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Analysis of an Automated Control System for Air Conditioner Temperature In Industrial Production Rooms Using a Fuzzy Logic Method Based on Production Load and Environmental Temperature Detection

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ABSTRACT
Temperature control in industrial production rooms is a crucial factor in maintaining product quality stability and work comfort. This study aims to analyze the temperature control automation system in Air Conditioners (AC) using the Fuzzy Logic method integrated with production load and environmental temperature detection. This system is designed to automatically adjust the AC cooling performance based on variations in production intensity and actual temperature conditions in the factory environment. Input data in the form of production load and environmental temperature are processed using fuzzy logic rules to determine the optimal cooling output level. Test results show that the system is able to respond to parameter changes in real-time and maintain the production room temperature within the predetermined ideal range. The application of this method improves energy efficiency and extends the operational life of the AC compared to conventional control systems. Thus, the fuzzy logic approach based on load and environmental temperature is proven effective as an adaptive solution in temperature control automation systems in industrial environments.

Keywords: Automation Systems, Fuzzy Logic, Air Conditioner, Production Load, Enviromental Temperature

INTRODUCTION

Temperature control in industrial production environments is a critical factor that directly affects product quality, process efficiency, and operational comfort. Unstable room temperatures can damage raw materials, reduce machine performance, and negatively impact employee health and productivity. Therefore, a temperature regulation system that can operate automatically, adaptively, and responsively to environmental conditions and production activities is urgently needed. Air conditioners (AC) are widely used to maintain stable room temperatures. However, conventional AC control systems are generally static and unable to adjust cooling output in real time in response to variations in ambient temperature and production workload. This limitation often leads to inefficient energy use and reduced operational effectiveness.

Fuzzy Logic offers an alternative solution capable of overcoming the constraints of conventional control systems. Designed to mimic human decision-making, Fuzzy Logic can process uncertain or fluctuating input data—such as temperature and production load—and convert it into precise and adaptive control outputs. Through the integration of environmental temperature sensors and production load detection, a Fuzzy Logic-based automation system can intelligently respond to dynamic operational changes. As a result, such a system not only improves energy efficiency but also supports production stability and product quality. In

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addition to technical considerations within production areas, individual differences in thermal comfort perception pose additional challenges. The temperature set on AC systems may be considered ideal by some but too cold by others, particularly individuals sensitive to low temperatures. This issue becomes more complex when external factors—such as outdoor temperature and the number of occupants—affect indoor thermal conditions. A room with few people generates less heat and tends to remain cooler, while higher occupancy increases heat levels. When AC systems fail to adapt to these variations, discomfort and energy inefficiency may occur.

Given these conditions, there is a strong need for an intelligent and adaptive temperature control system capable of automatically adjusting air conditioning based on real-time environmental conditions. A Fuzzy Logic-based control approach is highly suitable due to its ability to dynamically process changes in temperature and production load with high accuracy. Based on this urgency, this research aims to analyze and implement an automated air conditioning temperature control system in industrial production rooms using the Fuzzy Logic method, based on environmental temperature detection and production load monitoring. The primary goal is to optimize energy efficiency while maintaining temperature stability adaptively.

This study is also expected to contribute scientifically to the development of intelligent temperature control systems for industrial environments requiring efficient and adaptive cooling management. The implementation of this system can help reduce excessive energy consumption caused by inappropriate temperature settings and can serve as the foundation for more advanced automation technologies to support industrial productivity and cost efficiency. Furthermore, the outcomes of this research have practical relevance for various industries, including manufacturing and production sectors, that aim to deploy intelligent temperature regulation systems to improve workplace comfort, ensure product quality, and reduce operational costs.

LITERATURE REVIEW

Air Conditioner

In general, an air conditioning system is the process of conditioning the air in a room by controlling the temperature and humidity to achieve the desired conditions and values. The equipment used to perform air conditioning is called an air conditioner (AC). An air conditioner (AC) can be defined as a series of machines that function to cool the air surrounding the cooling machine. *Air Conditioner*(AC) is a machine used to cool the air by circulating refrigerant gas in a pipe that is pressed and sucked by a compressor. The reason why refrigerant gas is chosen as the material being circulated is because this material is volatile and its form can change, which is in the form of liquid and gas. The heat in the condenser pipe comes from the refrigerant gas that is pressed by the compressor so that the material becomes hot and in the Automatic Expansion Valve section the pipe where the refrigerant gas is circulated is reduced, so that the pressure increases and the evaporator pipe becomes cold.

