Three-Way Aircon-To-Fan Control Plug Using A Smartphone

Jeferson Balbuena, Dhomer Taguinod Bangayan, Christopher Balajadia, Ertie Abana, Jemart Doctolero, John Mark Visoria

Master of Engineering Program
School of Engineering, Architecture, and Information Technology Education, University of Saint Louis
Tuguegarao City, Cagayan

Abstract— **This study developed an aircon-to-fan plug that has a three-way control using a smartphone to help reduce power consumption when using window-type aircon. It utilized manual switching, timer switching, and temperature-based switching. The general operation of the device is managed by a microcontroller. A mobile application was developed using MIT App Inventor. This mobile application must first be connected to the device using Bluetooth technology for the different control mechanisms to work. The accuracy testing of the device in terms of manual switching, timer switching, and temperature switching shows that it worked as it was intended to. The device was able to reduce power consumption by 30% and energy costs by 37% over a 12-hour period of use. People who already have air conditioning in their homes will benefit from the device since it will allow them to lower the amount of energy they use while still maintaining a comfortable temperature inside their homes.**

Keywords— *aircon, plug, smartphone, microcontroller, mobile application*

I. INTRODUCTION

One of the most certain effects of climate change is an increase in heat exposure levels, and there is ample evidence that excessive heat has harmful effects on health [1]. Although there is a high mortality risk associated with heatwaves in warmer temperate areas as well, heat exposure is more dangerous in tropical and subtropical regions [2]. Due to what is known as the urban heat island (UHI) effect, heat exposure is particularly dangerous in big cities. Additionally, regions with already rising temperatures are those with rapid population increase and urbanization [3]. This puts an increasing number of people in danger.

Air conditioning (AC) is promoted as an effective solution to reduce heat stress and protect from heat exposure by providing indoor thermal comfort to avoid heat-related health problems [4]. Although there are several good reasons for increased AC use, it is important to question the energy consumption of AC. It is the main culprit behind the spike in electricity bills since air conditioners consume a lot of power. Currently, a body of research work has been reported in research paers in response to challenges around AC control optimization to reduce energy consumption.

Several research works have been proposed to optimize AC systems and address on-off control issues under different constraints. The related works can be summarized in three approaches: control medium, control mechanisms, and plugs development. In the control medium, some studies propose AC control using personal computers [5] and mobile devices [6]. Personal computers are especially useful in buildings with multiple air conditioning units, whereas mobile devices are mostly used to control air conditioning in homes. For control mechanisms, previous studies introduced the use of automatic on and off based on a timer [7], the presence of humans [8], and indoor temperature [9]. The basic off-timer of AC systems has been improved by previous studies to not just turn off at the desired time but also turn on again after a specified time. On the other hand, a previous study addressed the problem where people do not turn off the air conditioner due to personal savings awareness or being anxious to go out. Another study on the control mechanism of AC systems proposed a control solution that would adaptively regulate the indoor temperature despite changes in outdoor temperature after looking up the optimum values solved from an optimization scheme using an Elman neural network (NN)-based estimator.

Many studies also developed AC system control by creating electrical plugs or switches. One of these electric plugs was created to automatically turn off the air conditioner after a set amount of time preprogrammed by the user while simultaneously switching on the electric fan, thereby maintaining the cold from your air conditioner within the room [10]. Another device is the multipurpose SMS-activated programmable timer switch that turns appliances on and off when a text message is sent [11]. The power of the Internet of Things (IoT) has also been incorporated into a smart plug for usage monitoring and energy reduction in AC systems. The development of electrical plugs for energy conservation is the most ideal solution because they can be utilized by older versions of air conditioners and there is no need to tweak their current architecture. However, existing plugs have some limitations, like a limited and outdated control mechanism, and although they can be controlled remotely, the process of control is still manual.

