

# Improvement of an Energy Consumption and Economic Assessment of an Automated Temperature Controller of Air Conditioning System

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**ABSTRACT** – Currently, the main issue with regards to global challenge of reducing greenhouse gas emissions is to accomplish an efficient and cost-effective renewable energy technology. Therefore, it is crucial to propose a mechanism to address this issue. The main objective of this paper is to assess energy consumption of the newly designed automated temperature controller of an air conditioning system in term of usage of electricity. The methodology of this research is conducted by utilizing Fuzzy Logic control algorithm that is embedded into the automated temperature controller device. Result shows that the energy consumption of the air conditioning system that employ the newly proposed automated temperature controller perform 19% better than the conventional remote controller.

## 1. INTRODUCTION

The main challenge when dealing with temperature control of an air-conditioning system is with regards to maintaining the desired temperature. Traditionally, the temperature is controlled manually by adjusting the desired value using a remote controller. However, there are disadvantages when practicing the conventional approach such as wasting of energy, and this led to high energy consumption. Owing to this reason, an improved approach needs to be explored and implemented. To improve way in controlling current system, an automatic temperature control system needs to be put in place [1]. Room temperature apparently give impact to several human responses. A study investigating effect on task performance in office environment has shown that temperature of 24°C is preferred and could influence the productivity [2]. Moreover, the air conditioner ownership in Malaysia is 65% and its daily use time was 6 hours on average [3]. With the frequent and uncontrolled use of air conditioners, electrical power consumption is simultaneously increased as it consumes a large proportion of energy (above 50% of consumption).

In the development of an automatic air conditioner temperature controller, it is important to use an algorithm to maintain operation of the ambient temperature. One of the intelligent control systems, Fuzzy Logic Control (FLC) is a good solution to many control problems. The fuzzy models can represent the highly nonlinear processes and can combine a priori knowledge smoothly with process data information. Most control systems need to control the system's

mathematical model, but the FLC just needs to control the system's input and output signals measurement [4].

## 2. METHODOLOGY

The process flow chart diagram and overview of the automatic temperature controller is shown in Figure 1. First, the process began with the temperature sensor, which detects the ambient temperature and transmits the signal to the microcontroller and sends it to the IR receiver to adjust the temperature of air conditioner. Temperature data including air conditioner temperature (AC temperature), ambient room temperature as well as the data time during operation of the data logging shield connected to the Arduino Mega.

The energy consumption of the compressor and the electricity cost spent on the air conditioner are calculated using Equation 1 until Equation 3 [5-6].

$$Unit (Wh) = P * t \quad (1)$$

$$EER (Btu/Wh) = q_c / E \quad (2)$$

$$Electric bills (RM) = Cost per unit * Units \quad (3)$$

where,  $P$  = Power consumption (Watt),

$t$  = time of compressor operate (Hour),

$EER$  = Energy Efficiency Ratio (Btu/Wh),

$q_c$  = Output cooling energy (Btu),

$E$  = Electrical energy consumption in Watt-Hour (Wh),

$Units$  = Power usage (kWh),

$Cost per unit$  = RM 0.218 per kWh (1-200kW)

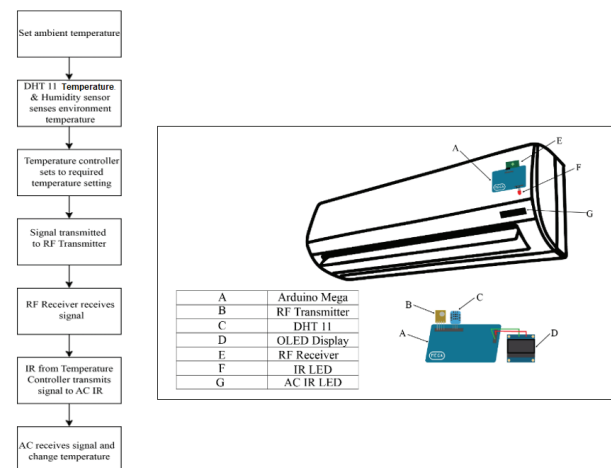


Figure 1 Overview of Automated Temperature Controller

### 3. FUZZY LOGIC CONTROL (FLC) ALGORITHM DEVELOPMENT

The air conditioning system is first developed with a Mamdani fuzzy model. It consists of two inputs, the room temperature and the humidity obtained from DHT 11 temperature and the humidity sensor. The system has one output to control the speed of the compressor. Temperature and humidity are known to be between 0 °C to 100 °C and 0 % to 100 % respectively. Increased input has three triangular membership functions as shown in Figure 2. Output, which is ambient temperature, is taken as a percentage from 0 % to 100 % and has three membership functions. The rules for the air conditioning system are listed in Table 1.