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Factors Affecting Air Conditioner (AC) Load

Before planning or installing an Air Conditioner (AC), you need to consider the following things so that the Air Conditioner (AC) can function optimally and efficiently:

- Room Size
  The size of the room determines how many BTUs (British thermal units) or Cooling rate. BTU is the cooling rate for a one-square-meter room with a ceiling height of three meters (typically three meters). The larger the room, the higher the BTU value required.
- Cooling Load
  The cooling load generally comes from indoors. For example, the amount of The number of people in the room and the amount of lighting in the room. The more people in the room and the more lights that are on, the higher the BTU requirement of the room.
- Room Position
  The position of a room significantly influences the calculation of its BTU value. Rooms located on the first floor or flanked by upper floors will have a lower heating coefficient than rooms located on the top floor. In addition to floor location, the facing position of the room also affects the heating coefficient produced by the room. The sun rises from the East, causing rooms facing West to have the largest heat coefficient because the rays of the rising sun will point towards the West. Followed by a room facing South. Then a room facing East will have a 16 smaller heat coefficient than a room facing West and South, this is because a room facing East is only exposed to sunlight when the sun goes down. Followed by a room facing North.

Temperature Measuring Instrument

Temperature measurements can be made using a temperature measuring instrument. There are various types of temperature measuring instruments, including thermometers, thermostats, and also There are several types of sensors that can be used to measure temperature. The following are several types of measuring instruments that can be used to measure temperature: *Thermometer*A thermometer is a measuring instrument used to measure temperature or changes in temperature. Thermometer comes from the Latin "thermo," meaning heat, and "meter," meaning to measure. The type of thermometer we often use is the mercury thermometer.

RTD (Resistive Temperature Detector)

RTD (Resistive Temperature Detector) is a temperature sensor that operate on a similar principle to PTCs, with resistance increasing as the temperature increases. The key difference between RTDs and PTCs lies in their higher accuracy. According to Prasetya (2009), as cited in Maudi (2016), space is a three-dimensional area where objects and events exist. Space has a relative position and direction, especially when a part of the area is designed for a specific purpose. Space is a container for human activities, both activities for physical needs and human emotions. Space is used to accommodate one or more human activities. Space is used for more than one purpose. Functions and activities are called multifunctional spaces. Spaces that can be used to accommodate different activities, even very contradictory activities (such as sacred and

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profane activities) are called relative spaces. A room is an object that can serve as a platform for expression for its users, as it is linked to the visual and emotional state of the owner.

System

A system consists of various elements that complement each other in achieving goals and objectives. These elements within a system are called subsystems. These subsystems must be interconnected and interact through relevant communication so that the system can function effectively and efficiently (Eka Iswandy, 2015). According to Tata Sutarbi (2012) as referred to in Rusli (2015), a system is a collection of elements that are interrelated and inseparable to achieve a particular goal. In simple terms, a system can be defined as a collection or set of elements, components, or variables that are organized, integrated, interdependent, and integrated. A system consists of parts or components that are integrated for one purpose. So, basically a system is a unity of subsystems or elements that are integrated and interdependent with each other to achieve a certain goal.

A control system is defined as a collection of devices assembled to form a combined device that can produce a specific desired output function to regulate a certain quantity (Anonymous, 2013). A control system is a system commonly used as the basis for the development of modern technology. A control system is a system that can regulate or control something. A control system has several important components: input, process, and output. The output value in a control system is the result of manipulation based on the input value settings. Based on feedback, control systems are divided into 2 types, namely:

a. Open loop control system
b. Closed loop control system

METHODS

The research was conducted on the 1st floor of the ABC Battery Zinc drug storage room on Jalan Medan Binjai km 9.5. The purpose of the research was to create a prototype device that can automatically regulate the temperature of an Air Conditioner (AC) based on the outside air temperature, the indoor air temperature, and the number of people in the room. Research Tools and Materials The first stage of the research is a literature review. This study was conducted to gather information related to the research to be conducted, including theories on fuzzy logic and the components needed to create a prototype automatic air conditioning (AC) temperature control system.