This study developed an electrical plug that improves the analog-type aircon-to-fan timer plug that is commercially available. This version of the aircon-to-fan plug utilizes a digital control mechanism through a mobile application. This electrical plug has a three-way control mechanism which has not been implemented in previous studies. Aircon-to-fan switching can be done manually, using a timer, and based on indoor temperature.

II. RELATED WORKS

Reducing energy consumption and ensuring thermal comfort are two important considerations in designing an air conditioning (AC) system. An AC system, originally operated on an on/off control mechanism, was retrofitted in a study [5] to enable the application of new controllers. This study deals with independent control methods for the AC system based on the thermostat on/off control, digital on/off control, digital on/off control with a personal computer (DPC), and fuzzy logic control (FLC). Measurements were made at a time interval of one minute for set point temperatures of 22, 23, and 24 C. The room air temperature, energy consumption, and energy saving were analyzed for all control methods. The experimental results showed that these controls saved energy consumption and improved indoor comfort significantly for a building AC system compared to a thermostat on/off control method.

As the energy consumption of air-conditioning (AC) accounts for about 40% of total residential energy, therefore, applying a smart control system to the use of AC to achieve the effects of comfy and energy savings should be able to generate a positive effect on the energy consumption of overall residential. A study [6] used the smart control system of the intelligent building lab to transmit a message to AC for its implementation of the next operating step through an indoor temperature sensor to achieve energy saving effect.

In buildings, air conditioning is one major part of power consumption. In a study [7], they examined the effect of an intermittent control strategy for air conditioning on energy saving in western-exposed rooms under subtropical weather conditions. The strategy applied periodic deactivation and reactivation to the air conditioners. Room temperatures, power consumption, and readings from sensors of air conditioners of two identical rooms were monitored and analyzed. For indoor temperatures, they found that the deactivation of the air conditioner for 15 minutes resulted in temperature peaks that were 4 to 5 °C higher than the control room. The reactivation of the air conditioner was able to cool down the room within 10 min based on the built-in sensor. However, due to the location and resolution of the sensor, the overall temperature from the four temperature and humidity sensors was still higher than the target setting, which may cause thermal discomfort. For power consumption, the strategy led to power peaks while reactivating, but the summation was 2.9% lower.

With the development of society and the economy, air conditioning has also become an integral part of our lives and it allows us to enjoy warmth in winter and cool in summer. However, there is also a phenomenon that people do not turn off the air conditioner due to personal savings awareness or anxiety to go out. A paper [8] designed a system where the air-conditioning room is automatically turned off if there is no one in half an hour. A pyroelectric sensor was used to detect the presence of people in the room, and a wind speed sensor detects whether the air conditioner is on. If the room is empty and the air conditioner is not turned off for more than half an hour, the system automatically turns off the air conditioner. The system can reduce the waste of resources, it can also reduce environmental pollution, and realize economic and social benefits.

Being reliant on Air Conditioning (AC) throughout the majority of the year, desert countries with extremely hot weather conditions such as Qatar are facing challenges in lowering weariness costs due to AC On-Off switching while maintaining an adequate level of comfort under a wide range of ambient temperature variations. To address these challenges, a paper [9] investigates an optimal On-Off control strategy to improve the AC utilization process. To overcome the complexities of online optimization, an Elman Neural Networks (NN)-based estimator is proposed to estimate real values of the outdoor temperature, and make offline optimization available. By looking up the optimum values solved from an offline optimization scheme, the proposed control solutions can adaptively regulate the indoor temperature regardless of outdoor temperature variations.

Air conditioners are people's best friends during the hot summer months. They're also the main culprit behind the spike in our electricity bills since air conditioners consume a lot of power. So, to save the people from the heat without bankrupting themselves, the Panther's aircon-to-fan timer [10] can come to the rescue. It will automatically turn off the air conditioner after a set amount of time preprogrammed by the user, thereby lowering the electricity bill. The best part is that the user will just follow these three simple steps: plug the air conditioning unit and electric fan into the Panther Aircon-to-Fan Timer, turn both appliances on, and set the mechanical timer to indicate the number of hours they want the air conditioner to remain on before switching to the fan.

