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LOW-COST DEVICE FOR CO₂ - BASED AIR RECUPERATOR CONTROL TO REDUCE ENERGY CONSUMPTION WITHOUT ALTERING MINIMUM HEALTH PARAMETERS

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Abstract. One way to prevent accidents and reduce costs in enclosed environments with a Variable Refrigerant Flow (VRF) system is through enabling technologies that continuously monitor these installations. This work aims to reduce electricity expenses while simultaneously improving the indoor air quality with an intelligent air renewal system that maintains the CO_2 level below 1000ppm. According to (NBR - 16401-3, 2008), air renewal reduces pollutant concentrations, including CO_2, contributes to equipment preservation and efficiency, as well as maintaining a minimum hygiene standard. According to data obtained from PROCEL/Eletrobrás (PPH, 2019), the average electricity consumption in households (based on 2663 energy bills) is 159.73 kWh/year. To obtain the results, it was necessary to develop the code in the C language and test it in two experiments: VRF system + Commercial Appliance (without modulation), VRF system + Commercial Appliance (with Arduino UNO modulation). Additionally, DHT11 sensors were used to collect humidity and temperature data, MHZ-19B CO_2 sensor, SCT013 current sensor, and the energy analyzer (AE200). After analyzing the data, a reduction of 11% in energy consumption was measured.

Keywords: Electric Energy Consumption, Health, Air renewal, Indoor air quality.

1. INTRODUCTION

The beginning of the 20th century was the period when enabling technologies for air conditioning and refrigeration systems were born worldwide. The emergence of these technologies began with the solution to a problem related to printing on hot days. Engineer Willis Carrier conceived the idea of removing humidity from the factory by cooling the air through artificially cooled ducts. Over the years, the air conditioning system evolved and became available for commercial and residential use. In the early 20th century until the mid-1980s, engineers were primarily concerned with energy consumption. However, in that decade, a serious incident occurred in a hotel in Philadelphia that resulted in the death of 34 people due to collective pneumonia contamination.

As a result, the World Health Organization (WHO) recognized Sick Building Syndrome (SBS).According to the Brazilian Association of Refrigeration, Air Conditioning, Ventilation, and Heating (ABRAVA, in its booklet on Indoor Air Quality, 2020), it informs about the consequences of untreated air in indoor environments: respiratory diseases, drowsiness, lack of energy, olfactory discomfort, thermal discomfort, and headaches. Additionally, an adult breathes about 450 liters of air per hour, 10,000 liters per day, and spends about 93% of their day indoors (where indoor air can be 2 to 5 times more polluted than outdoor air), 5% inside a car, and 2% outdoors. In addition to health-related problems, there is a considerable increase in electricity consumption due to thermal comfort.

Having an air conditioning system is not something dispensable; on the contrary, it is essential to maintain the quality of life.According to data obtained by PROCEL/Eletrobrás (PPH, 2019), the average electricity consumption in households (based on 2663 energy bills) is 159.73 kWh/year. According to FEDRIGO et al. (2009), only through energy efficiency measures will it be possible to reduce about 20% of electricity consumption in Brazil. Furthermore, knowledge of the first technology developed for air conditioning and refrigeration, its advancements, problems related to inadequate ventilation, and the increase in electricity costs contributed to the development of this project. It is based on an intelligent air renewal system integrated with a Variable Refrigerant Flow (VRF) system that activates it based on a set parameter. Therefore, this work is capable of reducing electricity costs by 11% and decreasing the incidence of respiratory diseases caused by high levels of CO_2.
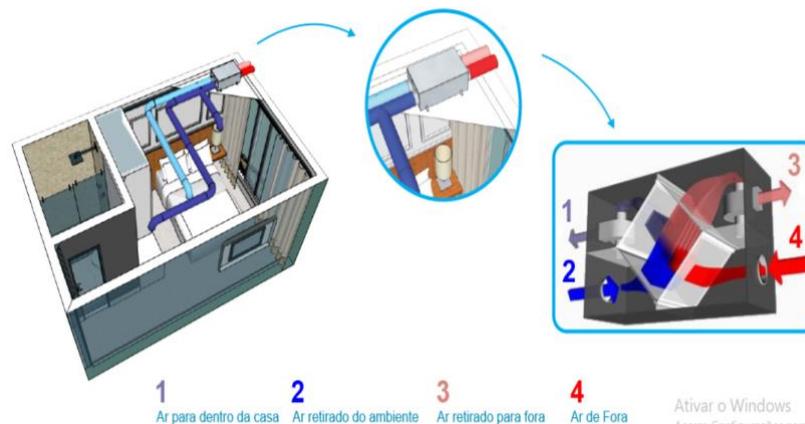
2. METHODOLOGY