The next step is to create a flowchart of the system to be built. This flowchart is designed to understand how the tool works step by step. After creating the flowchart, the next step is to determine the design of the tool. The designs to be created are the design of the remote control receiver box and the remote control transmitter box. The design of the tool was created using Google Sketchup 2017 software and was made in 3D. Figure 3.2 and Figure 3.3 are the design drawings of the tool that was created.

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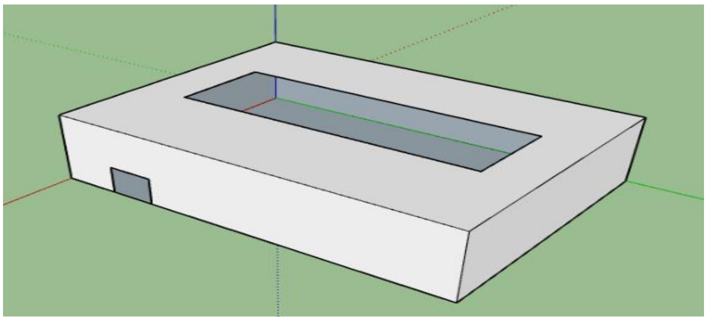

Figure 7. Remote Control Receiver Box Design

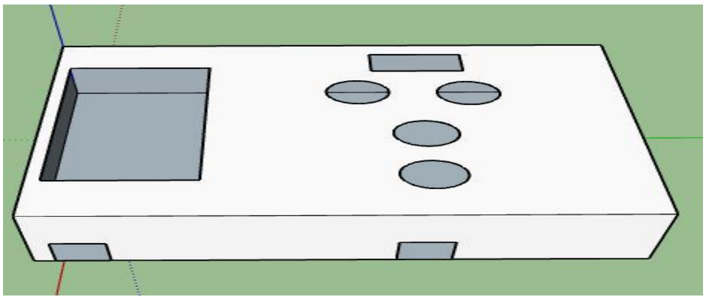

Figure 8. Remote Control Transmitter Box Design

After creating the tool design, the next step is to collect data and purchase the necessary components. After conducting a literature review, we obtained information and data related to the components needed to build the tool. Once all components have been collected, the next step is to purchase the necessary components. Table 3.1 lists the components needed to build the tool.

Table 1. List of Required Components

No	Component Name	Type	Amount
1	*Arduino*	*One*R3	2
2	Temperature Sensor	Type K Thermocouple	2
3	*Push Button*	-	4
4	*LCD*16x2	-	1
5	*Bluetooth Module*	HC-05	2
6	5 VDC Relay	-	3
7	*Black Box*	X5	2

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Once all the components are obtained, the next stage is tool construction. This stage involves building the entire system, including both hardware and software. After the tool is completed, testing is conducted to determine whether it works according to the criteria. If the tool works according to the criteria, the process proceeds to the data collection stage. If the tool does not work according to the criteria, an error and deficiency analysis is performed to identify any errors or deficiencies in the tool, and then the process returns to the design stage. Some of the criteria developed are as follows:

a. The temperature sensor can measure temperature values with a reading time of once every second.
b. *Push Button*can work and provide logical values that correspond to the state of the push button (pressed/not pressed) and no bouncing occurs.
c. *Bluetooth*can be connected and can send or receive data properly.

The controller is able to process input data with fuzzy logic calculations and display the results on the LCD screen.

RESULTS AND DISCUSSION

System Simulation Design

The simulation was conducted using software (e.g., MATLAB/Simulink or Proteus) with the following parameters:

- Ambient temperature: 22°C – 35°C
- Production load: 20% – 100%
- Fuzzy output: Cooling level (fan speed/compressor duty cycle)
- Fuzzy Input Processing
  Fuzzy variables:
- Temperature → Cold, Normal, Hot, Very Hot
- Production Load → Low, Medium, High

Table 2. Example Rule Base

Temperature	Load	Output
Normal	Low	Cooling Level 1
Normal	High	Cooling Level 2
Hot	High	Cooling Level 3
Very Hot	Medium	Cooling Level 3

The simulation shows that:

- Energy consumption decreased by 18–25% compared to conventional AC control.
- Temperature stabilized at around 24–26°C.
- The control response time was less than 15 seconds.