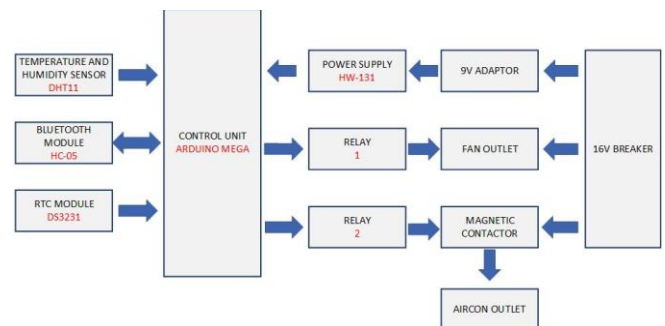## III. METHODS

A. Hardware Development

Fig. 1.   The block diagram of the device.

The device is composed of a microcontroller, temperature sensor, Bluetooth module, real-time clock module, relay module, power supply module, voltage adaptor, outlets, magnetic contactor, and a circuit breaker as shown in Fig. 1. The microcontroller used in the device is an Arduino Mega Microcontroller, which is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The microcontroller serves as the brain of the device, ordering the actions based on the input data. To control the aircon and the fan, the device should first be connected to the mobile application using a Bluetooth module. The HC-05 Bluetooth module was used because it is a popular Bluetooth module that can add two-way (full-duplex) wireless functionality. A real-time clock (RTC) module was also utilized in the device for its timer functionality. The module is a low-cost, extremely accurate RTC chip from Maxim. It handles all timekeeping functions and communicates with the microcontroller over I2C. The relay module used in this study is a two-channel module which is for the aircon and the fan. A power supply module and a 9-volt adaptor were used in the device to supply power to the microcontroller and the other modules. One outlet each for the fan and the aircon was connected to the relay module. However, a magnetic contactor was connected to the air conditioning outlet. The magnetic contactor is an electromechanical switch used in the device for its "on and off" process. Through the switch contacts, the magnetic contactor takes care of transferring energy from one place to another. A 16-volt circuit breaker was also utilized to protect the device from damage caused by an overcurrent or short circuit.
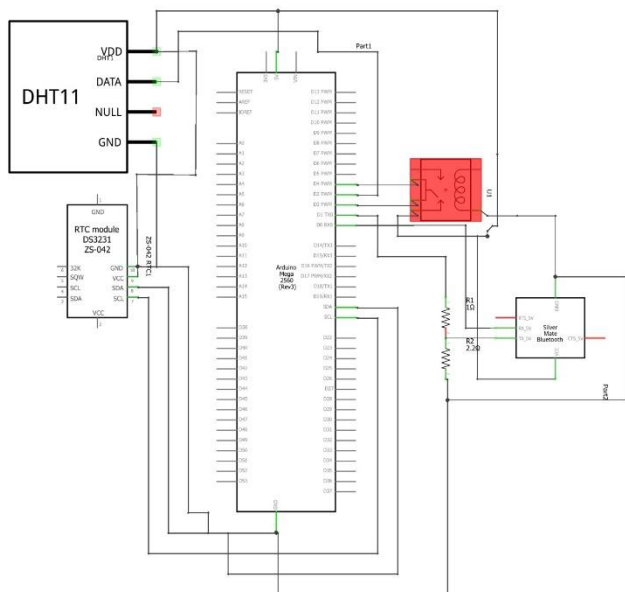

Fig. 2.   The schematic diagram of the device.