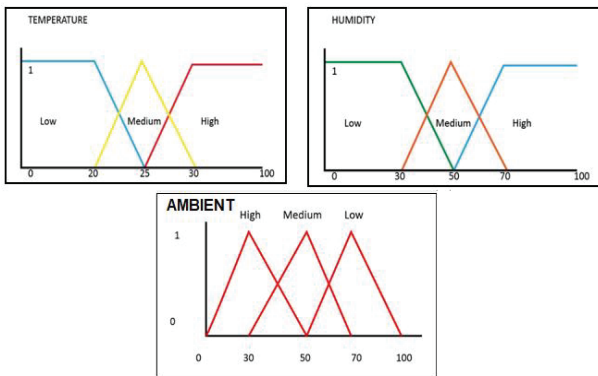


Figure 2 Temperature, Humidity and Ambient Membership Function

Table 1 Rule based of Mamdani-type FLC

Rules	Temperature (Input)	Humidity (Input)	Ambient Temperature (Output)	Air Conditioner Temperature
1.	Low	Low	High	23°C
2.	Low	Medium	High	23°C
3.	Low	High	Medium	22°C
4.	Medium	Low	High	23°C
5.	Medium	Medium	Medium	22°C
6.	Medium	High	Low	21°C
7.	High	Low	Medium	22°C
8.	High	Medium	Low	21°C
9.	High	High	Low	21°C

### 4. RESULT AND DISCUSSION

The result of the performance between 3 approaches namely, via manual temperature controller, Automatic temperature controller (using If-else code) and Automatic temperature controller (using FLC technique) are illustrated in Figure 3 and Table 2. Result shows that the energy consumption (in the unit of Watt-Hour, Wh) of the air conditioning system that employ the newly proposed automated temperature controller (via FLC algorithm) perform 19% better than the conventional remote controller.

### 5. CONCLUSION

In conclusion, by utilizing the flexibility of FLC algorithm, it is possible to reduce the energy consumption as well as the electricity bill as a whole.

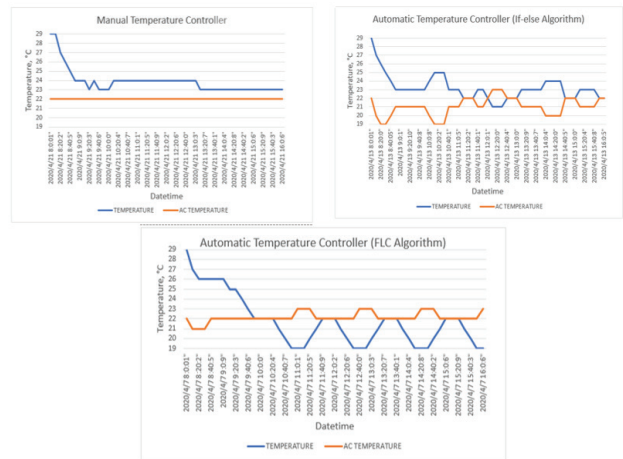


Figure 3 Graph of fluctuation of temperature between 3 different approaches

Table 2 Performance comparison between 3 approaches

	Manual Temperature Controller (Experiment 1)	Automatic Temperature Controller with If-else Algorithm (Experiment 2)	Automatic Temperature Controller with Fuzzy Logic Control Algorithm (Experiment 3)
Cooling	Stable	Moderate speed in cooling	Quick cooling
Compressor working time	8 hours	6.83 hours	6.5 hours
Energy Consumption	9360 Wh	7991.1 Wh	7605 Wh
Energy Efficiency Error	1.39	1.63	1.71
Electric Bills	RM 2.04 per day	RM 1.74 per day	RM 1.65 per day

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### REFERENCES

- [1] A. M. Zungeru, M. Mangwala, J. Chuma, B. Gaebolae, and B. Basutli, "Design and simulation of an automatic room heater control system," *Heliyon*, vol. 4, no. 6, pp. 5037-5044, 2018.
- [2] O. Seppänen, W. Fisk, and Q. Lei, "Effect of Temperature on Task Performance in Office Environment," *Lawrence Berkeley Natl. Lab.*, p. 11, 2006.
- [3] T. Kubota, S. Jeong, D. Toe, and D. Ossen, "Energy Consumption and Air-Conditioning Usage in Residential Buildings of Malaysia," *Journal of International Development Cooperation.*, vol. 17, no. 3, pp. 61–69, 2011.
- [4] PennState, "Air Conditioner Efficiency," 2018, [Online] Available: [https://www.engineeringtoolbox.com/air-conditioner-efficiency-d\\_442.html](https://www.engineeringtoolbox.com/air-conditioner-efficiency-d_442.html).
- [5] Tenaga Nasional Berhad, "Pricing & Tariffs - Tenaga Nasional Berhad," 2018. [Online]. <https://www.tnb.com.my/residential/pricing-tariffs>.
- [6] J. Lei et.al, "Model predictive control based on fuzzy linearization technique for HVAC systems temperature control," in *2006 1st IEEE Conference on Industrial Electronics and Applications*, 2006.