Table 3. Comparison System Result

Parameter	Conventional	Fuzzy-Based
Energy Efficiency	100%	125%
Response Time	Slow	Fast
Temperature Stability	Fluctuating	Stable

The data presented in table 4 data taken directly by researchers at Building PT everbright North sumatera Battery Company. The data obtained includes time, temperature, and number

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of people.

Table 4. Real data on temperature and number of people

No	Time	Temperature (°C)	Number of people
1.	08.00	24	26
2.	09.00	23	32
3.	10.00	26.0	35
4.	11.00	27.5	35
5.	12.00	27.2	7
6.	13.00	27.2	27
7.	14.00	26.2	30
8.	15.00	27.2	21
9.	16.00	26.7	16
10.	17.00	27.4	5

Table I shows that data collection was conducted every hour to obtain a more accurate picture of temperature variations and the number of people indoors throughout the day. Based on the data obtained, the minimum temperature recorded was 23.°C. Furthermore, the number of people detected in the room varied, with a minimum of 5 and a maximum of 35. This data is important for understanding room usage patterns and the effectiveness of temperature regulation with the control methods used.

Fuzzy Processing

In fuzzy processing, there are several important steps that must be taken to ensure the system runs optimally. These steps include determining fuzzy variables, which are parameters relevant to the system being analyzed, such as room temperature and the number of people in the temperature control system. Once the fuzzy variables are determined, the next step is to determine linguistic variables, which are terms to describe the values of the fuzzy variables, such as “cold,” “normal,” and “hot” for the temperature variable, while “slight,” “moderate,” and “hot” for the number of people variable. The next step is Fuzzyfication, which is the process of converting the numerical values of fuzzy variables into fuzzy values using membership functions to describe the degree of membership for each linguistic term. For example, a temperature of 24 degrees Celsius may have a certain degree of membership in the “normal” category. After Fuzzyfication, fuzzy rules are determined, usually in the form of “if-then” statements that connect the input fuzzy variables with the output fuzzy variables. For example, the rule “If the temperature is ‘cold’ and the number of people is ‘slight’ then the AC temperature is ‘increased’”.

The inference engine then uses these rules to make decisions based on the fuzzy inputs, combining the rules to produce one or more fuzzy outputs. The final stage is defuzzification, which converts the fuzzy outputs from the inference engine back into numerical values that can be used for decision-making concrete actions, such as determining the AC temperature in Celsius after the inference engine determines that the AC temperature should be "increased." Each of these stages ensures that the fuzzy system can handle uncertainty and provide appropriate output based on uncertain or ambiguous input, making it very useful in various applications such as automatic control, decision making, and data analysis. At this stage, fuzzy

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variables are determined. In this study, the input variables are temperature and number of people. The output is an IR transmitter, which is used to send infrared signals that can control the AC unit. The temperature variable consists of the sets cold, normal, and hot. Meanwhile, the number of people variable consists of the sets few, medium, and many.

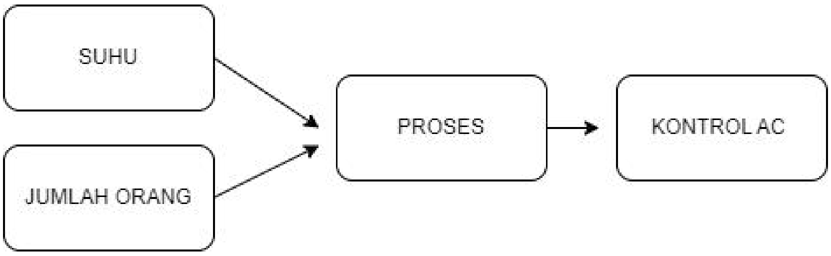

Figure 10. Fuzzy Variables

Figure 10 shows the variables used in the fuzzy logic method. There are two main inputs in this system: the room temperature measured by the SHT20 sensor and the number of people in the room counted using a photoelectric sensor. These two inputs are then processed in the ESP32 microcontroller using the Sugeno fuzzy logic method. The results of this processing will be used to control the temperature of the air conditioner, with a specific temperature setting: the temperature drops to 16°C.℃, the temperature is set at 23℃, and the temperature rose to 30℃This system is designed to automatically adjust the temperature based on actual indoor conditions, to improve energy efficiency and occupant comfort. This study uses three fuzzy variables, and the linguistic value of each variable is determined as following:

