consume is given on figure 7 and Power consumption with time data graph is given on figure 8

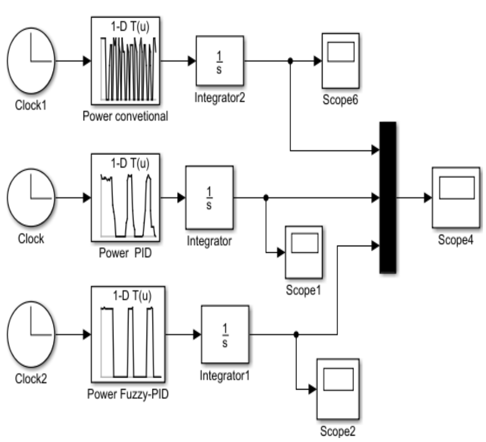

Figure 7. Simulink Model of Power Consume

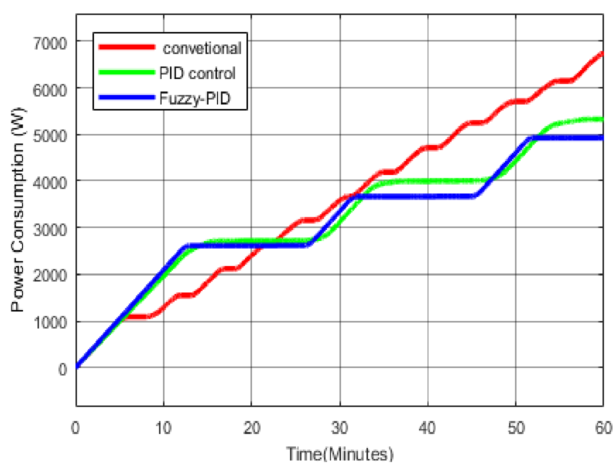

Figure 8. Power Consumed with Time Using Conventional, PID and Fuzzy-PID Control Monitoring Process

During the experimental work, 60-minute Experimental Power consumption data were collected for the proposed Egg Incubator system. In the experimental work, different kinds of controllers, like Conventional, PID, and Fuzzy-PID control, in the egg Incubator. In figure 6, the experimental data had been inserted in the MATLAB Simulink model, which can produce a Power consumption graph changing with time. Figure 7, 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 minute during operation. On the other hand, the PID controller had been taken at 5330 W minute and the fuzzy-PID had been taken at 4945 W 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.

5.4 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

5.5 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× 2

=44772Watt hour $=\frac{44772}{1000}$ kWh= 44.772 kWh

Now the efficiency improvement of PID control compared to the Conventional Controller

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

$\frac{= 56.0028-44.772}{56.0028} \times 100$ = 20.05%

5.6 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 W hour

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 efficiency improvement of Fuzzy-PID compared to the Conventional Controller

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

$\frac{= 56.0028-41.538}{56.0028} \times 100$ =25.83%

The Calculation shows that Fuzzy-PID is more energy efficient than PID and Conventional Controller.

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

For controlling the temperature in the egg incubator, we use different techniques like Conventional, PID and Fuzzy-PID Controller. During the experiment work conventional controller takes 56.0028 kWh total power consumption in 21 days of incubation. For energy saving PID Controller can takes 44.772 kWh total power consumption in 21 days of incubation. Further energy saving we use fuzzy-PID controller in the incubator. During the experimental work total power is consumed 41.538 kWh during 21 days of Incubation.

Power Consumption Variation with time in Conventional, PID and Fuzzy-PID Monitoring Process is given on figure 9

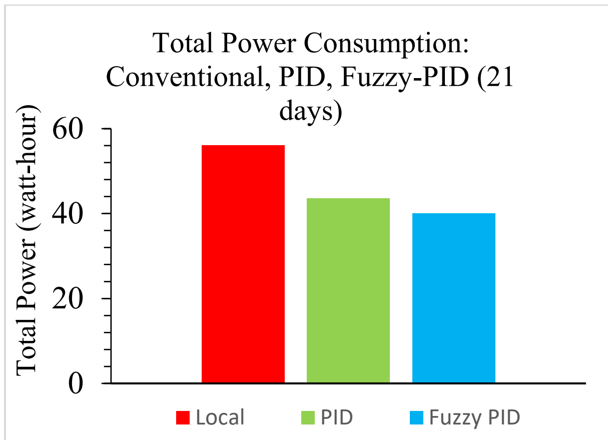

Figure 9. Power Consumption Variation with time in Conventional, PID and Fuzzy-PID Monitoring Process

For comparison, the Conventional controller takes too much power consume than PID Controller and fuzzy-PID controller is more energy efficient than PID controller.

5.8 Proposed improvement

In our proposed system minimizes the fluctuation and energy consumption of the existing incubator system and provide the energy-saving solution to this system.

Conclusion

The Energy-saving egg incubator system has been investigated in this research by controlling the temperature and maintaining the humidity 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 namely Conventional, PID, and Fuzzy-PID controller. The brightness of the bulb can't be controlled in a conventional system. Therefore, a PID and Fuzzy-PID controller 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 was 38°C. For 21 days of incubation, the conventional controller consumed 56.08 kWh; however, PID consumed 44.77 kWh, whereas Fuzzy-PID consumed only 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 controllers have lower power consumption compared to other controllers and found effective and efficient method in this purpose.

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