The database used in this project to achieve its objectives was based on articles related to energy efficiency (PROCEL/Eletrobrás), indoor air quality (ABRAVA), understanding the C language by the Arduino platform, and how

air renewers function. All of these sources contributed to the foundation of this work. After reading these documents, the process involved creating and implementing the operational code on the Arduino board and then observing, measuring, and analyzing the data obtained. It's important to highlight the operational logic of the air renewers.

The operating logic of an air renewer follows three steps:

1. The air extracted from the indoor environment (either cold or hot) is moved by the motor, passes through the filter, and reaches the thermal recovery cell, where it transfers thermal energy to its components, and then the air is released to the outside.

2. The supply air is drawn from the outside by the motor, passes through the filter, where it is purified, and then passes through the recovery cell that absorbs a portion of the thermal energy from the inside, and subsequently, the air is supplied to the indoor environment.

3. In this way, the indoor air and the outdoor air intersect through the thermal recovery cell, reducing thermal energy losses and operational costs for heating or cooling the air.

Figure 1 illustrates the operation of the air renewer.

| 1 | 2 | 3 | 4 |
| Ar para dentro da casa | Ar retirado do ambiente | Ar retirado para fora | Ar de Fora |

Source: https://sicflux.com.br/wp-content/uploads/2023/06/CATALOGO_PRODUTOS_SICFLUX.pdf

Figure 1: Air Renewer Operation Logic.

This operating process is the simplest in the market. Based on this logic, this project developed a technology aimed at reducing energy consumption and simultaneously decreasing health risks due to high levels of carbon dioxide in indoor environments. In the test room where the tests were conducted, the following criteria were used: temperature regulation under ambient conditions ranging from 22.5°C to 25.5°C at a relative humidity of 65%, following (ASHRAE, 2005) guidelines. The selected temperature was 24°C, with a data collection interval of 35 minutes for each established phase.

- Phase 1: Commercial equipment operating without modulation. In this phase, data collection and the activation of the air renewer were performed at a single point in the test area, near the opening of the test room. The commercial equipment remained continuously operational without undergoing any kind of modulation by the sensors and the developed code.

- Phase 2: Commercial equipment operating with modulation by the Arduino component. Under the same location conditions and using similar equipment as in phase 1. The air renewer was only activated when the MHZ-19b sensor (CO_2 sensor) detected a minimum index of 750 ppm (parameter used in accordance with the NBR 16401-3, 2008 specification), renewing the air in the conditioned environment.

By analyzing the data from the two experiments, it can be observed that phase 2 showed satisfactory reductions in electricity consumption. Figure 2 represents the project layout within the test environment.

Figure 2: Project Layout.

Figure 3 represents the test environment in full operation with load variation over the estimated time.

Figure 3: Testing environment.

In addition to the mentioned equipment, the following sensors were used:
- DHT11 - Temperature and Humidity;
- MHZ19B – CO_2;
- SCT013 - Current;
- 10KΩ Resistors;
- 100uF Capacitor;
- Energy Analyzer - AE200.