The 5-volts and ground of the Bluetooth module, real-time clock module, temperature sensor, and relay module are connected to the 5-volts power pin and ground pin of the Arduino Microcontroller as presented in Fig. 2. The RX pin of the microcontroller is connected to the TX pin of the Bluetooth module with a 1-ohm resistor while the TX pin of the microcontroller is connected to the RX pin of the Bluetooth module with a 2.2-ohms resistor. The SDA pin and SCL pin of the RTC module is connected to the SDA pin and SCL pint of the microcontroller, respectively. The data pin of the temperature sensor is connected to digital pin 2 of the microcontroller. The input pin 1 of the relay module is connected to the digital pin 3 of the microcontroller while the input pin 2 of the relay module is connected to the digital pin 4 of the microcontroller.

B. Calculation of Power Consumption

The power consumption of using the air conditioning alone and the device was tested and computed to determine the energy saved when using the device. An electric meter was connected to the device to measure the power consumption as shown in Fig. 3.

Fig. 3.   Testing of Power Consumption.

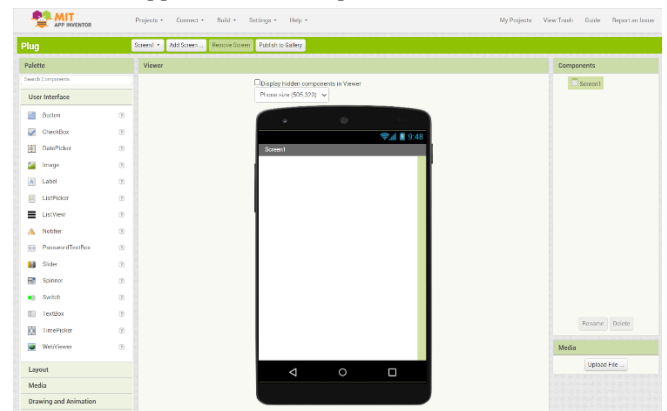### C. Mobile Application Development

Fig. 4.   MIT App Inventor.

In the development of the mobile application, the MIT App inventor shown in Fig. 4 was used to construct the program. MIT App Inventor is a web application integrated development environment originally provided by Google and now maintained by the Massachusetts Institute of Technology. It uses a graphical user interface (GUI) which allows users to drag and drop visual objects to create an application that can run on Android devices. In creating App Inventor, Google drew upon significant prior research in educational computing, and work done within Google on online development environments.

D. Device Connection to Smartphone

The flowchart that can be found in Fig. 5 should be followed to make use of the device. Installing the mobile application into a smartphone comes first in the process. After the installation has been completed successfully, the application must be opened to connect using Bluetooth communication. If the connection is successful, the temperature and humidity are shown in the mobile app, and the control mechanisms are ready to go to work.
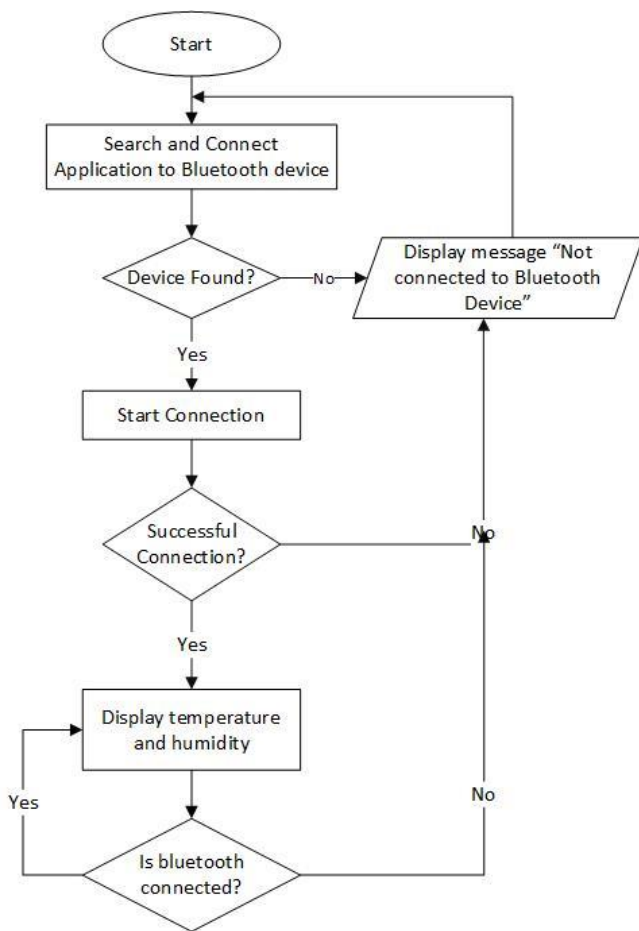