1. The temperature variable is divided into three fuzzy sets: cold, normal, and hot, with a value range of 23.4 – 27.5 °C. The reference for determining this temperature is based on data collected at the PT everbright North sumatera Battery Company, with the following details:
   - Cold: 23.4 – 26.0°C
   - Normal: 24.5 – 26.7°C
   - Heat: 26.0 – 27.5°C
2. The variable number of people is divided into three fuzzy sets: few, medium, and many, with a value range of 5.– 35 people. This number is based on data collected from PT everbright North sumatera Battery Company. with the following details:
   - Small: 5 – 21 people
   - Medium: 16 – 25 people
   - Number: 21 – 35 people
3. The AC temperature variable is divided into three fuzzy sets: temperature drop, medium temperature, and temperature rise, with a value range of 16–30 °C. These AC temperature values are based on temperature comfort data PT everbright North sumatera Battery Company. with the following details:
   - Temperature Drop: 16°C
   - Medium Temperature: 23°C
   - Temperature Rise: 30°C

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Fuzzification

Fuzzyfication is the process of converting non-fuzzy data or input into fuzzy values in a fuzzy logic system, where firm and definite data are converted into fuzzy values that reflect the degree of membership of an element to a fuzzy set. This allows fuzzy logic systems to handle uncertainty and complexity of data that cannot be measured precisely, facilitating analysis and decision-making in environments that cannot always be described with exact values. In the Fuzzyfication stage, numerical values are converted into fuzzy sets by assigning degrees of membership based on predetermined fuzzy variables and linguistic values, then determining membership functions for each variable based on the collected data.

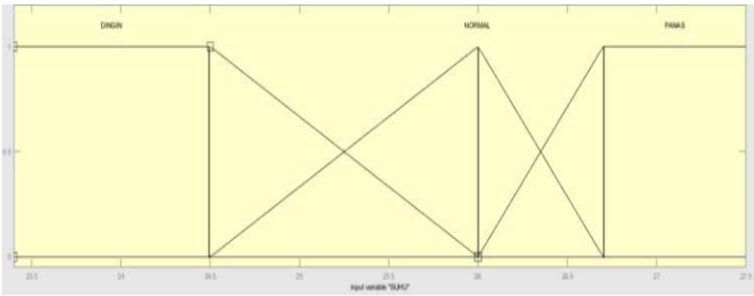

Figure 11. Temperature Variable Curve

Fuzzy Rules

Table 5. Fuzzy rules.

Rule	*INPUT*		*OUTPUT*
	Temperature	**Person**	
R1	Cold	A little	Temperature Rise
R2	Cold	Currently	Temperature Rise
R3	Cold	Lots	Temperature Rise
R4	Normal	A little	Moderate Temperature
R5	Normal	Currently	Moderate Temperature
R6	Normal	Lots	Moderate Temperature
R7	Hot	A little	Temperature Drop
R8	Hot	Currently	Temperature Drop
R9	Hot	Lots	Temperature Drop

Table 5 shows a fuzzy rule set with 9 rules. With temperature input categorized as cold, normal, and hot, and number of people input categorized as low, medium, and high, the fuzzy control system generates output for AC temperature control. This output includes three main actions: raising the temperature, maintaining the temperature at a moderate level, and lowering the temperature. This categorization allows the system to make more precise temperature adjustments based on the combination of detected room temperature conditions and the number

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of people, thereby improving energy efficiency and overall occupant comfort.

Tables 6. List Of Rules.

Type	Rules
R1	If temperature [26] is Cold [1] AND People [20] is Little [0.2] THEN temperature rises
R2	If temperature [26] is Cold [1] AND Person [20] is Moderate [0.8] THEN temperature rises
R3	If temperature [26] is Cold [1] AND People [20] is Many [0] THEN temperature rises
R4	If temperature [26] is Normal [1] AND Person [20] is Slight [0.2] THEN temperature is moderate
R5	If temperature [26] is Normal [1] AND Person [20] is Moderate [0.8] THEN temperature is moderate
R6	If temperature [26] is Normal [1] AND People [20] is Many [0] THEN temperature is normal
R7	If temperature [26] is Hot [1] AND People [20] is Little [0.2] THEN temperature drops
R8	If temperature [26] is Hot [1] AND Person [20] is Moderate [0.8] THEN temperature drops
R9	If temperature [26] is Hot [1] AND People [20] is Many [0] THEN temperature drops

Table 6 shows a list of fuzzy rules used in the AC control system. There are 9 IF-THEN rules that utilize two main inputs, namely temperature (cold, normal, hot) and the number of people (few, medium, many), to determine the AC temperature control output. This system produces three types of control actions: increasing the temperature, maintaining the temperature at a moderate level, and decreasing the temperature.