Figure 4 shows the layout of the Arduino board and sensors that participated in the data collection. This device created by the authors is a contribution of the work, which has the potential to become a product, and thus, generate a patent.
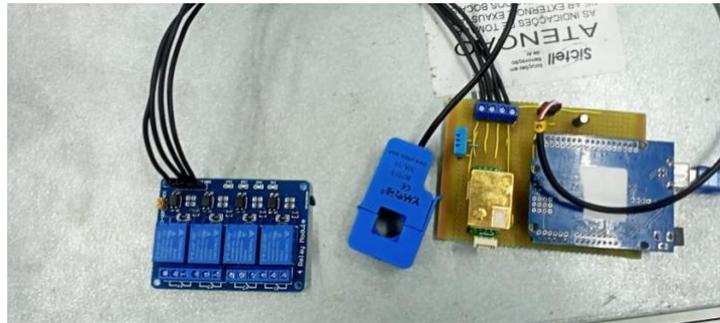
Figure 4: Arduino board layout.

Figure 5: Commercial equipment - air recuperator used in the project.

Figure 5: Air recuperator.

2.1 Flowchart of the code

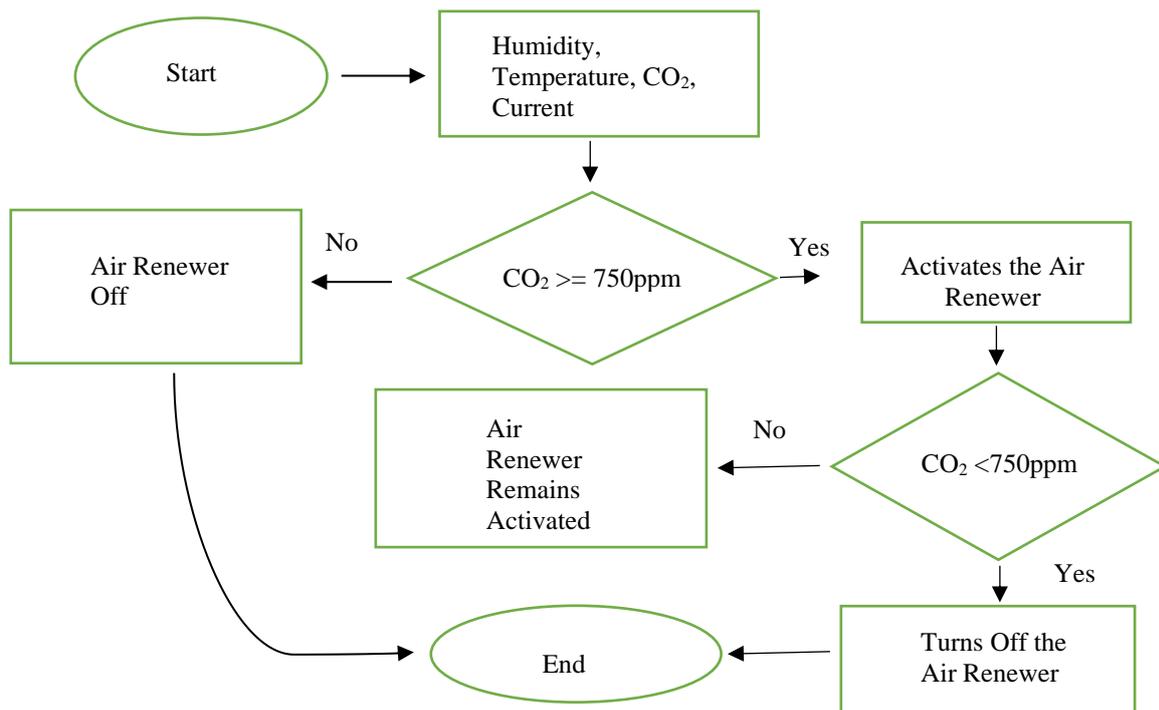Figure 6 displays the flowchart of the developed code:

Figure 6: Code Flowchart.

3. RESULT

After data collection and processing, graphs were generated using the Python platform. Through these graphs, the importance of the code developed and implemented on the microcontroller to modulate the commercial equipment can be measured. This demonstrates that this project is not just a simple science fair idea but a technology that has come to change people's quality of life. In the second phase of the research, modulation with the program developed and implemented on the Arduino board was used. It was fed with code that allows the air renewer to be activated when the MHZ19b sensor (CO_2 sensor) detects a minimum index of 750ppm, thus renewing the air in the conditioned environment. Furthermore, it is important to note that in experiment 2, it was evident that there is a peak in energy consumption between points 3 and 5 on the graph (these points are distributed in 5-minute intervals) due to the air renewer motors being activated immediately after the gas sensor detects an increase in carbon dioxide in the environment.