Fig. 5.   Flowchart of Connecting the Device to the Mobile Device using the Application

IV.   RESULTS AND DISCUSSION

A. The Hardware Device

The device is made of sturdy plastic as presented in Fig. 6. It has one universal air conditioning outlet and one universal fan outlet. The input and output voltages at which the device can operate are 220 volts AC. The device will work with all window-type air conditioners. It has a maximum operating capacity of 3000 watts. The device has no minimum timer, which is an improvement over a previous study [10], which had a timer of up to eight hours.

Fig. 6.   The Three-Way Aircon-To-Fan Control Plug

B. The Mobile Controller Application

The card-based design approach was used to create the mobile application's user interface shown in Fig. 7. In a prior study, participants rated this kind of layout well in terms of its efficiency [12]. This is because the users can only see one screen at a time, which enables them to better visualize the data without requiring them to worry about where to go or what to click on next. The utilization of the card-based system design allowed for the bridging of the gap between interaction and usability [13] in a synchronized manner, which resulted in the creation of a user interface design that was consistent across all devices.

The connection status between the smartphone and the device can be seen at the top of the user interface. The current room temperature in Celsius and humidity in percentage can be seen below the connection status. The user

has the option of controlling the fan and air conditioning manually when necessary. The user may choose what automatic controls they want for the device. If the user chooses the timer control, they should turn on the timer switch in the mobile app and input the hours and minutes they want the aircon to turn off and the fan to turn on. If the user chooses the thermostat, they should turn on the thermostat switch in the mobile app and enter their desired temperature and minimum temperature. When the device detects a room temperature equal to the inputted desired temperature, the aircon will turn off and the fan will turn on. The aircon will turn on and the fan will turn off again when the device detects a room temperature equal to the inputted minimum temperature.
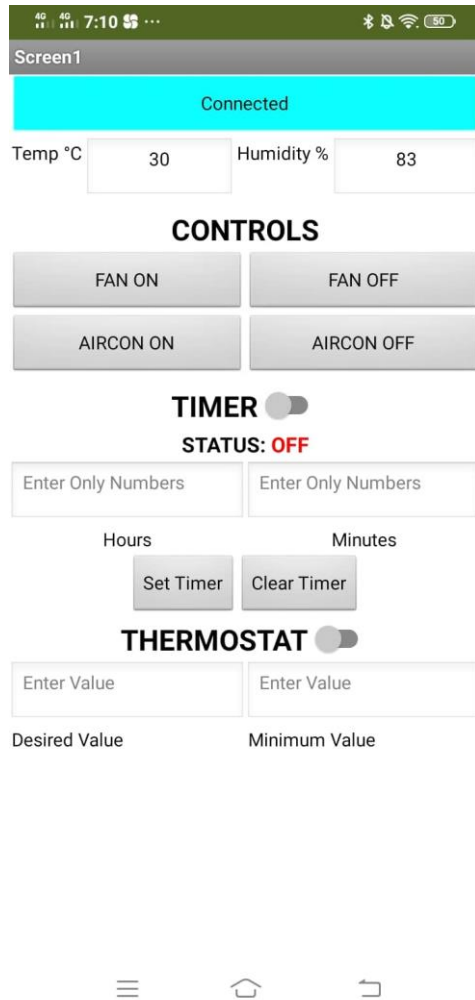

Fig. 7. Mobile Application User Interface

C. Accuracy Testing of the Device

The accuracy of the device in terms of manual switching, timer switching, and temperature switching was tested to make sure that it worked as it was intended to. The result of the testing is shown in the succeeding tables.

