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# Smart Thermostat for Air-Conditioning and Energy Conservation Solutions for City Land Grand Central Residences

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## ABTRACT

Heating Ventilation Air-conditioning (HVAC) has the highest share in the electricity load of around 42% in homes and 39% in commercial buildings; our country having the 2nd most expensive power rate in Asia Pacific Region. According to the Quezon Power (Philippines) Lid. Co. (QPPL) managing director Frank Thiel, the Philippines would also experience a power crisis during 2022 summer months amidst the demand increase with scarce energy reserves and volatile price of fossil fuel; "Power demand is expected to increase on 2022 as the economy starts to recover and restrictions become looser" stated during the Asian Power Thermal Energy Conference. Thus, this encouraged the researchers to develop a Smart AC Controller that comes with an android mobile app, cloud computing applications, Artificial Intelligence through Machine Learning working with various input and output devices to balance comfort and maximize energy conservation without having to compromise their thermal comfort, that will result to a lower monthly electricity bill.

***Keywords:*** *Energy Conservation, Temperature, Humidity. Smart Thermostat, Demand Side Management, Particulate*

## INTRODUCTION

Energy consumption is an important index on the development of a country and the spectacular growths in industrial and economic sector during the past century has been correlated to the abundant use on the supply of inexpensive energy generated from fossil fuels. Therefore, rapid changes within the industry as well as the economy strongly affect the energy consumption of a country. While various establishments and properties are being built and developed, the demand for domestic electricity consumption within the country rapidly accelerates. The rise in electric energy consumption in the Philippines is expected in the upcoming years due to the natural population growth, demographic changes such as ageing of the population and change in household number, economic activity and development.

Heating Ventilation Air-conditioning (HVAC) has the highest share in the electricity load of around 42% in homes and 39% in commercial buildings; our country having the 2™ most expensive power rate in Asia Pacific Region. According to the Quezon Power (Philippines) Ltd. Co. (QPPL) managing director Frank Thiel, the Philippines would also experience a power crisis during 2022 summer months amidst the demand increase with scarce energy reserves and volatile price of fossil fuel; “Power demand is expected to increase on 2022 as the economy starts to recover and restrictions become looser” stated during the Asian Power Thermal Energy Conference. Thus, this encouraged the researchers to develop a flexible, user friendly and low-cost system that allows the user to automate the control settings of their air conditioning units efficiently, and maximize energy conservation without having to compromise their thermal comfort, that will result to a lower monthly electricity bill.

This study, therefore, uses a cloud-based android mobile application namely “ColdSmart” coined by Prof. Fernando Jaminola Jr, to automate the control settings of air conditioner through a Raspberry Pi with internet connectivity, and other sensors for additional control features such as; Smart Schedule, Global Controls, HVAC Zoning, Weather Tracking and Indoor Air Quality. It will be beneficial to both Electric Utilities and electricity consumers overall since the primary aim of this study is energy conservation for user comfort, and in compliance as well to the R.A 11285 also known as the Energy Efficiency and Conservation Act of 2018.

### *Objectives of the Study*

This study aims to design and develop a comprehensive cloud-based IoT Smart AC Controller, complemented by an Android mobile application, and empowered by Cloud Computing and Artificial Intelligence through Machine Learning, all with the primary purpose of enhancing comfort and promoting energy conservation for the esteemed Property Managers and residents of City Land Grand Central Residences in Mandaluyong City. It entails the creation of a cutting-edge IoT prototype that seamlessly automates the control settings of air conditioning units, transcending conventional infra-red remote controls. This automation is facilitated through a user-friendly mobile application that enables users to set their preferred configurations, schedules, and controls. The Android Mobile Application will boast worldwide compatibility, accommodating various AC brands with standard infrared remote controls. It will implement an intelligent occupancy tracking system utilizing motion sensors, ensuring HVAC zoning by automatically powering down air conditioning units when spaces are unoccupied, thus optimizing energy consumption. Users will have the freedom to customize temperature and operational modes based on their preferences, implementing specific schedules that cycle through cooling, automatic, dry, and fan modes. Furthermore, our system offers the convenience of remotely powering on/off air conditioning units for safety and comfort. Leveraging data from the Open Weather Map's Weather Information API, we will utilize temperature and relative humidity data as references for optimal comfort settings, ensuring a comfortable environment while conserving energy. In addition, our innovative solution will go beyond traditional AC control by incorporating air quality monitoring, detecting and alerting users to dangerous air pollutants like PM10 particles, including molds, spores, dust, and pollen, thus ensuring a healthier living environment.