With the analysis of the obtained data, it can be concluded that the average consumption of the commercial equipment without modulation during 35 minutes is 134.13 kW, while the average consumption of the commercial equipment with Arduino modulation during 35 minutes is 119.47 kW. Therefore, this technology is capable of satisfactorily reducing electricity costs by 11% and decreasing the incidence of diseases caused by high CO_2 levels.

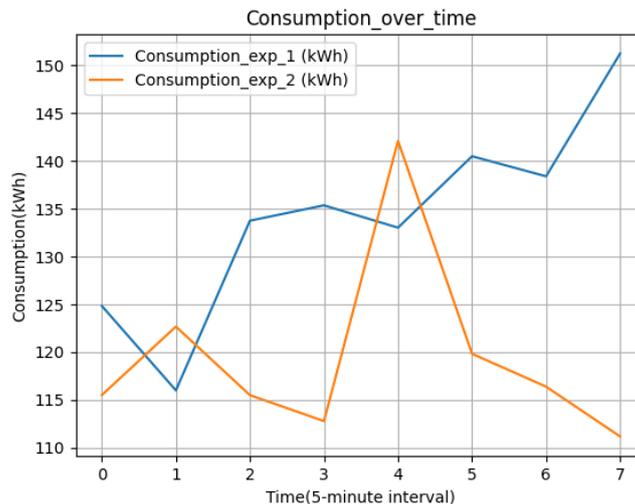Figure 7 represents the two phases of the project.

Figure 7: Consumption graph over time.

Comparing the curves of phases 1 and 2 of the project, taking the averages of their powers and calculating with the rate of R$0.74 per kWh (Neoenergia, 2022). The average consumption of the commercial equipment without modulation during 35 minutes is 134.13 kW, while the average consumption of the commercial equipment with Arduino modulation during 35 minutes is 119.47 kW. By taking the difference between these values, it can be observed that there is a reduction of 30.576 MJ, which corresponds to a 10.85% savings. The test environment operates from 7:00 AM to 10:00 PM, totaling 15 hours of operation, but there are some intervals, allowing for 13 net hours of operation. Therefore, the values in Mega joules were converted to kWh for both experiments and multiplied by the tariff charged by Neoenergia, resulting in the following values: R$19,566.82 for experiment 1 and R$17,430.66 for experiment 2. It can be inferred that there is an estimated reduction of approximately 11%.

4. CONCLUSION

In conclusion, the continuous development of air conditioning and refrigeration technologies throughout the 20th and 21st centuries has played a crucial role in enhancing indoor comfort and preserving human health. The evolution of these systems, from the early days of experimentation to complex modern systems, has brought significant benefits to people's quality of life. However, it has also presented challenges, particularly related to energy consumption and indoor air quality. Awareness of the importance of indoor air quality has become paramount, given the significant amount of time people spend indoors. The Sick Building Syndrome (SBS) has highlighted the risks associated with inadequate ventilation and air contamination, leading to a deeper understanding of the measures necessary to ensure healthy indoor environments.

The presented project, which integrates an intelligent air renewal system with Variable Refrigerant Flow (VRF) technology, represents a significant advancement in this context. By addressing both energy efficiency and indoor air quality, it not only reduces electricity costs by 11% but also contributes to the reduction of respiratory diseases related to high CO_2 levels. This innovative approach not only aligns with current concerns about health and sustainability but also offers a practical and effective solution to the challenges faced by modern air conditioning systems.

Therefore, as we continue to advance in the 21st century, it is imperative that we further explore innovative technologies, adopt sustainable practices, and promote awareness to ensure that our indoor environments are not only comfortable but also safe and healthy for everyone. Striking a balance between comfort, energy efficiency, and air quality is essential to building a future where human needs are in harmony with the environment.

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