TABLE I. ACCURACY TESTING OF THE MANUAL SWITCHING OF THE DEVICE

Trial	Button Pressed	Aircon Status	Fan Status
1	Fan On	Off	On
2	Fan Off	Off	Off
3	Fan On	Off	On
4	Fan Off	Off	Off
5	Fan On	Off	On
6	Fan Off	Off	Off
7	Fan On	Off	On
8	Fan Off	Off	Off
9	Fan On	Off	On
10	Fan Off	Off	Off
11	Aircon On	On	Off
12	Aircon Off	Off	Off
13	Aircon On	On	Off
14	Aircon Off	Off	Off
15	Aircon On	On	Off
16	Aircon Off	Off	Off
17	Aircon On	On	Off
18	Aircon Off	Off	Off
19	Aircon On	On	Off
20	Aircon Off	Off	Off

The manual switching of the fan and the aircon was tested using the device. The researchers conducted 20 trials to check if the device responds to the button being pressed. The testing results in Table I show the 100% accuracy of the device in responding to the button pressed. From these results, it is clear that the user can use the mobile application as a remote control to manually turn on and turn off the aircon and fan. This feature is useful for most window-type air conditioners and electric fans that were purchased without a remote control. Also, this feature is an upgrade to the manual bypass feature of a previous study [10] to override the timer for continuous aircon use because the user does not need to stand and go to the device to manually override it.

TABLE II. TABLE 2. ACCURACY TESTING OF THE TIMER SWITCHING OF THE DEVICE

Day	Timer Set	Start Time	Aircon Status	Fan Status	End Time	Aircon Status	Fan Status
1	1 hr. 30 mins.	8:00 PM	On	Off	9:30 PM	Off	On
2	2 hr. 45 mins.	7:00 PM	On	Off	9:45 PM	Off	On
3	3 hr. 15 mins.	9:00 PM	On	Off	12:15 AM	Off	On
4	4 hr. 20 mins.	10:00 PM	On	Off	2:20 AM	Off	On
5	5 hr. 40 mins.	11:00 PM	On	Off	4:40 AM	Off	On
6	6 hr. 20 mins.	6:30 AM	On	Off	12:50 PM	Off	On
7	7 hr. 30 mins.	7:15 AM	On	Off	2:45 PM	Off	On
8	8 hr. 45 mins.	8:20 AM	On	Off	5:05 PM	Off	On
9	9 hr. 50 mins.	9:40 AM	On	Off	7:30 PM	Off	On
10	10 hr. 15 mins.	9:55 AM	On	Off	8:10 PM	Off	On

Table 2 displays the findings of the timer-switching test that was conducted with the use of the device. During the test period of ten days, the device's compliance with the timer's instructions to turn off the air conditioner and turn on the fan

was flawless. Because the timer that can be set for the device has a range that is greater than 8 hours, the findings suggest that the device is superior to similar work [10].

TABLE III.   ACCURACY TESTING OF THE TEMPERATURE SWITCHING OF THE DEVICE

Trial	Desired Value	Minimum Value	Starting Temp	Aircon Status	Fan Status	End Temp	Aircon Status	Fan Status
1	17 °C	25 °C	28 °C	On	Off	17 °C	Off	On
2	18 °C	25 °C	28 °C	On	Off	18 °C	Off	On
3	19 °C	25 °C	28 °C	On	Off	19 °C	Off	On
4	20 °C	25 °C	28 °C	On	Off	20 °C	Off	On
5	21 °C	25 °C	28 °C	On	Off	21 °C	Off	On
6	17 °C	25 °C	17 °C	Off	On	25 °C	On	Off
7	18 °C	25 °C	18 °C	Off	On	25 °C	On	Off
8	19 °C	25 °C	19 °C	Off	On	25 °C	On	Off
9	20 °C	25 °C	20 °C	Off	On	25 °C	On	Off
10	21 °C	25 °C	21 °C	Off	On	25 °C	On	Off