## MATERIALS AND METHODS

### *Research Design*

The research employed a Descriptive Survey Design as the primary research method. This approach was chosen because it best suited the objective of describing and interpreting the current conditions and requirements for the development of a cloud-based 10T prototype with an Android Mobile application aimed at efficient energy conservation and occupant management for condominiums and condotels.

### *Sampling Technique*

Purposive Sampling was used to select participants for the study. The researchers targeted unit owners and engineering managers of condominiums and condotels in highly urbanized cities of the Philippines, with a specific focus on Cityland Grand Central Residences in Mandaluyong City, Metro Manila. This method was chosen to ensure that participants possessed the relevant knowledge and experience to provide valuable insights into the research topic.

### *Locale of the Study*

The study was conducted primarily at Cityland Grand Central Residences in Mandaluyong City, Metro Manila. This location was chosen due to its relevance to the research topic and the availability of suitable participants.

### *Research Instruments*

Structured survey questionnaires were the primary research instruments used to collect data. These questionnaires were designed to gather information about prevailing conditions, requirements, and perspectives related to energy conservation and occupant management in condominiums and condotels. Informed consent forms were attached to the questionnaires to ensure the voluntary participation of the selected respondents and to emphasize the confidentiality and anonymity of their responses.

### *Data Gathering Procedure*

Prior to data collection, the researchers, in collaboration with their thesis adviser, Prof. Fernando Jaminola Jr., drafted a formal letter of request seeking approval from the Condominium Manager of Cityland Grand Central Residences. After receiving approval, the researchers personally approached the selected participants and distributed the questionnaires. This personal approach aimed to enhance the accuracy, reliability, and validity of the responses. Respondents were assured that their identities would be kept strictly anonymous, and their data would be treated with the utmost confidentiality.

### *Analysis of the Data/Statistical Treatment*

Thematic Analysis was employed to interpret the responses gathered from the selected respondents, particularly the condominium manager of Cityland Grand Central Residences. This qualitative analysis method allowed the researchers to identify recurring themes, patterns, and insights within the data. The results of the analysis were used to develop strategies and ideas for the successful development of the cloud-based 10T prototype and Android Mobile application for energy conservation and occupant management in condominiums and condotels. Statistical treatment was not applied, given the qualitative nature of the data analysis.

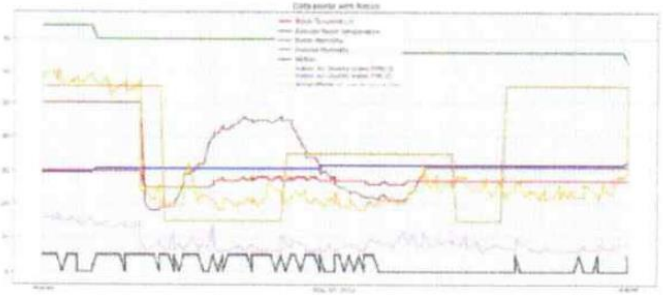

**Figure 1.** Data with Air-conditioner set to ON

## RESULTS AND DISCUSSION

Findings were derived based on the following development process:

Worldwide compatibility of any air conditioner brands such as Carrier shown in figure 7, Everest in figure 8 and the like with standard Infrared remote controls for comfort settings.within Aparri including the Managers or Employees and Customer or Visitors.