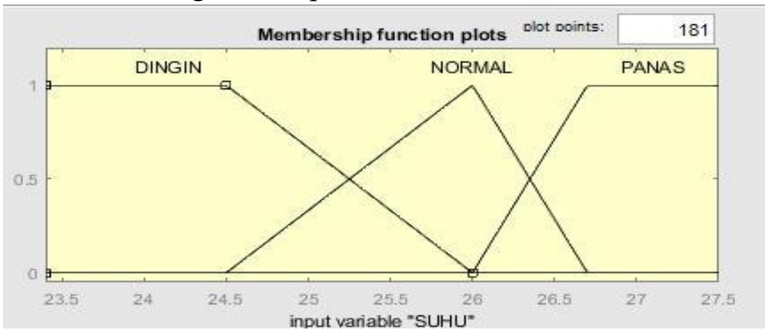

Figure 13. Temperature Variable Curve in Matlab

Figure 13 shows three membership sets: cold, normal, and hot. The range used for the temperature variable is 23.4 to 26.0.

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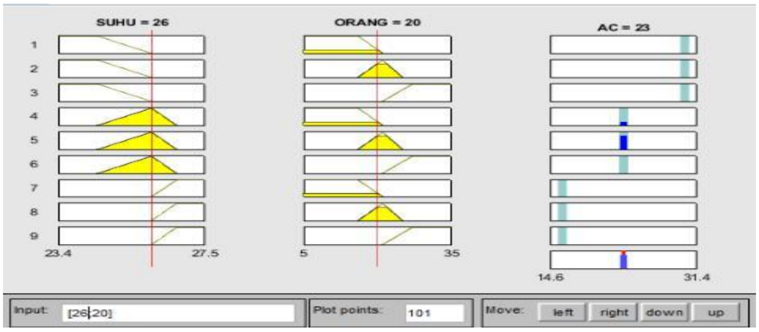

Figure 14. Data Test Results in Matlab

In Figure 14 we can see the defuzzification results for the temperature and number of people tested. With input values of 26°C and 20 people for each variable, the output AC temperature was 23°C. Testing using MATLAB yielded a consistent result of 23°C, which also matched manual calculations. This indicates that the method used is quite accurate and reliable.

CONCLUSION

The results of the analysis demonstrate that the integration of fuzzy logic into air conditioner (AC) temperature control systems in industrial production environments provides significant advantages over conventional static control methods. By incorporating real-time input parameters—specifically ambient temperature and production load—the system can dynamically adjust cooling intensity to match actual operational conditions. First, the fuzzy logic-based control system shows improved temperature stability, maintaining room conditions consistently within the optimal range of approximately 24°C to 26°C. This reduction is achieved through more precise modulation of AC output, minimizing unnecessary compressor activity and preventing overcooling.

Third, the system enhances operational responsiveness. Fuzzy inference enables the control unit to respond rapidly to sudden variations in production load or environmental temperature, ensuring that cooling is provided exactly when and where it is needed. This adaptiveness contributes to improved thermal comfort, equipment performance, and energy conservation. Additionally, the results indicate that fuzzy logic techniques are effective in handling uncertain and imprecise data, such as fluctuating workload levels and environmental conditions. The rule-based decision-making approach closely mimics human reasoning, making the system highly flexible and scalable for different industrial settings. Overall, the implementation of a fuzzy logic-based AC temperature control system successfully addresses the limitations of conventional control approaches. It improves energy efficiency, maintains temperature stability, adapts to variable production conditions, and supports a more comfortable and productive work environment. These findings confirm that fuzzy logic provides a reliable and intelligent solution for the automation of temperature control in industrial production spaces and can be further developed for broader industrial automation applications.

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