The results of testing the device with the air conditioner turned on and the fan turned off are presented in Table 3, as well as the results of testing the device with the air conditioner turned off and the fan turned on based on the desired temperature and the minimum temperature. It may be deduced from the outcome that the apparatus has a temperature-switching accuracy of 100%. Even if the process of switching temperatures has already been investigated in the past [5], [7], this device is superior because the cold temperature has a greater chance of remaining below the minimum value set for a longer amount of time because of the fan that is switched on.

D. Power Consumption

The first test was the use of the aircon only. In this test, the kWh of a 1.0 HP non-inverter window air conditioner that was running for 12 hours was measured using an electric meter. The calculation also uses 10.52 PHP/kWh as the power provider charge and a 12% VAT to compute the daily power consumption.

$$Total\ kWh\ for\ 12\ Hour\ used = 8.95\ kWh$$
$$8.95\ kWh * 10.52\frac{PHP}{kWH} = 94.154\ PHP$$
$$94.154\ PHP * 12\%\ VAT = 11.29848\ PHP$$
$$94.154\ PHP +\ 11.29848\ PHP = 105.45248\ PHP$$
$$105.45248\ PHP * 30\ Days = \mathbf{3163.5744\ PHP}$$

The second test was using the device where the timer is set to 8 hours for automatically switching off the aircon and switching on the fan. This test was also done for 12 hours. The same aircon and room were used in this test. Also, the same PHP/kWh and 12% VAT were used in the calculation. For the electric fan, a 16-inch stand fan with a wattage of 80 watts was used.

$$Total\ kWh\ for\ 12\ Hour\ used = 6.29\ kWh$$
$$6.29\ kWh * 10.52\frac{PHP}{kWH} = 66.1708\ PHP$$
$$66.1708\ PHP * 12\%\ VAT = 7.940496\ PHP$$
$$66.1708\ PHP +\ 7.940496\ PHP = 74.111296\ PHP$$
$$74.111296\ PHP * 30\ Days = \mathbf{1993.0645\ PHP}$$

The third test was utilizing the temperature switching of the device. The desired temperature was set to 18 °C and the minimum temperature was set to 25 °C. This test was also done for 12 hours. The same aircon, fan, and room were used in this test. Also, the same PHP/kWh and 12% VAT were used in the calculation.

$$Total\ kWh\ for\ 12\ Hour\ used = 7.56\ kWh$$
$$7.56\ kWh * 10.52\frac{PHP}{kWH} = 79.5312\ PHP$$
$$79.5312\ PHP * 12\%\ VAT = 9.543744\ PHP$$
$$79.5312\ PHP +\ 9.543744\ PHP = 89.074944\ PHP$$
$$89.074944\ PHP * 30\ Days = \mathbf{2395.47974\ PHP}$$

The results show that when using the device, the power consumption is reduced by 30%. This value is higher than the previous studies [6][7] that also created other control mechanisms for air conditioning. Furthermore, depending on the automatic switching mechanism used, the consumer can save up to 37% on energy costs. This is a very big saving for consumers who are using air conditioning and electric fans in their homes. They will experience thermal comfort without expending so much energy.

V. CONCLUSION

In this paper, a three-way aircon-to-fan control plug that can be operated with a smartphone was developed. The user of the device has the option of manually turning on and off the air conditioner as well as the electric fan, or they can enable automatic control. Through the use of the mobile application, users can configure the device to automatically switch from an air conditioner to an electric fan at a specified time. When the automatic temperature-based controller is being used, the device is also capable of turning the air conditioning on and off and vice versa. Overall, users can cut down on the amount of electricity they use by utilizing the device.