To save energy, it allows the occupants to choose the desired day and night temperature and operational mode based on their preferences; by cycling compressor cooling, automatic, dry, and fan-mode through specific time and day schedule Figure 3 shows the smart

**Figure 2.** Carrier air conditioner and Remote Control

Occupancy sensors track status of users, and auto adjusts settings for optimum comfort and energy conservation. Shown here are the data points monitored when the air conditioner is on; the red line indicates the room temperature; blue for the outside temperature forecast from the app, maroon for the actual room humidity from the 10T; green for outside forecast humidity, black for motion of occupants, yellow (PM2.5) and pink (PM10) values for indoor air quality index, black for the movement of occupants, gold for aircon mode (like compressor, auto, dry and fan-mode) with different time schedules on a calendar day, refer in Fig 1.

schedule of the mobile app. The picture on the left depicts the capability of the occupants to add and customize their preferred day and time for schedule, temperature, various commands and modes shown on the right picture.

Smart control for the user to power on/off their air conditioning units anywhere at any time for safety, convenience and comfort. Shown in Figure 6 is the air conditioner's state depending on the chosen control of the user.

**Use Weather Information Application**

Programming Interface (APT) from Open Weather Map and utilize (1) temperature and

**Figure 3.** Everest air conditioner and Remote Control

**Figure 4.** Smart Schedule of Mobile App

(2) relative humidity data as a reference for optimal comfort settings. Based on the graph above Room Humidity (maroon) as depicted in


**Figure 5.** Control of Air-conditioners anywhere and anytime

Detects dangerous air pollutants like (1) PM10 are 10 micrometers and smaller coarse particles such as molds, spores, dust, and pollen; PM2.5 arc 2.5 micrometers and smaller fine particles like Carbon Dioxide (C02), tobacco smoke; fumes from kerosene, burning candles, oil lamps, cooking, vehicles, and other noxious gases that may harm occupant's health; and prompts through the Android Mobile App and directly on the Smart Thermostat. Shown on the left picture is the indication that the air


**Figure 6.** Weather Tracking mobile apps

quality inside the room is harmful and polluted with noxious gasses that arc dangerous to our health. It then prompts the app to open the windows for clean ventilation.


**Figure 8.** Air Quality mobile

## CONCLUSION

The research findings have demonstrated several key aspects of the system's

functionality. Firstly, it has been established that the system is capable of interfacing with a wide range of HVAC brands, including well-known names such as Carrier and Everest. This compatibility hinges on the system's ability to utilize Artificial Intelligence and Machine Learning to store and automate various HVAC functions, encompassing fan speed, Eco mode, fan mode, and compressor mode, among others. Secondly, the system has proven its proficiency in tracking the presence of occupants via motion sensors. However, it's worth noting that the two C02 detectors used in the tests did not exhibit the desired responsiveness. It is recommended that future assessments involve detectors from different manufacturers with user-configurable features to address this limitation.

Thirdly, the system has demonstrated its effectiveness in scheduling HVAC functions based on diverse air-conditioning modes, including compressor cooling, auto, dry, and fan modes. This showcases its adaptability in catering to various comfort preferences.
Furthermore, the research underscores the system's ability to provide users with remote control over their air conditioning, contingent on internet connectivity. This feature enhances comfort and convenience by allowing users to adjust their HVAC settings from anywhere at any time.

Moreover, the study has validated the feasibility of using weather tracking as a reference point for automating comfort levels. However, it's essential to acknowledge that there may be disparities between the system's readings and the actual weather conditions, including temperature and humidity.

Lastly, the research highlights the system's successful implementation of an air quality monitoring system. This system is capable of alerting occupants to hazardous levels of pollutants, spanning from PM10 particles like molds, spores, dust, and pollen to finer PM2.5 particles, which encompass substances such as carbon dioxide (C02), tobacco smoke, fumes from kerosene, and other harmful gases detrimental to health. In conclusion, the research findings underscore the potential and functionality of the system, while also pointing out areas for improvement and future exploration.

## RECOMMENDATION

Based on the system, the two (2) CO2 sensors that were used is unreliable and unresponsive and the user requirements were not met. Apart from this, it was proven that the motion detector (passive infra-red) works in terms of functionality, usability, reliability and portability. Further studies for more responsive an affordable user-configurable CO: detectors need to be undertaken in the future to produce a dual input and fool-proof detection of human presence in a confined space.

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