The researchers recommend adding a presence detector to the device so that it can also automatically switch off the aircon when there is no person detected in the room. Also, an energy meter can be added to the device so that the user can track the power consumption over time in the mobile application.

REFERENCES

[1]   G. Forzieri, A. Cescatti, F. B. e Silva, and L. Feyen, "Increasing risk over time of weather-related hazards to the European population: a data-driven prognostic study," The Lancet Planetary Health, vol. 1, no. 5, pp. e200–e208, Aug. 2017, doi: 10.1016/s2542-5196(17)30082-7.

[2]   K. Lundgren-Kownacki, E. D. Hornyanszky, T. A. Chu, J. A. Olsson, and P. Becker, "Challenges of using air conditioning in an increasingly hot climate," International Journal of Biometeorology, vol. 62, no. 3, pp. 401–412, 2018, doi: 10.1007/s00484-017-1493-z.

[3]   United Nations, "2014 revision of the World Urbanization Prospects | Latest Major Publications - United Nations Department of Economic and Social Affairs," Un.org, 2014. https://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html

[4] B. G. Anderson and M. L. Bell, "Weather-Related Mortality," Epidemiology, vol. 20, no. 2, pp. 205–213, Mar. 2009, doi: 10.1097/ede.0b013e318190ee08.

[5] H. Nasution, K. Sumeru, A. Abdul Aziz, and Mohd. Yusoff Senawi, "Experimental Study of Air Conditioning Control System for Building Energy Saving," Energy Procedia, vol. 61, pp. 63–66, 2014, doi: 10.1016/j.egypro.2014.11.907.

[6] P. H. Wang and J. Y. Lin, "Using Smart Controlled AC and Ceiling Fan to Save Energy," Simulation, Prediction and Evaluation, vol. 2, pp. 21–28.

[7] T. Y. Hu et al., "A Study on Control Strategy for Air Conditioning of Western Exposed Rooms in Subtropical Region," Energies, vol. 15, no. 3, p. 731, Jan. 2022, doi: 10.3390/en15030731.

[8] M. Tan, Z. Chen, X. Lv, M. Yu, J. Guo, and Q. Fan, "Automatic shutdown system for unmanned air-conditioned room," Journal of Physics: Conference Series, vol. 1544, no. 1, p. 012069, May 2020, doi: 10.1088/1742-6596/1544/1/012069.

[9] M. Al-Azba, Z. Cen, Y. Remond, and S. Ahzi, "An Optimal Air-Conditioner On-Off Control Scheme under Extremely Hot Weather Conditions," Energies, vol. 13, no. 5, p. 1021, Feb. 2020, doi: 10.3390/en13051021.

[10] H. Team, "Benefits of an Aircon to Fan Timer," Extension Cord, Transformer, AVR Supplier: Panther Products Philippines, May 03, 2022. https://panther.ph/benefits-of-an-aircon-to-fan-timer/ (accessed Nov. 21, 2022).

[11] J. M. Albalos, "Multipurpose SMS Activated Programmable Timer Switch," International Journal of Scientific & Engineering Research, vol. 10, no. 7, pp. 1974–1987.

[12] E. C. Abana, "Usability of 'Traysi': A Web Application for Tricycle Commuters," International Journal of Advanced Computer Science and Applications, vol. 10, no. 7, 2019, doi: 10.14569/ijacsa.2019.0100738.

[13] J. Kiruthika, S. Khaddaj, D. Greenhill, and J. Francik, "User Experience Design in Web Applications," 2016 IEEE Intl Conference on Computational Science and Engineering (CSE) and IEEE Intl Conference on Embedded and Ubiquitous Computing (EUC) and 15th Intl Symposium on Distributed Computing and Applications for Business Engineering (DCABES), Aug. 2016, doi: 10.1109/cse-euc-dcabes.2016.253.